# PALYNOSTRATIGRAPHIC AND PALYNOFACIES INVESTIGATION OF THE OLIGOCENE-MIOCENE UNITS IN THE KARS-ERZURUM-MUŞ SUB-BASINS (EASTERN ANATOLIA)

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

RECEP HAYRETTİN SANCAY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
GEOLOGICAL ENGINEERING

AUGUST 2005

Approval of the Graduate School of Natural and Applied Sciences

Prof. Dr. Canan ÖZGEN
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy.

Prof. Dr. Asuman Günal TÜRKMENOĞLU
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Doctor of Philosophy.

Prof. Dr. Demir ALTINER
Supervisor

Examining Committee Members

| | | |
|---|---|---|
| Prof. Dr. Demir Altıner | (METU, GEOE) | |
| Prof. Dr. Cemal Göncüoğlu | (METU, GEOE) | |
| Prof. Dr. Asuman Günal Türkmenoğlu | (METU, GEOE) | |
| Assoc. Prof. Dr. Kağan Tekin | (HU, GEOE) | |
| Assoc. Prof. Dr. Sevinç Özkan Altıner | (METU, GEOE) | |

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : Recep Hayrettin SANCAY

Signature :

## ABSTRACT

## PALYNOSTRATIGRAPHIC AND PALYNOFACIES INVESTIGATION OF THE OLIGOCENE-MIOCENE UNITS IN THE KARS-ERZURUM-MUŞ SUB-BASINS (EASTERN ANATOLIA)

SANCAY, Recep Hayrettin

Ph.D., Department of Geological Engineering

Supervisor: Prof. Dr. Demir Altıner

August 2005, 364 pages

Eleven dinoflagellates, acritarchs, and pollen biozones have been identified on the basis of 43 pollen, 20 spores, 13 fungal spores, 70 dinoflagellates, 3 acritarchs, 2 organic-walled green algae, and 5 incertae sedis taxa in Upper Eocene to Pliocene sediments combined from Muş, Tekman, Tercan-Aşkale, Pasinler-Horasan basins and the Bayburt-Kars Plateau in this study. FADs of Compositae (tubuliflorae type), *Slowakipollis hipophäeoides*, *Mediocolpopollis compactus*, *Monoporopollenites gramineoides* and Umbelliferae at the base of Rupelian, FAD of *Wetzeliella gochtii* in the “middle” Rupelian, LAD of *Ascostomocystis potane* in the late Rupelian, LAD of *Wetzeliella gochtii* in the “latest” Rupelian, LAD of *Deflandrea* spp. in the latest Chattian, peak occurrences of *Chriptoredium* spp. in the early and late Aquitanian, FAD of *Hystrichosphaeropsis obscura*, followed by FAD of *Membranilarnacea* ?*picena* in the late Aquitanian should have particular emphasis for palynostratigraphic divisions in regional correlations and indicate that a continuous deposition took place in the

Eastern Anatolia from Late Eocene to the end of the Early Miocene. An acritarch called *Ascostomocystis potane* has been recorded for the first time in the middle-upper Rupelian sediments of the Eastern Anatolia. Data obtained from nine dinoflagellate-acritarch eco-groups defined in this study give impotant clues on the paleogeography of the region suggesting that relatively deeper marine deposition prevailed during the Late Eocene, which was followed by a shallowing-upward deposition during the Oligocene in Hınıs-Muş-Van, Tekman, Tercan-Aşkale, and Pasinler-Horasan basins. These basins were also characterized by an Early Miocene regional transgression, and terrestrial (lacustrine and fluvial) deposition during the Late Miocene-Pliocene whereas terrestrial conditions have been predominating since Late Eocene in the Bayburt-Kars Plateau. Changes in relative sea level in the Eastern Anatolian sub-basins well match with the eustatic sea level curves. Paleoclimatological reconstructions of the Eastern Anatolian Oligocene-Miocene sediments suggest temperate to subtropical climates in which mean annual temperatures vary between 15,6 to 21,3 °C, mean temparatures of the coldest and the warmest month are 5.0 to 13.3 °C and 24.7 to 28.1 °C, respectively, and mean annual precipitation is 1122.0 to 1522.0 mm.

Keywords: Oligocene-Miocene, Eastern Anatolia, palynostratigraphy, paleoecology, paleogeography, paleoclimate.

## ÖZ

## KARS-ERZURUM-MUŞ HAVZALARI (DOĞU ANADOLU) OLİGOSEN-MİYOSEN BİRİMLERİNİN PALİNOSTRATİGRAFİSİ VE PALİNOFASİYES ÖZELLİKLERİ

SANCAY, Recep Hayrettin

Doktora, Jeoloji Mühendisliği Bölümü

Danışman: Prof. Dr. Demir Altıner

Ağustos 2005, 364 s.

Muş, Tekman, Tercan-Aşkale, Pasinler-Horasan havzaları ile Bayburt-Kars platosu Üst Eosen-Pliyosen çökellerinde yapılan palinolojik çalışmalarda tür ya da cins düzeyinde tanımlanan toplam 43 pollen, 20 spor, 13 fungal spor, 70 dinoflagellat, 3 akritark, 2 organik kavkılı yeşil alg ve 5 kökeni bilinmeyen palinomof ile 11 dinoflagellat, akritark ve pollen biyozonu tanımlanmıştır. Doğu Anadolu Üst Eosen-Alt Miyosen çökellerinin bölgesel korelasyonuna olanak sağlayan bu biyozonlar Compositae (tubuliflorae-type), *Slowakipollis hipophäeoides*, *Mediocolpopollis compactus*, *Monoporopollenites gramineoides* ve Umbelliferae'nın FAD'ının Rupeliyen tabanı; *Wetzeliella gochtii'nin FAD*'ının "orta" Rupeliyen; *Ascostomocystis potane*'nin LAD'ının geç Rupeliyen; *Wetzeliella gochtii*'nin LAD'ının en geç Rupeliyen; *Deflandrea* spp.'nin LAD'ının en geç Şattiyen; *Chriptoredium* spp.'nin bolluk zonunun erken ve geç Akitaniyen; *Hystrichosphaeropsis obscura'nın* FAD'ının, ve takip eden *Membranilarnacea*? *picena'nın* FAD'ının geç Akitaneyen olduğunu ortaya koymuştur. Çalışılan sedimanların paleocoğrafik dağılımları hakkında önemli ipuçları veren ve bu çalışmada tanımlanan 9 dinoflagellat-akritark eko-grupları, söz konusu havzalarda Geç Eosen boyunca göreceli derin denizel, Geç Oligosen'de gittikçe sığlaşan denizel, Erken Miyosen'de bölgesel transgresyon ve Geç Miyosen-Pliyosen döneminde ise karasal (gölsel-akarsu) çökelimin etkin olduğunu ortaya koymuştur. Tanımlanan eko-gruplara dayanarak Bayburt-Kars platosunda Geç Eosen'den başlayarak karasal koşulların egemen olduğu söylenebilir. Palinomorflara dayanarak Doğu Anadolu alt havza çökelleri için oluşturulan deniz seviyesi eğrisi, global deniz seviyesi eğrileri ile büyük benzerlikler sunmaktadır. Doğu Anadolu Oligosen-Miyosen sedimanlarının paleoiklimsel değerlendirmeleri ise ortalama yıllık sıcaklık değerlerinin 15,6-21,3 °C olduğunu; en soğuk ve en sıcak ay sıcaklık değeri ortalamalarının 5.0-13.3 °C ile 24.7-28.1 °C; ortalama yıllık yağış miktarının ise 1122.0-1522.0 mm arasında değiştiğini ortaya koymuştur.

Anahtar Kelimeler: Oligosen-Miyosen, Doğu Anadolu, palinostratigrafi, paleoekoloji, paleocoğrafya, paleoiklim.

To my wife and daughter

## ACKNOWLEDGEMENTS

First of all, I would like to thank my sponsor Turkish Petroleum Corporation (TPAO) because without their permission and financial support, this study would not be possible.

I am greatly indepted to my supervisor Dr. Demir Altıner for his guidance. I am also greatful to Dr. Asuman G. Türkmenoğlu, Dr. Kağan Tekin, and Dr. Cemal Göncüoğlu for their valuable contributions during the study.

I owe many thanks to Dr. Zühtü Batı from Turkish Petroleum Corporation Research Center Group. This study could not be completed without his help, experience, and encouragement.

I really appreciate to the field geologists from Turkish Petroleum Corporation Exploration Group, Ömer Şahintürk, Ahmet Çaptuğ and Bülent Sadioğlu for their great effort during the field study and sharing us their priceless experience on the Eastern Anatolia.

Special thanks go to Dr. Lucy E. Edwards from USGS and Kaya İ. Ertuğ from Turkish Petroleum Corporation Research Center for their valuable contributions during the identification of the dinoflagellates.

I am also indepted to Sehrab A. Shikhlinsky from Azerbaijan Republic State Oil Company (SOCAR) for sharing his regional experiences with us on Caspian and neigbouring areas.

Micropaleontologists Sabri Kirici and Uğraş Işık, and nannopaleontologist Nihal Akça made important contributions in the calibration of palynomorph biozonations.

I want to thank Dr. Ercüment Sirel from Ankara University for his valuable discussions about the distribution of benthic foraminifers in Turkey.

I would like to thank Dr. Volker Mosbrugger and Dr. Tursten Utescher from Institute and Museum of Geology and Palaentology in Tübingen, Germany and M. Serkan Akkiraz from Dokuz Eylül University for their technical support in paleoclimatologic reconstructions by CLIMSAT.

I owe many thanks to palynology technician Hasan Can who helped a lot in the preperation of palynological slides.

Finally, my wife deserves special thanks for her patience and encouragement during this study.

TABLE OF CONTENTS

# LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

# CHAPTER 1

# INTRODUCTION

## 1.1. Purpose and Scope

Petroleum potential of the Oligocene-Miocene sediments in the Eastern Anatolia has been proved by the existence of source rocks, oil seeps, and probable reservoir rocks, but they have not adequately been studied paleontologically and, thus, biostratigraphic framework has not been established yet. Oligocene-Miocene sediments, possessing similar geochemical and lithological properties with the Maykopian sediments of the Caspian Region, have been determined as a result of the field and drilling activities in the Eastern Anatolia (e.g. Batı and Alişan, 1991; Sancay et al., 2003) but some uncertanities about their ages and depositional environments have not been resolved yet. Therefore, Kars, Erzurum, Muş sub-basins (Eastern Anatolia) are investigated palynologically in this study to;

1. Determine bio-chronostratigraphic units of Oligocene-Miocene sediments.
2. Determine palynofacies, paleoclimatological and ecological factors affecting deposition of the Oligocene-Miocene sediments.
3. Determine the stratigraphic position and distribution of Lower Oligocene sediments (non-deposition or erosion).
4. Estimate the paleogeographic distribution of Oligocene-Miocene sediments.

A total of 357 samples were collected at the field from 10 stratigraphic sections (Kükürtlü, Kömürlü, Kötek, Kelereşdere, Çamlıca-Pisyanlı, Çirişlitepe, Ebulbahar, Ağgelin, Ahlat, and Zırnak) and analysed palynologically to document the distribution of palynomorphs and construct the biostratigraphic zonations in order to establish a biostratigraphic framework of Oligocene-Miocene sediments.

Relative abundances of the palynomorphs have been calculated based on at least 200 counts for each sample for quantitative and qualitative palynological analyses. Percentages of the organic matter (kerogen) constituents have been determined by visual examination for palynofacies investigations.

## 1.2. Previous Studies

Earlier studies carried out in the Eastern Anatolia are mostly products of mapping activities of General Directorate of Mineral Research and Exploration (MTA) and Turkish Petroleum Corporation (TPAO) geologists (e.g. Erentöz, 1954; Kıraner, 1957; Ürgün, 1961; İlker, 1966; Tokel 1966; Özcan, 1967; Birgili 1968; Özyeğin, 1968; Dinçer, 1969; Elnaif, 1969; Ünal, 1970; Sungurlu, 1967, 1971, and 1972; Soytürk, 1973; Erdoğan and Soytürk, 1974; Şahintürk and Kasar, 1979 and 1980; Şahintürk, 1992; Üngör, 1992; Şahintürk et al., 1997 and 1998a; Uğur, 2000). All of those studies are published as company reports.

Concerning the stratigraphy of the Oligocene-Miocene sediments undertaken in this study, several studies have been carried out in the second half of 20$^{th}$ century. Biostratigraphical, lithostratigraphical and tectonical studies on the region will be mentioned separately in a chronological order in the following part.

Demirtaşlı and Pisoni (1965) identified the Adilcevaz limestone, measured as 800 m thick in the type locality called Dikis mahallesi very close to Adilcevaz town, Van. The upper part of Adilcevaz limestone of Demirtaşlı and Pisoni (1965) is later indicated as a Burdigalian reefal limestone member of the Aşkale Formation by Şahintürk and Kasar (1980). They suggested that the lowermost part of the Adilcevaz Limestone contains relatively arenitic Aquitanian limestones and can be correlated with similar lithologies in Muş and Van basins. Arenitic and lithic limestone layers of the lowermost part of the Aşkale Formation conformably overlie the sanstone-marl intercalations belonging to the uppermost part of the Kelereş Formation in the Muş Basin. There is no observation on a probable unconformity in the field. Therefore, transition between Aşkale and Kelereş formations and similarly boundary between the Oligocene and the Miocene sediments seem conformable in the Muş Basin.

Only a few biostratigraphical and paleontological studies have been carried out in the Eastern Anatolia. One of the most detailed micropalentological studies in the Muş region was Sakınç's Ph.D. thesis, later published as Sakınç (1982). He investigated Eocene, Oligocene, Miocene and Quaternary sediments and identified several bio-chronostratigraphic units. According to Sakınç (1982), the Eocene is represented by a non-fosilliferous siltstones and is uncomformably overlain by the Lower Oligocene sediments. The Oligocene consists of Lower Oligocene (Lattorfian), "middle" Oligocene (Rupelian) and Upper Oligocene (Chattian) sediments and covers most of the studied area, and is conformably overlain by the Aquitanian sediments. Sakınç (1982)'s observation on the comformable transition between the Upper Oligocene and the Lower Miocene sediments is quite consistent with this study but the boundary between the Upper Eocene and the Lower Oligocene sediments is conformable as it will be discussed in the palynology chapter.

Ertuğ et al. (1995) investigated the dinoflagellate biostratigraphy of the Oligo-Miocene sediments in the Tekman Basin to the northeastern part of Muş. The Upper Oligocene-Lower Miocene Gümüşali Formation, lithostratigraphic equivalent of the Kelereş Formation in the Muş Basin, and the Lower-Middle Miocene Alibonca Formation (Akçan and Mescitli members), lithostratigraphic equivalent of Aşkale Formation in the Muş Basin, have been taken into consideration in their study. They have identified four dinoflagellate biozones in the ?Upper Oligocene-Middle Miocene sediments. Detailed discussion on their dinoflagellate biozones is going to be given in the palynology chapter of this study.

Örçen (2001) investigated the Early-Middle Miocene marine connections of Turkey in Taurus and Arabic platforms based on Miogypsinidae species. He indicated that the marine connection was prevailed during the Aquitanian and Burdigalian time span between the Southeastern Anatolia and Arabic platform.

Sirel (2003) investigated three sections in the north of Maraş (Ahırdağ stratigraphic section) and in the northeastern part of Muş (Kelereşdere and Norkagakdere stratigraphic sections) where he analysed large benthic foraminifer taxa of shallow water nature. The Ahırdağ stratigraphic section seems to be comparable with the Kelereşdere section and it includes sediments of Middle to Upper Eocene, Oligocene, and Oligocene-Miocene boundary (shallow benthic foraminiferal zonations of SB17-SB24). The main difference between two sections is the dominance of carbonates (mostly limestones) in the Ahırdağ section whereas the Kelereşdere section is mainly composed of clastic lithologies interfingering with limestone beds. According to Sirel (2003), Upper Eocene sediments unconformably overlie the ophiolithic mélange and comformable sedimentation without any depositional break took place until the Early Miocene in the Ahırdağ section where four biostratigraphic units have been distinguished. Similarly, continuous deposition from Late Eocene to Early Miocene in the Muş Basin is reported in this study where eleven palynomorph biozones are documented.

Although, many lithostratigraphic units have been identified in previous studies of the Eastern Anatolia, most of the time, it is very complicated to compare litostratigraphic units in different sub-basins and sometimes even within the same basin itself.

Kurtman and Akkuş (1971) investigated the stratigraphy of the Eastern Anatolia basins in terms of their petroleum potential. They reported that, Muş-Hınıs-Malazgirt sub-basins have consisted of Upper Cretaceous, Eocene, Oligocene, Miocene, and Pliocene sediments that were separated by unconformity surfaces. They have suggested that a thick succession of Oligocene sediments include sandstone-marl intercalations with some limestone interbeds and unconformably overlie the Eocene sediments. Aquitanian sediments are represented by sandy limestones and marl lithologies whereas Burdigalian sediments are characterized by reefal limestones which are widely distributed in this basin. According to Kurtman and Akkuş (1971), the contact between Oligocene and Miocene sediments is unconformable but they did not give any detail about the type of the unconformity and reasons to put an unconformity surface to the Oligo-Miocene boundary without any depositional break.

Gedik (1985) investigated the Tekman Basin in terms of geology and petroleum potential of the region. He indicated that Paleocene sediments are absent in the Tekman Basin. He believed that the Upper Cretaceous sediments became positive areas and were eroded in the Paleocene, thus, this period was represented by the time of erosion. After this erosional phase, Eocene transgression took place. Turbiditic, shallow marine, reefal, and even terrestrial conditions in some places were dominating during the Eocene. Oligocene deposits reflect shallow water/lacustrine environments. Early Miocene transgression supplied the connection of the Tekman Basin with neighbouring basins. Deep marine to reefal sediments deposited in this period. Finally, the sea withdrew and the terrestial conditions started to dominate through the end of the Early Miocene in the Tekman Basin and lacustrine and fluvial deposition took place.

Şaroğlu and Yılmaz (1987) investigated the geological evolution and the basin models of the Eastern Anatolia in the neotectonic period. Stratigraphy of 8 different regions (from west to east Karlıova-Bingöl, Muş, Ahlat-Adilcevaz, Karayazı-Tekman, Hınıs, Zırnak, Erzurum-Pasinler-Horasan, and Kağızman-Tuzluca) have been documented in their paper separately as it is given in the following paragraphs and then depositional history of the Eastern Anatolia has been discussed.

The Burdigalian Adilcevaz Formation unconformably overlies the basement and is unconformably overlain by the Upper Miocene Solhan Volcanics in the Karlıova-Bingöl region. Seymen and Aydın (1972) suggested that the lowermost part of the Adilcevaz Formation might be Aquitanian in age. Solhan Volcanics are unconformably overlain by the Zırnak Formation of which coal layers were dated as Middle-Late Pliocene by Nakoman (1968).

The Lower Miocene Adilcevaz Formation conformably overlies the Aquitanian Ebulbahar Formation in the Muş Basin (Ünal, 1970). Similar to the Karlıova-Bingöl region, an unconformable relationship has been reported between the Adilcevaz Formation, Solhan Volcanics, and the Zırnak Formation. The Zırnak Formation including lacustrine limestones and is Late Miocene-Pliocene in age in this region. The sea withdrew at the end of the Early Miocene in the Muş Basin (Şaroğlu and Yılmaz, 1987).

Şaroğlu and Yılmaz (1987) reported that, the Burdigalian Adilcevaz Formation unconformably overlies the Eocene-Oligocene(?) Ahlat Formation and is unconformably overlain by the Middle-Upper Miocene Aktaş and Develi formations in the Ahlat-Adilcevaz region. Develi Formation, marine in character, is gradational to the lacustrine carbonates known as the Çukurtarla Limestone which may correspond to the Zırnak Formation in the Muş Basin. Terrestrial conditions in the depositional environment became dominant during Middle-Late Miocene in this region.

The Burdigalian Haneşdüzü Formation, consisted of marine carbonates, unconformably overlies the Oligocene Çığılgan Formation and unconformably overlain by the Middle Miocene, marine to lacustrine, Mescitli Formation and the volcanics in the Karayazı-Tekman region. Upper Miocene Yastıktepe Formation, representing lagoonal conditions, unconformably overlies the Mescitli Formation and is unconformably overlain by the Çullu Formation of Pliocene age. The sea withdrew from the region in the Middle Miocene (Şaroğlu and Yılmaz, 1987).

According to Şaroğlu and Yılmaz (1987), the Oligocene Aktuzla Formation is gradational to the Güzelbaba Limestone which is Early Miocene in age in Hınıs. Terrestrial facies of the Alibonca Formation unconformably overlies the Güzelbaba Limestone and is believed to be Late Miocene in age. The Zırnak Formation of Pliocene age overlies the older units unconformably in this region.

The Aquitanian Aktuzla Formation is gradational to the Burdigalian Güzelbaba Limestone which is unconformably overlain by the Upper Miocene and terrestrial Alibonca Formation around Zırnak. Similar to other regions, the Pliocene Zırnak Formation unconformably overlies the older units in this basin Şaroğlu and Yılmaz (1987).

According to Şaroğlu and Yılmaz (1987), Erzurum, Pasinler, and Horasan basins were acted as a single basin before the neotectonic period, but then they were separated due to the volcanism and neotectonic deformations at the beginning of the neotectonic period. The Lower Miocene Haneşdüzü Formation, consisting of marine carbonates, unconformably overlies the Oligocene Çığılgan Formation and is unconformably overlain by the Middle Miocene Mescitli Formation which is in turn overlain by the Upper Miocene, terrestrial Yastıktepe Formation. The Pliocene Horasan Formation represents the youngest unit in this region and unconformably overlies the older units. The sea withdrew from the region in the Middle Miocene (Şaroğlu and Yılmaz, 1987).

Şaroğlu and Yılmaz (1987) suggested that the Kağızman-Tuzluca Basin is very distinct because it has quite thick Pliocene sediments and does not have marine Lower Miocene sediments which are very common in many localities of the Eastern Anatolia. Eocene sediments belonging to the paleotectonic period are unconformably overlain by the Pliocene Tuzluca Formation in the Kağızman-Tuzluca Basin. Pleistocene sediments unconformably overlie the Tuzluca Formation. According to Şaroğlu and Yılmaz (1987), this region was a land from Eocene to Pliocene time interval during which the deposition did not take place. Therefore, they believed that the northern border of the peneplane, occurred in the Early Miocene in the Eastern Anatolia, did not reach to this region.

According to Şaroğlu and Yılmaz (1987), sedimentation seems to be continuous from Oligocene to Aquitanian in the paleotectonic period in the Eastern Anatolia and followed by Burdigalian reefal deposition representing the last marine sediments and the last products of the paleotectonic period. They claimed that the Eastern Anatolia had a peneplane like morphology at the end of the Early Miocene. The Middle Miocene sediments are cropped out in very limited locations where they are mainly regressive in nature and represent a deposition occurred in shallow marine to lagoonal conditions in the Eastern Anatolia. As a result of the compressional tectonism in the Middle Miocene, the region became elevated and the sea withdrew completely through the Late Miocene (Şaroğlu and Yılmaz, 1987). Intensive tectonism and volcanism promote very high sedimentation rates in the Eastern Anatolia during the neotectonic period, as it was elsewhere reported by Demirer et al. (1996), more than 1900 m of lacustrine sediments were deposited in Pliocene.

According to Yılmaz et al. (1988), Oligocene Ağcakoca Formation conformably overlies underlying terrestrial sediments of Ahlat Formation in the Hınıs region. Havur (1972) reported an Early Miocene age for the upper part of the unit. Lower Miocene Haneşdüzü Formation, corresponding to Alibonca Formation of Soytürk (1973) and Adilcevaz Limestone of Demirtaşlı and Pisoni (1965) represents neritic-shallow marine conditions where reef accumulations were able to took place. According to Rathur (1965) and Soytürk (1973), this unit unconformably overlies Oligocene sediments. However, Yılmaz et al. (1988) suggested that this contact is not an unconformity surface. Regressive conditions were dominating at the end of the Oligocene and terrestrial deposition might even has taken place in some regions at that time. Later, transgressive deposition was dominant in the Early Miocene. These repeating regressive-transgressive cycles may lead misinterpretations on the nature of the boundary between Oligocene and Miocene sediments. However, as it was reported by Yılmaz et al. (1988), neither any depositional break nor a hiatus was indicated during that time.

According to Yılmaz et al. (1988), Tekman-Karayazı and Hınıs sub-basins acted as a single basin from Maastrichtian to the Early Miocene but they became separated in the Middle(?)-Late Miocene as two different basins. Therefore, Upper Miocene-Pliocene sediments were identified as separate units by Yılmaz et al. (1988) due to the local differences and interfingering volcanics related to compressional tectonism.

Akay et al. (1989) briefly described the lithostratigraphic units of Tertiary Muş sub-basin. The oldest sediments in Tertiary are known as the Kızılağaç Formation of Lutetian-Bartonian age, described for the first time by Göncüoğlu and Turhan (1983) overlies Bitlis Metamorphics with an angular unconformity. The Ahlat Formation consists mainly of terrestrial and marine reddish sandstones, siltstones and conglomerates deposited following the subsidence that was occurred after the orogenesis. According to Akay et al. (1989), bottom relationships of the Ahlat Formation can not be observed but it seems to be thrusted over the Zırnak Formation in the southeastern part of their study area. However, it is gradational to the overlying sediments belonging to Norkovak, Gerisor, and Yazla (Kelereş) formations. Although there is no direct age data obtained from the unit, it consists of pebbles of Middle Eocene and is conformably overlain by the Lower Oligocene-Upper Eocene Norkovak and Gerisor formations. Therefore, the Ahlat Formation is interpreted as the latest Eocene in age. The Norkovak Formation is gradational to the underlying the Ahlat Formation and overlying the Yazla (Kelereş) Formation. Nannofossil data suggest the latest Eocene-Early Oligocene age for this unit (Uysal, 1986). The Gerisor Formation is gradational to the underlying Ahlat Formation and the overlying Yazla (Kelereş) Formation. According to Sakınç (1982) *Nummulites vascus* and *Nummulites intermedius* occurrences in the unit suggest an Early Oligocene age. The thickest unit (about 3300 m) of the Tertiary Muş Basin is the Yazla (Kelereş) Formation which is gradational to the underlying Ahlat, Norkovak, and Gerisor formations and the overlying Adilcevaz Formation. According to Akay et al. (1989), a Late Oligocene age has been assigned to the Yazla (Kelereş) Formation, and an Early Miocene age has been assigned to the

Adilcevaz Formation based on nannofossil and foraminifer data. Some studies reported that the boundary between Yazla (Kelereş) and Adilcevaz formations are unconformable (e.g. Elnaif, 1969; Soytürk, 1973) in the Muş Basin. However, Akay et al., (1989) and some other earlier researchers (e.g. Kıraner, 1957; Dinçer, 1968; Ünal, 1970; Sakınç, 1982) believed that this boundary is conformable and they suggested that the Yazla (Kelereş) Formation is transitional to the Adilcevaz Formation. An Oligocene-Early Miocene age has been assigned to the Yazla (Kelereş) Formation in this study and the boundary between the Oligocene and the Miocene has been suggested to be comfromable in the Muş Basin.

Ercan et al. (1990) studied radiometric, isotopic, and geochemical properties of the Neogene-Quaternary volcanics in the Eastern and Southeastern Anatolia. They indicated 11.2-1.5 Ma from the andesites and 4.61-0.71 Ma ages from the basalts (identified as Karakurt Volcanics by Bozkuş, 1993) cropped out in the Pasinler-Horasan Basin, which suggest a Late Miocene to Early Pliocene age.

Bozkuş (1990) studied the stratigraphy of the northeastern part of the Oltu-Narman (Kömürlü) Tertiary Basin. He reported that the basement of the basin consists of Permo-Carboniferous acidic volcanics, and Lower Cretaceous volcanosedimentary rocks. Sedimentary rocks of the region are represented by Eocene shallow marine sediments (Dağdibi and Karataş formations) unconformably overlain by Oligocene and Oligo-Miocene terrestrial and lacustrine deposits interfingered by some volcanics and Upper Miocene and younger volcanics unconformably overlying the older units. However, as far as the earlier studies in the region and this study are considered, the general litostratigraphic setting has been given wrong in his study. According to Bozkuş (1990), Oligo-Miocene sediments are represented by Delikbaş, Susuz, Kömürlü, and Penek formations. The reddish Delikbaş Formation unconformably overlies Upper Cretaceous sediments and is gradational to the overlying the Susuz Formation. The Delikbaş Formation is believed to be Oligocene in age because Akyol (1964) identified Oligocene palynomorphs from the coal layers within the unit and

Bozkuş (1990) reported that the 25±3 Ma age obtained in the basalts occurred in the upper part of the unit by the K/Ar isotope data. The Susuz Formation conformably overlies the Delikbaş Formation. An Oligo-Miocene age was assigned for this unit. The Kömürlü Formation conformably overlies the Susuz Formation and is conformably overlain by the Penek Formation. Lower part of the Kömürlü Formation has brownish marls with some coal interbeds and is distinguished as the Balkaya Member whereas the upper part of the unit is represented by light, gray-coloured marls known as the Tekirtepe Member. No palynomorphs and age data have been obtained from the coal beds in the Kömürlü Formation. However, since it conformably overlies the Oligocene-Miocene Susuz Formation and is unconformably overlain by the Upper Miocene-Pilocene Penek Formation, the probable age of the Kömürlü Formation is interpreted as Miocene by Bozkuş (1990). Similar to the Kömürlü Formation, the Penek Formation has no age diagnostic taxa. However, this unit has some andesitic volcanics reported as Late Miocene in age by Erentöz (1954). Therefore, the probable age of the Penek Formation is interpreted as Late Miocene-Pliocene by Bozkuş (1990). However, this stratigraphic interpretation has to be revised because, the Penek Formation has been defined below the Kömürlü Formation and is Oligocene in age as it was given in Şahintürk et al. (1998b) and Uğur (2000). The Kömürlü Formation conformably overlies the Penek Formation and is Oligocene-Early Miocene in age. The unconformably overlying Upper Miocene-Pilocene unit should be corresponding to the Zırnak Formation.

Şengüler and Toprak (1991) investigated the petrographic properties of the lignites of the Pliocene Zırnak Formation from Varto, Hınıs, Bulanık, and Malazgirt. They suggested that these lignites were deposited in freshwater swamps.

Bozkuş (1993) also studied the stratigraphy of the eastern part of the Pasinler-Horasan Basin. He reported that the oldest rocks in the study area are Lower Cretaceous ophiolitic rock units which are unconformably overlain by the Oligocene Çayırarası Formation and the Upper Miocene-Lower

Pliocene Karakurt Volcanics. The youngest units of the region, Pliocene Aras and Horasan formations, unconformably overlie older units.

Geochemical properties (source rock potential and organic facies properties) of the Oligo-Miocene sediments of the Eastern Anatolia in Pasinler-Horasan and Tercan-Aşkale basins were studied by Tekin (2002). She suggested that the source rock depositon occurred in the lagoonal, remnant sea, and lacustrine environments in the Pasinler-Horasan and Tercan-Aşkale basins during Late Oligocene to Late Miocene. According to Tekin (2002), source rocks have “fair” to “excellent” source rock potential in that most of them have Type II kerogen (HI=300-650 mgHC/gTOC) and only a few have Type I kerogen (HI>3650 mgHC/gTOC). Dominant organic matter type has been reported as amorphous in the source rocks. Tekin, (2002) stated that those amorphous organic matter could be originated from the algae-bacteria, and marshy(?) herbaceous plants in the non-marine facies and marine phytoplanktons and sporomorphs in the marine facies. She also summarized the evolution of the Oligo-Miocene sediments in these basins as follows: The Penek Formation was deposited under terrestrial-very shallow marine-transitional conditions during the Late Oligocene to Early Miocene and consisted of reworked material from Eocene and older sediments related to the Eocene tectonism. Thickness of this unit varies depending on the paleotopography. For instance, it is relatively thin in the Pasinler-Horasan Basin but very thick in the Tercan-Aşkale Basin. She reported that the overlying Kömürlü Formation, deposited in shallow marine-lagoonal-transitional conditions, was only observed in the Tercan-Aşkale Basin. Therefore, a hiatus should be indicated between the Lower-Middle Miocene and underlying Upper Oligocene-Lower(?) Miocene sediments in the Pasinler-Horasan Basin; whereas this relationship is interpreted as nonconformable in the shallow marine-lagoonal-transitional conditions, has observed only in the Tercan-Aşkale Basin. Early-Middle Miocene period was represented by the relatively stabilized depositional conditions changing from shallow marine to the west to terrestrial to the east. According to Tekin (2002), Pasinler-Horasan and Tercan-Aşkale basins were acting as a single basin until the end of the Middle Miocene during which they were peneplained.

As far as the tectonic evolution of the basins is considered, the Eastern Anatolia gets so much attention from different researchers (e.g. Erinç, 1953; Altınlı, 1966; Ketin, 1966; Şengör, 1980; Şaroğlu et al., 1980; Şaroğlu and Güner, 1981; Şengör and Yılmaz, 1981; Şaroğlu, 1985; Şaroğlu and Yılmaz, 1987 and 1991; Yılmaz et al., 1988).

One of the most classical study on the tectonic units of Turkey was carried out by Ketin, (1966). He distinguished four tectonic belts as Pontids, Anatolids, Taurids, and border folds in Turkey. According to Ketin (1966), the Eastern Anatolia should be evaulated as a part of Taurids.

According to Şengör et al. (1979) and Şengör (1980), neotectonic period was started in the Middle Miocene as a result of the collision of Eurasian and Arabian plates along the Bitlis suture zone following the closure of the Neotethys. Because of the compressional tectonic regime dominating during the neotectonic period, E-W directioned basins occurred associated with complicated thrusts, faultings, foldings, cracks, and volcanism. Those basins are defined as "intermontane basins" by Şaroğlu and Güner (1981) and they indicated that Tertiary Muş basin is a characteristic example of such basins.

Şengör (1980) studied the neotectonic events of Turkey and identified pre-Tertiary rocks in the Eastern Anatolia as "East Anatolian Accretionary Complex". He suggested that this complex may be considered as an extension of Anatolid and Taurid paleotectonic belts.

Şaroğlu and Güner (1981) studied relations between geomorphology, tectonism, and volcanism in the Eastern Anatolia. They suggested that the Eastern Anatolia had peneplane or peneplane-like structures in the beginning of the neotectonic period.

Barka (1984) argued that both compressional and extentional tectonic regimes played an important role during the neotectonic period in the Eastern Anatolia.

Similar to the earlier studies carried out in the Eastern Anatolia (e.g. Şengör, 1980; Şengör et al., 1980; Şengör and Yılmaz, 1981), Gedik (1985) also suggested that the Tertiary sediments in the Tekman Basin have been affected by the Alpine orogenesis and N-S trending compressional regime causing E-W trending thrusts as it was also reported by Şaroğlu and Yılmaz, (1987). According to Gedik (1985), Palandöken Mountains, occurred before the Late Campanian, and elevated at the end of Burdigalian, could be responsible from the separation of Tekman and Pasinler basins.

Şengör et al. (1985) stated that the N-S shortening in the Eastern Anatolia has caused many distributed conjugate wrench faults, E-W trending folds and thrusts. They classified Muş-Van and Pasinler basins as ramp basins related to thrust faults. According to Şengör et al. (1985), in spite of the fact that the compressional tectonic regime was dominating in wide areas, the strike-slip tectonic regime seems also important at least in a local scale.

Şaroğlu and Yılmaz (1987) argued that the neotectonic period started in the Middle Miocene in the Eastern Anatolia. E-W directioned foldings, high-angular thrusts, N-S directioned extensional cracks, NE-SW directioned left-handed and NW-SE directioned right-handed strike-slip faults are the major components of the neotectonic period (Şaroğlu and Yılmaz, 1987). Basins occurred either as a pull-apart basin formation process between those strike-slip faults or intermontane basin mechanism corresponding to anticlines bounded by ridges in this period.

Yılmaz et al. (1988) studied the tectonic evolution of the cental Eastern Anatolia and distinguished three main tectonic stages in the Hınıs region as follows; pre-Maatrichtian-Paleocene period, Late Eocene to Early Miocene period, and Middle(?)-Late Miocene to Recent period. They suggested that the sediments were deposited from Maastrichtian to Pliocene including many transgresssive-regressive cycles and unconformably overlie older successions. They reported that two main thrusting events; one occurred before the Maastrichtian and the other one occurred at the end of the Eocene. In general, the sedimentation was started transgressively in the

Maastrichtian, became regressive at the end of the Eocene, both transgressive and regressive conditions dominated in the Oligocene respectively, transgressively in the Early Miocene and regressive in the Middle Miocene. According to Yılmaz et al. (1988), completely terrestrial conditions became dominant in the region in the Middle(?)-Late Miocene as a result of the last regressive event.

Yılmaz (1989) investigated the differences between the tectonic lines of Caucasia and the Northeast Anatolia. He mainly focused on the metamorphics and ophiolithic belts seen as basement rocks in the Eastern Anatolia.

As far as surface geology of the Eastern Anatolia is concerned, wide areas were covered by volcanic rocks. The Eastern Anatolia has been subjected to intensive volcanism through the geologic history and associated volcanic rocks have been studied by many researchers (e.g. Lahn, 1945; Pasquare, 1965; Tokel, 1979 and 1984; Innocenti et al., 1982a and b; Yılmaz et al., 1987; Pearce et al., 1990; Keskin et al., 1998). Volcanic rocks may play an important role to establish stratigraphic framework of the region by means of radiometric datings. There is a general agreement on the origin of the volcanics that is the partial melting of the mantle caused by the collision of Eurasian and Arabian plates during the neotectonic period and the subduction event from Late Cretaceous to Eocene (e.g. Yılmaz et al., 1987).

# CHAPTER 2

# GEOLOGY

## 2.1. Regional Geology

Pontides from north, Southeast Anatolian suture zone from south, the Karlıova triple junction of the North Anatolian and South Anatolian faults from west (Allen, 1969; Arpat and Şaroğlu, 1972; Şengör, 1979) border the Eastern Anatolia subbasins. Sub-basins lie towards Georgia, Armenia and Iran to the East (Figure 1). Eastern Anatolia occupies the northwestern part of the Turkey-Iran plateu (Şengör and Kidd, 1979).

Some characteristics of the Eastern Anatolia basins are as follows:

-mostly intermontane,

-have E-W long axis and N-S short axis,

-shallow in general,

-separated mostly by major faults, folds, and ophiolites in some places,

-about 6000 meters of sediment were deposited from Late Maastrichtian to Present,

-located on the "East Anatolian Accretionary Prism or Region" of Şengör, (1980),

-gained their ultimate shape after the Late Miocene time,

-Upper Eocene and younger sediments are important for oil industry, older sediments were affected by intensive tectonism,

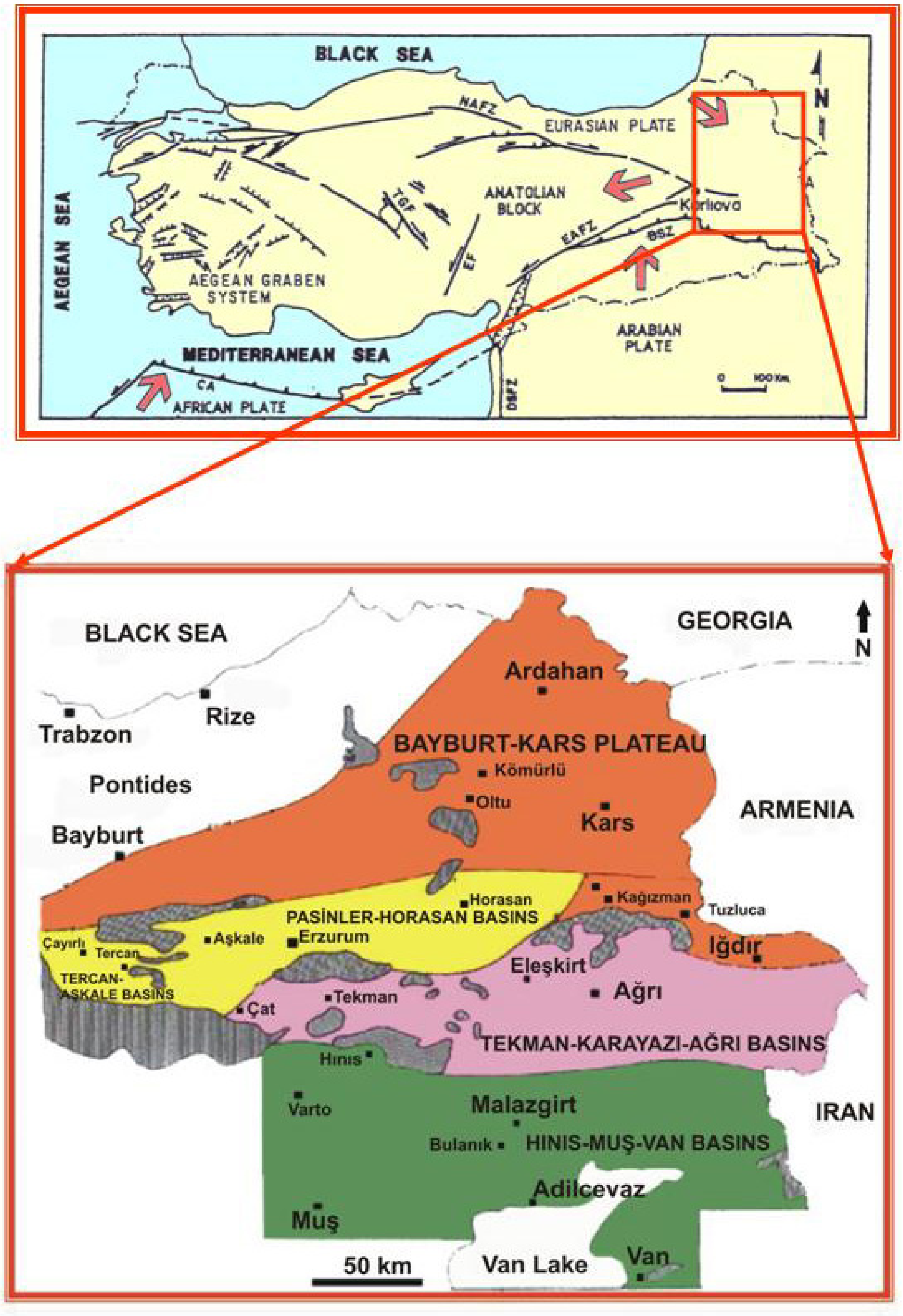



Figure 1. Location map of the Eastern Anatolia subbasins. (NAFZ: North Anatolian Fault Zone, EAFZ: East Anatolian Fault Zone, TGF: Tuz Gölü Fault, EF: Ecemiş Fault, DSFZ: Death Sea Fault Zone, BSZ: Bitlis Suture Zone: Grey and shaded areas, ophiolites. (modified from Koçyiğit, 1991 and Şahintürk et al., 1998b).

-Upper Oligocene-Lower Miocene rocks have source rock, Lower-Middle Miocene rocks have reservoir characteristics, and Upper Miocene rocks have sealing properties.

Compressional nature of the dominant tectonic regime on the Eastern Anatolia basins was reported by the studies of Mc Kenzie (1976) and Alptekin (1973). Tchalenko (1977) also indicated that the region has extended in the E-W direction as a result of the N-S directioned compressions.

In general, following sub-basins (intermontane) can be distinguished from North to South in the Eastern Anatolia (Figure 1).

- The Bayburt-Kars Plateau (Kars basin)
- Tercan-Aşkale and Pasinler-Horasan sub-basins
- Tekman-Karayazı-Ağrı sub-basins
- The Hınıs-Muş-Van sub-basin.

Şaroğlu and Güner (1981) and Şaroğlu (1985) have identified 4 depositional/tectonic stages in the evolution of the Eastern Anatolia (Figure 2).

1. Paleozoic-Lower Mesozoic metamorphic rocks, (related to Bitlis-Pötürge crystalline nappes).
2. Upper Cretaceous ophiolithic mélange (remnant of the Tethyan oceanic realm) (Şengör and Yılmaz, 1981; Yılmaz, 1993).
3. Paleocene (?)-Eocene-Early Miocene aged sedimentary rocks.
4. Upper Miocene, Neotectonic Period, dominated by terrestrial clastics (Şengör, 1980; Şengör and Yılmaz, 1981).

The first and the oldest unit is Paleozoic in age and represented by metamorphics such as gneiss, micaschist, granite, marbles, crystalline limestones, and meta-volcanics. Savcı et al. (1979) and Perinçek (1980), argued that the upper levels of those metamophics could be Early Mesozoic in age. Second unit is represented by Upper Cretaceous ophiolithic mélange consisting of sandstone, tuff, limestone blocks, basic and ultrabasic rocks, that tectonically overlie the metamorphics. Şengör (1980) and Şengör et al.

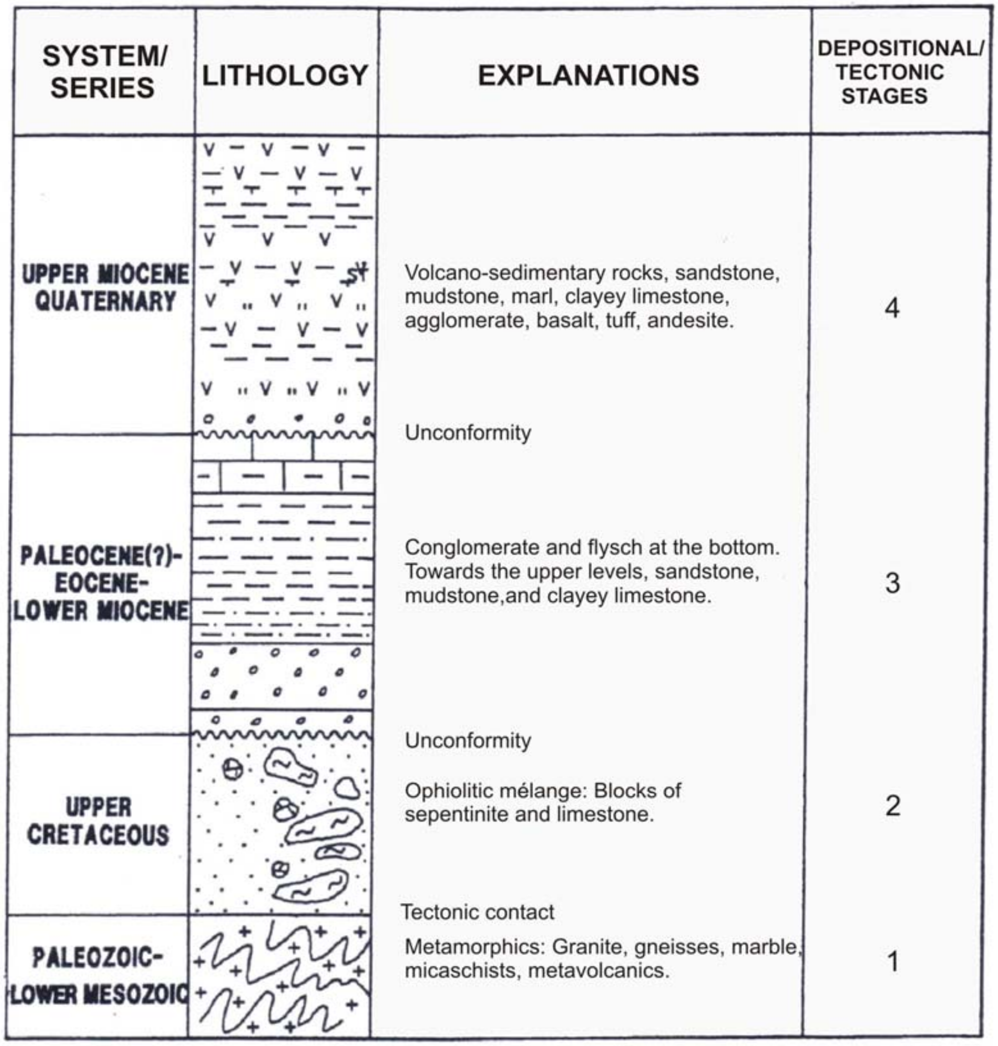



Figure 2. Depositional/tectonic stages in Eastern Anatolia basins (after Şaroğlu, 1985).

(1980) interpreted this unit as a product of the northern branch of the Neotethys. According to Şengör (1980), these two units correspond to the East Anatolian Accretionary Complex occurred by the elongation of Anatolid and Taurid.

In general, since Eastern Anatolian basins have been shaped following the Eocene tectonism (Yılmaz, 1993; Yılmaz et al., 1993), the rocks affected by the Eocene and/or older tectonism have been named as the basement consisting of the Jurassic-Upper Cretaceous mélange (known as Sakaltutan Complex), occurred during the closure of the Tethyan Ocean (Şengör and Yılmaz, 1981). Jurassic-Cretaceous sedimentary rocks of the Sakarya-Pontide plate (Şahintürk and Kasar, 1979; Şengör and Yılmaz, 1981; Şahintürk et al., 1997), thrusted over this mélange and Middle Eocene ophiolitic mélange (known as the Kağızman complex), believed to be a product of Eocene tectonism (Şengör, 1980; Şengör and Yılmaz, 1981; Şaroğlu, 1985; Şahintürk et al., 1997). Upper Eocene-Pliocene sedimentary and volcano-sedimentary lithologies overlie all these rock units.

Third unit is characterized by the complete sedimentary successions of Paleocene(?)-Eocene to Lower Miocene sedimentary rock units consisting of limestone, argillaceous limestone, sandstone, and siltstone. Those sedimentary rocks are shallowing-upward in character and unconformably overlie older units belonging to the first and the second periods. Compressional regime was active in this period related to the collision of Arabian and Laurasian plates. (Yılmaz, 1993). The region was uplifted due to the compressive tectonic regime after Late Eocene, converted to positive areas and eroded. It has been seen an intensive Eocene reworking in Oligo-Miocene sediments in this study. Sediments belonging to the third period started with the relatively deeper marine Eocene sediments with a limited extend followed by relatively shallower marine Oligocene sediments and completed by the quite shallow marine to reefal and wide-spread Lower Miocene sediments. According to Şaroğlu and Güner (1981), no major depositional break present in this period. However, the boundary between the Middle and Upper Eocene sediments could not be observed in the field. Since Upper Eocene sediments include pebbles derived from Middle Eocene sediments (Ünal, 1970), this boundary has been interpreted as unconformable by Şaroğlu and Güner (1981). They also suggested that the limited occurrence of marine Eocene sediments at the beginning of the third period could be related to either erosion or nondeposition. According to Şaroğlu and Güner (1981), a very thick succession of Oligocene sediments conformably overlies the Upper Eocene sediments and is conformably overlain by the Aquitanian and Burdigalian sediments. They also suggested that the boundary between Oligocene and Lower Miocene successions is not clear but should be somewhere between the clay-dominated parts and the limestone-dominated parts in the Hınıs-Muş-Van Basin. Burdigalian sediments are reefal limestones as they are in the Kelereşdere section and could be commonly seen in most of the regions in the Eastern Anatolia. According to Şaroğlu (1999), the sea regressed at the end of the Late Miocene and large lakes occupied wide areas in the region.

The last and the youngest unit consists of terrestrial sediments (sandstone, claystone, siltstone, and marl), volcanics (basalt, andesite, rhyolite, dasite, tuff and agglomerate) originated from N-S directioned extensional cracks (Şaroğlu et al., 1980) and associated tectonic events from Late Miocene to Recent. Sediments distinguished as the fourth unit unconformably overlie the third unit. The Eastern Anatolia was affected by an intense tectonic regime in the beginning of the Late Miocene (neotectonic period of Şengör, 1980). Şaroğlu (1999) suggested that the neotectonic period has started with a peneplane-like geomorphology on which deposition was taking place in shallow lakes and rivers in the Eastern Anatolia. Then, as a result of the extensive foldings, anticlines seen as ridges and synclines seen as basins have occurred. According to Şengör and Kidd (1979), the Eastern Anatolia became a high plateau similar to Tibet after the Late Miocene and the crust was thickened as a result of the collisional tectonism. However, recent geophysical investigation of the Eastern Anatolia revealed contrasting information with the Tibet-model of crustal thickening (Türkelli et al., 2003). Şengör (1980) and Şengör and Yılmaz (1981) argued that the westward escape of the Anatolian plate from the Karlıova triple junction has started in this period. Faulting system of this tectonic regime produced channel ways for alkaline-calc-alcaline volcanic activity (andesite, basalt, rhyolite, tuff, agglomerate) that covered whole basin in the Late Miocene-Pliocene. Upper Miocene-Pliocene volcanics can be used as index horizons in the correlation of subbasins. According to Şaroğlu and Güner (1981), volcanics of this period could be found as a nuclei in the anticlines while they separated synclines into two subbasins. For instance, Nemrut volcanics are believed to be responsible from the separation of Muş-Van Basin into two subbasins known as Muş and Van basins (Şaroğlu, 1999). Similarly, Etrüsk Mountain separated Çaldıran and Muradiye basins, and Göze and Zor mountains separated Kağızman-Tuzluca and Doğubeyazıt-Gürbulak and Iğdır basins.

In general, the fourth unit was represented dominantly by terrestrial clastics and synchronous volcanics. Intensive tectonism activated the strike-slip faults and converted basins into intermontane basins (Şaroğlu and Yılmaz, 1987) or complex pull-apart basins in the Pliocene (Şengör et al., 1985). Continuous tectonic activity and volcanic eruption centers formed higher topographies and, thus, separated Pasinler-Horasan and Tercan-Aşkale basins (İlhan, 1969). Terrestrial clastic deposition took place in the Late Pliocene.

Soytürk (1973) and Erdoğan and Soytürk (1974) also investigated the evolution of Eastern Anatolia basins. Soytürk (1973) studied in the Murat Basin. He suggested that, rudist limestones deposited in shallowing marine conditions in Late Cretaceous. Two main “tectono-environmental cycles” have been distinguished by Soytürk (1973); Middle Paleocene-Late Eocene cycle and Late Eocene-Early Miocene cycle. Middle Paleocene transgression, Late Paleocene regression, and Early-Middle Eocene transgression and their corresponding lithologies were dominating the region, respectively. He suggested that terrestrial deposition took place in the Late Eocene in this region. Oligocene transgression and continuous subsidence of the basin resulted very thick (more than 3000 m) sedimentary succession. Towards the end of the Oligocene, basin was shallowed, became a shallow platform (reefal limestone deposition), and even a lagoon (evaporite deposition) in the Early Miocene in the northern part between Alibonca and Aktuzla towns. Then, basin was uplifted and became a positive area and terrestrial conditions (mainly remnant-sea lakes and fresh water lakes) have dominated the region during the Middle-Late Miocene. This basin uplifted again at the end of the Late Miocene and extreme continental conditions took place. Pliocene volcanics were alternated with lacustrine sediments. The intensive volcanism and erosional phase dominated the conditions in Quaternary (Soytürk, 1973).

Erdoğan and Soytürk (1974) on the other hand, studied in the Tekman Basin, located on the northern part of Murat Basin. They suggested that, different than the Murat Basin, the first transgression took place in the Middle Eocene and resulted relatively shallower depositional conditions in the Tekman Basin. Similar to Soytürk (1973), they also reported an uplifting event at the end of the Middle Eocene, then, an erosional phase, a terrestrial deposition in the Late Eocene, and the Oligocene transgression. The transgression continued in the Early Miocene and the sea level rise over the boundaring basement rocks of the basin caused a connection with the neighbouring basins where common and extensive reefal accumulations took place whereas deposition similar to Oligocene occurred in the deeper parts of the Tekman Basin due to the subsidence. Basin kept deepening in the Middle Miocene but was uplifted at the end of the Middle Miocene, the sea withdrew, and brackish to fresh water environments were dominated the region, respectively in the Late Miocene accompanied by intensive volcanism. The region was uplifted and sedimentation continued in fresh water lakes in the Pliocene. Later, similar to the Murat Basin, intensive volcanism and erosion were dominated the Quaternary.

## 2.2. Stratigraphy

General stratigraphic settings of the Eastern Anatolia sub-basins and general lithostratigraphical properties of the studied stratigraphic sections in these basins will be mentioned in this part briefly.  A total of ten stratigraphic sections have been investigated in this study (Figure 3).

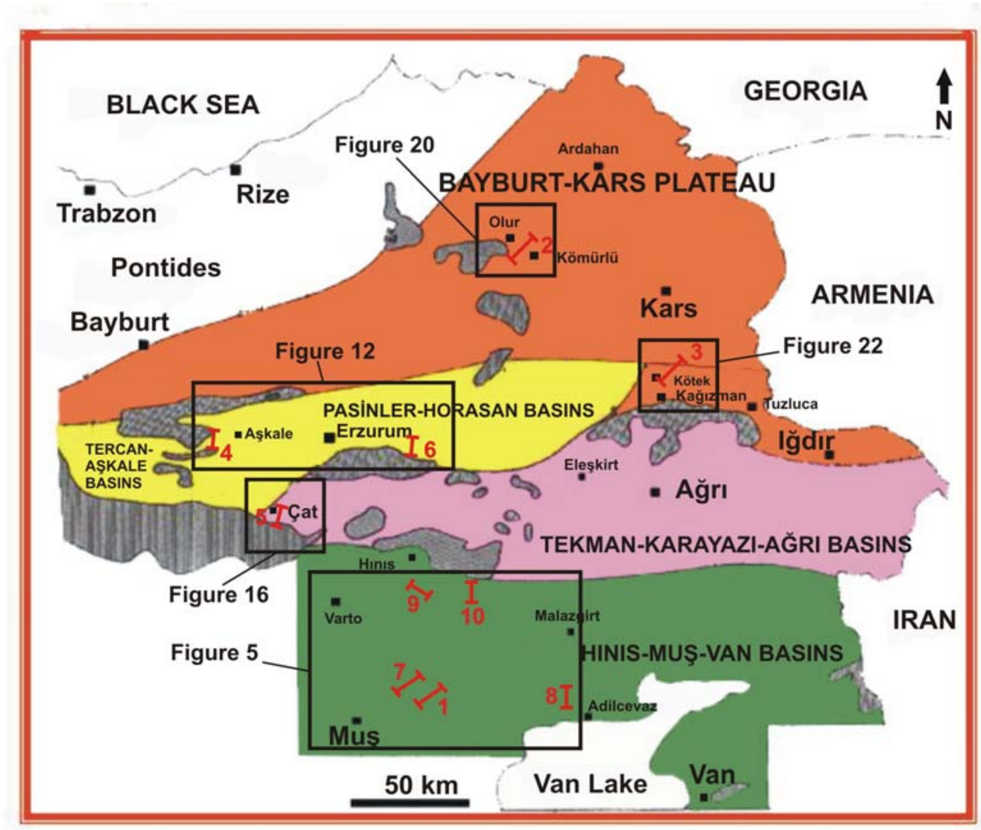



Figure 3. Locations of the studied stratigraphic sections in this study, 1. Kelereşdere; 2. Kömürlü; 3. Kötek; 4. Kükürtlü; 5. Çirişlitepe; 6. Pisyanlı-Çamlıca; 7. Ebulbahar; 8. Ahlat; 9. Ağgelin; 10. Zırnak; Grey and shaded areas represent ophiolites (modified from Şahintürk et al., 1998b).

### 2.2.1. Hınıs-Muş-Van Basin

Hınıs-Muş-Van Basin is defined as a intermontane basin which is 80 km long, 20 km wide (Şaroğlu and Güner, 1981), and is located in the northern part of Bitlis metamorphics and the eastern part of North Anatolian Fault zone and comprises Hınıs, Varto, Malazgirt, and Bulanık towns around the city of Muş (Figure 1). In general, this basin consists of Upper Cretaceous ophiolitic mélange as a basement, Middle Eocene to Lower Miocene marine sedimentary rocks, and Upper Miocene to Recent terrestrial sedimentary rocks associated with intensive volcanism (Figure 4).

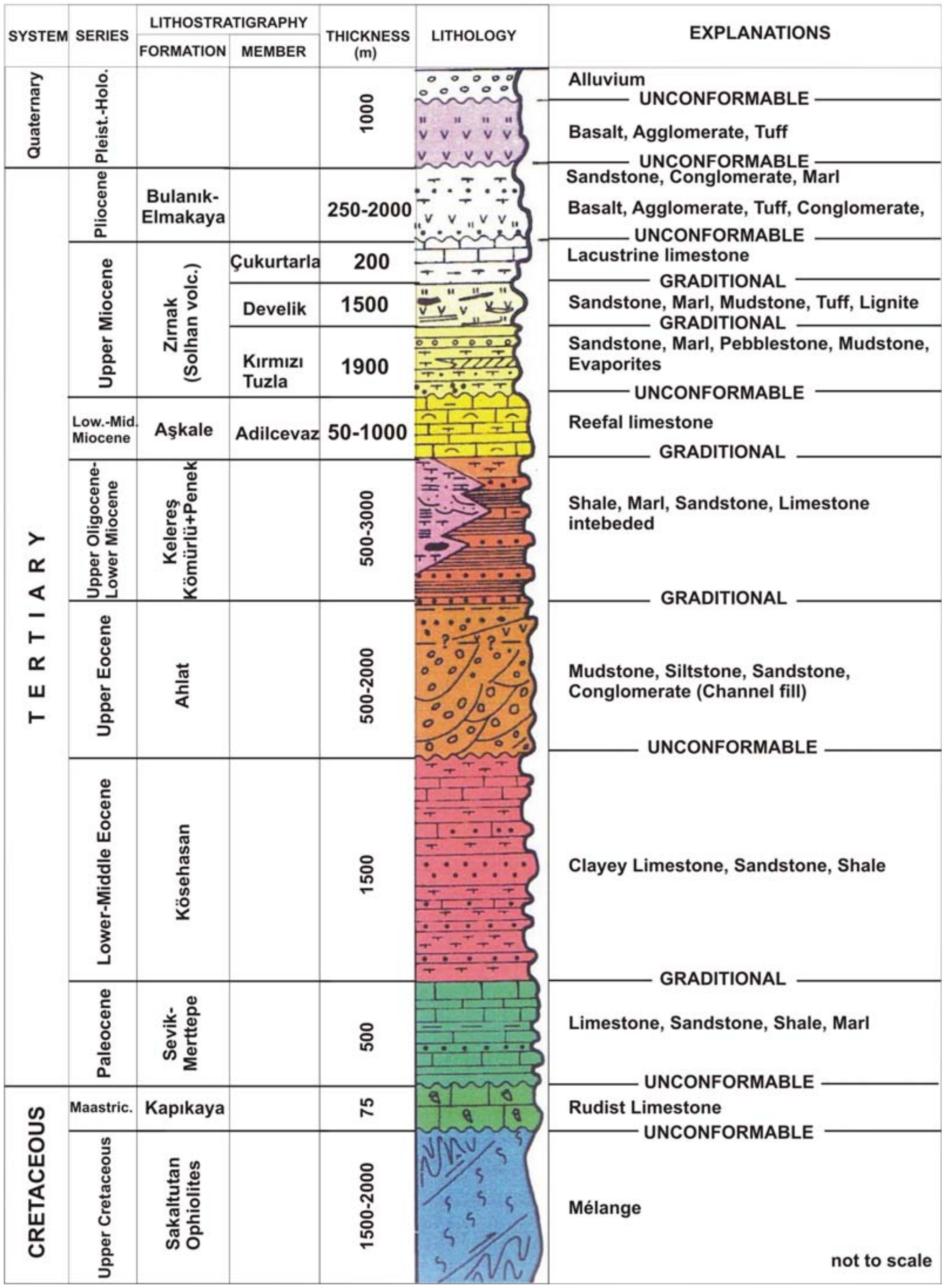



Figure 4. Generalized stratigraphic section of Muş Basin (Şahintürk and Erdem, 2002 modified after Soytürk, 1973).

The Sakaltutan Ophiolithic Complex are unconformably overlain by limestones with rudists known as the Kapıkaya Formation of Maastrichtian age (the oldest rocks outcropping in the area). The Kapıkaya Formation is unconformably overlain by the Paleocene Sevşik-Merttepe formations which includes mostly limestones, shales, marls, and sandstones. The Merttepe Formation is conformably overlain by clayey limestones, shale and sandstones belonging to Lower-Middle Eocene Kösehasan Formation. Upper Eocene to Lower Miocene sedimentary package including Ahlat, Kelereş, and Aşkale formations unconformably overlies the older sucsessions and are unconformable overlain by the Upper Miocene-Pliocene Zırnak Formation. These sediments are the main interest of this study and five sections have been measured and sampled in the Hınıs-Muş-Van Basin (Figure 5) from this interval.

Kelereşdere section is located in the northeastern part of Muş (Figures 3 and 5). The Ahlat Formation, Late Eocene in age, is located at the bottom of the section and is characterized by reddish, well-sorted, thick-bedded sandstones, siltstones and conglomerates at the bottom and greenish to yellow silty marls and sandtones at the top. Conglomerates include pebbles derived from different sources such as volcanics, ophiolites, metamorphics, and limestones. It has a tectonic contact (reverse fault) with the underlying Middle-Upper Miocene Zırnak Formation. The Ahlat Formation is unconformably overlain by the Upper Oligocene-Lower Miocene sandstone-marl intercalations and some bioclastic reefal limestones, which are known as the Yazla (Kelereş) Formation. The Yazla (Kelereş) Formation, shallow marine in nature, is represented by a very thick sedimentary succession. It was dominated by greenish to gray, fine to medium-grained sandstone and claystone layers at the bottom and sandstone-marl alternations towards the top. This unit has been measured as 3250 m in this study in the type locality Kelereşdere Valley (Figure 6). This thickness reaches up to 4250 m in the Ebulbahar Valley. Towards the northern part of the Muş Basin, the Yazla (Kelereş) Formation passes into more transitional and terrestrial deposits characterized by deltaic sandstones, clayey

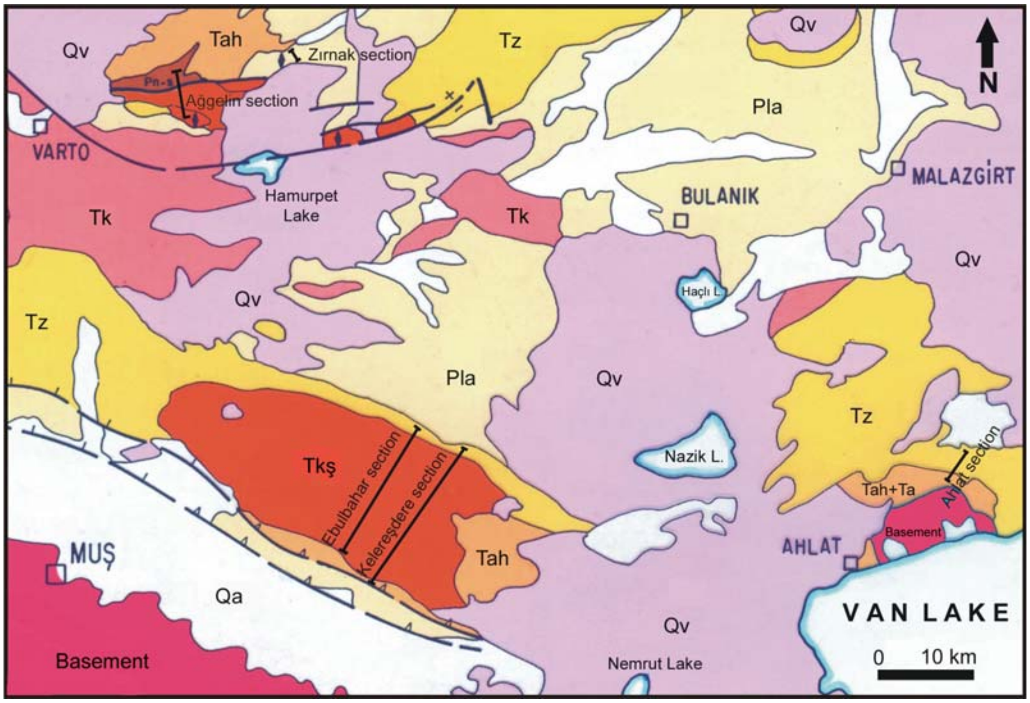



Figure 5. Geological map of the Hınıs-Muş-Van Basin and the location of the Kelereşdere, Ebulbahar, Ağgelin, Zırnak, and Ahlat sections, Qa: Alluvium; Qv: Volcanis; Pla: Aras Formation; Tz: Zırnak Formation: Tk: Zırnak Formation, Karakurt Member; Ta: Aşkale Formation: Tkş: Kelereş Formation; Tah: Ahlat Formation; Pn-s; Sevik Formation, (from Şahintürk and Erdem, 2002 modified after Soytürk, 1973).

limestones, siltstones, laminated shales and coal interbeds known as Kömürlü and Penek formations. The Lower-Middle Miocene Aşkale Formation, represented by arenitic-lithic limestones, shales, marls, sandstones, gypsums, conformably overlies the Yazla (Kelereş) Formation. The Adilcevaz member of the Aşkale Formation is characterized by reefal limestones which are Burdigalian in age (Demirtaşlı and Pisoni, 1965). The Aşkale Formation is unconformably overlain by sedimentary, volcano-sedimentary rocks of Upper Miocene-Pliocene Zırnak Formation. Volcanic rocks known as Karakurt-Solhan volcanics have been occasionally seen horizantally and vertically transitional to the Zırnak Formation. Dominant

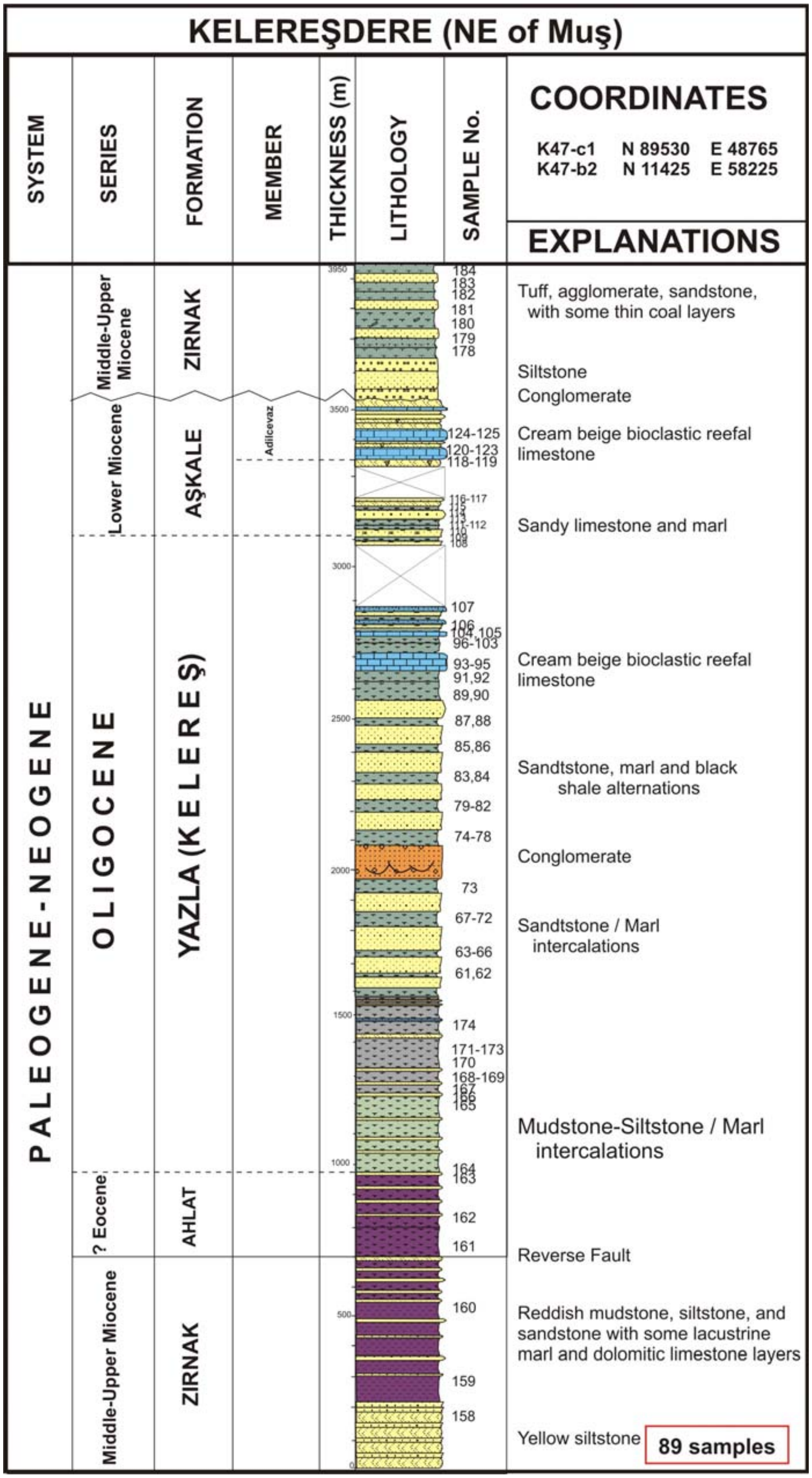



Figure 6. The Kelereşdere stratigraphic section and sample locations.

lithologies of the Zırnak Formation are tuff, agglomerates, sandstones, mudstones, marls, lacustrine carbonates, and evaporites.

Ebulbahar section is located in the northeastern part of Muş (Figures 3 and 5). There are conglomerates at the bottom of the section followed by a very thick sucsession of rhytmic greenish to dark gray marl and yellowish to gray sandstone alternations (Figure 7). Towards the top of the section, thicknesses of the sandstone and marl layers increase and some limestone interbeds seem to be dominated. Yellowish to light brown clayey limestones and yellowish siltstones of the Aşkale Formation conformably overlie the Yazla (Kelereş) Formation. Yellowish siltstones, sandstones, and beige to light-yellow tuffs of the Zırnak Formation unconformably overlie the older units.

Ağgelin section is located in the southern part of Hınıs (Figures 3 and 5). Gray to green marls and gray to reddish siltstones belonging to the Penek Formation are seen at the bottom of the section (Figure 8). The Kömürlü Formation conformably overlies the Penek Formation and composed of gray to green and black, marls, moderate to badly-sorted, macro fosilliferous and lime-cemented sandstones with abundant cracks. The top of the Kömürlü Formation is represented by a tectonic contact (reverse fault) and this unit is unconformably ovarlain by the clayey limestones, sandstones, and marls of the Sevik, Merttepe, and Kösehasan formations.

Zırnak section is located in the northwestern part of Malazgirt (Figures 3 and 5). Zırnak Formation has been sampled at this section. It consists of greenish marls, tuff, and reddish to gray siltstones at the bottom. Some thin coal layers, yellowish sandstone and siltstone alternations seem to be dominated at the top. Lacustrine, macro fosilliferous clayey limestones of the İncesu Member of the Zırnak Formation are seen at the uppermost part of the section (Figure 9).

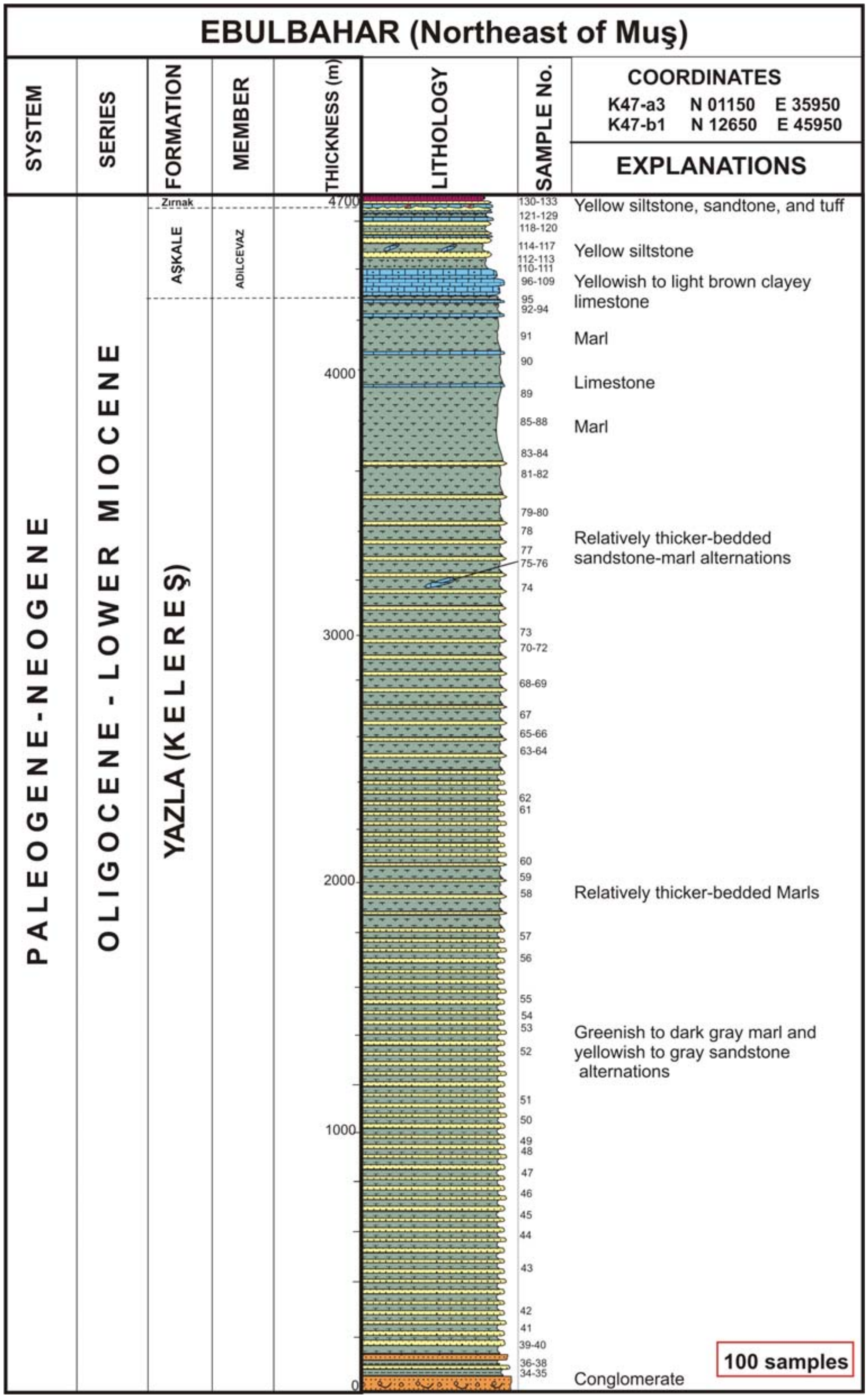



Figure 7. The Ebulbahar stratigraphic section and sample locations.

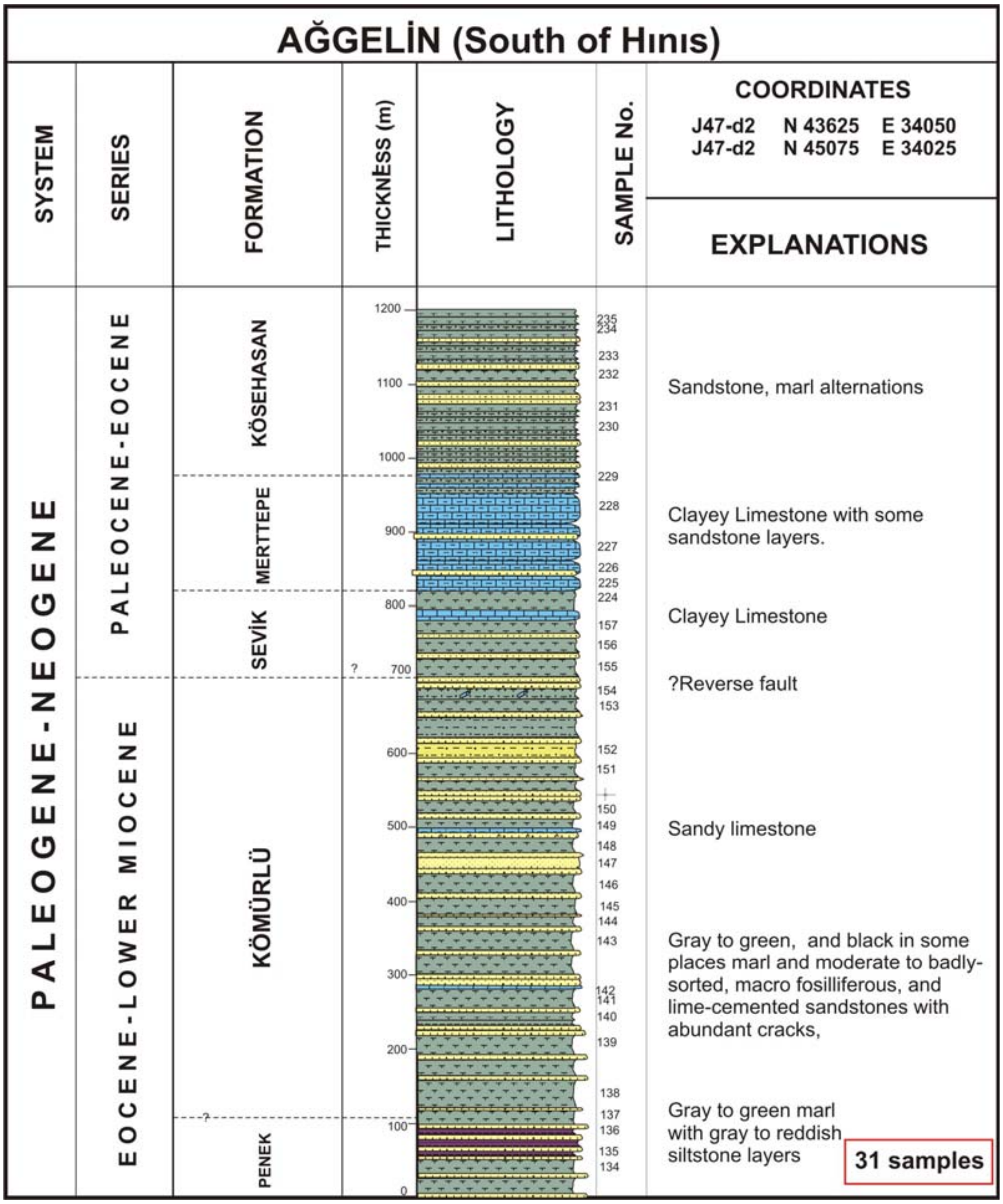



Figure 8. The Ağgelin stratigraphic section and sample locations.

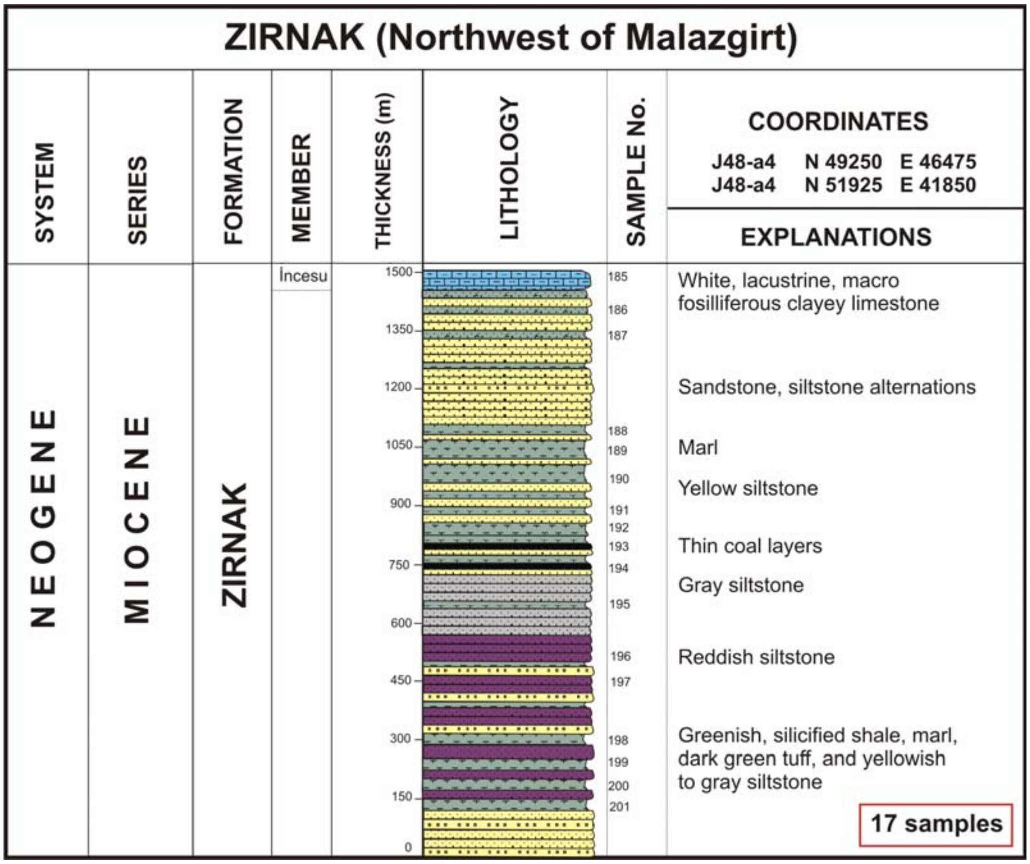



Figure 9. The Zırnak stratigraphic section and sample locations.

Ahlat section is located in the northwestern part of Adilcevaz (Figures 3 and 5). The Ahlat Formation composed of reddish, badly-sorted siltstones, sandstones, and conglomerates at the bottom and green to reddish silty marls towards the top and is seen at the bottom of the section (Figure 10). This unit is unconformably overlain by the clayey limestones, and cream to beige bioclastic limestones of the Aşkale Formation. Light cream tuff, reddish siltstones and marls of the Zırnak Formation are seen at the uppermost part of the section and unconformably overlie the older unit.

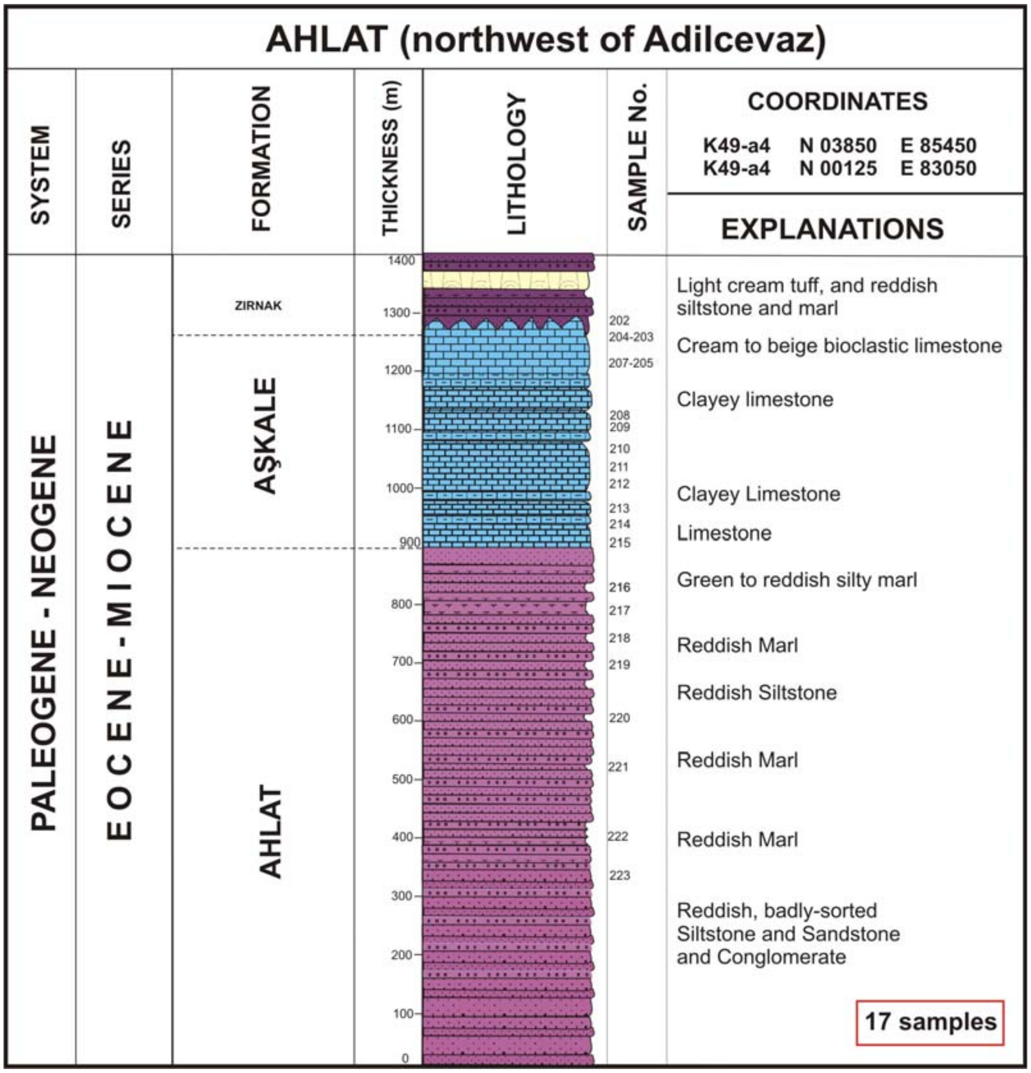



Figure 10. The Ahlat stratigraphic section and sample locations.

2.2.2. Pasinler-Horasan and Tercan-Aşkale Basins

The Pasinler-Horasan Tertiary Basin is located in the east of Erzurum with a E-W long axis and comprises Pasinler and Horasan towns (Figure 3). The Middle Eocene Kağızman Complex, is believed to be a product of the Eocene tectonism and observed as a basement in this basin (Figure 11) (Şahintürk and Kasar, 1979). It is unconformably overlain by Upper Eocene volcano-sedimentary rocks known as Bulkasım and Narman

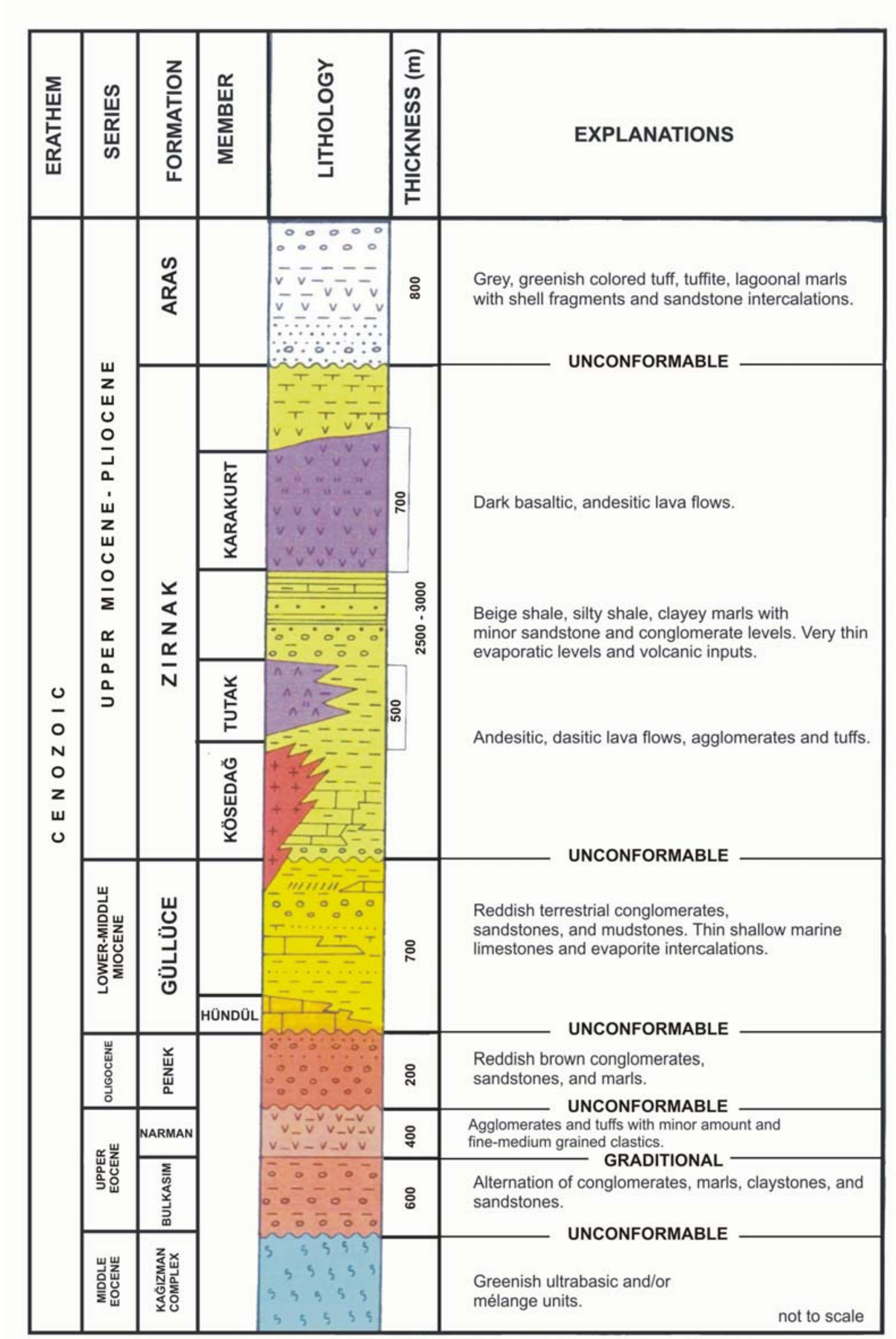



Figure 11. Generalized section of the Pasinler-Horasan Basin (modified from Şahintürk et al., 1998b).

Formations, and was first defined by Sungurlu (1971). The Bulkasım Formation corresponding to the Ahlat Formation in the Hınıs-Muş-Van Basin and the Aktaş Conglomerate in the Adilcevaz Region (Demirtaşlı and Pisoni, 1965), was distinguished at the bottom of this volcano-sedimentary succession by the sedimentary rock-dominant nature and includes pebbles derived from the Kağızman Complex, conglomerates, and sandstones. According to Şahintürk and Kasar (1979), Bulkasım Formation is about 600 m thick, shallow marine in character and gradational to the overlying Narman Formation. This unit is about 400 m thick and mostly composed of volcanic rocks such as agglomerate, tuff, and lava and rarely siliciclastic lithologies of claystone and marl (Şahintürk and Kasar, 1979). The Penek Formation, first defined by Sungurlu (1971) unconformably overlies Bulkasım and Narman formations and is mostly composed of conglomerates, sandstones, and marls. The Penek Formation, corresponding to lower levels of Soytürk (1973)'s Gümüşali Formation, Sakınç (1982)'s Kelereş Formation, Özyeğin (1968)'s Ebulbahar Formation in the Muş-Hınıs-Van basins and Bozkuş (1993)'s Çayarası Formation in the Pasinler-Horasan Basin, was deposited in shallow marine conditions and believed to be Oligocene in age based on its stratigraphic position (Sungurlu, 1971; Şahintürk and Kasar, 1979; Tekin et al., 2000). This unit is about 200 m thick and mostly composed of reddish, badly-sorted, conglomerates, sandstones, and marls (Şahintürk and Kasar, 1979). The Güllüce Formation consists of reddish conglomerates, sandstones, and claystones with some gypsum layers and unconformably overlies Eocene and Oligocene sediments, and even rocks belonging to the basement in places. This unit was first defined by Sungurlu (1972) and reported as Early-Middle Miocene in age. Şahintürk and Kasar (1979) and Üngör (1992) also suggested the same age for this unit but Demirer et al. (1996) and Uğur (2000) argued that the age of the Güllüce Formation might be Late Miocene. Early-Middle Miocene reefal limestones observed in this unit was identified as the Hündül Limestone Member by Sungurlu (1972). In general, the Güllüce Formation is about 700 m thick and represents shallow marine depositional conditions (Şahintürk and Kasar, 1979). The Zırnak

Formation, first defined by İlker (1967) and corresponding to the Horasan Formation of Rathur (1966) and unconformably overlies the older sediments. This unit is mainly composed of clastic lithologies such as conglomerates, sandstones, silty shale, shale, marls, carbonates such as dolomites and dolomitic limestones and some syn-sedimentary volcanics such as basalt, andesite, tuff and tuffites. The Zırnak Formation is about 2500-3000 m thick and represents terrestrial, lacustrine, and transitional depositional conditions (Şahintürk and Kasar, 1980). Although the age of the unit was reported as Pliocene by İlker (1967), its age was estimated as Middle-Late Miocene by Soytürk (1973), Late Miocene-Pliocene by Erdoğan and Soytürk (1974), and Late Miocene by Demirer et al. (1996). Radiometric age datings obtained from the Karakurt Volcanics suggest Late Miocene-Pliocene for the unit (Ercan et al., 1990; Bigazzi et al., 1996; Keskin et al., 1998). The youngest unit of the Pasinler-Horasan Basin is the Aras Formation that unconformably overlies the Zırnak Formation. This unit was first defined by Sungurlu (1971) and it corresponds to upper levels of the Horasan Formation in the Pasinler Horasan Basin (Rathur, 1966), Soytürk (1973)'s Bulanık Formation in the Murat Basin, and Erdoğan and Soytürk (1974)'s Zırnak Formation in the Tekman Basin. The Aras Formation represents terrestrial depositional conditions and is mainly composed of claystones, marls, tuffs and tuffites. Because of their similar lithologies, it is not possible to distinguish Zırnak and Aras formations in many cases (Şahintürk, personal communication, 2005). The age of the unit was reported as Pliocene by Sungurlu (1971) and Demirer et al. (1996) based on its stratigraphic position.

Pisyalı-Çamlıca section, located in the southwestern part of Pasinler, has been studied in this basin (Figures 3 and 12). Kağızman Complex is seen as a basement in this basin and is unconformably overlain by conglomerates, black shales, limestones, marls, greenish to gray sandstones, and volcanics of the Narman Formation (Figure 13). Cream to beige, macro fosilliferous reefal limestones and marls of the Hündül Member of the Aşkale Formation unconformably overlie the Narman Formation and are unconformably overlained by the volcanics of the Zırnak Formation.

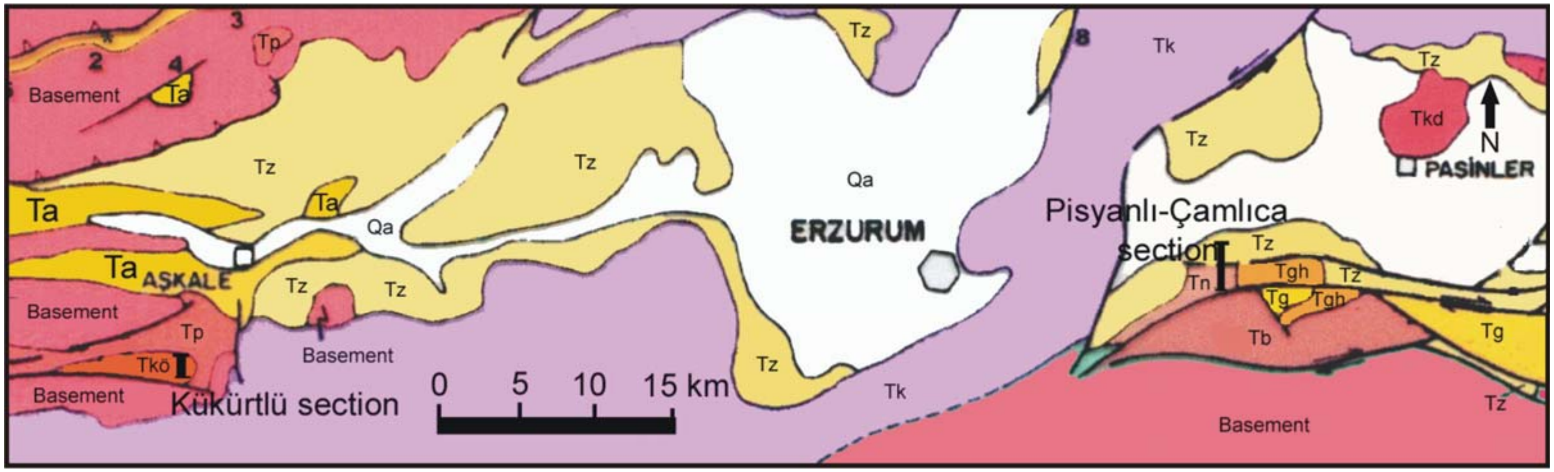



Figure 12. Geological map of the Pasinler-Horasan and Tercan-Aşkale Basins and the location of the Kükürtlü and Pisyalı-Çamlıca sections, Qa: Alluvium; Tz: Zırnak Formation: Tk: Zırnak Formation, Karakurt Member; Tkd: Kösedağ Dacite; Ta: Aşkale Formation: Tg: Güllüce Formation; Tgh: Hündül Limestone, Tkö: Kömürlü Formation; Tp: Penek Formation; Tn; Narman Formation, (modified from Şahintürk et al., 1998a).

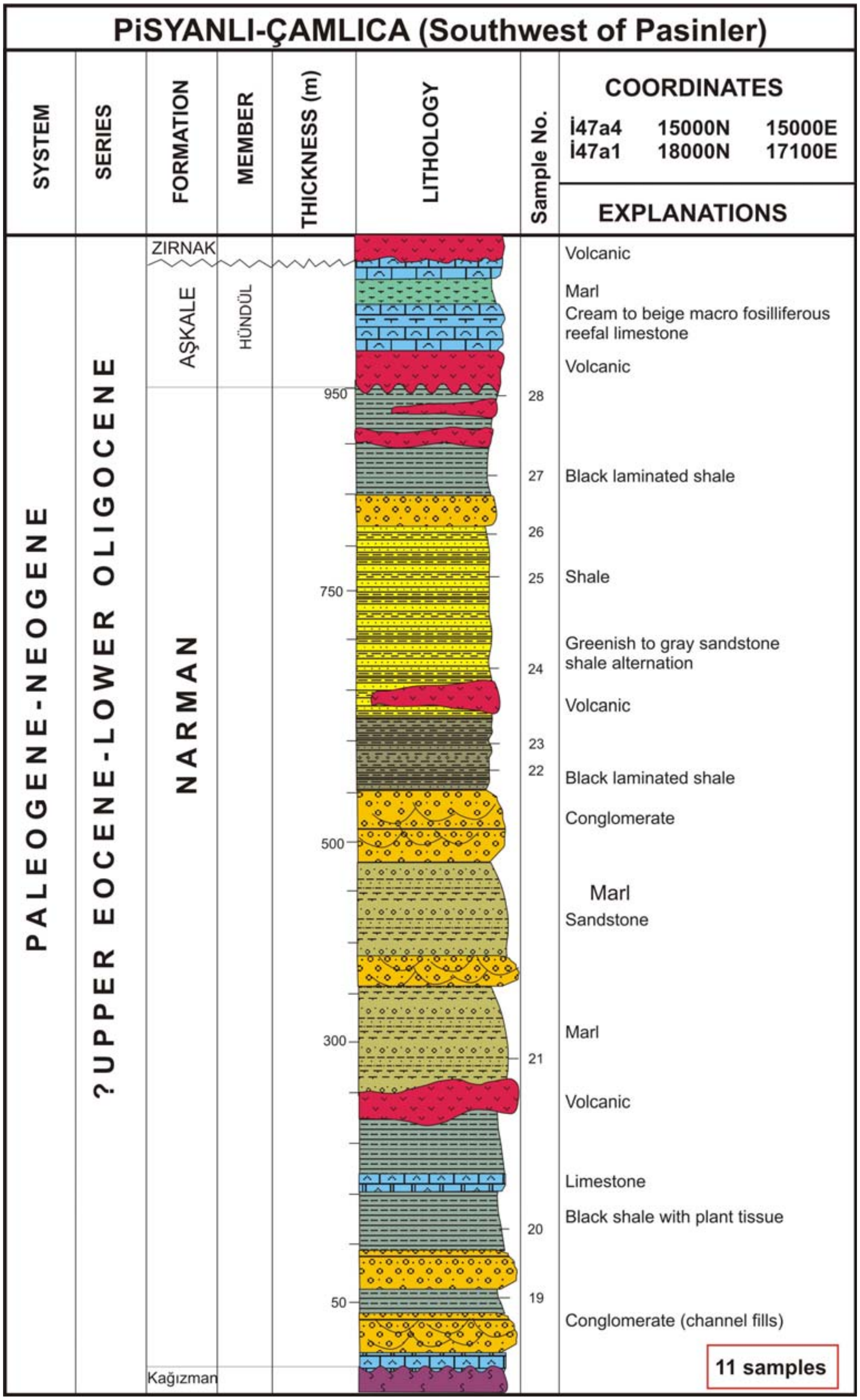



Figure 13. The Pisyanlı-Çamlıca stratigraphic section and sample locations.

The Tercan-Aşkale Basin comprises Tercan, Aşkale towns, and the eastern part of Erzurum (Figure 3 and 12). Jurassic-Cretaceous sedimentary rocks, Upper Cretaceous Sakaltutan Ophiolitic Complex and related metamorphic rocks such as serpentinite, peridodite, gabbro, radiolarite, and limestone blocks from different ages are encountered as basement rocks in this basin (Figure 14). Jurassic-Cretaceous basement rocks thrusted and, thus, bordered the Tertiary basins from the north and northwest (Şahintürk and Kasar, 1979; Şahintürk et al., 1997). The Penek Formation is about 1200 m thick, Late Oligocene to Early-(Middle?) Miocene in age, was deposited in terrestrial to shallow marine conditions, and unconformably overlies the basement (Figure 14) (Sungurlu, 1971; Şahintürk and Kasar, 1980; Tekin et al., 2000). This unit is mainly composed of reddish coloured clastic lithologies such as conglomerates, sandstones, and mudstones. Lithostratigraphic and chronostratigraphic equivalents of the Penek Formation in different studies have been listed above in the section of the Pasinler-Horasan Basin. The Penek Formation is gradational to the overlying Kömürlü Formation that is about 400 m thick and was first identified by Sungurlu (1971). Lithologies of these two formations seem to be interfingering in some places. The Kömürlü Formation is dominantly composed of dark brown to black laminated shales, bituminous clayey limestones, silty marls, fine-grained sandtones, and coal layers. This unit is very rich in organic matter and represents transitional depositional environments, changing from deltaic to terrestrial swamps. Similar to the Penek Formation, the age of the Kömürlü Formation ranges from Late Oligocene to Early-(Middle?) Miocene (Sungurlu, 1971; Şahintürk and Kasar, 1980; Tekin et al., 2000). The Aşkale Formation, first identified by Sungurlu, (1971) is gradational to the Kömürlü Formation towards the eastern part of the basin but it unconformably overlies the basement, Kömürlü and Penek formations at the western part of the basin. This unit is about 1000 m thick, mainly composed of marl, sandtone, reefal limestone, and gypsum, represents typically shallow marine depositional environments, and is Early Miocene in age (Şahintürk and Kasar, 1980). However, Tekin et

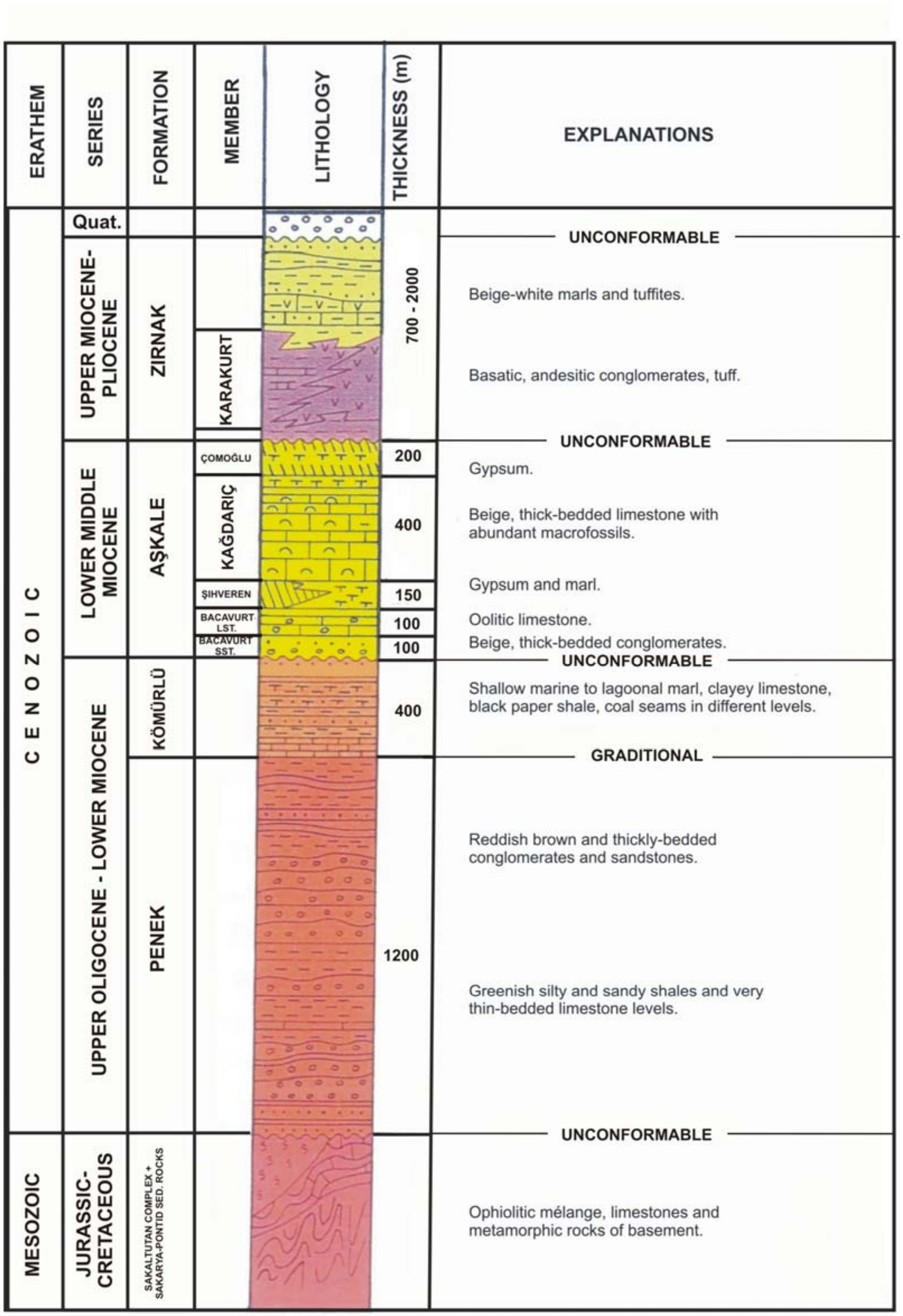



Figure 14. Generalized section of the Tercan-Aşkale Basin (modified from Şahintürk et al., 1998b).

al. (2000) suggested Middle Miocene as the youngest age of the unit and also Şahintürk (1992) suggested Early-Middle Miocene age. Şahintürk and Kasar (1980) have identified five different members interfingering both vertically and laterally in the Aşkale Formation. The Bacayurt Sandstone Member is about 100 m thick, deposited in shallow marine conditions, and mainly composed of conglomerates and sanstones. The Bacayurt Limestone Member is about 100 m thick, comformably overlying the Bacayurt Sandstone Member, Early Miocene in age, deposited in shallow marine conditions, and mainly composed of oolithic limestones. The Şıhveren Gypsum Member is about 150 m thick, comformably overlying the Bacayurt Limestone Member, mainly composed of gypsum with some marls and claystones, and reflecting regressive conditions. The Kağdariç Limestone Member is about 400 m thick, conformably overlies the Şıhveren Gypsum Member but it uncomformably overlies the basement to the south, Early-Middle Miocene in age (Tekin et al., 2000), deposited in shallow marine conditions, and mainly composed of reefal limestones. The Çomoğlu Gypsum Member is about 200 m thick, comformably overlies the Kağdariç Limestone Member, mainly composed of gypsum with some marls, and reflects reggressive conditions. Similar to the Pasinler-Horasan Basin, the Zırnak Formation unconformably overlies older sediments in the Tercan-Aşkale Basin. Based on radiometric age datings from the volcanics, this unit is Late Miocene-Pliocene in age (Ercan et al., 1990; Bigazzi et al., 1996; Keskin et al., 1998). Dominant lithologies are conglomerates, sandstones, claystones, marls, tuffs, and agglomerates known as the Karakurt Volcanics (Şahintürk and Kasar, 1980). The youngest unit of the basin is Plio-Quaternary sediments.

Kükürtlü and Çirişlitepe sections have been studied in this basin. Kükürtlü section is located in the western part of Aşkale (Figures 3 and 12). The Kömürlü Formation composed of grayish to green conglomerates and sandstones, clayey limestones at the bottom, and sandstone-shale intercalations, and organic-rich, laminated shales and marls towards the top (Figure 15). This unit is unconformably overlain by the tuff and volcanics of

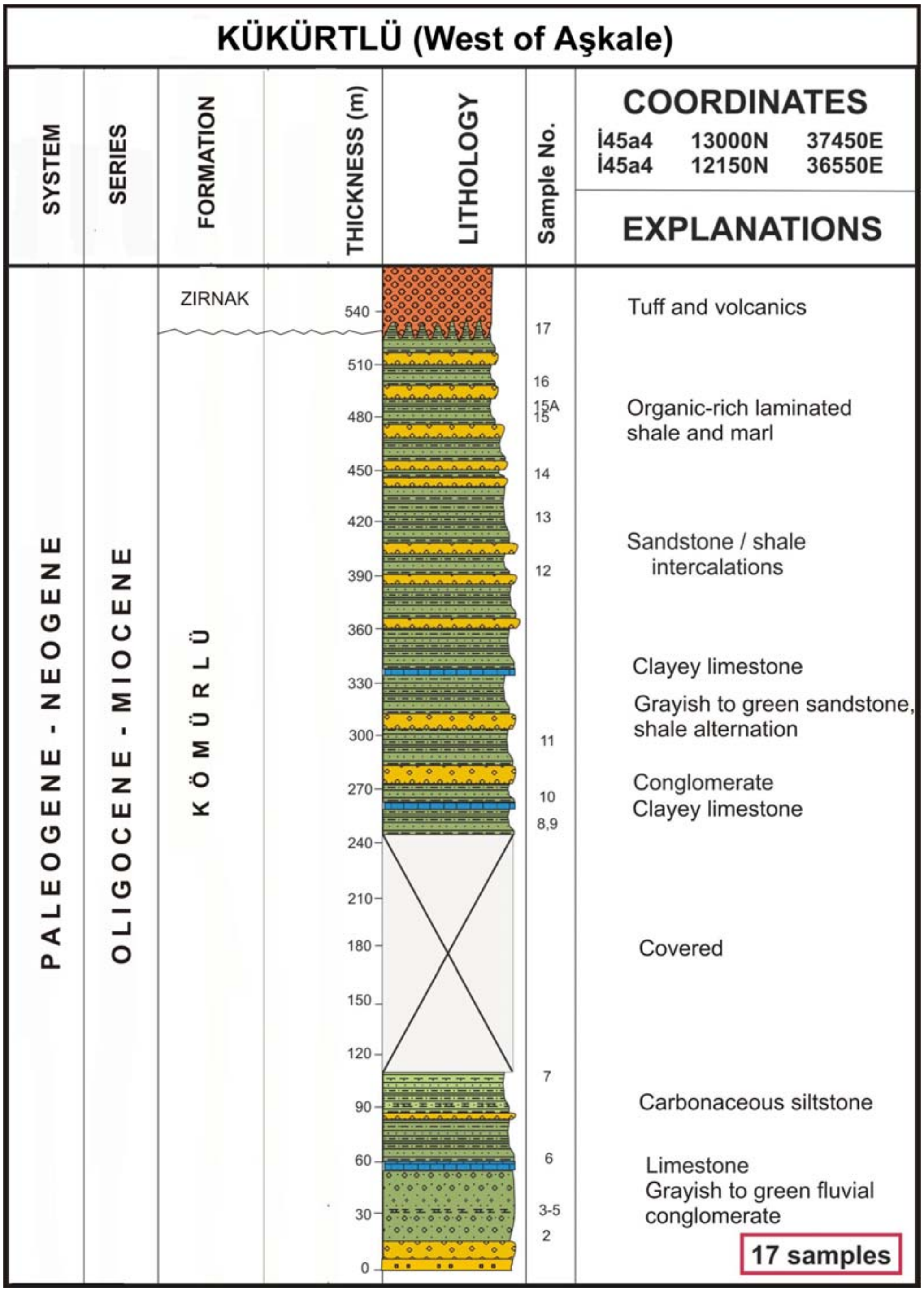



Figure 15. The Pisyanlı-Çamlıca stratigraphic section and sample locations.

the Zırnak Formation.

Çirişlitepe section is located in the southern part of Çat (Figures 3 and 16). Kağızman Complex are seen at the bottom of this section as basement. Nummulitic limestones known as Dündar Member of the Bulkasım Formation unconformably overlie the basement and are conformably overlain by the Kömürlü Formation. The Kömürlü Formation is consisted of marls, siltstones, and the channel deposits at the bottom (Figure 17), and greenish to gray

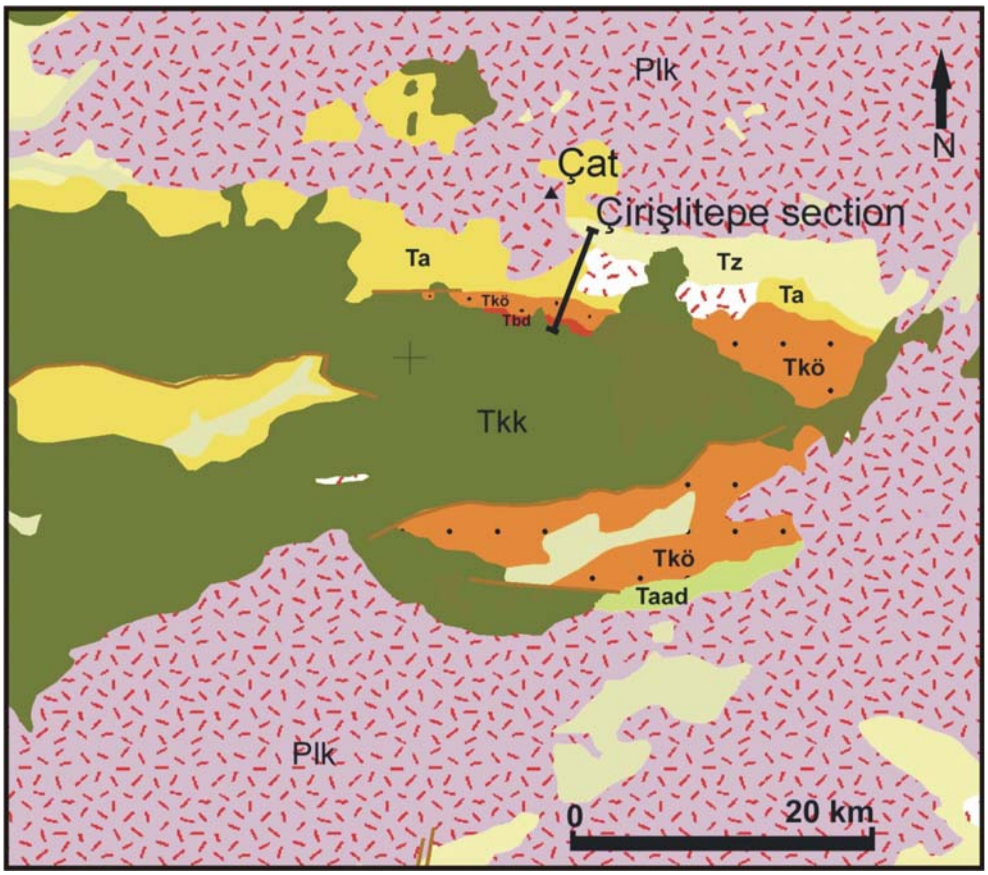



Figure 16. Geological map of the Çat area, Tz: Zırnak Formation; Plk: Zırnak Formation, Karakurt Member; Taad: Adilcevaz Limestone; Ta: Aşkale Formation; Tkö: Kömürlü Formation; Tbd: Bulkasım Formation, Dündar Member; Tkk: Kağızman Complex, (modified from geological map of Turkey, Erzurum quadrane, 1:500.000 series complied by Niyazi Tarhan, 2002).

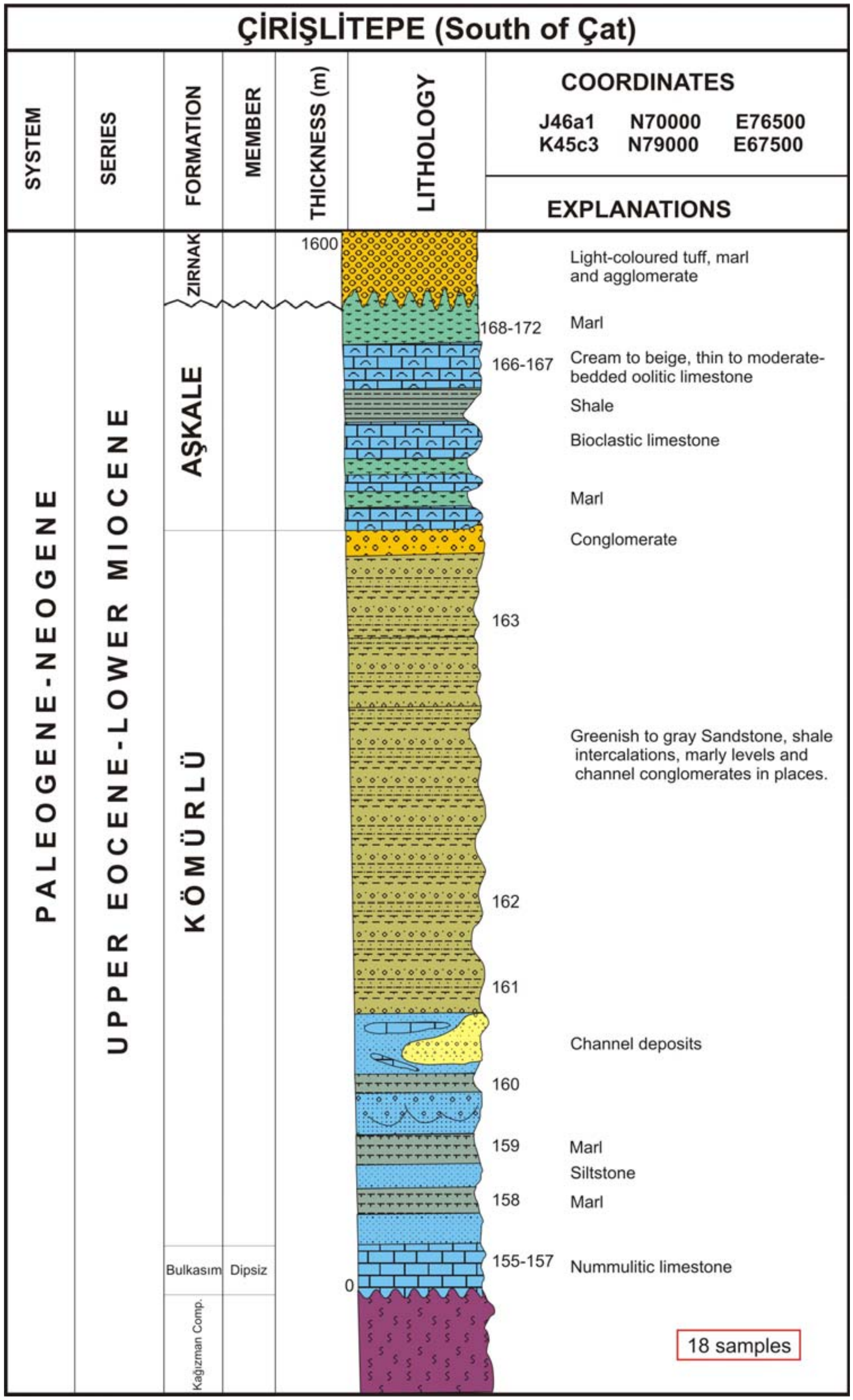



Figure 17. The Pisyanlı-Çamlıca stratigraphic section and sample locations.

sandstone and shale alternations towards the top. There is a conglomerate layer at the uppermost part of the Kömürlü Formation. This unit is conformably overlain by the Aşkale Formation which is represented by marls and bioclastic limestones at the bottom, shales, marls, and cream to beige, thin to moderate-bedded oolitic limestones at the top. Light gray tuff, agglomerates, and marls of the Zırnak Formation unconformably overlie the older units.

### 2.2.3. Bayburt-Kars Plateau (Kars-Tuzluca Basin)

The Bayburt-Kars Plateau comprises Ardahan, Olur, Kağızman, Tuzluca towns, and lies towards the Georgia and Armenia (Figure 3). Similar to the Tercan-Aşkale Basin, Jurassic-Cretaceous sedimentary rocks and metamorphic rocks are observed as a basement in this basin (Figure 18) (Şahintürk and Kasar, 1979; Şahintürk et al., 1998b; Uğur, 2000). The Penek Formation, Late Oligocene to Early-(Middle?) Miocene in age and deposited in terrestrial conditions, unconformably overlies the basement (Figure 18) (Şahintürk and Kasar, 1979; Uğur, 2000). This unit is mainly composed of reddish, and badly-sorted clastic lithologies such as conglomerates, sandtones, mudstones, blocks belonging to the basement, and some volcanic inputs such as agglomerates and tuffs. The Penek Formation is gradational to the overlying Oligo-Miocene Kömürlü Formation. The Kömürlü Formation is composed of conglomerates, sandstones, and shale intercalations at the bottom, grading into laminated shales, marls, and coal layers, and thin gypsum layers at the top. The Upper Miocene-Pliocene Zırnak Formation and Karakurt Volcanics unconformably overlie the Kömürlü Formation (Şahintürk and Kasar, 1979; Uğur, 2000). The Zırnak Formation is dominantly composed of clastic lithologies such as conglomerates, sandtones, siltstones, claystones, shales, marls, and coals. This unit yields producable salt beds in Tuzluca town and neighbouring regions. Karakurt Volcanics are extensively exposed in the Kars-Tuzluca Basin (Figure 19).

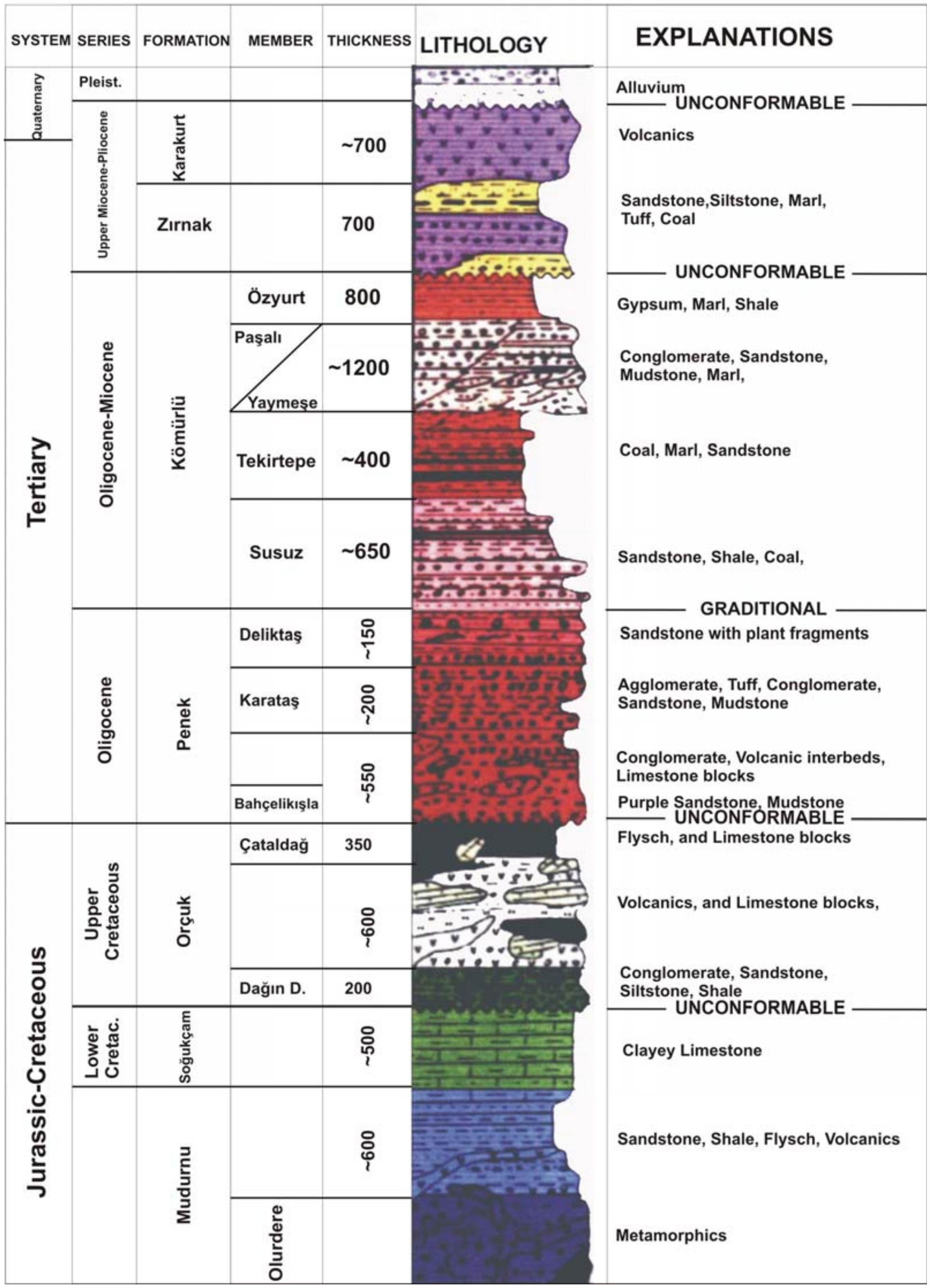



Figure 18. Generalized section of the Kars-Tuzluca Basin (Bayburt-Kars plateau) (modified from Uğur, 2000).

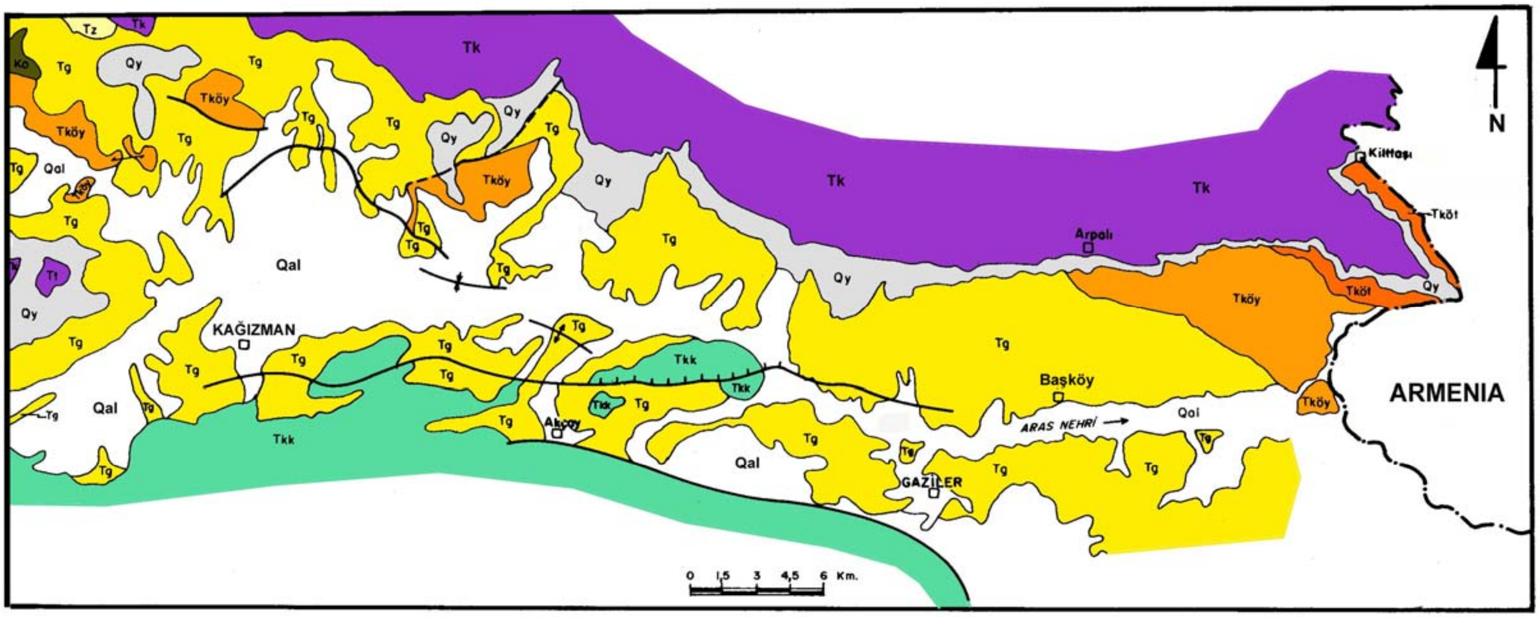



Figure 19. Geological map of the Bayburt-Kars Plateau (Kars-Tuzluca Basin), Qa: Alluvium; Tz: Zırnak Formation; Tkö: Kömürlü Formation; Tp: Penek Formation; Tkö: Kömürlü Formation; Tköt: Kömürlü Formation, Tekirtepe Member; Tköy: Kömürlü Formation, Yaymeşe Member; (from Uğur, 2000).

They cover almost all Tertiary sediments and lie towards the Georgia and Armenia (Figure 19). The youngest units of the basin are represented by the Pliocene Aras Formation, Mio-Quaternary volcanics, and Quaternary alluvials which unconformably overlie the older units (Şahintürk and Kasar, 1989).

Kömürlü and Kötek sections have been studied in this basin. Kömürlü section is located in the southeastern part of Olur (Figures 3 and 20). Conglomerates, sandstones, siltstones, marls, laminated shales, grayish to black paper shales, and coal layers are the dominant lithologies of the Kömürlü Formation (Figure 21). This unit is unconformably overlain by the tuffs and volcanics of the Zırnak Formation.

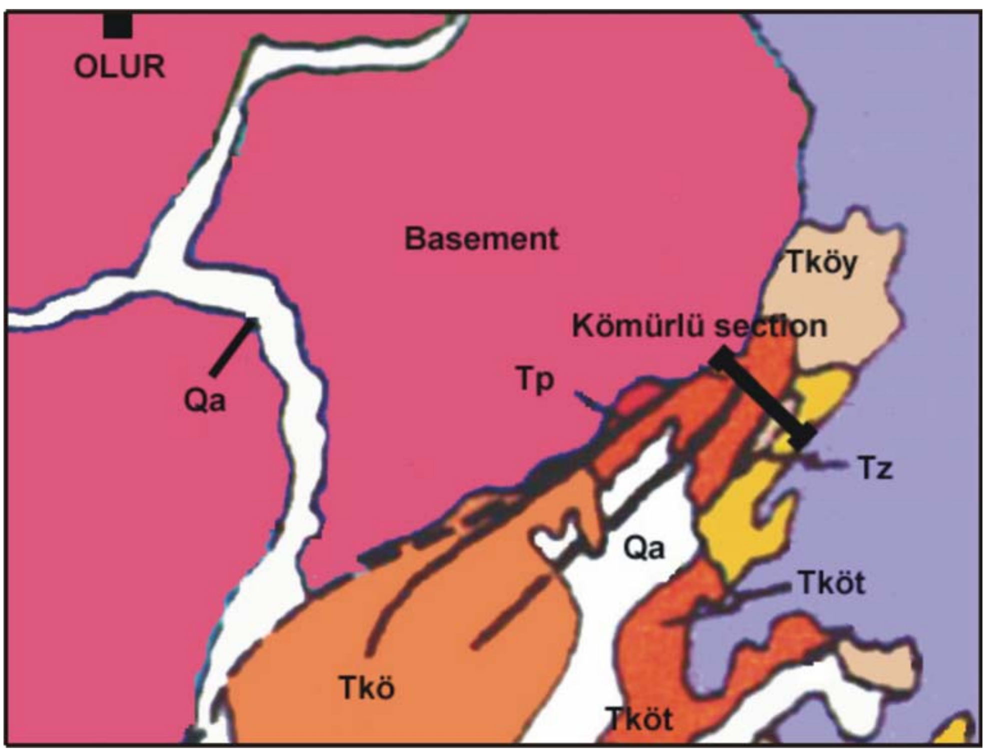



Figure 20. Geological map of the Olur region (Kars-Tuzluca Basin), Qa: Alluvium; Tz: Zırnak Formation; Tkö: Kömürlü Formation; Tp: Penek Formation; Tkö: Kömürlü Formation; Tköt: Kömürlü Formation, Tekirtepe Member; Tköy: Kömürlü Formation, Yaymeşe Member; (modified from Uğur, 2000).

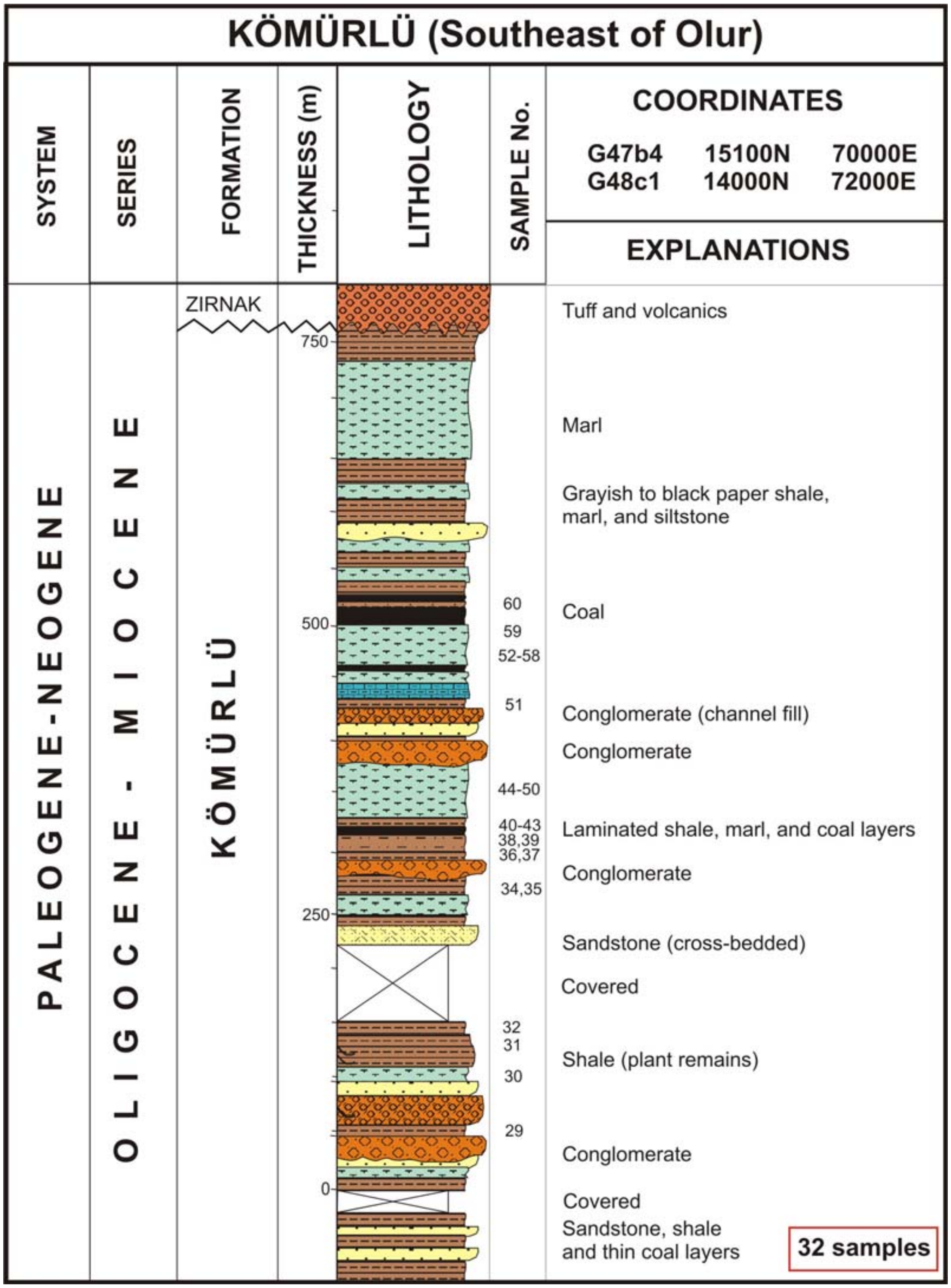



Figure 21. The Kömürlü stratigraphic section and sample locations.

Kötek section is located in northwestern part of Kağızman (Figures 3 and 22). Limestones of the Upper Cretaceous Orcuk Formation are unconformably overlain by the Kömürlü Formation which is mainly consisted of gray to green, moderate to well-sorted, thick-bedded, macro fosilliferous sandstones, black marls, laminated shales and thin coal layers (Figure 23). Reddish conglomerates and mudstones of the Güllüce Formation unconformably overlie the Kömürlü Formation. Tuffs of the Zırnak Formation are seen at the uppermost part of the section and unconformably overlie the older units.

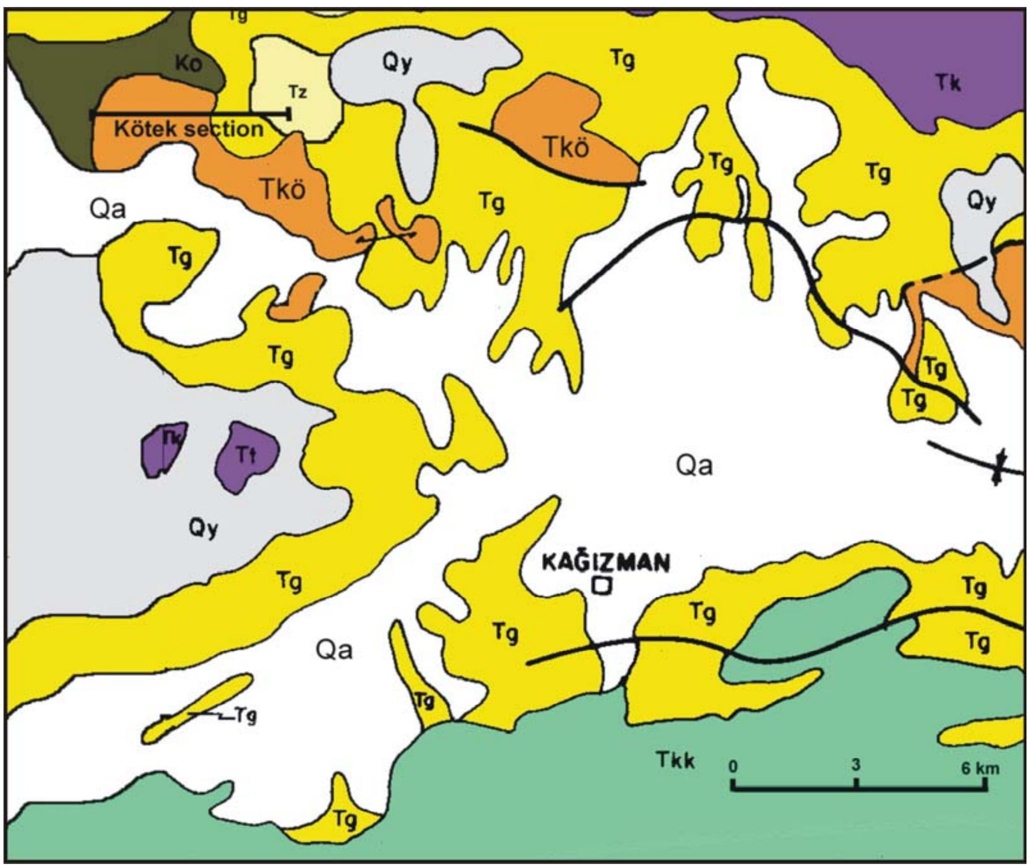



Figure 22. Geological map of the Kağızman region (Kars-Tuzluca Basin) (modified from Uğur, 2000).

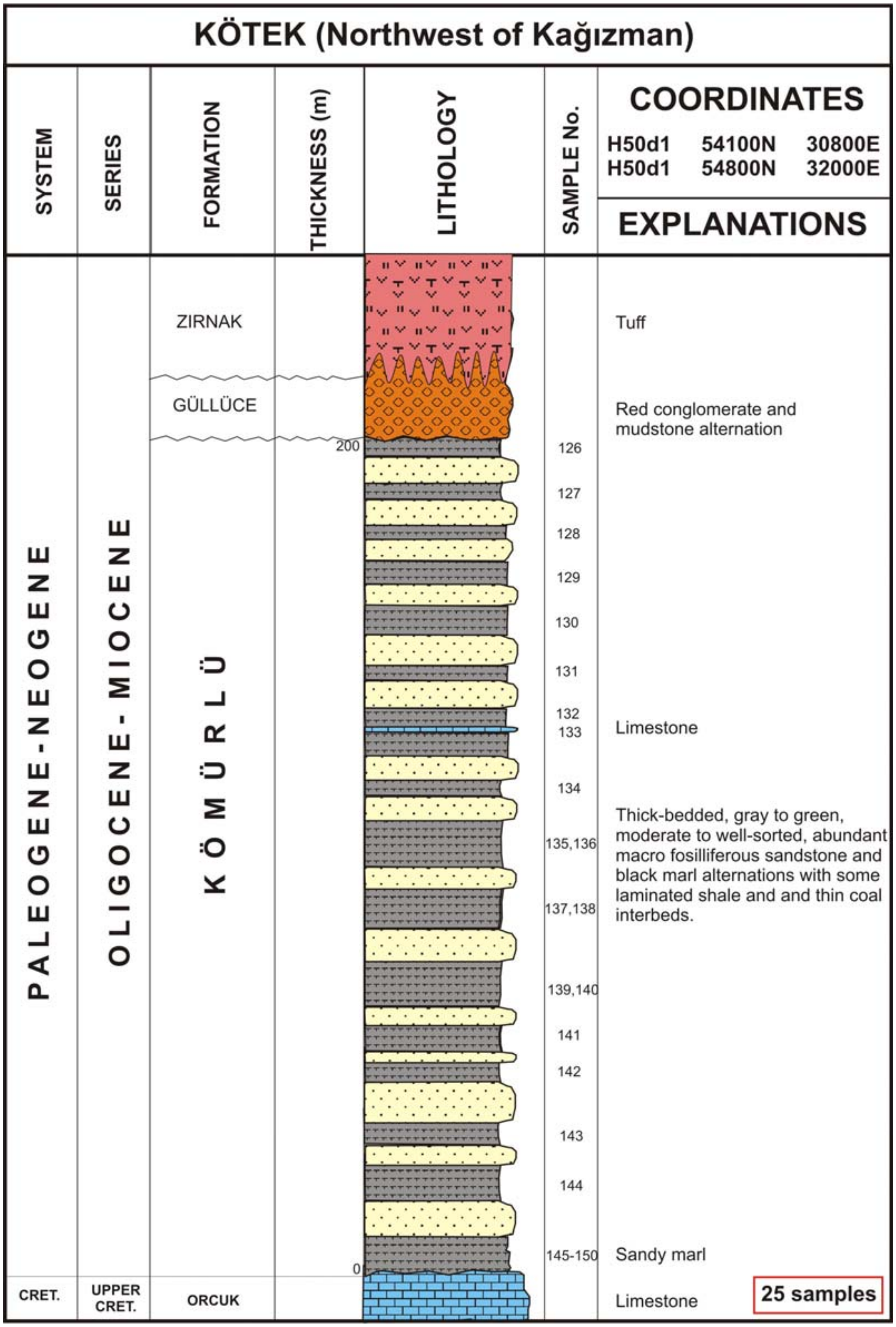


Figure 23. The Kötek stratigraphic section and sample locations.

# CHAPTER 3

# PALYNOLOGY

## 3.1. Introduction

Oligocene-Miocene sediments of the Eastern Anatolia have yielded diverse and abundant palynomorph groups belonging to different spore, pollen, fungal spore, dinoflagellate, acritarch, and fresh water algae. Palynological analyses have been carried out by means of biologic microscope but flourescent microscope has also been used to see morphological variations of the light-coloured palynomophs and to detect the percentages of the organic matter constituents in palynofacies analysis. Three sets of slides have been prepared for each sample and relative abundances of palynomorphs have been documented based on at least 200 grains. Most of the studied samples have moderate to well-preserved palynological assemblages. Bisaccate pollen (*Pityosporites* spp.) are predominantly occurring and seem consistently in all the studied samples with changing abundances of other spore-pollen and dinoflagellate taxa. As a result of their wind-blown nature by means of air sacs, occurrences of very high abundances in every section have been interpreted as to be overrepresented. Other most commonly occurring terrestrial palynomorphs are as follows; Pollen (Compositae, Umbelliferae, Gramineae, *Tricolpopollenites* spp., *Tricolporopollenites* spp., *Inaperturopollenites hiatus*, *Periporopollenites multiporatus*, *Polyporopollenites undulosus*, *Triatriopollenites* spp., *Slowakipollis hipophaeoides*, *Mediocolpopollis compactus*, *Lusatisporites perinatus*, and *Ephedripites* sp.) Spore (*Cingulatisporites* spp., *Saxosporis* sp., *Cicatricosisporites* sp., *Verrucatosporites* spp., and *Leiotriletes* spp.). *Pediastrum* spp., *Ovoidites parvus*, *Ovoidites ligneolus*, and *Botryococcus braunii* are the commonly occurring species of fresh water algae. As far as marine palynomorphs are concerned, species of *Spiniferites*, *Chiropteridium*, *Deflandrea*, *Wetzeliella*, *Thalassiphora*, *Homotryblium*, *Dapsilidinium*, *Cordosphaeridium*, and *Polysphaeridium* are the most abundant dinoflagellate taxa identified in the samples. As miscellaneous palynomorphs, chitinious foraminiferal linings, tasmanites, acritarchs, and some unidentified aquatic organisms have been recorded.

## 3.2. Material and Method

Ten stratigraphic sections (Kelereşdere, Kömürlü, Kötek, Kükürtlü, Çirişlitepe, Pisyanlı-Çamlıca, Ebulbahar, Ahlat, Ağgelin, and Zırnak) have been measured and sampled during the field study (Figure 3).

Measured sections are composed mainly of clastics (shales, marls, silty marls, sandstones, siltstones, claystones, and conglomerates) and interfingering with limestones, volcanics, volcano-sedimentary rocks and coal beds (see also Appendix C for the details of the sample lithologies). All analysed material have been stored in the Palynology Laboratory Archive of the Turkish Petroleum Corporation Research Center, Ankara. A total of 357 samples have been taken from the field. Distribution of the samples in different sections can be seen in Table 1.

Table1. Distribution of the samples collected from the field.

| Sections | Number of Samples |
|---|---|
| Kükürtlü section | 17 samples |
| Çamlıca-Pisyanlı section | 11 samples |
| Kömürlü section | 32 samples |
| Kelereşdere section | 89 samples |
| Kötek section | 25 samples |
| Çirişlitepe section | 18 samples |
| Ebulbahar section | 100 samples |
| Ağgelin section | 31 samples |
| Ahlat section | 17 samples |
| Zırnak section | 17 samples |

Relative abundances of the palynomorphs have been calculated based on at least 200 counts for each sample excepting the samples in which this procedure is not possible. If the samples do not yield enough palynomorphs, more than one slide have been investigated to obtain two hundred grains. Abbreviations used for different relative abundances seen in the Appendix B and corresponding number of counts are as follows:

Super Abundant (S): more than 100 specimens (% 50 or more).

Abundant (A): between 20-100 specimens (%10-50).

Common (C): between 6-20 specimens (%3-10).

Rare (R): between 2-6 specimens (% 1-3).

Present (P): only 1 specimen (% 0.5).

Percentages of the organic matter (kerogen) constituents (Appendix B) have been determined by visual examination according to Burges (1974) classification. In this classification, following groups can be distinguished:

1. Amorphous mass (structureless, disseminated, and translucent organic matter constituents).

2. Coaly particules (opaque, subangular to angular particules originated from coalified plants)

3. Woody particules (subangular to angular particules with an observable internal structure originated from plants)

4. Herbaceous particules (transparent plant debris, cellular structures of plants originated from cuticles, spore, pollen, fungal spore, fresh water algae, resin etc.)

Digital images of the palynomorphs, nannofossils, and foraminiferas have been taken by means of Leica DC200 digital camera system. Fossil distribution charts (biostratigraphic correlation diagram) and lithostratigraphic logs have been drawn by StrataBugs and Corel Draw softwares respectively.

### 3.3. Sample Processing

Standart palynological processing techniques suggested by Ediger (1984, 1986a, b) have been applied to all samples (Figures 22-23). Figure 24 illustrates the normal procedure for a sedimentary rock other than a coal whereas Figure 25 shows the process necessary for the oxidation of coaly materials. Ediger (1986a) indicated that the following four stages should be followed during the palynological sample processing. These are; Initial Processes, Demineralization, Maceration, and Final Processes.

#### 3.3.1. Initial Processes

Initial processes can be grouped into three main stages. First stage is the weighting of the samples. Depending on the lithology, the amount of the sample, necessary to get enough palynomorphs, varies. For instance, 5 g of sample is plenty for coals which is mostly very rich in organic matter and palynomorphs, whereas at least 10-20 g of sample for marls and shales, and 20-50 g of sample for relatively coarser grained lithologies such as siltstones and sandstones has to be processed (Traverse, 1988; Batı, 1996; Sancay, 2000). In the second stage, samples have to be crushed and pulverized in a

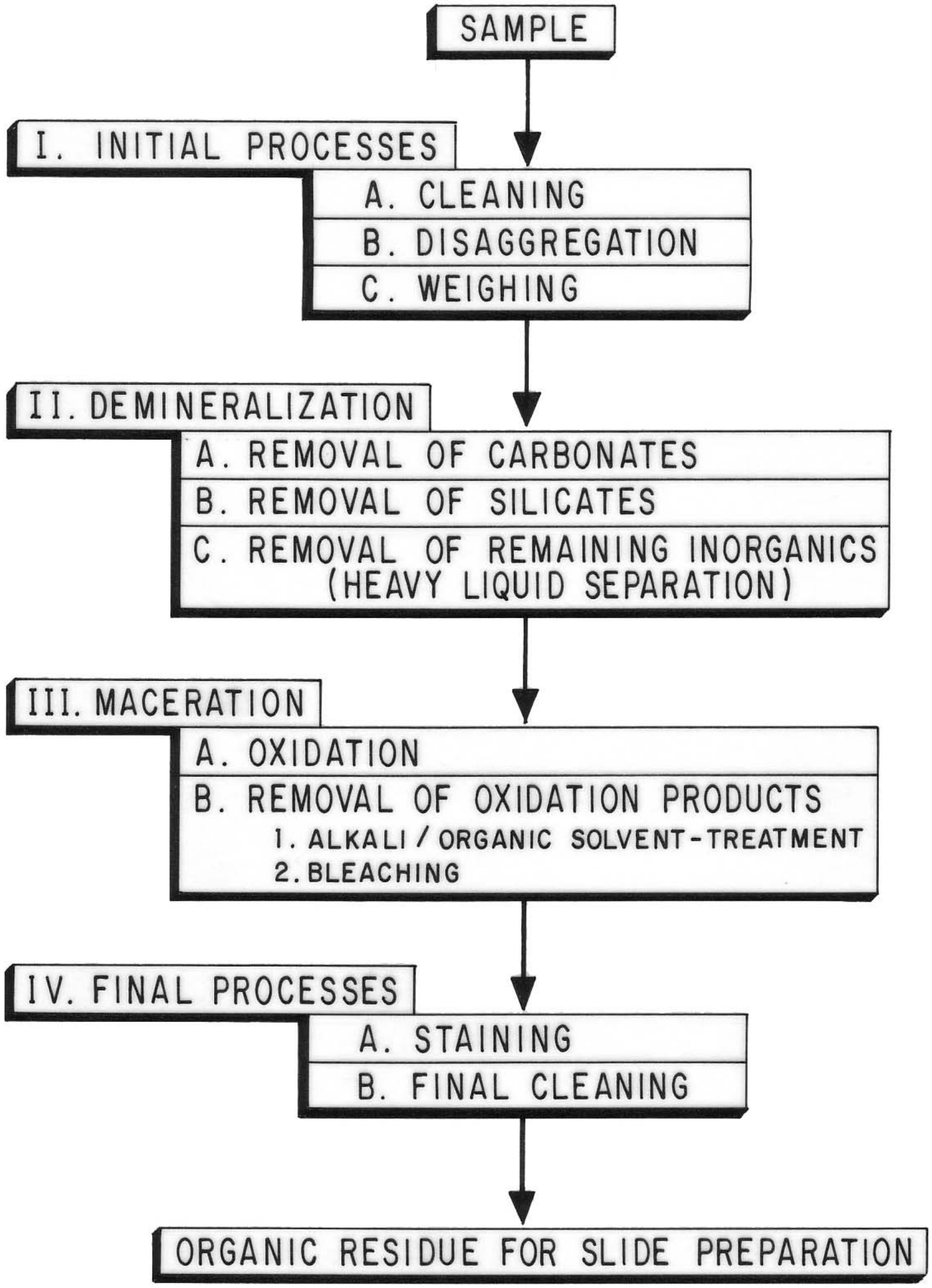



Figure 24. Palynological sample processing diagram (Ediger, 1986a).

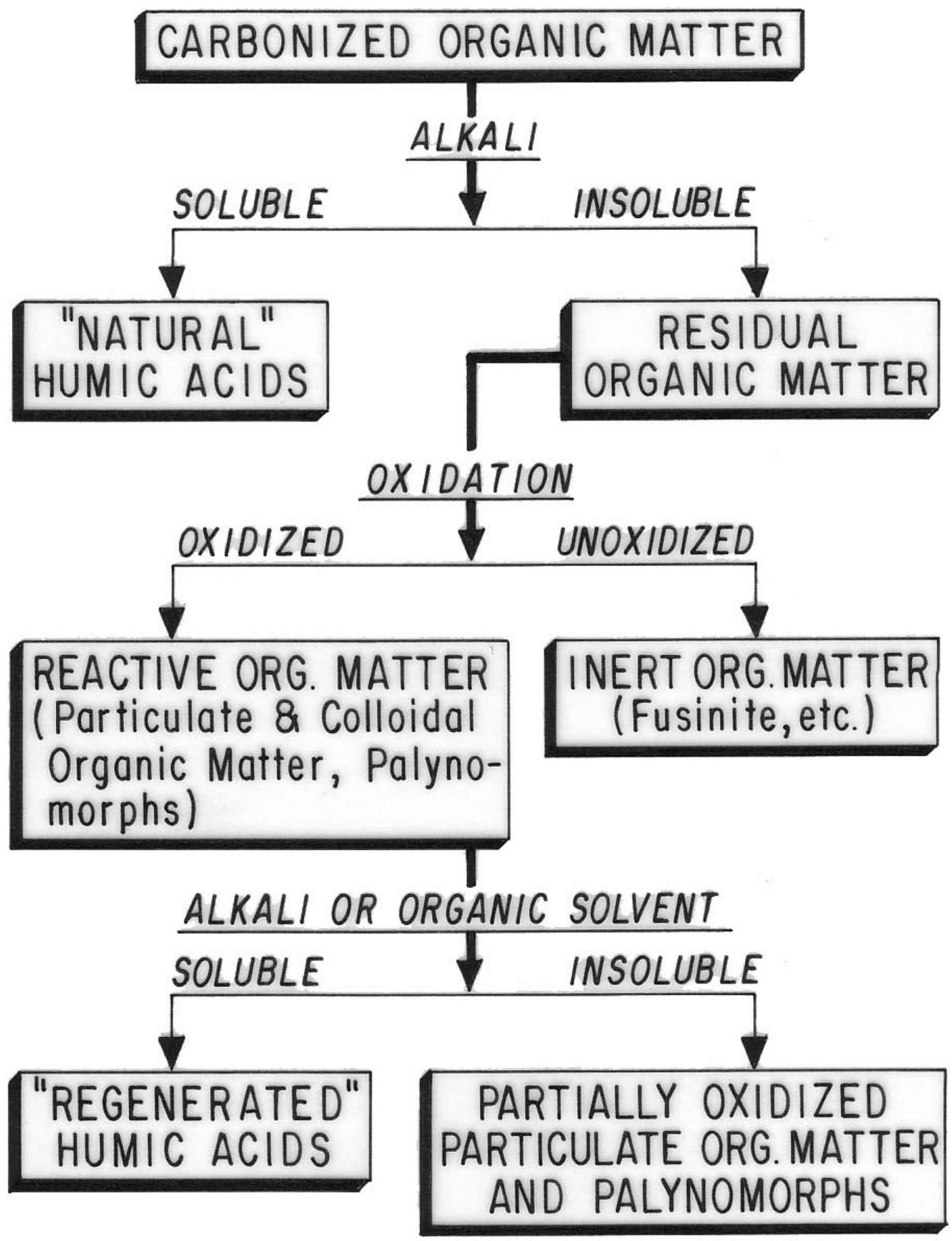



Figure 25. Oxidation and alkali or organic solvent-treatment of the carbonized organic matter (Ediger, 1986a).

hard-steel cup down to a size of < 1 mm for coals and < 2 mm for shales and marls (Batı, 1996) to increase the reaction rate of the sample during the acid treatments. Third stage is the cleaning of the samples. Especially for the cutting samples, drilling mud has to be removed from the samples by washing. Samples are taken to the 300 ml of plastic beakers, 150-200 ml of water is added, and stirred. After the grains are settled down at the bottom of the beaker, the suspended water is poured out. This process is called decantation and has to be repeated two or three times.

### 3.3.2. Demineralization

This stage is very important for the palynological sample preparation and performed to get rid of all the minerals such as carbonates and silicates within the sample. In order to remove carbonates, 50 ml of HCl (33 %) is added to the beakers. The HCl-added samples are stirred until the chemical reaction is completly over. Then, the samples are decanted for two or three times to remove the calcium compounds such as $CaCl_2$. In order to remove silicates, 30-40 ml of HF (40 %) is added to the beakers. Then the beakers are left on a hot (about $50^o$ C) and stirring plate for three hours. Similar to carbonate removing, after the chemical reaction is over, samples are decanted for two or three times. The sample is centrifuged (for two minutes and in 2500 rpm) in 50 ml of plastic tubes for three times. Then, in order to check whether the oxidation is necessary or not, some of the residue is taken on the slide with water and the color of the palynomorphs is examined under the microscope. The residue includes both organics (organic matter and palynomorphs) and heavy minerals. Therefore, heavy density separation has to be performed. Samples are taken to the 12 ml of glass tubes and filled up with $ZnCl_2$, which has a specific gravity of 2.1-2.2 g/$cm^3$, and centrifuged (this time for 7-8 minutes and again in 2500 rpm). After the centrifuging, the floating organic matter can be easily distinguished at the top of the glass tube. These organics are taken to another glass tube by pipette and filled up with water and centrifuged again two or three times to get rid of all the $ZnCl_2$ in the residue.

### 3.3.3. Maceration

As it has been mentioned above, if the color of the palynomophs are so dark, oxidation has to be applied to the samples to lighten the colors of the palynomorphs and to break up massive organic matter to release captured palynomorphs. Recent palynomorphs are mostly light yellow in color but they get darker as the maturity of the rock gets increased. In other words, as the rock gets burried, the palynomorphs loose their oxygen, become rich in carbon and, look much darker by time. Therefore, oxidation stage reversed those processes and makes palynomorphs to gain their lost oxygen back. Generally, nitric acid ($HNO_3$ 65 %) is used for marls and shales, and  Schulze solution (a mixture of 1 g of potassium chlorate ($KClO_3$) and 10-15 ml of nitric acid) is used for coals. 0.5-1 ml of water and 10-15 ml of nitric acid or Schulze solution are added to the organic residue and, then, the residue is immediately centrifuged. Hot bath may be helpfull for the high-ranked coals to increase the reaction time. After the oxidation, undesired oxidation products so called regenerated humic acids (Ediger, 1984) have to be removed. To do that, 15-20 seconds of KOH (5 %) or dilute $NH_4OH$ treatment is performed and, then the residue is washed by water and centrifuged.

### 3.3.4. Final Proccesses

This stage includes final cleaning. The organic residue is examined under the microscope, and if it still contains some undesired particules of 1-2 micron-size, alcohol is added to the organic residue in 12 ml glass tubes and centrifuged (for about 15-20 seconds in 1500 rpm). After the centrifuging, undesired particules will be seen as floating and palynomorphs will sink down. Floating particules are poured out and the residue is washed with water and put in a glass tube filled with water and 2-3 drops of alcohol. The residue is ready to be mounted for palynological preparations.

### 3.4. Palynological Preparation

Cellocise and elvacite are commonly used to prepare palynological slides. A drop of cellocise and about 4 ml of a mixture of organic residue and water are stirred at the center of a cover slip on a hot table (40-50 $^{o}$C). When the samples are dried on the hot table, they are inverted and mounted onto a 25x75 mm glass slide. 2-3 drops of elvacite are used as a mounting media and left for about 8 hours on the hot table.

### 3.5. Palynology

A total of 156 palynomorph species have been identified in this study composed of 43 pollen, 20 spores, 13 fungal spores, 70 dinoflagellates, 3 acritarchs, 2 organic-walled green algae, and 5 incertae sedis. Relative abundances of the palynomorphs have been calculated based on at least 200 counts. As a result of the detailed palynological analysis by means of biologic and flourescent microscopes, relative abundances of both terrestrial (spore, pollen, fungal spore, and fresh water algae) and marine (dinoflagellate) palynomorph groups and stratigraphically important palynological events have been documented and, thus, the age and depositional environment of the Oligocene-Miocene sediments in the Eastern Anatolia have been investigated. Digital images of the stratigraphically important selected taxa have been given in the plates in Appendix A and relative abundances of the identified palynomorph taxa can be seen in Appendix B.

#### 3.5.1. Taxonomy, Nomenclature and Classification

As it has been stated in Traverse (1988), taxonomy of the palynomorphs in the Cenozoic has been always problematic due to the scarsity of fossil angiosperms, different evolutionary rates of the various organs of angiosperms, and problems in precise identification. Therefore, using of only form-generic names of the palynomorphs have not been commonly preferred in most of the earlier studies (Traverse, 1988). However, if the identification of the palynomorph is absolutely positive, in this case its form-generic name has been used.

In this study, form-generic and morphological classification have been used together. Whenever a form-generic name can be assigned to a certain taxon, using form-genera is prefered to document the relationships between the fossil taxa and their nearest living relatives to some extend. In general, the code suggested by I.C.B.N. (1983) on names of plant taxa, fossil or extant have been followed in this study although some problems still exist in the application. As it was emphasized by Batı (1996), the taxonomic problems of Cenozoic palynomorphs have not been solved because an internationally accepted and unique classification for Cenozoic has not been proposed yet. Ediger (1986a) claimed that there is no other option rather than keeping the current system in nomenclature for easy communication since none of the already suggested solutions is able to solve the taxonomic problems in palynology.

Thomson and Pflug (1953) and C.C.D.L. (Corsin, Carette, Danze and Laveine) (1962) classifications have been used in most of the earlier palynological studies in Turkey (e.g. Akyol, 1964; Arslan, 1979; Alişan, 1981 and 1984; Akgün et al., 1986; Ediger, 1990; Akyol and Akgün, 1992; Akgün et al. 1995; Batı, 1996). They classified spore and pollen grains into two main groups as Gymnospermous (saccate and non-saccate) and angiospermous for pollen, and alet, monolete and trilete for spores. I have also followed the taxonomic classification suggested by Thomson and Pflug (1953) who divided spores and pollen in 2 main groups as Sporites and Pollenites. Potonié (1956), on the other hand, suggested a classification so called “Turmal System” for spores and pollen similar to military setting of Roman army in which the largest unit was the Anteturma, and the others are

Turma, Subturma and Infraturma in descending order corresponding to Class, Order, Family and Subfamily respectively.

Taxonomic classification of fungal spores is also very problematic. The classification suggested by Van der Hammen (1954a and b), Rouse (1959 and 1962), and Elsik (1968 and 1981) are most commonly used in the classification of fungal spores. I have also followed their classification in which all fungal spores are grouped as Sporae Dispersae. This taxonomic classification is based on morphological variations of the fungi such as shape, number of cells, and number of pores. In this study, as it was suggested by Batı (1996), fungal spores are divided into 3 main groups as follows: dispersed fungal spores, fruiting bodies, and fungal hyphae. Most of the fungal spores, which have no or little stratigraphic importance, have been grouped into “stratigraphically unimportant fungi” in this study.

Taxonomic classifications of Tappan (1980) and Bold et al. (1980) for the organic-walled green algae (*Pediastrum* sp. and *Botryococcus* sp.) and Lentin and Williams (1993), Fensome et al. (1993) for dinoflagellates have been followed in this sudy.

Since detailed descriptions of the all taxa have been reported by the authors who first identified them following the rules of I.C.B.N., (1983) detailed morphological descriptions of the taxa described in genus level will be mentioned here whereas only author names and publication years of the taxa described in species level will be given. However, variations seen in some of the palynomorph taxa such as Compositae, *Deflandrea*, and *Wetzeliella* have stratigraphic importance and they will be mentioned in detail.

### 3.5.2. Palynomorphs

Palynomorphs belonging to pollen, spores, fungal spores, organic-walled green algae, incertae sedis, acritarchs, and dinoflagellates have been identified in this study and will be mentioned below in this order.

3.5.2.1. Pollen

Pollen have been classified into 2 main groups as gymnospermous (gymnospermous saccate and gymnospermous non-saccate) and angiospermous pollen. The list of the identified pollen belonging to those groups are as follows:

Gymnospermous saccate pollen:

Genus: ***Pityosporites*** Seward, 1914

**Remarks:** This genus belonging to modern genus *Pinus* has been divided into “hypoxylon-group” and “diploxylon-group” by Rudolph (1935) but later indicated as *Abietineaepollenites microalatus* and *Pollenites labdacus* respectively by Potonié (1958). Then, Thomson and Pflug (1953) included them as form-genus *Pityosporites*. In the studied samples, the taxa belonging to *Pityosporites* are represented by 3 different species as *Pityosporites microalatus*, *Pityosporites libellus*, and *Pityosporites labdacus* but almost 95 % of the identified species are *Pityosporites microalatus*. Therefore, I prefer not to count them separately and evaulate them together as *Pityosporites* spp. as it can be seen in Appendix B.

Type species: ***Pityosporites antarcticus*** Seward, 1914

*Pityosporites microalatus* (Potonié, 1931a) Thomson and Pflug, 1953

(Plate 20, Figure 1)

**Dimension:** 80-100 microns.

*Pityosporites labdacus* (Potonie, 1931a) Thomson and Pflug, 1953

(Plate 22 , Figures 1, 2 )

**Dimension:** 70-90 microns.

*Pityosporites libellus* (Potonié, 1931a) Nakoman, 1966

(Plate 21, Figure 2)

**Dimension:** 80-100 microns.

Gymnospermous non-saccate pollen:

Genus: ***Inaperturopollenites*** Pflug and Thomson *in* Thomson and Pflug, 1953

Type species: ***Inaperturopollenites dubius*** (Potonié and Venitz, 1934) Pflug and Thomson *in* Thomson and Pflug, 1953

*Inaperturopollenites hiatus* (Potonié, 1931a) Pflug and Thomson *in* Thomson and Pflug, 1953

(Plate 21, Figures 3, 4)

**Dimension:** 30-40 microns.

*Inaperturopollenites dubius* (Potonié and Venitz, 1934) Pflug and Thomson *in* Thomson and Pflug, 1953

(Plate 22, Figures 4, 5)

**Dimension:** 25-30 microns.

*Inaperturopollenites polyformosus* (Thiergart, 1937) Pflug and Thomson *in* Thomson and Pflug, 1953

(Plate 22, Figure 6)

**Dimension:** 30-35 microns.

*Inaperturopollenites magnus* (Potonié, 1934) Pflug and Thomson, 1953 *in* Thomson and Pflug, 1953

(Plate 22, Figure 7)

**Dimension:** 80-90 microns.

Genus: ***Ephedripites*** (Bolkhovitana, 1953) Potonié, 1958a

Type species: ***Ephedripites mediolobatus*** (Bolkhovitina, 1953) Potonié, 1958a

*Ephedripites* sp.

(Plate 21, Figures 5-7)

**Description:** Pollen grain which is elongate-oval to broadly elliptical in shape. It has typically several longitudinal ribs run from one pole to another. Polar axis is always longer than the equatorial axis. It has two-layered wall and thin, slightly infrapunctate exine.

**Dimension:** 40-50 microns.

Angiospermous pollen:

Genus: ***Monocolpopollenites*** Pflug and Thomson, 1953

Type species: ***Monocolpopollenites tranquillus*** Pflug and Thomson, 1953

*Monocolpopollenites tranquillus* Pflug and Thomson, 1953

(Plate 22, Figure 8)

**Dimension:** 40-45 microns.

*Monocolpopollenites minus* Nakoman, 1966

(Plate 22, Figure 9)

**Dimension:** 25-30 microns.

Genus: ***Monoporopollenites*** Meyer, 1956

Type species: ***Monoporopollenites gramineoides*** Meyer, 1956

*Monoporopollenites gramineoides* Meyer, 1956

(Plate 23, Figures 2-4)

**Dimension:** 30-40 microns.

*Monoporopollenites* sp.

(Plate 26, Figure 1)

**Description:** Pollen grain which has smooth to scabrate ornemantation. It is thin walled and the pore is poorly defined without an anulus.

**Dimension:** 24 microns (1 specimen).

Family: Umbelliferae

(Plate 23, Figure 9; Plate 24, Figure 17-19)

**Description:** Small, dicolporate pollen grains. İt seems constricted in the middle with distinct colpi.

**Dimension:** 25-40 microns.

Genus: ***Sparganiaceaepollenites*** Theiergart, 1937

Type species: ***Sparganiaceaepollenites convexus*** Theiergart, 1937

*Sparganiaceaepollenites neogenicus* Krutzsch, 1970

(Plate 23, Figures 5-7)

**Dimension:** 25-35 microns.

Genus: ***Zonalapollenites*** Pflug in Thomson and Pflug, 1953

Type species: ***Zonalapollenites igniculus*** (Potonie, 1931a) Pocock, 1968

*Tsugapollenites* sp.

(Plate 23, Figure 1)

**Description:** It has circular to oval circular body surrounded by a narrow blade equatorially.

**Dimensions:** 85-100 microns.

Genus: ***Dicolpopollis*** Pflanz, 1956

Type species: ***Dicolpopollis kockeli*** Pflanz,1956

*Dicolpopollis kalewensis* (Potonié, 1960a) emend. Ediger et al., 1990

(Plate 21, Figure 8)

**Dimensions:** 25-30 microns.

*Dicolpopollis* sp.

(Plate 23, Figure 8)

**Description:** Disulcate pollen grain which is irregularly elliptical to trapezoidal in shape. It has triangular amb with pointed apices. The exine is almost hyaline to infragranulate to infrapunctate and composed of short collumellae with a tectum. It has two sulci subparallel to each other in equatorial view.

**Dimensions:** Equatorial diameter is 20-24 microns.

Genus: ***Triatriopollenites*** Pflug *in* Thomson and Pflug, 1953

Type species: ***Triatriopollenites rurensis*** Pflug and Thomson *in* Thomson and Pflug, 1953

*Triatriopollenites excelsus* Pflug *in* Thomson and Pflug, 1953

(Plate 21, Figure 10)

**Dimensions:** 20-24 microns.

Genus: ***Momipites*** Wodehouse, 1933

Type species: *Momipites coryloides* Wodehouse, 1933

*Momipites* sp.

(Plate 22, Figure 10)

**Description:** Triporate pollen grain which is triangular to subtriangular in shape. It has three, simple, small, and usually circular pores located equatorially on the corners without an annulus. It has smooth or finely scabrate to punctate ornamentation on the surface.

**Dimensions:** 20-24 microns.

Genus: ***Corsinipollenites*** Nakoman, 1965

Type species: ***Corsinipollenites oculus noctis*** (Thiergart, 1940) Nakoman, 1965

*Corsinipollenites oculus noctis* Nakoman, 1965

(Plate 21, Figures 13, 14)

**Dimensions:** 35-55 microns.

Genus: ***Subtriporopollenites*** Pflug and Thomson *in* Thomson and Pflug, 1953

Type species: ***Subtriporopollenites anulatus*** Pflug and Thomson *in* Thomson and Pflug, 1953

*Subtriporopollenites simplex* (Potonié and Venitz, 1934) Thomson and Pflug, 1953

(Plate 23, Figure 13)

**Dimensions:** 40-50 microns.

Genus: ***Tricolpopollenites*** Pflug and Thomson *in* Thomson and Pflug, 1953

**Remarks:** Pollen belonging to *Tricolpopollenites* genera are evaluated as *Tricolpopollenites* spp., but most of the identified species belonging to this genus are following two species: *Tricolpopollenites microhenrici* and *Tricolpopollenites henrici* .

Type species: ***Tricolpopollenites parmularius*** (Potonié, 1934) Pflug and Thomson *in* Thomson and Pflug, 1953

*Tricolpopollenites henrici* (Potonie, 1931b) Thomson and Pflug, 1953

(Plate 22, Figures 11, 12)

**Dimension:** 35-40 microns.

Genus: ***Tricolporopollenites*** Pflug and Thomson *in* Thomson and Pflug, 1953

**Remarks:** Similar to *Tricolpopollenites*, species belonging to this genus were counted together as *Tricolporopollenites* spp., but most of the identified species belonging to this genus are following two species: *Tricolporopollenites cingulum*, *Tricolporopollenites pseudocingulum*, and *Tricolporopollenites megaexactus*.

Type species: ***Tricolporopollenites dolium*** (Potonié, 1931a) Thomson and Pflug, 1953

*Tricolporopollenites cingulum* (Potonié, 1931a) Thomson and Pflug, 1953

(Plate 22, Figures 13-16)

**Dimension:** 30-35 microns.

*Tricolporopollenites pseudocingulum* (Potonié, 1931b) Thomson and Pflug, 1953

(Plate 21, Figures 17-19; Plate 22, Figures 17-18)

**Dimension:** 35-45 microns.

*Tricolporopollenites euphorii* (Potonié, 1931b) Thomson and Pflug 1953

(Plate 21, Figure 16; Plate 22, Figure 20)

**Dimension:** 40-50 microns.

Family: Compositae

Compositae (tubuliflorae-type A)
(Plate 24, Figures 1-4, 6, 7, 11)

**Remarks:** Tricolporate pollen belonging to Compositae Family and is comparable with *Compositoipollenites* (Potonié, 1951) Potonié, 1960b or *Echitricolporites spinosus* (Vander Hammen, 1956) ex Germeraad et al., 1968 but it is clearly different in that presence of colpi is doubtfull in *Compositoipollenites* and, thus, it seems to be triporate and the spines of *Echitricolporites spinosus* are larger than *Tubulifloridites antipodica*).
**Description:** Tricolporate, echinate pollen grain with spherical to subprolate in shape. Colpi are long extending about 2/3 of the diameter. The exine is thick and the thickness of exine stratification is about 1 μm. The columellae are small and mostly obscure. The ora are 3.5-4 μm wide and about 2 μm high. Tectum is very thin and looks microperforate. Spines are 1-2 μm high, 1-1.5 μm wide and regularly distributed.
**Dimension:** 20-25 microns.

Compositae (tubuliflorae-type B)
(Plate 24, Figures 5, 8-10, 12, 13; Plate 25, Figures 3-6)

**Remarks:** Tricolporate pollen can be comparable with *Echitricolporites spinosus* (Van der Hammen, 1956) Germeraad et al., 1968, *Echitricolporites mcneillyi* Germeraad et al., 1968 and *Echitricolporites minutus* Regali et al., 1974 but it is clearly different with smaller size and much thinner exine.
**Description:** Tricolporate, echinate pollen grain with spherical to subprolate in shape. Colpi are long extending about 3/4 of the diameter. Differing from the Compositae (tubuliflorae-type A), this species is larger with smaller spines and has a thick and more obvious tectal layer with a slightly undulate and rugose surface. The exine is thick in the middle but gets thinner towards

2.5-4 μm wide and about 5-10 μm high. Tectum is thick with low spines which are less than 1 μm high and regularly distributed.
**Dimension:** 25-35 microns.

Compositae (liguliflorae-type)
(Plate 24, Figures 14, 15)

**Description:** Pollen grains are fenestrate, distinctly lophate, echinate, spines on the ridges, and spherical in shape. Surface of the grain is separated by raised ridges forming polygonal pattern with small spicules. Exine is fairly thin.
**Dimension:** 25-35 microns.

Compositae-type pollen
(Plate 24, Figure 16; Plate 25, Figures 7, 8)

**Remarks:** This genus is different than *Echiperiporites estelae* Germeraad et al., 1968, *Malvacipolloides densiechinata* Anzotegui and Garralla, 1985, and *Echitricolporites maristellae* Muller et al., 1987 in being stephanocolporate.
**Description:** Pollen grains are stephanocolporate, have strongly echinate sculpture and spherical shape. It belongs with an affinity to the family of Malvaceae. This genus is very distinct with having strong spines with robust mammiform bases. Colpi are short, about 8-10 μm long, and narrow. The ora are circular to elliptical, 4-4.5 μm wide and about 7-8 μm high. Exine is 1.8-2.4 μm thick and stratified. Collumella are 0.8-1.4 μm thick and forming very distinct mammiform bases. Tectum is very thin, perforate and microgranulate. Conical spines are 3-5 μm high and 2-3 μm wide, sharply pointed, regularly distributed, and placed center of the mammiform bases.
**Dimension:** 55-65 microns.

Family: Dipsacaceae
(Plate 26, Figure 15)

**Dimension:** 70-80 microns.

Genus: ***Ilexpollenites*** (Thiergart, 1937) Potonié, 1960b

Type species: ***Ilexpollenites iliacus*** Potonié, 1960b

*Ilexpollenites* sp.

(Plate 21, Figure 9)

**Description:** Ticolporate grain with ovoid to elipsoidal outline. It has an exine with free-standing pillae or clavae.

**Dimensions:** 50-55 microns.

Genus: ***Slowakipollis*** Krutzsch, 1962

Type species: ***Slowakipollis cechovici*** (Pacltova, 1958) Krutzsch, 1962

*Slowakipollis hipophaeoides* Krutzsch, 1962

(Plate 21, Figures 11, 12; Plate 26, Figures 2-5)

**Dimensions:** 25-35 microns.

Genus: ***Mediocolpopollis*** Krutzsch, 1959

Type species: ***Mediocolpopollis compactus*** Krutzsch, 1959

*Mediocolpopollis compactus* Krutzsch, 1959

(Plate 21, Figure 15; Plate 26, Figures 6, 7)

**Dimensions:** 30-40 microns.

Genus: ***Artemisiaepollenites*** Nagy, 1969

Type species: ***Artemisiaepollenites cellularis*** Nagy, 1969

**Artemisiaepollenites** sp.

(Plate 23, Figure 10)

**Description:** Small tricolporate pollen grain with tectum on the outline.
**Dimension:** 20-25 microns.

Genus: ***Intratriporopollenites*** Pflug and Thomson *in* Thomson and Pflug, 1953

Type species: ***Intratriporopollenites instructus*** Pflug and Thomson *in* Thomson and Pflug, 1953

*Intratriporopollenites instructus* Pflug and Thomson *in* Thomson and Pflug, 1953

(Plate 23, Figures 16, 17)

**Dimension:** 30-40 microns.

Genus: ***Extratriporopollenites*** (Pflug, 1952 *in* Thomson and Pflug, 1952) Pflug *in* Thomson and Pflug, 1953

Type species: ***Extratriporopollenites fractus*** Pflug *in* Thomson and Pflug, 1953

*Extratriporopollenites* sp.

(Plate 28, Figures 9)

**Description:** Pollen grain with concavely triangular shape. It has three equatorial pores with distinct pore channels.
**Dimensions:** 30-40 microns.

Genus: ***Boehlensipollis*** Krutzsch, 1962

Type species: ***Boehlensipollis hohli*** Krutzsch, 1962

*Boehlensipollis hohli* Krutzsch, 1962

(Plate 23, Figure 14 )

**Dimension:** 25-30 microns.

Genus: ***Tetracolporopollenites*** Pflug and Thomson *in* Thomson and Pflug, 1953

Type species: ***Tetracolporopollenites sapotoides*** Pflug and Thomson *in* Thomson and Pflug, 1953

*Tetracolporopollenites obscurus* Pflug and Thomson *in* Thomson and Pflug, 1953

(Plate 25, Figure 10)

**Dimension:** 30-35 microns.

*Tetracolporopollenites manifestus* (Potonie, 1931b) Thomson and Pflug, 1953

(Plate 25, Figure 11)

**Dimension:** 20-25 microns.

Genus: ***Polyporopollenites*** Pflug *in* Thomson and Pflug, 1953

Type species: ***Polyporopollenites undulosus*** (Wolff, 1934) Thomson and Pflug, 1953

*Polyporopollenites undulosus* (Wolff, 1934) Thomson and Pflug, 1953

(Plate 23, Figure 19; Plate 25, Figures 13, 14)

**Dimension:** 30-40 microns.

*Polyporopollenites stellatus* (Potonié and Venitz, 1934) Thomson and Pflug, 1953

(Plate 23, Figure 18)

**Dimension:** 40-45 microns.

Genus: ***Polyvestibulopollenites*** Pflug *in* Thomson and Pflug, 1953

Type species: *Polyvestibulopollenites verus* (Potonié, 1931b) Thomson and Pflug, 1953

*Polyvestibulopollenites verus* (Potonie, 1931b) Thomson and Pflug, 1953

(Plate 23, Figure 20; Plate 26, Figure 14)

**Dimension:** 30-40 microns.

Genus: ***Periporopollenites*** Pflug and Thomson *in* Thomson and Pflug, 1953

Type species: ***Periporopollenites multiporatus*** Pflug and Thomson *in* Thomson and Pflug, 1953

*Periporopollenites multiporatus* Pflug and Thomson *in* Thomson and Pflug, 1953

(Plate 25, Figure 12; Plate 26, Figures 12, 13)

**Dimension:** 25-30 microns.

*Periporopollenites stigmosus* (Potonie, 1931b) Thomson and Pflug, 1953

(Plate 27, Figures 1-3)

**Dimension:** 15-25 microns.

Genus: ***Polyadopollenites*** Pflug and Thomson *in* Thomson and Pflug, 1953

Type species: ***Polyadopollenites multipartitus*** Pflug and Thomson *in* Thomson and Pflug, 1953

*Polyadopollenites* sp.

(Plate 25, Figure 15)

**Description:** Polyad of 12 to 16 cells round and discoidal, two to four cells thick at the middle. The component cells are closely attached with each other and interior cells.

**Dimension:** 70-80 microns.

3.5.2.2. Spores

Spores are classified into 2 main groups as monolete spores and trilete spores and the list of the identified spores belonging to those groups are as follows:

Monolote Spores:

Genus: ***Laevigatosporites*** Ibrahim, 1933

Type species: ***Laevigatosporites vulgaris*** (Ibrahim, 1932) Ibrahim, 1933

*Laevigatosporites haardti* (Potonié and Venitz, 1934) Thomson and Pflug, 1953

(Plate 27, Figure 4)

**Dimension:** 35-45 microns.

Genus: ***Verrucatosporites*** Pflug and Thomson *in* Thomson and Pflug, 1953

Type species: ***Verrucatosporites alienus*** (Potonié, 1931c) Thomson and Pflug, 1953

*Verrucatosporites alienus* (Potonié, 1931c) Thomson and Pflug, 1953

(Plate 27, Figure 6)

**Dimension:** 45-60 microns.

*Verrucatosporites favus* (Potonié, 1931c) Thomson and Pflug, 1953

(Plate 26, Figure 9; Plate 27, Figure 5)

**Dimension:** 55-70 microns.

*Verrucatosporites scutulum* Nakoman, 1964

(Plate 27, Figure 7)

**Dimension:** 60-65 microns.

Genus: ***Echinatosporites*** Akyol, 1964

Type species: ***Echinatosporites gratus*** Akyol, 1964

*Echinatosporites bifurcus* Akyol, 1964

(Plate 27, Figures 8-10)

**Dimension:** 45-60 microns.

Trilete Spores:

Genus: ***Appendicisporites*** Saad and Ghazaly, 1976

Type species: *Appendicisporites aegyptiaca* Saad and Ghazaly, 1976

*Appendicisporites* sp.

(Plate 28, Figures 11)

**Description:** Trilete spore with an elliptical in shape. It is very distinct with having long appendices.

**Dimension:** 55-60 microns.

Genus: ***Baculatisporites*** Pflug and Thomson *in* Thomson and Pflug, 1953

Type species: ***Baculatisporites primarius*** (Wolff, 1934) Thomson and Pflug, 1953

*Baculatisporites primarius* (Wolff, 1934) Thomson and Pflug, 1953

(Plate 27, Figure 17)

**Dimension:** 60-65 microns.

Genus: ***Cicatricosisporites*** Potonié and Gelletich, 1933

Type species: ***Cicatricosisporites dorogensis*** Potonié and Gelletich, 1933

*Cicatricosisporites* sp.

(Plate 26, Figure 19; Plate 28, Figures 7, 8)

**Description:** Trilete spore which has a rounded to triangular amb and convex sides. It typically has several concentrically arranged parallel ribs on the surface as an ornamentation.

**Dimensions:** Equatorial diameter is 45-60 microns.

Genus: ***Cingulatisporites*** Thomson in Thomson and Pflug,1953

Type species: ***Cingulatisporites levispeciosus*** Pflug *in* Thomson and Pflug, 1953

*Cingulatisporites macrospeciosus* (Potonié and Gelletich, 1933) Nakoman, 1966

(Plate 28, Figures 1, 2)

**Dimension:** 50-60 microns.

Genus: ***Echinatisporis*** Krutzsch, 1959

Type species: *Echinatisporis longechinatus* Krutzsch, 1959

*Echinatisporis longechinatus* Krutzsch, 1959

(Plate 26, Figure 20)

**Dimension:** 55-60 microns.

*Echinatisporis* sp.

(Plate 28, Figure 10)

**Description:** This species is different than *Echinatisporis longechinatus* İn having relatively shorter spines.

**Dimensions:** 30-35 microns.

Genus: ***Leiotriletes*** (Naumova, 1937) Potonié and Kremp, 1954

Type species: ***Leiotriletes sphaerotriangulus*** (Loose, 1932) Potonié and Kremp, 1954

*Leiotriletes microadriennis* Krutzsch, 1959

(Plate 27, Figures 13, 15)

**Dimension:** 40-45 microns.

*Leiotriletes adriennis* (Potonié and Gelletich, 1933) Krutzsch, 1959

(Plate 27, Figures 11, 12, 14)

**Dimension:** 55-60 microns.

*Leiotriletes dorogensis* (Kedves, 1960) Kedves, 1961

(Plate 27, Figure 16

**Dimension:** 70-80 microns.

Genus: ***Lusatisporites*** Krutzsch, 1963

Type species: ***Lusatisporites punctatus*** Krutzsch, 1963

*Lusatisporites perinatus* Krutzsch, 1963

(Plate 28, Figures 3, 4)

**Dimension:** 60-70 microns.

Genus: ***Magnastriatites*** Germeraad et al., 1968

Type species: ***Magnastriatites howardii*** Germeraad et al., 1968

*Magnastriatites howardii* Germeraad et al., 1968

(Plate 27, Figure 18)

**Dimension:** 40-45 microns.

Genus*:* ***Retitriletes*** Pierce, 1961

Type species: ***Retitriletes globosus*** Pierce, 1961

*Retitriletes fragilis* Schuler and Sittler, 1969
(Plate 25, Figure 16)

**Dimension:** 70-75 microns.

*Genus:* ***Saxosporis*** Krutzsch, 1963

Type species: ***Saxosporis duebenensis*** Pierce, 1961

*Saxosporis* sp.
(Plate 26, Figure 17, 18; Plate 28, Figure 6)

**Description:** Trilete spore subcircular to oval in shape and it has spiny elements on the surface

**Dimension:** 30-50 microns.

Genus: ***Trilites*** (Cookson, 1947), Couper, 1953

Type Species: ***Trilites tuberculiformis*** Cookson, 1947

*Trilites multivallatus* (Pflug *in* Thomson and Pflug, 1953) Krutzsch, 1959
(Plate 28, Figure 3)

**Dimension:** 50-60 microns.

Reworked trilete spore
(Plate 27, Figures 19, 20)

**Dimension:** 70-80 microns.

3.5.2.3. Fungal Spores

Even though Oligocene-Miocene sediments in the Eastern Anatolia are very rich in fungal spore, most of them have no or little stratigraphic importance. Therefore, except for following fungal spores, which are reported as stratigraphically important in previous studies (Ediger, 1981, 1982; Ediger and Alişan, 1989; Elsik et al., 1990), *Anatolinites dongyingensis, Psilodisporites gunniae, Dyadosporonites okayi, Hypoxylonites* sp., *Biporisporites* sp., remaining fungal spores are evaluated as stratigraphically unimportant fungi (mostly composed of *Inapertisporites, Dicellaesporites, Pluricellaesporites, Multicellaesporites* and Hyphae).

Dispersed Fungal Spores:

Class Fungi Imperfecti
Fungi Sporae Dispersae

Genus: ***Inapertisporites*** Van der Hammen, 1954

Type species: ***Inapertisporites variabilis*** Van der Hammen, 1954

*Inapertisporites rotundus* Ediger, 1981
(Plate 29, Figure 1)

**Dimension:** 25-30 microns.

Genus: ***Diporisporites*** Van der Hammen, 1954

Type species: ***Diporisporites elongatus*** Van der Hammen, 1954

*Diporisporites* sp.
(Plate 29, Figure 5)

**Description:** Diporate fungal spore which is unicellate, elongate, fusiform in shape. Wall is thin and finely granulate. Exine seems thinned around the pores.

**Dimension:** 30-35 microns.

Genus: ***Psilodiporites*** Varma and Rawat, 1963

Type species: ***Psilodiporites hammenii*** Varma and Rawat, 1963

*Psilodiporites gunniae* Varma and Rawat, 1963

(Plate 29, Figures 8, 9)

**Dimension:** 30-35 microns.

Genus: ***Striadiporites*** Varma and Rawat, 1963

Type species: ***Striadiporites reticulatus*** Varma and Rawat, 1963

*Striadiporites sanctaebarbarae* Elsik and Jansonius, 1974

(Plate 29, Figure 10)

**Dimension:** 30-35 microns.

*Striadiporites* sp.

(Plate 29, Figure 11)

**Description:** This specimen is very similar to *S.sanctaebarbarae* but differs in having fusiform to elongate body and relatively less distinct striates on its surface.

**Dimension:** 40-45 microns.

Genus: ***Dicellaesporites*** Elsik, 1968 emend. Sheffy and Dilcher, 1971

Type species: ***Dicellaesporites popovi*** Elsik, 1968

*Dicellaesporites* sp.

(Plate 29, Figures 2, 3 )

**Description:** Dicellate and inaperturate fungal spore with an elliptical body.

**Dimension:** 30-40 microns.

Genus: **Polyadosporites** Van der Hammen, 1954

Type species: ***Polyadoporites suescae*** Van der Hammen, 1954

*Polyadosporites orbis* Ediger, 1981

(Plate 29, Figure 18)

**Dimension:** 40-45 microns.

*Genus:* ***Anatolinites*** Elsik et al., 1990

*Type species:* ***Anatolinites dongyingensis*** (Ke and Shi, 1978) Elsik et al., 1990

*Anatolinites dongyingensis* (Ke and Shi, 1978) Elsik et al., 1990

(Plate 29, Figures 14-16)

**Dimension:** 65-80 microns.

*Genus:* ***Pluricellaesporites*** Van der Hammen, 1954

Type species: ***Pluricellaesporites typicus*** Van der Hammen, 1954

*Pluricellaesporites* sp.

(Plate 29, Figure 12)

**Description:** Fungal spore with elongate to elliptical body. It has three or more septa and a quite thick wall which gets thinner towards the proximal region. Pore is located at the end of the proximal area.

**Dimension:** 50-55 microns.

*Genus* ***Multicellaesporites*** (Elsik, 1968) Sheffy and Dilcher, 1971

Type species: ***Multicellaesporites nortonii*** Elsik, 1968

*Multicellaesporites* sp.

(Plate 29, Figure 13)

**Description:** Inaperturate and multicellate fungal spore with quite thick septa. Exine is smooth or finely granulate. Terminal cells are rounded and smaller than the middle cells. Dimension of this fungal spore varies depending on the number of cells ranging from 30 to even more than 100 microns.

**Dimension:** 60-70 microns.

Fruiting Bodies:

*Genus:* ***Trichothyrites*** Rosendahl, 1943

Type species: ***Trichothyrites pleistocaenicus*** Rosendahl, 1943

*Trichothyrites* sp.

(Plate 29, Figure 19)

**Description:** Circular and radiate, fruiting-body with ostiole surrounded by mostly tetragonal cells with thickened walls. Central cells mostly have thicker walls than the surrounding cells and form a dark neck around the ostiole.

**Dimension:** 80-100 microns

Fungal Hyphae: Multiseptate fungal spores or hyphae which is very thin and long. Exine is medium melanin in color. Septa are regularly distributed, closely spaced and perforated.

(Plate 29, Figure 20)

**Dimension:** 400-500 microns.

3.5.2.4. Organic-walled Green Algae

Division Chlorophyta Pascher, 1914

Class Chlorophyceae Kützing, 1843

Order Chlorococcales Marchand, 1895 orth. mut. Pascher, 1915

Family Hydrodictyaceae (Gray) Dumortier, 1829

Genus: ***Pediastrum*** Meyen, 1829

Type species: ***Pediastrum duplex*** Meyen, 1829

*Pediastrum* sp.

(Plate 20, Figures 8-11)

**Description:** Freshwater algae seem as flat, plate-like feature, circular to disc-shaped colonies occurred by irregularly triangular cells. The size and the shape of the individual cells are almost the same. They are seen mainly as 2 or 3 rings or rows in arrangement.

**Dimension:** 70-100 microns

**Remarks:** This species may be comparable with the fossil species Form 2P and 3P of Ediger and Batı (1988a and b) in number of rows and number of individual cells and *Pediastrum kajaitites* Wilson and Hoffmeister and *Pediastrum delicatites* Wilson and Hoffmeister in processes, number of rings, size and shape of the inner and outer cells.

Family **Botryococcaceae** N. Wille, 1909

*Genus:* ***Botryococcus*** Kutzing, 1849

Type species: ***Botryococcus braunii*** Kutzing, 1849

*Botryococcus braunii*.

(Plate 8, Figures 19, 20)

**Dimensions:** 30-80 microns

3.5.2.5. Acritarchs

Group ACRITARCHA Evitt, 1963a

Genus: ***Artemisiocysta*** Benedek, 1972

Type species: ***Artemisiocysta cladodichotoma*** Benedek, 1972

*Artemisiocysta cladodichotoma* Benedek, 1972

(Plate 15, Figure 6-8)

**Dimensions:** 70-85 microns.

Genus: ***Ascostomocystis*** Drugg and Loeblich Jr., 1967

Type species: ***Ascostomocystis hydria*** Drugg and Loeblich Jr., 1967

*Ascostomocystis potane* Drugg and Loeblich Jr., 1967

(Plate 16, Figures 1-20)

**Dimensions:** 75-95 microns.

Genus: ***Cyclopsiella*** (Drugg and Loeblich Jr., 1967) Head et al., 1989

Type species: ***Cyclopsiella elliptica*** (Drugg and Loeblich Jr., 1967)

*Cyclopsiella lusatica* (Krutzsch, 1970) Strauss and Lund, 1992

(Plate 2, Figures 19, 20)

**Dimensions:** 80-90 microns.

3.5.2.6. Incertae Sedis

*Genus:* ***Ovoidites*** (Potonié, 1951) Krutzsch, 1959

Type species: ***Ovoidites ligneolus*** (Potonié, 1931d) Potonié, 1951

*Ovoidites ligneolus* (Potonié, 1931d) Potonié, 1951

(Plate 20, Figures 12, 13)

**Dimensions:** 70-80 microns.

*Ovoidites parvus* (Cookson and Dettman) Nakoman, 1966

(Plate 20, Figures 14, 15)

**Dimensions:** 80-85 microns.

Scolecodont

(Plate 17, Figures 15, 16)

**Dimensions:** 90-100 microns.

Tasmanites

(Plate 17, Figures 11, 12)

**Dimensions:** 90-100 microns.

Unidentified chorate fragments

(Plate 7, Figures 19, 20)

**Dimensions:** 200-250 microns.

3.5.2.7. Dinoflagellates

Division DINOFLAGELLATA (Bütschli, 1885) Fensome et al., 1993
Subdivision DINOKARYOTA Fensome et al., 1993
Class DINOPHYCEAE Pascher, 1914
Subclass PERIDINIPHYCIDAE Fensome et al., 1993
Order GONYAULACALES Taylor, 1980
Suborder GONYAULACINEAE (Autonym)
Family GONYAULACACEAE Lindemann, 1928
Subfamily GONYAULACOIDEAE (Autonym)

Genus: ***Achilleodinium***, Eaton, 1976

Type species: ***Achilleodinium biformoides*** Eaton, 1976

*Achilleodinium biformoides* (Eisenack, 1954) Eaton, 1976

(Plate 11, Figures 9-12)

**Dimensions:** 90-100 microns.

Genus: ***Achomosphaera*** Evitt, 1963a

Type species: ***Achomosphaera ramulifera*** (Deflandre, 1937) Evitt, 1963a

*Achomosphaera alcicornu* (Eisenack, 1954) Davey and Williams, 1966a

(Plate 10, Figure 5)

**Dimensions:** 100-110 microns.

Genus: ***Apteodinium*** Eisenack, 1954 emend. Lucas-Clark, 1987

Type species: ***Apteodinium granulatum*** Eisenack, 1958 emend. Sarjeant, 1985 emend. Lucas-Clark, 1987

*Apteodinium australiense* (Deflandre and Cookson, 1955) Williams, 1978

(Plate 4, Figure 19)

**Dimensions:** 50-65 micron

Genus: ***Areosphaeridinium*** Eaton, 1971

Type species: ***Areosphaeridinium diktyoplokus*** (Klump, 1953) Eaton, 1971

*Areosphaeridinium diktyoplokus* (Klump, 1953) Eaton, 1971

(Plate 10, Figure 7)

**Dimensions:** 80-90 microns.

Genus: *Batiacasphaera*, Drugg, 1970 emend. Dörhöfer and Davies, 1980

Type species: ***Batiacasphaera compta*** Drugg, 1970

*Batiacasphaera* sp.

(Plate 20, Figure 1)

**Description:** Archeophyle is apical type A. Cyst is typically spherical to subspherical. Operculum is free. Surface of the cyst is granulate or punctoreticulate.

**Dimensions:** 40-45 micron

Genus: ***Chiropteridium*** Gocht, 1960

Type species: ***Chiropteridium lobospinosum*** (Gocht *in* Weiler, 1956) Gocht, 1960

*Chiropteridium galea* Maier, 1959 emend. Sarjeant, 1983

(Plate 8, Figures 3, 4)

**Dimensions:** 90-100 microns.

*Chiropteridium lobospinosum* (Gocht *in* Weiler, 1956) Gocht, 1960

(Plate 8, Figures 5-13)

**Dimensions:** 100-120 microns.

Genus: ***Cleistosphaeridium*** Davey et al., 1966

Type species: ***Cleistosphaeridium diversispinosum*** Davey et al., 1966

*Cleistosphaeridium* sp.

(Plate 1, Figure18)

**Description:** Chorate dinoflagellate cysts with subspherical to ovoidal body. Archeophyle is apical. Tips of the non-tabular processes are acuminate, bifurcate or branched.

**Dimensions:** 80-90 microns

Genus: ***Cordosphaeridium*** Eisenack, 1963a emend. He Chengquan, 1991

Type species: ***Cordosphaeridium inodes*** (Klump, 1953) Eisenack, 1963a emend. Morgenroth, 1968 emend. Sarjeant, 1981

*Cordosphaeridium cantharellus* (Brosius, 1963) Gocht, 1969

(Plate 4, Figures 7-10; Plate 14, Figures 1, 9, 11-14)

**Dimensions:** 100-110 microns.

*Cordosphaeridium fibrospinosum* Davey and Williams, 1966b

(Plate 14, Figures 2-6, 8, 10, 15-19)

**Dimensions:** 100-110 microns.

*Cordosphaeridium inodes* (Klump, 1953) Eisenack, 1963a emend. Sarjeant, 1981

(Plate 1, Figure 17)

**Dimensions:** 90-100 microns.

*Cordosphaeridium minimum* (Morgenroth, 1966) Benedek, 1972

(Plate 7, Figure 6)

**Dimensions:** 55-60 microns.

*Cordosphaeridium* sp.

(Plate 8, Figure 14)

**Description:** Chorate hystrichospheres with spherical to ellipsoidal body. Archeophyle is precingular. Operculum is free. Processes are regularly distributed and solid or hollow.

**Dimensions:** 80-100 microns

Genus: ***Cribroperidinium*** Neale and Sarjeant, 1962 emend. Helenes, 1984

Type species: ***Cribroperidinium sepimantum*** Neale and Sarjeant, 1962

*Cribroperidinium tenuitabulatum* (Gerlach, 1961) Helenes, 1984

(Plate 4, Figures 18, 20)

**Dimensions:** 80-85 microns.

*Cribroperidinium* sp.

(Plate 4, Figure 17; Plate 20, Figure 4)

**Description:** Gonyaulacoid specimen with an apical horn and granular ornamentation on the surface. Archeophyle is precingular.

**Dimensions:** 85-90 micron.

Genus: ***Dapsilidinium*** Bujak et al., 1980

Type species: ***Dapsilidinium pastielsii*** (Davey and Williams, 1966b) Bujak et al., 1980

*Dapsilidinium pseudocolligerum* (Stover, 1977) Bujak et al., 1980

(Plate 1, Figures 9, 10; Plate 13, Figures 9, 10)

**Dimensions:** 60-80 microns.

Genus: ***Distatodinium*** Eaton, 1976

Type species: ***Distatodinium craterum*** Eaton, 1976

*Distatodinium biffii* Brinkhuis et al., 1992

(Plate 5, Figure 20)

**Dimensions:** 75-80 microns.

*Distatodinium ellipticum* (Cookson, 1965) Eaton, 1976

(Plate 5, Figure 19)

**Dimensions:** 70-80 micron

*Distatodinium* sp.

(Plate 20, Figure 7)

**Description:** Archeophyle is apical. Operculum is detached. Cyst is elliptical in shape. It has short, tubular, broad, and hollow processes. Surface of the cyst is smooth or finely reticulate.

**Dimensions:** 80-90 microns.

Genus: ***Diphyes*** Cookson, 1965 emend. Goodman and Witmer, 1985

Type species: ***Diphyes colligerum*** Deflandre and Cookson, 1955 emend. Cookson, 1965 emend. Goodman and Witmer, 1985

*Diphyes colligerum* Deflandre and Cookson, 1955 emend. Cookson, 1965 emend. Goodman and Witmer, 1985

(Plate 18, Figure 12)

**Dimensions:** 60-70 microns.

Genus: ***Ennaedocysta*** Gerlach, 1961

Type species: ***Ennaedocysta pectiniformis*** (Gerlach, 1961) Stover and Williams, 1995

*Ennaedocysta pectiniformis* complex (Gerlach, 1961) Stover and Williams, 1995

(Plate 4, Figures 1-6; Plate 13, Figures 5, 6)

**Dimensions:** 80-90 microns.

Genus: ***Fibrocysta*** Stover and Evitt, 1978

Type species: ***Fibrocysta bipolaris*** (Cookson and Eisenack, 1965) Stover and Evitt, 1978

*Fibrocysta* sp.

(Plate 7, Figures 1-3)

**Description:** It has a spherical body with many numerous small solid processes. Ercheophyle is precingular. Cyst has a large hollow apical process.

**Dimensions:** 100-110 microns.

Genus: ***Glaphyrocysta*** Stover and Evitt, 1978

Type species: ***Glaphyrocysta rectiintexta*** (Cookson, 1965) Stover and Evitt, 1978

*Glaphyrocysta*-group

(Plate 13, Figures 1-4)

**Description:** It has lenticular to sphaerical shaped endophragm. Paratabulation is lacking. Archeophyle is apical type A.

**Dimensions:** 80-100 microns.

Genus: ***Hafniasphaera*** Hansen, 1977

Type species: ***Hafniasphaera septata*** (Cookson and Eisenack, 1967) Hansen, 1977

*Hafniasphaera* sp.

(Plate 15, Figures 1-5)

**Description:** This genus is very similar to *Spiniferites* but different in having relatively thicker body and punctate ornamentations on its surface.

**Dimensions:** 60-75 microns.

Genus: ***Heteraulacacysta*** Drugg and Loeblich Jr., 1967

Type species: ***Heteraulacacysta campanula*** Drugg and Loeblich Jr., 1967 emend. Bujak *in* Bujak et al., 1980

*Heteraulacacysta* sp.

(Plate 7, Figure 18; Plate 15, Figure 20)

**Description:** It has a large spherical body. Archeophyle is precingular. There is a large septa around cingular area.

**Dimensions:** 90-100 microns.

Genus: ***Homotryblium*** Davey and Williams, 1966b

Type species: ***Homotryblium tenuispinosum*** Davey and Williams, 1966b

*Homotryblium plectilum* Drugg and Loeblich Jr., 1967

(Plate 3, Figures 1, 3, 5, 8, 10-12; Plate 10, Figures 17-20)

**Dimensions:** 80-90 microns.

*Homotryblium tenuispinosum* Davey and Williams, 1966b

(Plate 3, Figure 4)

**Dimensions:** 90-100 microns.

*Homotryblium oceanicum* Eaton, 1976

(Plate 7, Figure 4)

**Dimensions:** 60-70 microns.

*Homotryblium plectilum/vallum* Stover, 1977

(Plate 3, Figures 7, 9)

**Description:** Cyst is chorate with a spherical body. Archeophyle is apical type A. Periphragm is smooth or finely ornamented. Processes have characteristically two or three slender tubes in cylindrical form. It differs from *Homotryblium plectilum* in having paracingular taeniate processes.

**Dimensions:** 70-80 microns.

*Homotryblium vallum* Stover, 1977

(Plate 3, Figures 2, 6)

**Dimensions:** 70-80 microns.

Genus: ***Hystrichokolpoma*** Klumpp, 1953 emend. Williams and Downie, 1966a

Type species: ***Hystrichokolpoma cinctum*** Klumpp, 1953

*Hystrichokolpoma cinctum* Klumpp, 1953

(Plate 12, Figure 2, 3)

**Dimensions:** 90-100 microns.

*Hystrichokolpoma pusillum* Biffi and Manum, 1988

(Plate 1, Figures 1-8)

**Dimensions:** 35-40 microns.

*Hystrichokolpoma rigaudiae* Deflandre and Cookson, 1955

(Plate 3, Figures 13, 14; Plate 7, Figure 7; Plate 11, Figures 17, 18, 20)

**Dimensions:** 75-85 microns.

Genus: ***Hystrichosphaeropsis*** Deflandre, 1935 emend. Sarjeant, 1982

Type species: ***Hystrichosphaeropsis ovum*** Deflandre, 1935

*Hystrichosphaeropsis obscura* Habib, 1972

(Plate 2, Figures 7, 8)

**Dimensions:** 60-65 microns.

Genus: ***Impagidinium*** Stover and Evitt, 1978

Type species: ***Impagidinium dispertitum*** (Cookson and Eisenack, 1965) Stover and Evitt, 1978

*Impagidinium* sp.

(Plate 2, Figures 14-17)

**Description:** Cyst is subspherical to ovoidal in shape. Archeophyle is precingular occurred by the loss of paraplate 3''. Surface of the cyst seems microreticulate.

**Dimensions:** 55-60 microns.

Genus: ***Lingulodinium*** Wall, 1967 emend. Dodge, 1989

Type species: ***Lingulodinium machaerophorum*** (Deflandre and Cookson, 1955) Wall, 1967

*Lingulodinium machaerophorum* (Defladre and Cookson, 1955) Wall, 1967

(Plate 8, Figures 1, 2; Plate 12, Figures 16-19)

**Dimensions:** 70-80 microns.

Genus: ***Membranilarnacia*** Eisenack, 1963b emend. Williams and Downie, 1966b

Type species: ***Membranilarnacia leptodermata*** (Cookson and Eisenack, 1958) Eisenack, 1963b

*Membranilarnacia ?picena* Biffi and Manum, 1988
(Plate 2, Figures 1-6)

**Description:** Archeophyle is apical type A. Cyst is holocavate with a subspherical body. Operculum is simple. Typically, sulcal notch of the cyst is short and narrow and numerous solid processes look like continuous veil-like extophragm around the cyst in the ambital view.

**Dimensions:** 55-60 microns.

Genus: ***Membranophoridium*** Gerlach, 1961 emend. Stover and Evitt, 1978

Type species: ***Membranophoridium aspinatum*** Gerlach, 1961

*Membranophoridium aspinatum* Gerlach, 1961
(Plate 11, Figures 13-15)

**Dimensions:** 65-75 microns.

Genus: ***Nematosphaeropsis*** Deflandre and Cookson, 1955 emend. Wrenn, 1988

Type species: ***Nematosphaeropsis balcombiana*** Deflandre and Cookson, 1955

*Nematosphaeropsis* sp.
(Plate 11, Figure 16)

**Description:** Cyst is small, spherical with numerous processes. It has ectophragmal ribbon-like interconnecitons between the tips of the processes.

**Dimensions:** 55-60 microns.

Genus: ***Operculodinium*** Wall, 1967

Type species: ***Operculodinium centrocarpum*** Deflandre and Cookson, 1955

*Operculodinium microtriainum* Islam, 1983
(Plate 6, Figure 13; Plate 13, Figure 15)

**Dimensions:** 90-100 microns.

*Operculodinium* sp.

(Plate 1, Figures 19, 20; Plate 6, Figures 16-20; Plate 13, Figures 16-20)

**Description:** Cyst is ovoidal to subspherical with a microgranulate surface. Archeophyle is precingular, type P. Operculum is free. It has numerous small, thin, nontabularly arranged, folded, and subconical processes.

**Dimensions:** 60-80 microns.

Genus ***Pentadinium*** Gerlach, 1961 emend. Benedek et al., 1982

Type species: ***Pentadinium laticintum*** Gerlach, 1961 emend. Benedek et al., 1982

*Pentadinium galileoi* Sancay et al., submitted

(Plate 7, Figures 14-16; Plate 19, Figures 1-16)

**Dimension:** Overall diameter 57-70 micrometers (holotype), Endocyst diameter 42-55 microns.

*Pentadinium laticinctum* Gerlach, 1961 emend. Benedek et al., 1982

(Plate 20, Figure5 )

**Dimensions:** 80-90 microns.

*Pentadinium imaginatum* Benedek, 1972

(Plate 11, Figures 7,8)

**Dimensions:** 65-75 microns.

Genus: ***Polysphaeridium*** Davey and Williams, 1966b emend. Bujak et al., 1980

Type species: ***Polysphaeridium subtile*** Davey and Williams, 1966b emend. Bujak et al., 1980

*Polysphaeridium zoharyi* (Rossignol, 1962) Bujak et al., 1980

(Plate 2, Figures 12, 13; Plate 4, Figures 11, 12; Plate 6, Figure 11; Plate 7, Figures 8-12; Plate 13, Figures 11-13)

**Dimensions:** 70-80 microns.

*Polysphaeridium* sp.

(Plate 1, Figures 14,15; Plate 13, Figures 14)

**Description:** Archeophyle is apical type A. Cyst is chorate with a subspherical body. Operculum is free. Endophragm is characteristically thicker than the periphragm. Processes are smooth, hollow, circular in cross-section, uniform in shape and size, and expanded distally.

**Dimensions:** 70-80 microns.

Genus: ***Reticulatosphaera*** Matsuoka, 1983 emend. Bujak and Matsuoka, 1986

Type species: ***Reticulatosphaera actinocoronata*** (Benedek, 1972) Bujak and Matsuoka, 1986 emend. Bujak and Matsuoka, 1986

*Reticulatosphaera actinocoronata* (Benedek, 1972) Bujak and Matsuoka, 1986 emend. Bujak and Matsuoka, 1986

(Plate 3, Figures 19, 20; Plate 6, Figure 12; Plate 12, Figure 4)

**Dimensions:** 35-45 microns.

Genus: ***Riculacysta*** Stover, 1977

Type species: ***Riculacysta perforata*** Stover, 1977

*Riculacysta* cf. *perforata* Stover, 1977

(Plate 6, Figures 14, 15)

**Description:** Archeophyle is apical type A. Cyst is chorate with a subspherical body. Operculum is free. This genus is very distinct in having skirtlike feature occurred by the ectophragm and processes in different length. Autophragm is puntoreticulate and includes characteristically solid, slender, and distally branched processes which are connected by discontinuous perforate to trabecular ectophragm. Dorsal processes are shorter than the ventral processes.

**Dimensions:** 100-120 microns.

Genus: ***Spiniferites*** Mantel, 1850 emend. Sarjeant, 1970

**Remarks:** Dinoflagellate species belonging to this genera is widely distributed in the palynological slides but most of them have no or little stratigraphic importance. Therefore, they have been evaulated as *Spiniferites* spp.

Type species: ***Spiniferites ramosus*** (Ehrenberg, 1838) Mantell, 1854

*Spiniferites mirabilis* (Rossignol, 1964) Sarjeant, 1970

(Plate 3, Figures 15, 16; Plate 4, Figures 13, 14, 16; Plate 15, Figures 9-10)

**Dimensions:** 70-80 microns.

*Spiniferites pseudofurcatus* (Klump, 1953) Sarjeant, 1970 emend. Sarjeant, 1981

(Plate 3, Figures 17, 18)

**Dimensions:** 80-90 microns.

Genus: ***Systematophora*** Klement, 1960 emend. Stancliffe and Sarjeant, 1990

Type species: ***Systematophora areolata*** Klement, 1960

*Systematophora placacantha* (Deflandre and Cookson, 1955) Davey et al., 1969 emend. May, 1980

(Plate 1, Figure 16; Plate 2, Figures 9-11; Plate 15, Figures 17-19)

**Dimensions:** 80-90 microns.

Genus: ***Tenua*** Eisenack, 1958 emend. Sarjeant, 1985

Type species: ***Tenua hystrix*** Eisenack, 1958

*Tenua hystrix* Eisenack, 1958

(Plate 20, Figure 6)

**Dimensions:** 70-80 microns.

Genus: ***Thalassiphora*** Eisenack and Gocht, 1960 emend. Benedek and Gocht, 1981

Type species: ***Thalassiphora pelagica*** (Eisenack, 1954) Eisenack and Gocht, 1960 emend. Benedek and Gocht, 1981

*Thalassiphora pelagica* (Eisenack, 1954) Eisenack and Gocht, 1960 emend. Benedek and Gocht, 1981

(Plate 5, Figures 1-5; Plate 10, Figures 8-12)

**Dimensions:** 75-80 microns.

Genus: ***Tuberculodinium*** Wall, 1967

Type species: ***Tuberculodinium vancampoae*** (Rossignol, 1962) Wall, 1967

*Tuberculodinium vancampoae* (Rossignol, 1962) Wall, 1967

(Plate 5, Figures 15-18; Plate 10, Figures 13-16)

**Dimensions:** 80-90 microns.

Order PERIDINIALES Haeckel, 1984

Suborder PERIDINIINEAE (Autonym)

Family PERIDINIACEAE Ehrenberg, 1831

Subfamily DEFLANDREOIDEAE Bujak and Davies, 1983

Genus: ***Brigantedinium*** Reid, 1974

Type species: ***Brigantedinium simplex*** Wall, 1965

*Brigantedinium* sp.

(Plate 17, Figure 2, 9, 10)

**Description:** It has spheric body with thick wall. It looks similar to *Batiacasphaera sphaerica* but relatively larger.

**Dimensions:** 70-80 microns.

Genus: ***Deflandrea*** Eisenack, 1938 emend. Lentin and Williams, 1976

**Remarks:** Although *Deflandrea* commonly occurs in Paleocene and Eocene sediments, it was first identified by Eisenack (1938) in Oligocene successions in Germany. Stover (1973) suggested that some features such as shape of the cyst (outline of the periblast in dorso-ventral view), horn development, completeness of the tabulation, archeophyle, types and distribution of sculpturing, and position and size of the endoblast and periblast are very usefull for assigning relative ages to the *Deflandrea*-bearing sediments and determining phylogenetic lineages of *Deflandrea*. In general, lenght/width ratio of the cyst decreases, clarity of tabulation and prominence of sulcus and cingulum decrease, apical and antapical horn development gets subdued, sculpturing gets coarser, endoblast occupies most of the pericoel, and outline of the cyst becomes more rotund as the rock gets younger. For instance, two different types of archeophyle have been distinguished by Stover (1973). He suggested that the STYLE A archeophyle, small in size and mostly elongate and its operculum is mostly hinged, found in Paleocene sediments whereas STYLE B archeophyle, large, broad, commonly have corresponding opening in the endophragm and its operculum is mostly free, occurred in both Paleocene and Eocene sediments. In additionally, horn development of the *Deflandrea* varies drastically in time. Strong horn development is generally seen in the *Deflandrea* species in Paleocene but it gets reduced and the endoblast occupies most of the pericoel with decreasing geological age. Endoblast almost completely fills the pericoel and the outline of the periphragm is rounded in Oligocene species. Since their morphological properties might have a stratigraphic importance, I have prefered to give main properties of *Deflandrea* and *Wetzeliella* species identified in this study.

Type species: ***Deflandrea phosphoritica*** Eisenack, 1938

*Deflandrea phosphoritica* Eisenack, 1938
(Plate 5, Figures 7, 11, 13; Plate 9, Figures 8-12)

**Remarks:** This species is the most commonly occurring *Deflandrea* species in the samples.

**Description:** Archeophyle is intercalary formed by opening of plate 2a. Outline of the periphragm in dorso-ventral view is five-sided to roundly triangular and antapical horns are slightly concave. There is an opening on the anterior dorsal surface of periphragm. Endophragm is smooth and thicker than the periphragm. The endoblast occupies most of the pericoel in dorso-ventral view.

**Dimensions:** 80-100 microns.

*Deflandrea leptodermata* Cookson and Eisenack, 1965
(Plate 5, Figure 11; Plate 9, Figures 13-14)

**Description:** Archeophyle is intercalary, very broad, and the only indication of the tabulation. There is an opening on the anterior dorsal surface of periphragm. It has granulate sculpture on the wall and smooth periphragm and endophragm. Very little difference between the lengths of periphragm and endophragm and the gently rounded antapical horn developments are very distinct for this species. The endoblast occupies most of the pericoel in dorso-ventral view.

**Dimensions:** 80-90 microns.

*Deflandrea spinulosa* Alberti, 1959

(Plate 9, Figures 15-16; Plate 20, Figure 2, 3 )

**Description:** Archeophyle is intercalary. There is an opening on the anterior dorsal surface of periphragm. Outline of the periphragm in dorso-ventral view is five-sided to roundly triangular and antapical horns are slightly concave. Endophragm is smooth and thicker than the periphragm. This species is different than the *Deflandrea phosphoritica* in having finely granulate, microechinate or faintly pitted sculpture. The endoblast occupies most of the pericoel in dorso-ventral view.

**Dimensions:** 80-100 microns.

Genus: ***Lejeunecysta*** Artzner and Dörhöfer, 1978 emend. Bujak *in* Bujak et al., 1980

Type species: ***Lejeunecysta hyalina*** (Gerlach, 1961) Artzner and Dörhöfer, 1978 emend. Sarjeant, 1984

*Lejeunecysta* sp.

(Plate 12, Figures 5-8)

**Description:** It has peridinioid ourline with slit-like archeophyle, brown in color.

**Dimensions:** 60-80 microns.

Genus: ***Palaeocystodinium*** Alberti, 1961

Type species: ***Palaeocystodinium golzowenze*** Alberti, 1961

*Palaeocystodinium golzowenze* Alberti, 1961

(Plate 10, Figure 8)

**Dimensions:** 100-110 microns.

Genus: ***Phthanoperidinium*** Drugg and Loeblich Jr., 1967 emend. Islam, 1982

Type species: ***Phthanoperidinium amoenum*** Drugg and Loeblich Jr., 1967

*Phthanoperidinium multispinum* Bujak *in* Bujak et al., 1980

(Plate 17, Figures 6, 7)

**Dimensions:** 55-60 microns.

*Phthanoperidinium* sp.

(Plate 17, Figure 5)

**Description:** Body is thick, spherical to triangular. Cyst has numerous tiped processes.

**Dimensions:** 55-60 microns.

Genus: ***Selenopemphix*** Benedek, 1972 emend. Bujak *in* Bujak et al., 1980

Type species: ***Selenopemphix nephroides*** Benedek, 1972 emend Bujak *in* Bujak et al., 1980 emend. Benedek and Sarjaent, 1981

*Selenopemphix nephroides* Benedek, 1972 emend Bujak *in* Bujak et al., 1980 emend. Benedek and Sarjaent, 1981

(Plate 7, Figure 5; Plate 12, Figures 9-11)

**Dimensions:** 55-60 microns.

Subfamily Wetzelielloideae (Vozzhennikova) Bujak and Davies, 1983

Genus: ***Wetzeliella*** Eisenack, 1938 emend. Lentin and Williams, 1976

Type species: ***Wetzeliella articulata*** Eisenack, 1938

*Wetzeliella articulata* Eisenack, 1938

(Plate 6, Figure 9; Plate 9, Figure 4)

**Dimensions:** 100-110 microns.

*Wetzeliella gochtii* Costa and Downie, 1976

(Plate 6, Figure 1; Plate 9, Figures 1, 2)

**Description:** Subpentagonal, subrhombic, subcircular in shape with a rounded outline. All horns are short and broad. It has two antapical horns but

right one is reduced if it is present. Small processes as aculeate spines are randomly distributed over the surface. Endophragm is very close to periphragm and, therefore, narrow but well-developed pericoel is present.
**Dimensions:** 105-120 micron.

*Wetzeliella symmetrica* Weiler, 1956
(Plate 9, Figure 5)

**Description:** Differs from other *Wetzeliella* species by having rhombic shape and four well-developed horns (seen as apical, antapical, and lateral horns) rather than subpentagonal shape and reduced and more rounded horns like *Wetzeliella gochtii*. Ornamentation is similar to *W. gochtii* in that small processes as aculeate spines are randomly distributed over the surface. It has soleiform Archeophyle .
**Dimensions:** 100-110 microns.

*Wetzeliella* sp.
(Plate 6, Figures 2-6, 9,; Plate 9, Figures 3, 6)

**Description:** Rhomboidal to pentagonal in shape. Two antapical and lateral horns are present. Small processes as aculeate spines are randomly distributed over the surface.
**Dimensions:** 90-110 microns

*Wetzeliella* cf. *ovalis* Eisenack, 1954
(Plate 6, Figure 8)

**Description:** This specimen is very similar to the holotype of *Wetzeliella ovalis* but precise identification could not be possible due to the poor preservation.
**Dimensions:** 100-110 microns.

Genus: ***Wilsonidium*** Lentin and Williams, 1976

Type species: ***Wilsonidium tabulatum*** (Wilson, 1967) Lentin and Williams, 1976

*Wilsonidium echinosuturatum* (Wilson, 1967) Lentin and Williams, 1976

(Plate 18, Figures 1-7)

**Dimensions:** 90-100 microns.

*Wilsonidium tabulatum* (Wilson, 1967) Lentin and Williams, 1976

(Plate 18, Figures 8-11)

**Dimensions:** 80-100 microns.

3.5.2.8. Chitinous Foraminiferal Linings

(Plate 8, Figures 17, 18; Plate 17, Figures 13, 14)

Chitinous inner layers of foraminifera can be preserved during the standard palynological sample processing and can be seen in palynological slides (Plate 8, Figures 17 and 18). They are only taken into consideration in paleoenvironmental evaulations in this study. Therefore, they are not classified and evaulated as chitinous foraminiferal linings. Their dimensions are various but generally 100-160 microns in length and 60-85 microns in breadth.

## 3.6. Biozonations

This section includes the biozonation work in which identified palynomorphs have been correlated with the biozonations of worldwide defined marine dinoflagellates and acritarchs from same latitudes. To do that, relative abundances of fossils have been calculated semiquantitatively ranging from present (for only one specimen) to super abundant (for more than 100 specimens). Bergreen and Van Couvering (1978) suggested FAD (First Appearence Datum) and LAD (Last Appearence Datum) for easy communication in biostratigraphy. FAD representing the oldest and lowest occurrences of the species and LAD representing the youngest and highest occurrences are used to define following biozonations. A time scale proposed by Berggren et al. (1995) has been used in this study because it is one of the most comprehensive studies for the Cenozoic geochronology and includes planktonic foraminifer and calcareous nannoplankton biostratigraphy, magnetostratigraphy, and radiometric ages. As a result, stratigraphic occurrences of some selected taxa and identified biozones in the context of this study, calibrated with worlwide-defined planktonic foraminifers (Bergreen et al., 1995) and calcareous nannoplanktons (Martini, 1971) can be seen on a bio-chronostratigraphic chart in Figure 26 and 27.

3.6.1. LE1 (*Wilsonidinium* Abundance zone)

Assigned Age: Late Eocene

Equivalent Planktic Zones: P16-P17

Equivalent Nannoplankton Zone: NP-19 to lower part of NP-21

Definition: This zone is distinct with the high occurrences of the nominate taxon. The bottom of the zone is not defined due to the inappropriate lithologies but the top of the zone is defined by the FAD of Compositae (tubuliflorae-type). This zone is very rich in dinoflagellates such as *Wilsonidinium echinosuturatum*, *Wilsonidinium tabulatum*, *Opeculodinium microtriainum*, *Opeculodinium* sp., *Paleocystodinium golzowense*, *Areosphaeridium diktyoplokum*, *Diphyes colligerum*, *Systematophora placacantha*, and spore-pollen such as *Extratriporopollenites* sp., *Verrucatosporites favus*, *V. alienus*, *V. scutulum, V.* sp., *Echinatisporites* sp., *Leiotriletes adriennis*, and *L. microadriennis*.

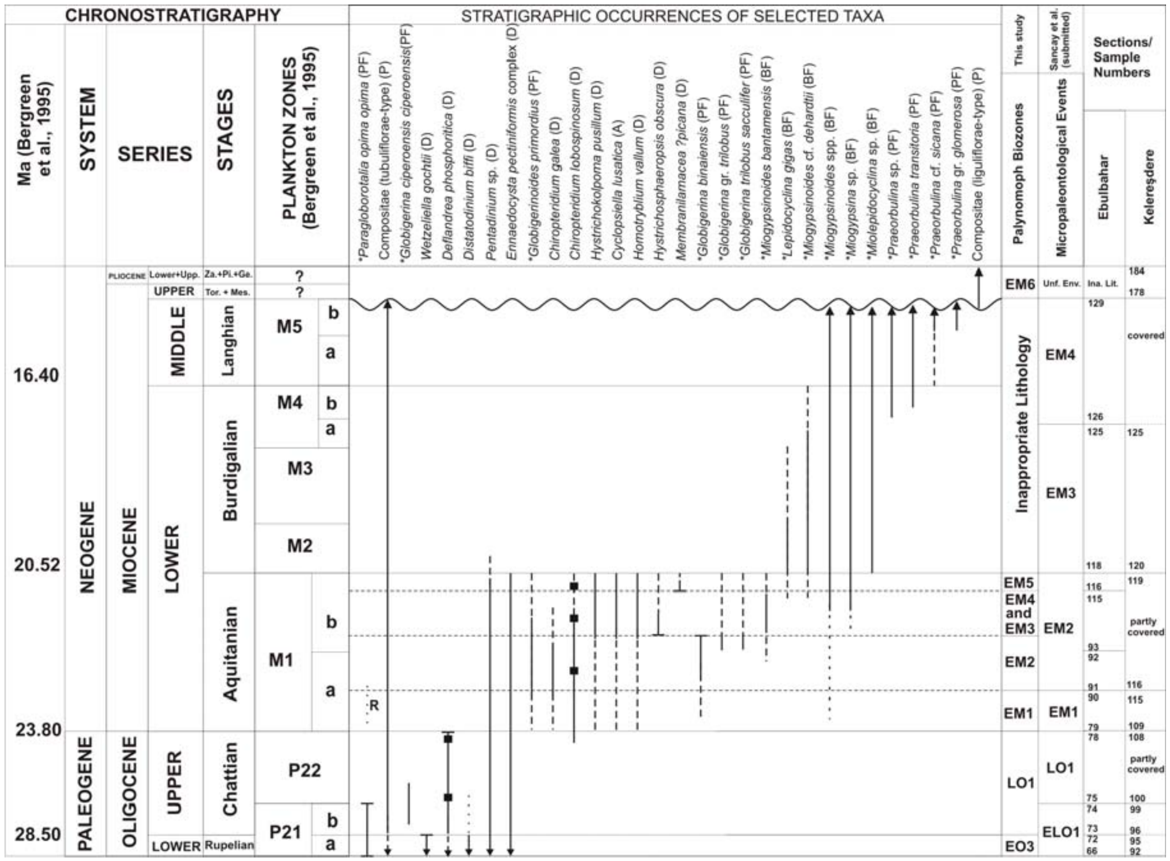


Figure 26. Bio-chronostratigraphic chart and the stratigraphic occurrences of selected taxa (PF: planktonic foraminifer; BF: benthic foraminifer; D: dinoflagellate; P: pollen; R: reworked; Unf. Env: unfavourable environment; Ina. Lit: inappropriate lithology; ■; peak occurrences; *: taxa identified in Sancay et al., submitted).

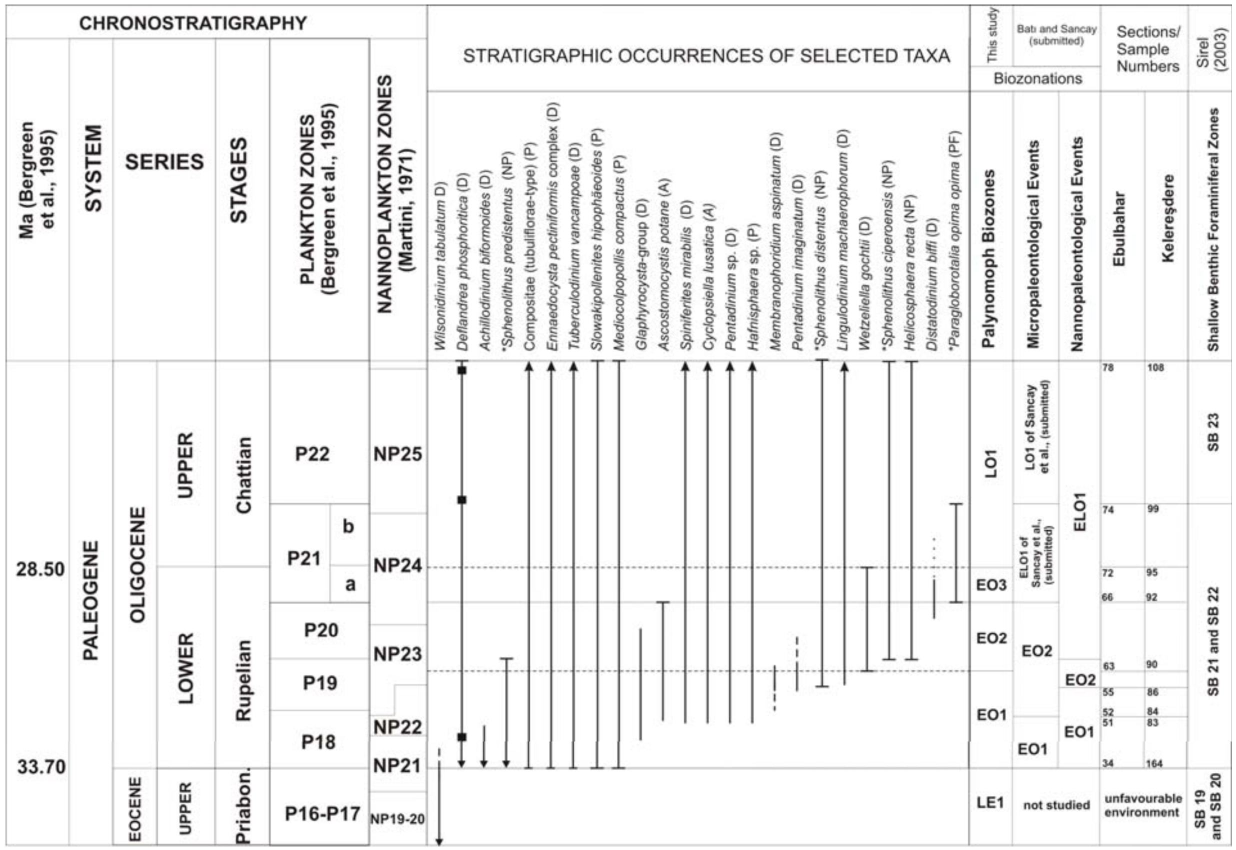



Figure 27. Bio-chronostratigraphic chart and the stratigraphic occurrences of selected taxa (PF: planktonic foraminifer; BF: benthic foraminifer; NP: Calcareous Nannoplankton; D: dinoflagellate; A: acritarch; P: pollen; ■; peak occurrences; *: taxa identified in Batı and Sancay, submitted).

3.6.2. EO1 (*Ascostomocystis potane* Interval zone)
Assigned Age: Early Oligocene (early-middle Rupelian)
Equivalent Planktic Zones: P18 to lower part of P20
Equivalent Nannoplankton Zone: NP-21 to NP-23

Definition: Because of the terrestrial dominant lithologies in the underlying sediments, base of the zone has been defined based on terrestrial palynomorphs. Compositae (tubuliflorae-type) occurs for the first time coinciding with the FADs of *Slowakipollis hipophaeoides*, *Mediocolpopollis compactus*, *Monoporopollenites gramineoides* and Umbelliferae at the base of the zone. The top of the zone is defined by the FAD of *Wetzeliella gochtii*. *Glaphyrocysta*-group, *Achillodinium biformoides*, *Membranophoridium aspinatum*, *Pentadinium imaginatum*, *Pentadinium* sp., *Spiniferites pseudofurcatus*, *Spiniferites* spp., *Hafnisphaera* sp., *Polysphaeridium zoharyi*, *Hystrichokolpoma rigaudiae*, *Tuberculodinium vancampoae*, *Ennaedocysta pectiniformis* complex, *Cyclopsiella lusatica*, *Opeculodinium microtriainum*, and peak occurrences of *Deflandrea phosphoritica* also recorded in this zone. Terrestrial spore, pollen and fresh water algae *Botryococcus braunii* and *Pediastrum* spp. are dominating this zone in the Kelereşdere section representing lacustrine to fluvial depositional conditions, whereas shallow marine successions in which *Deflandrea* spp. dominated dinoflagellate assemblage were recorded in the Ebulbahar section. Batı and Sancay, (submitted) have identified EO1 (Early Oligocene) zone in this interval based on foraminifers. The top of their zone is defined by the FAD of *Globigerina selli* but bottom of the zone could not be defined due to the unfavourable depositional environment. The age assignments based on foraminifers in their study and palynomorphs in this study are quite comparable. They have also distinguished EO1 and EO2 zones based on calcareous nannoplanktons in the interval that I have defined EO1 zone with palynomorphs in this study. Two major stratigraphically important nannofossil events have been recorded in this interval by Batı and Sancay, (submitted). These are the FAD of *Sphenolithus distentus* and the FADs of

*Helicosphaera recta* and *Sphenolithus ciperoensis*. According to Bergreen et al. (1995), the former event occurred 31.5 to 33.1 Ma in the nannoplankton zone of NP23 of Martini, (1971) whereas the latter event marks the base of the nannoplankton zone of NP24 in Martini (1971) and occurred at 29.9 Ma. Based on these event following biozones have been established. They have distinguished EO1 (*Sphenolithus predistentus* Interval Zone) and EO2 (*Sphenolithus distentus* Interval Zone) based on calcareus nannoplanktons. EO1 is defined by the FAD of *Sphenolithus distentus* but base of the zone can not be defined properly due to the unappropriate lithology. This zone is corresponding to planktonic foraminiferal zone of P18 and the lower part of P19 whereas EO2 zone is defined by the interval between the FAD of *Sphenolithus distentus* to the LAD of *Sphenolithus predistentus* and is corresponding to upper part of P19. Batı and Sancay (submitted) assigned an early Rupelian and early-middle Rupelian ages for EO1 and EO2 zones respectively. These results are also quite consistent with the age assignments for this interval based on palynomorphs in this study.

3.6.3. EO2 (*Wetzeliella gochtii* Interval zone)
Assigned Age: Early Oligocene (middle-late Rupelian)
Equivalent Planktic Zones: P19-P20
Equivalent Nannoplankton Zone: NP-23 and NP-24

Definition: This zone is defined by the interval between the FAD of *Wetzeliella gochtii* and the LAD of *Ascostomocystis potane. Distatodinium biffii* first occurs within this zone.
Discussion: EO2 zone, defined by the interval between the FAD of *Globigerina selli* and the FO of *Globorotalia opima opima* and corresponding to P20, based on microforaminifers have been identified in this interval by Batı and Sancay (submitted). They assigned an Early Oligocene age for this interval. This zone is conformably overlain by ELO1 zone, late Rupelian-early Chattian in age, of Sancay et al. (submitted). Both micropaleontological and calcareous nannofossil data indicated by Batı and Sancay (submitted)

suggest a Rupelian age for this interval and the results there are also consistent with the age assignments in this study.

3.6.4. EO3 (*Distatodinium biffii* Interval Zone)

Assigned Age: latest Rupelian

Equivalent Planktic Zones: P21a

Equivalent Nannoplankton Zone: lower part of NP24

Definition: Interval between the LAD of *Ascostomocystis potane* and the LAD of *Wetzeliella gochtii*. The eponymous species, *Distatodinium biffii*, ranges above and below the zone but has its highest abundance within this interval. LAD of *Ascostomocystis potane* is also coinciding with the FAD of *Globorotalia opima opima*. *Pentadinium* sp., *Ennaedocysta pectiniformis* complex, *Deflandrea phosphoritica* commonly occur and Compositae (tubuliflorae-type) also exist within this zone. Upper part of this zone could not be defined properly in the Kelereşdere section because of the unappropriate nature of lithology (reefal limestone) in the samples labeled as 93-95.

Discussion: Torricelli and Biffi (2001) reported that the FAD and LAD of *Wetzeliella gochtii* were in the Lower Oligocene from the Numidian Flysch in Oued El Guastal and El Gassaa sections in Tunisia. They also suggested that the LAD of this taxon can be used as an additional criterion for the identification of the *Clo* (*Chiropteridium lobospinosum*) Zone (Lower Oligocene) of Wilpshaar et al. (1996) in Mediterranean. As it was reported by Pross (2001), LAD of *Wetzeliella gochtii* is a diachronic event and varies from Rupelian to early Chattian. On the other hand, according to Stover and Hardenbol (1994), FAD of *Ascostomocystis potana* is very close to the base of the Rupelian and its last occurrence is in the middle Rupelian, in the calcareous nannoplankton zone NP23 of Martini (1971), and never occurs in the late Rupelian. I have not seen any *Ascostomocystis potane* in EO1 but Batı and Sancay (submitted) reported that this taxon occurred just below this zone corresponds to the middle/late Rupelian boundary. Therefore, reefal limestones (samples labeled as 93-95 in the Kelereşdere section) should represent the ?late Rupelian period.

EO3 zone is also corresponding to the lower part of ELO1 foraminifer zone, (*Globorotalia opima opima* Range Zone, which is defined by the complete range of *Globorotalia opima opima*, late Rupelian in age and corresponding to planktonic foraminifer zone of P21a) and the lower part of ELO1 calcareous nannoplankton zone (*Helicosphaera recta* Interval Zone which is indicated as late Early Oligocene (late Rupelian) in age and characterized by the presence of *Helicosphaera recta* and *Sphenolithus ciperoensis* and the absence of *Sphenolithus predistentus*, and corresponding to upper part of NP23 to NP25) of Sancay et al. (submitted). Both data derived from foraminifers and calcareous nannofossils are quite consistent with the age assignments in this study for this interval and suggest a late Rupelian age.

3.6.5. LO1 (*Deflandrea phosphoritica* peak zone)

Assigned Age: Chattian

Equivalent Planktic Zones: P21b and P22

Equivalent Nannoplankton Zone: upper part of NP24 and NP-25

Definition: Base of the zone is defined by the LAD of *Wetzeliella gochtii* and top of the zone is defined by the LAD of *Deflandrea phosphoritica* and FAD of *Chiropteridium galea*. *Distatodinium biffii* has its last appearance within this zone.

Discussion: It may correspond to the magnetic polarity chronozones C9n to base of C6Cn2r of Bergreen et al. (1995) and the lower part of the DO3 zone, Late Oligocene in age, (top of the youngest acme of *Deflandrea* spp.) of Biffi and Manum (1988), *Distatodinium biffii* (Dbi) Interval Zone of Brinkhuis et al. (1992) representing Late Oligocene-Early Miocene and *Distatodinium biffii* (Dbi) Interval Zone of Zevenboom (1996), indicating Late Oligocene to latest Oligocene ages. Latter two studies suggested that the FAD of *Distatodinium biffii* defines the base of the zone whereas the base of the youngest acme of

*Deflandrea* spp. can be used as a confirmatory event for the top. This zone corresponds to magnetic polarity chronozones C9n to base of C6Cn2r.

Similar age assignments have been documented by Sancay et al. (submitted) who distinguished ELO1 micoroforaminifer zone (early Chattian) and upper part of ELO1 calcareous nannoplankton zone (Chattian) in this interval.

Reworking from Eocene (*Echinatisporis* sp.) and Cretaceous (*Muderongia tetracantha* and *Discorsia nanna*) sediments has also been recorded in some of the samples in this zone.

3.6.6. EM1 (Transitional Zone)

Assigned Age: early Aquitanian

Equivalent Planktic Zones: ?P22 to M1

Equivalent Nannoplankton Zone: ?NP-25 to NN1

Definition: Transitional subzone is characterized by only a few occurrences of dinoflagellates such as *Homotryblium* sp. and *Spiniferites* sp., and a terrestrial freshwater algae called *Botryococcus braunii*.

Discussion: Brinkhuis et al. (1992) reported distinct increase in terrestrial palynomorphs, *Spiniferites*/*Achomosphaera* spp., and especially *Chriptoredium* spp., towards the Oligocene-Miocene boundary. They have claimed that sudden increase in shallow water indicators associated with increasing amount of reworking might be related to the relative fall in sea level. This regressive event has also been reported by Haq et al. (1988). Latter study indicates that the Oligocene-Miocene transition coincides with the base of their cycle TB1.4 corresponding to Chron C6Cr3 at about 25 Ma. Moreover, several stable isotope studies (Miller et al., 1985 and 1987; Biolzi, 1983) suggest a global cooling event and confirm the global nature of the relative fall in sea level at the Oligocene-Miocene boundary.

3.6.7. EM2 (*Chiropteridium* spp. Abundance Zone I)

Assigned Age: early-middle Aquitanian

Equivalent Planktic Zones: M1

Equivalent Nannoplankton Zone: NN1 and NN2

Definition: This zone is represented by the peak occurrences (including the first common occurrence) of *Chriptoredium galea* and *Chriptoredium lobospinosum*.

Discussion: It may be comparable with DN1 in which *Chiropteridium-Homotryblium-Systematophora* assemblage, LAD of *Chiropteridium* and *Deflandrea phosphoritica* reported (uppermost Oligocene to lower Lower Miocene; upper Chattian to lower Aquitanian) by de Verteuil and Norris (1996) in this zone. It also corresponds to *Chriptoredium* (Chi) Abundance Subzone (uppermost Oligocene-lowermost Miocene) of Brinkhuis et al. (1992); corresponding to top P22 through N4 planktonic foraminifer zones and basal NP25 through NN1 calcareous nannoplankton zones, and magnetic polarity chronozones C7n through C6Cr3.

3.6.8. EM3 (*Hystrichosphaeropsis obscura* interval zone)

Assigned Age: middle-late Aquitanian

Equivalent Planktic Zones: M1 to ?M2

Equivalent Nannoplankton Zone: NN1 and NN2

Definition: Base of the zone is defined by FAD of *Hystrichosphaeropsis obscura* and the last common occurrence of *Homotryblium vallum*. *Chiropteridium galea*, *Hetaraulacacysta* sp., *Cribroperidinium tenuitabulatum*, *Apteodinium spiroides* also first occur within this subzone. LAD of C*ordosphaeridium cantharellus* is within this zone. Top of the zone is not defined properly because of the unappropriate nature of the overlying lithology (limestone).

Discussion: This zone may be comparable with DN2 (lower Lower Miocene to middle Lower Miocene) of de Verteuil and Norris (1996). It is partly corresponding to *Ectosphaeropsis burdigaliensis* Interval Zone (Lower Miocene) of Brinkhuis et al. (1992), defined as an interval between the base of the youngest acme of *Deflandrea* spp., to the FAD of *Membranilarnacia ?picena*, corresponding to the basal N4 through N5 planktonic foraminifer zones and basal NN1 through NN2 calcareous nannoplankton zones, and magnetic polarity chronozones C6Cn2r to the base C6Ar.

3.6.9. EM4 (*Chiropteridium* spp. Abundance Zone II)
Assigned Age: late Aquitanian
Equivalent Planktic Zones: M1 to ?M2
Equivalent Nannoplankton Zone: NN1 and NN2

Definition: Last common occurrence of *Chiropteridium* spp. and the first common occurrence of *Homotryblium pusillum* occur within this zone. Top of the zone is not defined palynologically due to the unappropriate nature of the lithology.
Discussion: This zone is partly corresponding to upper parts *Ectosphaeropsis burdigaliensis* Interval Zone (Lower Miocene) of Brinkhuis et al. (1992); from the base of the youngest acme of *Deflandrea* spp., to the FAD of *Membranilarnacia ?picena*, corresponding to the basal N4 through N5 planktonic foraminifer zones and basal NN1 through NN2 calcareous nannoplankton zones.

EM3 and EM4 biozones can be correlated with the *Hystrichosphaeropsis obscura*-*Chiropteridium* spp. Assemblage Zone of Ertuğ et al. (1995) defined in the Akçan member of the Alibonca Formation, in the Tekman basin, Eastern Anatolia. They have distinguished this biozone based on the FAD of *Hystrichosphaeropsis obscura* and the epibole of *Chiropteridium* spp. Common occurrences of *Impletosphaeridium* sp., and *Hystrichokolpoma rigaudae* also reported for this biozone. According to Ertuğ et al. (1995), this biozone represents an Early Miocene (Aquitanian-Burdigalian) age. Supporting results are also obtained from the nannoplanktons that suggest Early Miocene (NN2 nannoplankton zone) age for the identified biozone.

EM1 through EM4 zones are corresponding to the *Ectosphaeropsis burdigaliensis* (Ebu) Interval zone of Brinkhuis et al. (1992), defined as an interval between the base of the youngest acme of *Deflandrea* spp., and the FAD of *Membranilarnacea* ?*picena*. They indicated that this zone represents Early Miocene time and corresponds to the magnetic polarity chronozones C6Cr3 to C6Cn3.

3.6.10. EM5 (*Membranilarnacea* ?*picena* interval zone)

Assigned Age: latest Aquitanian

Equivalent Planktic Zones: M2

Equivalent Nannoplankton Zone: NN2

Definition: Base of the zone is defined by FAD of *Membranilarnacea* ?*picena* but top of the zone is not defined due to an overlying unconformity surface. LAD of *Chiropteridium* spp., and *Thallasiphora pelagica* also occur within this zone.

Discussion: This zone is corresponding to *Membranilarnacia* ?*picena* (Mpi) interval zone (Early Miocene) of Brinkhuis et al. (1992) and Zevenboom (1996) and DM1b Subzone of Biffi and Manum (1988). The FAD of *Membranilarnacia* ?*picena* defines the base of the zone, top is undefined corresponding to magnetic polarity subchronozones C6Ar to base of C6An. Torricelli and Biffi (2001) also reported that *Membranilarnacia* ?*picena* has its FAD in the Aquitanian deposits from the Numidian Flysch in El Gassaa and Cap Serrat sections in Tunisia.

Due to the inappropriate lithologies (mostly limestone, carbonaceous sandstone with some silty marl intercalations in which palynomorphs occur sporadically) of the uppermost Aquitanian-Burdigalian sediments, most of the stratigraphically important dinoflagellates such as *Exochosphaeridium insigni*, *Extosphaeropsis burdigaliensis*, *Sumatradinium druggii*, *Sumatradinium soucouyantiae*, *Cousteaudinium aubryae* are missing in Eastern Anatolia. Sampling interval may also be another reason for the absence of these taxa because they have reduced stratigraphic ranges. Therefore, those intervals could not be correlated regionally based on dinoflagellate events.

Lower Miocene part of the Ebulbahar and Kelereşdere sections have been also investigated by Sancay et al. (submitted). They have distinguished two zones in the Aquitanian and two zones in the Burdigalian. Aquitanian foraminiferal zones of Sancay et al. (submitted) can be comparable with EM1 to EM5 palynomorph zones of this study. Based on the presence of planktonic foraminifers such as *Globigerinoides sacculifer* and *Globigerinoides binaensis*, and benthonic foraminifers such as *Miogypsina* sp., and *Miogypsinoides* sp., and *Miogypsinoides bantamensis*, an Aquitanian age has been suggested which is consistent with the Aquitanian ages assigned for the EM1 to EM5 zones in this study. Burdigalian part of the sections could not be studied palynologically due to the unappropriate lithologies (limestones).

3.6.11. EM6 (Compositae (liguliflorae-type) Assemblage zone)

Assigned Age: Late Miocene to Pliocene

Equivalent Planktic Zones: ?

Equivalent Nannoplankton Zone: ?

Definition: Completely terrestrial palynomophs and fresh water algae dominate this zone. Base of the zone is not defined properly because of the underlying unconformity surface. Compositae (liguliflorae-type), small Compositae (tubuliflorae-type), Dipsacaceae, *Periporopollenites multiporatus*, *Polyporopollenites undulosus*, *Monoporopollenites gramineoides*, *Botryococcus braunii*, and *Ovoidites parvus* commonly occur in the samples.

## 3.7. Terrestrial Palynomorphs

Palynological studies in the Eastern Anatolia are mostly carried out by TPAO on wells and surface stratigraphic sections. These studies are mainly based on terrestrial palynomorphs. Because of the absence of multidisciplinary studies in that region, uncertainities in the stratigraphic ranges of many fossils including dinoflagellates, planktonic and benthonic foraminifers, and nannoplanktons still exist. Biozonations established especially in the western and central part of the Turkey in the earlier studies of Benda (1971a and b), Benda et al. (1977), Benda et al. (1979), Ediger et al. (1990), and Batı (1996) have been attempted to be used in the Eastern Anatolia but it could not have been achieved properly.

As far as terrestrial palynomorphs are concerned, pollen belonging to Compositae family seem to be very important to establish biostratigraphic framework in the Eastern Anatolia. Compositae pollen have not been reported from the sediments older than the Late Oligocene throughout the world (e.g. Germeraad et al., 1968; Kemp and Harris, 1977; Hochuli, 1978; Muller, 1981). Barreda (1993) studied the Late Oligocene?-Miocene pollen of the Golfo San Jorge Basin, southeastern Argentina. He suggested that the lower part of the Chenque Formation could not be older than Late Oligocene based on the occurrences of pollen grains belonging to Compositae family. Batı and Alişan (1991) in their study on the biostratigraphy of Malazgirt-1 well in the Muş Basin, suspected that the first occurrences of Compositae pollen might be in the Late Oligocene in the Eastern Anatolia. This study is important as being the first study questioning the first occurrences of the Compositae pollen in Miocene. Stratigraphic distribution of Compositae pollen in Turkey has been studied by several researchers (Benda, 1971a and b; Benda et al., 1977; Benda et al., 1979; Akgün et al., 1986; Akgün and Akyol, 1987 and 1992; Ediger et al., 1990; Batı, 1996) mostly in Western Anatolian Neogene successions. They mainly suggested that Compositae occurred for the first time at the beginning of the Miocene in the western part of Turkey. However, palynostratigraphic analysis of the Eastern Anatolia claimed that Compositae pollen flourished earlier in the Eastern Anatolia (Batı and Alişan, 1991).

*Slowakipollis hipophaeoides* and *Mediocolpopollis compactus* also occur in Oligocene sediments in the Eastern Anatolia. They commonly occur in EO1 and LO1 zones, which are dated as late Rupelian and Chattian respectively in this study and are very good indicators of the Oligocene. According to Hochuli (1978), *Slowakipollis hipophaeoides* occurs in Lower-Middle Oligocene sediments whereas *Mediocolpopollis compactus* has much wider stratigraphic range from Late Eocene to Middle Oligocene in Central and Western Paratethys. Occurrences of *Slowakipollis hipophaeoides* in the Oligocene have also been reported by Gorin (1975) in Grande Limagne, France, and Chateauneuf (1980) in Paris Basin. *Mediocolpopollis compactus* has been recorded in the Upper Oligocene sediments of British Isles by Wilkinson and Boulter (1980) and “Middle” Oligocene sucsessions of Bristol Channel by Boulter and Craig (1979). These two species have also been identified in Hayrettin and Tokça formations to which Early-Middle Oligocene and Early Oligocene ages have been assigned by Akkiraz (2000) and Akkiraz and Akgün (2005) in the Çardak-Tokça Basin, Southwest Anatolia. Presence of *Slowakipollis hipophaeoides* and *Mediocolpopollis compactus* together with common to abundant occurrences of Compositae pollen (tubuliflorae-type) at the bottom of studied sections is stratigraphically important which supports the Rupelian occurrences of Compositae in the Eastern Anatolia. The earlier flourishment of Compositae pollen (tubuliflorae-type) may occur due to climatic conditions. In general, lower occurrences of *Quercus* and relatively higher abundances of Compositae pollen represent dry-arid conditions (Horowitz, 1992). The Eastern Anatolia was relatively colder and cooler than the Western Anatolia during Tertiary just like how it is today. Because tropical and subtropical elements such as *Tilia*, *Alnus*, *Carya* etc., recorded in Nortwestern and Western Anatolia Tertiary sediments (Batı, 1996; Akkiraz, 2000), do not exist or are very rare in the Eastern Anatolia. According to Akgün et al. (2004), mean annual temperatures (MAT) ranges between 17,2 to 20,8 °C and the mean temperatures of the coldest month (CMT) were between 9,6 to 13,3 °C in Oligocene in the Western Anatolia. However, Climsat software results of the Oligocene sediments in the Eastern Anatolia suggest relatively cooler conditions in that the mean annual temperatures were between 15,6 to 21,3 °C and the mean temperatures of the coldest month (CMT) were between 5,0 to 13,3 °C.

Palynologically, following palynomorph taxa have been commonly recorded in the studied sections; Pollen: Compositae (tubuliflorae-type, less ornamented, has thick exine, and small), *Dicolpopollis kalewensis*, *Monoporopollenites gramineoides*, *Ephedripites* sp., small/less ornamented Umbelliferae, *Polyvestibulupollenites verus*, Compositae-type pollen, *Tricolpopollenites* sp., *Tricolporopollenites* sp, *Periporopollenites multiporatus*, Spores: *Cingulatisporites* sp, *Retrilites fragilis*, *Lusatisporites perinatus*, *Echinatisporis* sp. (reworked from Eocene), *Cicatricosisporites* sp. Fungal spores: *Anatolinites dongyingensis*, *Biporisporites* sp., All *in situ* palynomorphs except Compositae, Umbelliferae and *Monoporopollenites gramineoides* have quite long stratigraphic ranges (Tertiary). *Monoporopollenites gramineoides* and small/less ornamented Umbelliferae can be traced back to Upper Oligocene (Batı, 1996 and references therein), but Compositae (tubuliflorae-type) and big/well ornamented Umbelliferae pollen were believed to be occurred in the beginning of the Miocene (Benda, 1971a and b; Benda et al., 1977; Benda et al., 1979; Ediger et al., 199O; Akyol and Akgün, 1992; Akgün et al., 1995; Batı, 1996). However, both nannopaleontological and micropaleontological data suggest Oligocene age for these samples. Moreover, in the lowermost parts of the studied sections, where very thick successions of clastic deposition took place, the base occurrence of Compositae (tubuliflorae-type) was placed in the Rupelian on the basis of worldwide defined dinoflagellate and acritarch biozonations. Therefore, Oligocene zonation of some palynomorphs should be fixed and stratigraphic ranges of common to abundant occurrences of Compositae (tubuliflorae-type) pollen should be prolonged untill the Rupelian in the Eastern Anatolia.

However, when the Lower Miocene part of the sections is considered, the palynomorph assemblage is composed of mostly following palynomorph taxa; Pollen: Compositae (tubuliflorae-type, well ornamented, big, (common to abundant), *Monoporopollenites gramineoides* (common), big/well ornamented

Umbelliferae (common), Dipsacaceae (common), suggesting an Early Miocene age. Relative abundances of Compositae pollen in this interval are quite higher as compared to the Western Anatolia, where the average frequencies are around 1 % (Akgün et al., 1986; Akgün and Akyol, 1987 and 1992).

Samples above the unconformity surface labeled as 178-184 in the Kelereşdere section, have the following palynomorph assemblage; Compositae (liguliflorae-type) *(*common), Compositae (tubuliflorae-type) (common), *Monoporopollenites gramineoides* (rare), big/well-ornamented Umbelliferae (rare), and interpreted as Late Miocene-Pliocene in age. This zone it is not recorded in the Ebulbahar Section due to an unappropriate nature of the lithology for palynological analysis.

## 3.8. Correlations of the palynomorph assemblages with other palynological studies in Turkey

Only a few palynological studies carried out in the Eastern Anatolian Tertiary sediments (Table 2) and most of them are in in the scope of exploration activities of TPAO in that region. The earliest study carried out by Akyol (1964) in Toprakkale-Oltu (Erzurum) coals. He assigned an Oligocene age for these coals based on the following palynomorphs; *Laevigatosporites haardti* (48 %), *Inaperturopollenites dubius* (20 %), *Inaperturopollenites emmaensis* (11 %), *Leiotriletes adriennis* (7 %), *Inaperturopollenites incertus* (4 %), *Triatriopollenites coryphaeus* (3 %), and *Monocolpopollenites zievelensis* (1 %). Coal samples derived from the Kömürlü Section (northeast of Oltu) have been investigated in the context of this study. Even though, they are also Oligocene in age, different palynomoph assemblages have been recorded (Apendix B) in which organic-walled green algae (*Botryococcus* and *Pediastrum*), *Anatolinites dongyingensis*, *Cingulatisporites* sp., *Cicatricosisporites* sp. *Periporopollenites multiporatus*, and *Monocolpopollenites tranquillus* predominate.

Table 2. List of the palynostratigraphic works used in this study for the correlation of the Oligocene-Miocene palynomorph assemblages in Turkey.

| Time \ Study | Akyol (1964) Erzurum, Edirne, İstanbul, | Nakoman (1964, 1966, 1967) Hayrabolu-Uzunköprü | Corsin and Nakoman (1967) Thrace Basin | Nakoman (1968) Istanbul | Benda (1971a, b) Western Anatolia | Akyol (1971, 1974) Istanbul | Benda et al. (1977) Greece | Benda et al., (1979) Greece | Ediger (1981b, 1982) Thrace Basin | Gerhard and Alişan (1986) Thrace Basin | Akgün and Akyol (1987) Akhisar | Ediger et al. (1990) Thrace Basin | Batı and Alişan (1991) Eastern Anatolia | Akgün and Akyol (1992) Isparta | Batı et al. (1993) Thrace Basin | Akyol and Akgün (1995) Thrace Basin | Batı (1996) Thrace Basin | Sancay et al. (submitted) Eastern Anatolia | Batı and Sancay (submitted) Eastern Anatolia |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pleistocene | | | | | | | | ■ | | | | | | | | | | | |
| Pliocene | | | | | ■ | | ■ | ■ | | | | | | | | | | | |
| Miocene | | | | ■ | ■ | | | | | | ■ | | ■ | ■ | | | | ■ | |
| Oligocene | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | | ■ | ■ | | ■ | ■ | ■ | ■ | ■ |
| Eocene | | | | | | | | | | | | | | | | | | | ■ |

Most of the earlier palynological studies in Tertiary sediments of Turkey were carried out in Thrace Basin (Nakoman, 1964, 1966 and 1967; Akyol, 1964; Corsin and Nakoman, 1967). They investigated 10 different coal seams between Hayrabolu and Uzunköprü in 5 different sectors (Keşan-Malkara region, Kalivya-Yörük region, Aliç-Türkobası-İbriktepe, south of the Karaburçak anticline, and north of the Karaburçak anticline). They mainly focused on the relative frequencies of spore-pollen and Incertae Sedis and excluded fungal spores, dinoflagellates and organic-walled algae in their study. A total of 249 spore-pollen species belonging to 58 genera have been identified in these studies and 48 of which were identified for the first time as a new species. They reported that *Polyvestibulopollenites verus* is dominating in Seam I (17 %), *Tricolpopollenites microhenrici* in Seams II (22 %) and III (26 %), *Inaperturopollenites dubius* in Seam IV (26.5 %), *Dicolpopollis kalewensis* in Seams V (20 %), VII (34 %), and IX (20 %), *Laevigatosporites haardti* in Seams VI (34 %), VIII (21 %), and X (25 %). In addition to the most abundant taxa, *Monocolpopollenites tranquillus*, *Monocolpopollenites areolatus*, *Triatriopollenites coryphaeus*, *Inaperturopollenites emmaensis*, *Tricolporopollenites cingulum*, *Monoporopollenites solaris*, *Verrucatosporites favus*, *Cicatricosisporites dorogensis*, and *Leiotriletes adriensis* also commonly occurred in their studied samples. They claimed that palynomorph assemblages identified in the coal seams are comparable with the Oligocene spore-pollen assemblages of Central Europe and assigned a Sannoisian (the earliest Oligocene) age for the seams I-VI and Stampian (Early Oligocene) for the seams VII-X and. However, Akyol and Akgün (1995) interpreted the age of the coal seams in Thrace Basin as “middle” to Late Oligocene based on the relative abundances of *Dicolpopollis kalewensis*. Moreover, studies of TPAO palynologists (e.g. Ediger, 1981b and 1982; Gerhard and Alişan, 1986; Ediger et al., 1990; Batı et al., 1993) documented that the Early Oligocene time was represented by marine clastics in which some index Early Oligocene dinoflagellates such as *Wetzeliella gochtii* and *Distatodinium ellipticum* occurred. Therefore spore-pollen assemblage reported by

Nakoman (1964, 1966 and 1967); Akyol (1964); Corsin and Nakoman (1967) should be Late Oligocene (Chattian) in age. Most of the taxa recorded in the studies mentioned above have also been identified in the Eastern Anatolian Oligocene-Miocene sediments but in diferrent quantities. For instance; *Dicolpopollis kalewensis*, *Triatriopollenites coryphaeus*, *Tricolporopollenites cingulum*, *Polyvestibulopollenites verus*, and *Tricolpopollenites microhenrici* are seen relatively in low abundances whereas Compositae, Gramineae, and Umbelliferae are recorded in high abundances in the Eastern Anatolia. This shift in the terrestrial palynomorph assemblages might be related to paleoclimatological conditions of which details will be given in following paragraphs. The Eastern Anatolia experienced relatively colder conditions than the Western and Central part of Turkey during Oligocene and Miocene.

Akyol (1964) assigned an Oligocene age for the coals of Arnavutköy, Küçükdoğanca (Edirne), Silivri-Büyükçekmece (İstanbul), and İbrice (Tekirdağ) but the main difference of his palynological assemblage from those of Nakoman's, Ediger's, and Batı's palynological assemblages is the absence of *Dicolpopollis kalewensis*, *Cingulatisporites macrospeciosus*, and *Leiotriletes microadriennis*. As far as the Eastern Anatolian Oligocene sediments are concerned, *Cingulatisporites macrospeciosus* commonly occurs accompanied by low frequencies of *Dicolpopollis kalewensis* and *Leiotriletes microadriennis*.

Nakoman (1968) investigated 4 samples, labeled as A1 to A4, from the Ağaçlı lignites (Istanbul) to which the latest Oligocene-Early Miocene age was assigned. He documented that A4 is dominated by *Triatriopollenites coryphaeus* (36 %), whereas A1, A2 and A3 are dominated by *Tricolporopollenites cingulum* (21 %, 22 %, and 15 %) respectively. These pollen have been recorded only in low frequencies in the Eastern Anatolian Oligocene-Miocene sediments due to climatic variations. He also suggested that *Subtriporopollenites simplex* occurred for the first time in the Early Oligocene whereas *Inaperturopollenites hiatus* has its first occurrence in the "middle" Oligocene. However, both of those pollen have been recorded from the Lower Oligocene sediments in the Eastern Anatolia in this study. Similar to assemblages of Akyol (1964), *Cingulatisporites macrospeciosus*, and *Leiotriletes microadriennis*, commonly observed in the Eastern Anatolia, are absent in the palynomoph assemblages of the Ağaçlı lignite.

Akyol (1971 and 1974) documented spore-pollen and Incertae Sedis assemblages of Avcıkoru-Şile (İstanbul). An Early Oligocene age has been assigned for the coals in this region based on the presence of Oligocene spore-pollen such as *Triatriopollenites coryphaeus* (6->50 %), *Dicolpopollis kalewensis* (2->50 %), *Tricolporopollenites cingulum* (2-25 %), *Triatriopollenites rurensis* (1-25 %), *Tricolpopollenites liblarensis* (1-10 %), *Verrucatosporites favus* (1-10 %) *Laevigatosporites haardti* (1-5 %), *Leiotriletes dorogensis* (1-5 %), together with the Early Oligocene pollen grain *Extratriporopollenites pompeckji* (< 1 -5 %). *T. coryphaeus*, *D. kalewensis*, *V. favus*, *L. haardti*, and *T. liblarensis* never reach 5 % and *T*. *rurensis* and *E*. *pompeckji* have not been detected in the Eastern Anatolian Oligocene sediments. Climate seems to be the main mechanism responsible from the distinct differences between the palynomorph assemblages of the same chronostratigraphic units in the Eastern and Western Anatolia.

Multidisciplinary studies (including palynomorphs, mammals, foraminifers, nannoplanktons, and radiometric ages) of Benda (Benda, 1971a and b; Benda et al., 1977; Benda et al., 1979) have been important in detecting the chronostratigraphic positions of the palynomorph assemblages in Turkey. Benda (1971a and b) distinguished 7 sporomorph association named with their type localities (Tokça sporomorph association, Early-“Middle” Oligocene; Kurbalık sporomorph association, Late Oligocene-Early Miocene; Kale sporomorph association, Early-Middle Miocene; Eskihisar sporomorph association, Middle Miocene; Yeni Eskihisar sporomorph association, Middle-Late Miocene; Kızılhisar sporomorph association, Pliocene; Akça sporomorph association, Pliocene and Pleistocene) for the Cenozoic sediments in Turkey. However, he did not give neither the number of the studied samples to establish those sporomorph associations nor the number of the taxa encountered in each asssociation. Some terms such as questionable, single, poor, frequent, and very frequent have been used in his pollen distribution charts. Later, Benda and Meulenkamp (1979) revised the chronostratigraphic positions of those sporomorph assemblages based on marine stages and radiometric ages. They suggested an Early Miocene (Burdigalian) age for the Kale sporomorph association, Early-Middle Miocene age for the Eskihisar sporomorph association (Burdigalian-Serravalian), Middle Miocene (Serravalian) age for the Yeni Eskihisar sporomorph association, and Late Miocene (Tortonian-Messinian) age for the Kızılhisar sporomorph association. Some palynomorphs (e.g. *Cicatricosisporites* sp., *Monocolpopollenites tranquillus*, *Triatriopollenites excelsus*, *Leiotriletes adriennis*, *Verrucatosporites favus*, *V.alienus*) reported in the Tokça sporomorph association of Benda (1971 a and b) have also been identified in the Oligocene sediments of the Eastern Anatolia but *Slowakipollis hipophaeoides* and *Mediocolpopollis compactus*, which were not seen by Benda, have also been recorded in the Oligocene in this study.

Even though most of the palynological studies (Benda, 1971a and b; Benda et al., 1977; Benda et al., 1979; Akgün et al., 1986; Akgün and Akyol, 1987 and 1992; Ediger et al., 1990; Batı 1996) carried out in western and central part of the Turkey suggested that Compositae was occurred for the first time at the beginning of the Miocene in Turkey, palynostratigraphic analysis of the Eastern Anatolia claimed that Compositae (tubuliflorae-type) flourished earlier in the Eastern Anatolia. Sancay et al. (submitted) have just reported that Compositae (tubuliflorae-type) can be traced back to Chattian and even to Rupelian in the Eastern Anatolia in their multidisciplinary study on the basis of world-wide defined dinoflagellate, planktonic foraminifer, and calcareous nannoplankton biozonations. This argument is also quite comparable with the results of Sirel (2003) in that SB21-22 shallow benthic foraminifer zones, Rupelian-early Chattian in age, have been identified at the same levels where I have Compositae (tubuliflorae-type) also supporting the early flourishment in the Eastern Anatolia. Climate might be the main driving factor on the earlier occurrences of Compositae (tubuliflorae-type) in this region. Relatively cooler conditions might be considered for the Eastern Anatolia than the Western Anatolia during the Oligocene. Additional evidences for the cooler climatic conditions in the Eastern Anatolia during the Oligocene can be traced from another dry-arid climate indicator (Horowitz, 1992) Chenopodiaceae. According to Benda (1971a, b and 1977), these taxa occur for the first time in the Kurbalık association (Late Oligocene) in the Western and Central Anatolia. However, palynological investigations of the Eastern Anatolia revealed that these pollen also existed in the Rupelian suggesting that colder conditions might also have promoted earlier flourishment of these taxa too. Moreover, supplimentery results have been indicated from the paleoclimatological reconstructions by coexistince approach technique (Climsat) of two regions.

Elsik et al. (1990) identified a fossil fungal spore called *Anatolinites dongyingensis* and suggested that this taxon is endemic in some Tertiary basins of Turkey such as Thrace Basin and Tekman Basin. Even though its stratigraphic range is given as Late Eocene to ?Early Miocene, Ediger (1981a), Ediger and Alişan (1989), and Batı (1996) reported that this taxon is found in Upper Oligocene sediments in high abundances together with common occurrences of *Dicolpopollis kalewensis* and *Polyvestibulopollenites verus*. *D. kalewensis* has a stratigraphic distribution which is quite similar to *A. dongyingensis*. It can be found in Upper Eocene to Pliocene sediments but reached an acme (about 10 %) in the Upper Oligocene of the Thrace Basin (Ediger, 1981a and 1982; Ediger and Alişan, 1989; Ediger et al., 1990; and Batı, 1996). Oligocene occurrences of *D. kalewensis* have also been reported by Nakoman (1966) and Akyol (1971) in the northwestern part of Turkey and by Boulter and Craig (1979) and Wilkinson et al. (1980) in the Northwestern part of Europe. Both *D. kalewensis* and *A. dongyingensis* have been recorded in the Oligocene sediments of the Eastern Anatolia but relatively in low frequencies. For instance, relative abundance of *A. dongyingensis* occur only between 0.5-1 % in the Rupelian and sometimes it does not exist. However, it may reach up to 5 % in the Upper Oligocene especially in the northern part of the Eastern Anatolia (Bayburt-Kars-Tuzluca Plateau) where terrestrial depositional conditions were dominating during the Oligocene. Therefore, general stratigraphic trends of *A*. *dongyingensis* and *D*. *kalewensis* documented by Ediger (1981a), Ediger and Alişan (1989), Ediger et al. (1990) Elsik et al. (1990), and Batı (1996) are more or less consistent with the Eastern Anatolia in that relative abundances of both taxa got increased from Lower Oligocene to Upper Oligocene. However, this trend is not so distinct for *D*. *kalewensis as A*. *dongyingensis* in the Eastern Anatolian Oligocene sediments. Because *D*. *kalewensis* is very rare if it is recorded and most of the case it is absent. According to Ediger et al. (1990), this palm pollen indicates subtropical climates. Since the Eastern Anatolia have experienced relatively colder paleoclimatic conditions than Western and Central parts of Anatolia during the Oligocene (Sancay et al., submitted), *D*. *kalewensis* might have been represented in low abundances.

Detailed qualitative and quantitative investigations of all palynomorph associations (including both marine and terrestrial palynomorphs) in the Thrace Basin were later carried out by Ediger (1982). He studied the Tertiary sediments in Abalar-1 well with 20 meters of sampling interval and documented the relative frequencies of spore-pollen, fungal spore, organic-walled algae, dinoflagellate, and Incertae Sedis. He distinguished a total of 17 palynozones (7 of which are spore-pollen coded as $SP_1$-$SP_7$, 5 of which are fungal spore coded as $F_1$-$F_5$, and 5 of which are dinoflagellate coded as $D_1$-$D_5$) and established detalied biostratigraphic framework for Tertiary sediments in the Thrace Basin. Ediger (1982) suggested that the common occurrences of *Dicolpopollis kalewensis* (pollen) and *Anatolinites dongyingensis* (fungal spore) occurred in the Upper Oligocene (Chattian), whereas *Wetzeliella gochtii* and *Distatodinium ellipticum* recorded in the Lower Oligocene (Rupelian) sediments. As far as marine palynomorphs are concerned, they were recorded in the same stratigraphic position with those of in the Oligocene sediments of the Eastern Anatolia.

Ertuğ et al. (1995) distinguished four dinoflagellate biozones from the ?Upper Oligocene-Lower Miocene sediments in Tekman Basin. The first biozone is *Homotryblium plectilum-Cordosphaeridium cantharellus* Assemblage Zone defined by high abundances of *Homotryblium plectilum* and *Cordosphaeridium cantharellus*. Following dinoflagellate taxa also co-occur in this zone: *Achomosphaera alcicornu*, *Cribroperidinium tenuitabulatum*, *Pentadinium laticinctum*, *Chriptoredium* spp., *Polysphaeridium zoharyi*, *Systematophora* sp., *Surculosphaera* sp., *Hystrichocolpoma cinctum*, and *Thalassiphora pelagica*. They assigned a ?Late Oligocene-Early Miocene age for the first biozone based on the relatively lower abundance values of Compositae, Umbelliferae, *Tsugapollenites* sp., because these pollen have been reported from Miocene sediments in earlier studies (Benda, 1971; Benda et al., 1977; Benda et al., 1979; Ediger et al., 199O; Akyol and Akgün, 1992; Akgün et al., 1995; Batı, 1996). The second biozone is named as the *Spiniferites mirabilis* epibole and is characterized by the presence of *Spiniferites mirabilis and Lejeunecysta hyalina* together with dinoflagellates that have been seen since the first biozone. According to Ertuğ et al. (1995) the increasing abundance of Compositae, Umbelliferae, *Tsugapollenites* sp. suggests an Early Miocene (Aquitanian) age for the second biozone. The third biozone is named as *Hystrichosphaeropsis obscura-Chriptoredium* spp. Assemblage Zone defined by the FAD of *Hystrichosphaeropsis obscura* and the epibole of *Chriptoredium* spp. Common occurrences of *Impletosphaeridium* sp., and *Hystrichocolpoma rigaudae* also reported for this biozone. According to Ertuğ et al. (1995), this biozone represents an Early Miocene (Aquitanian-Burdigalian) age. The FAD of *Hystrichosphaeropsis obscura* has also been recorded in this study but in the “late” Aquitanian. The fourth and the last biozone of Ertuğ et al. (1995) is *Sumatradinium* sp. epibole and is distinguished by the high abundances of name-diagnostic taxa and *Operculodinium centrocarpum*, *Lingulodinium machaerophorum*. Dominating taxon of other three biozones, and *Cordosphaeridium cantharellus* do not exist and *Chriptoredium* spp. last occur in this biozone. Ertuğ et al. (1995) assigned a Middle Miocene (Langhian-Serrevalian) age for this unit.

Batı (1996) defined two zones in the Upper Oligocene lignites of Thrace Basin. Even though, he assigned Late Oligocene (Chattian) age for both of the zones, Zone 2 was indicated as slightly younger than Zone 1 and may correspond to the upper part of Chattian. Main differences between these two zones have been given as follows; Gramineae, monoporate pollen grain, (*Monoporopollenites gramineoides-Monoporopollenites* cf. *gramineoides-Monoporopollenites polygonalis*) occur for the first time in Zone 2 which has also yielded increased frequencies of spores and decreased abundances of fungal spores and pollen. Additionally, some stratigraphically important taxa such as *Dicolpopollis kalewensis* and *Anatolinites dongyingensis* together with *Leiotriletes adriennis-Leiotriletes microadriennis, Laevigatosporites haardti-Laevigatosporites ovatus, Baculatisporites gemmatus-Baculatisporites primarius, Polyvestibulopollenites verus,* and *Cingulatisporites macrospeciosus* occur in the samples belonging to the Zone 2. Even though, Batı (1996) reported that the first occurrence of Gramineae represents a well defined stratigraphic level for the Upper Oligocene sediments in Thrace Basin, monoporate-based classification do not seem to be applicable to the Eastern Anatolia because this taxon was present since Rupelian in that region (Sancay et al., submitted; Batı and Sancay, submitted). Lower Oligocene occurrences of Gramineae (as *Monoporopollenites gramineoides* and *Monoporopollenites solaris*) in Turkey have also been reported by Nakoman (1967) from the coal seams of Kalivya and Arnavutköy and Benda (1971a) from the coals in Edirne, Kırklareli, Tekirdağ, and İstanbul. In these studies, very rare occurrences (about 1 %) of Gramineae in the Rupelian got increased towards the Middle Miocene and became frequent in the Upper Miocene-Pleistocene. The highest Oligocene occurrence of Gramineae has been detected by Benda et al. (1977) in Kahramanmaraş as 3.3 %. However, Akyol and Alişan (1982) and Akgün et al. (1986) in their palynological studies carried out in Soma lignites, Akgün and Akyol (1987) in Akhisar coals, Akyol and Akgün (1990) in Bigadiç, Kestelek, Emet, and Kırka argued that the first occurrence of Gramineae was in the Late Miocene and these taxa became more abundant in the Pliocene together with other Pliocene pollen such as Compositae and Umbelliferae. Later, Akgün and Akyol (1992) and Akgün et al. (1995) revised the first occurrence of Gramineae as Middle

Miocene as in  low abundances (up to 3 %). Moreover, Batı (1996) recorded Gramineae in the Late Oligocene in the Thrace Basin and mentioned as a personal communication with Akyol that the low abundances (1 % or less than 1 %) of Gramineae occur in the Upper Oligocene sediments in Turkey. On the other hand, multidisciplinary palynological investigations of the Eastern Anatolian Tertiary sediments revealed that pollen grains belonging to Gramineae, Compositae, and Umbellifera families were existed since Rupelian (Sancay et al., submitted; Batı and Sancay, submitted). Moreover, relative abundances of Compositae (tubuliflorae-type) in Rupelian sediments of the Eastern Anatolia might reach up to 5 % in some samples. As far as stratigraphic distributions of Gramineae in other countries are concerned, they can be traced back to Paleocene (Batı, 1996 and references therein).

### 3.9. Correlations of the palynomorph assemblages with other palynological studies in Europe

Correlation of the biozonations established for the Eastern Anatolia with those of in different basins is sometimes very challenging. Difficulties in correlation with the regional biozonations may due to the absence and/or scarcity of zonal marker species, poor preservation, and unfavourable depositional environments. Such difficulties in the correlations have been discussed by Berger (1992) who studied the biostratigraphic zonations of Swiss Molas Basin and the discrepancies between different correlation charts of Oligocene-Miocene sediments in Europe. According to Berger (1992), the main difference in different studies may be caused by the diachronous nature of the boundaries, varieties in stratigraphical positions and absolute ages of the boundaries, taxonomic problems, insufficient radiometric datings, reworking, endemism and provincialism, reworking, and difficulties in correlation of marine and terrestrial realms.  Van Simaeys (2004) indicated that local biostratigraphic studies may achive high resolution and successfully applied to regional correlations. However, because of the marginal marine (siliciclastic-dominated) conditions in depositional environments, absence of age-indicating index fossils, and the presence of tectonically/eustatically induced widespread unconformities, calibration of such studies to international time-scales (e.g. Berggren et al., 1995) is still quite problematic. Moreover, as it was emphasized in Van Simaeys (2004) and references therein, global climatic cooling, returning from pre-Oligocene greenhouse to present icehouse Zachos et al. (2001), is the main driving factor for many taxa to migrate much lower latitudes and thus, most of the biostratigraphic events used in calibration studies of Eocene-Oligocene sediments are diachronous. In addition, absence of chronostratigraphically important fossils especially in high latitudes also makes correlation of sediments belonging to different latitudes more complicated.

As it was emphesized by Benda et al. (1977), correlations of palynomorph assemblages in the Central-Western Europe and Mediterranean region based on changes in relative abundances and overall pollen spectra may lead misinterpretations. Therefore, regional correlations in these regions based on just first and last occurrences of selected taxa should be done in caution. Moreover, the palynological investigations of the Eastern Anatolia in this study proves that, major differences in the first and last occurrences of some taxa might be possible even just in the Mediterranean region related to climatic fluctuations. Therefore, regional and interregional correlations of palynomorph assemblages should be calibrated with worldwide-defined marine dinoflagellates, planktonic foraminifers, and nannoplanktons. Moreover, radiometric ages and magnetostratigraphy may also help to detect the exact chronostratigraphic positions of palynomorph associations.

Even though he mainly focused on spore-pollen assemblages, Hochouli (1978) first studied dinoflagellate cysts of the Southern Europe and documented the Oligocene-Miocene biostratigraphy and paleoclimate from the material derived from Switzerland and Austria. However, Powell (1986a, 1986b) was believed to be the first study which emphazises the importance of dinoflagellate cysts on Oligocene-Miocene transition in the Tethyan

Realm. Hochuli (1978) reported some Compositae (tubuliflorae-type) occurrences from Egerian sediments in Central and Western Paratethys but Egerian includes both Upper Oligocene and Lower Miocene. Therefore, Oligocene occurrences of Compositae remained still questionable in his paper.

Powell (1986a) investigated the latest Paleogene-earliest Neogene dinoflagellate cysts from the Lemne Section, Northwest Italy. He faced some difficulties to locate the upper ranges of *in situ Deflandrea* spp. and *Chiropteridium* spp. because of reworking. Those species are recorded in Lower Miocene sediments (above *Globorotalia kugleri* and *Globoquadrina dehiscens* planktonic foraminifer Zones) as trace components. Even though some early studies such as Williams (1975 and 1977), Williams and Brideaux (1975) and Bujak (1984) suggest Oligocene-Miocene boundary for the LAD of *Chiropteridium* spp., Williams and Bujak (1977 and 1985), Stover (1977), and Ioakim (1979) have recorded Early Miocene occurrences of the same species. Powell (1986a) interpreted that *Chiropteridium* spp. do not range up to the Oligocene-Miocene boundary and rare *Chiropteridium* occurrences in Lower Miocene sediments should be related to reworking. Hovewer, similar to many multidisciplinary studies (e.g. Brinkhuis et al., 1992) carried out in Oligocene-Miocene transition, common occurrences of *in-situ Chiropteridium* spp. identified in the Lower Miocene sediments of the Eastern Anatolia. Powell (1986a) also suggested that *Wetzeliella* spp., *Glaphyrocysta* spp., *Homotryblium plectilum*, *Cordosphaeridium gracile* do not range into Miocene. The LAD of *W. gochtii* occurred in NP25 calcareous nannoplankton zone. The LAD of *Thalassiphora pelagica*, *Chiropteridium mespilanum*, *Homotryblium floripes*, *Distatodinium craterum* recorded in Upper Oligocene while *Cordosphaeridium cantharellus* and *Bipolaribucina paradoxa* last occurred in Lower Miocene sediments in the Piedmont Basin. LAD of *Cordosphaeridium cantharellus* has also been reported from the Lower Miocene sediments in the Norwegian Sea (Manum, 1976) and Italy (Powell 1986a, b, and c; Biffi and Manum, 1988; and Brinkhuis, 1992). *Cordosphaeridium cantharellus* last occurred in the Lower Miocene sediments of Eastern Anatolia as well, but *Homotryblium plectilum* also recorded in Lower Miocene in low frequencies. Supportingly, Dybkjaer (2004) suggested that the LAD of *Homotryblium plectilum* occurred in Langhian (Middle Miocene) in the Danish area and Manum et al. (1989) reported that the LAD of the same species occurred in the upper Burdigalian of the Norwegian Sea.

Powell (1986b) documented the dinoflagellate cyst biozonation and defined eight biozones (seven of them further subdivided into two subzones and one of them into three subzones) in the Upper Oligocene-Middle Miocene sediments from Serole-Cortemillia sections (Langhian stratotype). Since the first occurrences seem to be more reliable than the last occurrences due to the reworking, dinoflagellate biozones of Powell are established based on the first occurrences of particular species. As indicated by Powell, Burdigalian stage can not be differentiated from the Aquitanian in the Piedmont Basin and encompasses whole of early Miocene and uppermost part of the Oligocene. LAN-1 Biozone was defined with the first occurrence of *Tuberculodinium vancampoae*, corresponding to planktonic foraminifera Zone P 22 (Upper Oligocene). LAN-2 Biozone was defined with the first occurrence of *Lejeunecysta* sp. A, *Nematosphaeropsis*? sp. A, *Batiacasphaera*? sp. A, *Thalassiphora* sp. A., corresponding to planktonic foraminifera Zone N 4 (Lower Miocene). The last occurrence of *Cordosphaeridium cantharellus* distinguishes the LAN-2A and LAN-2B sub-biozones. He used previous studies (e.g. Vervloet, 1966; Nicora, 1971) to calibrate the Upper Oligocene LAN-1 and lowermost Miocene LAN-2 biozones. Biolzi (1985), on the other hand, studied the same section and suggested that a hiatus encompasses P22 through N5 should be indicated at the Oligocene-Miocene boundary based on the planktonic foraminifers and calcareous nannoplanktons. Therefore, Oligocene-Miocene boundary interval studied by Powell (1986b) to define dinoflagellate cysts is not a complete section. LAN-3 Biozone was defined with the first occurrence of *Batiacasphaera scrobiculata* and *Spiniferites rubinus* corresponding to planktonic foraminifera Zone N 4 to N 5-7 (Lower Miocene). LAN-4 Biozone was defined with the first occurrence of *Thalassiphora* sp. C., corresponding to planktonic foraminifera Zone N 5-7 to N 8 (Lower to Middle Miocene). The first occurrence of *Palaeocystodinium* sp. A ssp. A distinguishes the base of sub-biozone LAN-4B. LAN-5 Biozone was defined with the first occurrence of *Invertocysta tabulata*, *Spiniferites membranaceus* corresponding to planktonic foraminifera Zone N 8 to N 10 (Middle Miocene). The first occurrence of *Palaeocystodinium* sp. A ssp. B distinguishes the LAN-5A and LAN-5B sub-biozones. LAN-6 Biozone was defined with the first occurrence of *Impagidinium aquaeductum*, *Systematophora* sp. A., *Amiculosphaera umbracula* and *Cerebrocysta* sp. A, corresponding to planktonic foraminifera Zone N 10 to N 11 (Middle Miocene). The last occurrence of *Cribroperidinium*? sp. A distinguishes the LAN-6A and LAN-6B sub-biozones. LAN-7 Biozone was defined with the first occurrence of *Hystrichosphaeropsis pontiana* corresponding to planktonic foraminifera Zone N 12 (Middle Miocene). The first occurrence of *Palaeocystodinium* sp. cf. *P. golzowense* and the last occurrence of *Palaeocystodinium* sp. A ssp. A determine the base of sub-biozone LAN-7B. LAN-8 Biozone was defined with the first occurrence of *Achomosphaera andolousiensis*, *Sumatradinium* sp. A and *Impagidinium strialatum* corresponding to planktonic foraminifera Zone N 12 to N 13-14 (Middle Miocene). The last occurrence of *Palaeocystodinium golzowense* distinguishes LAN-8A and LAN-8B sub-biozones. Most of the zonal markers of Powell (1986b) have not been recorded in the Eastern Anatolia. Two of the dinoflagellate events of Powell (1986b) can be comparable with our data in that the last occurrence of *Cordosphaeridium cantharellus* has also been observed in the Lower Miocene of the Eastern Anatolia, but the first occurrence of *Tuberculodinium vancampoae* was in the Rupelian not in the Chattian.

Biffi and Manum (1988) investigated four sections from the Marche Region (Central Italy) and documented dinoflagellate cyst stratigraphy of the Upper Eocene-Lower Oligocene sediments. They have distinguished seven dinoflagellate zones (three of them further subdivided into two subzones). Since Biffi and Manum (1988) identified several new and stratigraphically important taxa, it is not easy to correlate their assemblages with Powell (1986a and 1986b). Very few occurrences of *Helicosphaera recta* and *Sphenolithus ciperoensis* have been interpreted as reworking by Biffi and Manum (1988). They also suggested that the absence of the biozonal markers such as *Globigerina ciperoensis angulisuturalis*, *Globigerinatella insueta* and *Globorotalia kugleri* might indicate a hiatus at Oligocene/Miocene boundary in the Monte Canero Section, Central Italy. They summarized the significant biostratigraphical events in Oligocene/Miocene sediments as follows; Upper Oligocene sediments are represented by abundant *Chiropteridium plexus*, continuous occurrence of *Deflandrea phosphoritica* and common occurrence of *Pentadinium laticinctum*. Last occurrence of *Chriptoredium lobospinosum*, *C. partispinatum*, *Deflandrea phosphoritica* and first occurrence of *Hystrichosphaeropsis obscura* identifies the Oligocene/Miocene boundary. Lower Miocene sediments can be distinguished by the presence of *Impagidinium* spp., *Cordosphaeridium cantharellus*, *Apteodinium spiridoides*, *Tuberculodinium vancampoae* and *Hystrichosphaeropsis obscura*. Last occurrence of *Deflandrea phosphoritica* in the uppermost Chattian and the first occurrence of *Hystrichosphaeropsis obscura* in the Lower Miocene are biostratigraphically important dinoflagellate events which have also been detected in Eastern Anatolia. The first occurrence of *H*. *obscura* is a very important biostratigraphic event which was recorded in the Aquitanian sediments of the Eastern Anatolia. Many studies have been carried out regarding the exact time of this event and a general aggrement is that it occurred in the Early Miocene (Powell, 1992; de Verteuil and Norris 1996, Costa and Manum, 1988). Dybkjaer and Rasmussen (2000) suggested that the presence of *H*. *obscura* reflects an age not older than Burdigalian in Denmark. Similarly, Zevenboom et al. (1994) and Montanari et al. (1997) reported that the FAD of *H*. *obscura* occurred in the lower Burdigalian in the northwest and central parts of Italy. Williams et al. (1999) suggested that the FAD of this species occurred in the Burdigalian and its range varies between 18.93 to 7.34 Ma. Habib (1972) indicated that, even though it can be traced back to the Upper Eocene, the youngest occurrence (LAD) of *H.obscura* is in the Upper Miocene cores from the DSDP Leg 11, Grand Banks, offshore Eastern Canada. Drugg and Stover (1975) gave a range to the same species as Late Eocene to Miocene/Pliocene boundary. Manum (1976), on the other hand, suggested Early Miocene for the oldest occurrence (FAD) of the same species. Williams and Brideaux (1975) saw this species as *Hystrichosphaeropsis* sp. only in Middle-Upper Miocene sediments from Grand Banks corehole. Powell (1983) stated that *H. obscura* is more characteristic for Neogene as opposed to Oligocene. Similar to above mentioned researchers, Williams and Bujak (1985) indicated the range of *H.obscura* as Early to Late Miocene. Lenoir and Hart (1988) identified *H. obscura* in Burdigalian sediments from offshore Louisiana together with the common occurrences of *Polysphaeridium zoharyi*, *Cribroperidinium tenuitabulatum*, *Lejeunecysta hyalina*, *Tuberculodinium vancampoae*, *Hystrichocolpoma rigaduae*, *Hystrichocolpoma denticulata*, *Ligulodinium machaerophorum* and *Spiniferites* spp. Both Powell (1992) and Haq et al. (1987) agreed that the FAD of *H. obscura* occurred within the Aquitanian (close to the top of calcareous nannoplankton zone NN1). Same chronostratigraphical position may also be represented by the LAD of *Cordosphaeridium cantharellus* in Haq et al. (1987). Powell (1986a) believed that the FAD of *H. obscura* is more reliable than the FAD of *Melitasphaeridium choanophorum* and *Tuberculodinium vancampoae* to define the Oligocene-Miocene boundary. Additional information derived from Dybkjaer (2004) reporting that the first appearence of the same species occurred in lower to middle Burdigalian in Danish area. According to Dybkjaer the discrepancies in the FADs of the same species may be related to the erroneous chronostratigraphic assignment, different depositional environments, and misidentificaiton. FAD of *H.obscura* has been used to define the base of EM3 zone in this study and believed to be occurred in the middle-late Aquitanian in the Eastern Anatolia.

Heilmann-Clausen and Costa (1989) investigated the 20 m-thick Upper Oligocene?-Lower Miocene sediments from the Wunsterheide research well. They indicated that the lower two samples are Late Oligocene in age corresponding to D14 or D15 of Costa and Manum (1988) based on the presence of *Pentadinium laticinctum-imaginatum*, but *Rhombodinium draco* was also identified in those two samples and reflects a Rupelian age. *R*. *draco* is not present in the Eastern Anatolian samples but *P*. *imaginatum* has been recorded in the Rupelian sediments (EO1 zone). Third sample of Heilmann-Clausen and Costa (1989) includes *Wetzeliella gochtii* corresponding to D15 zone of Costa and Manum (1988) and indicates early Chattian. *W*. *gochtii* recorded in high abundances in EO2 and EOZ zones (middle-late Rupelian) in this study. The upper four samples of Heilmann-Clausen and Costa (1989) are believed to be Early Miocene in age and comparable with D16/D17 zones of Costa and Manum (1988) based on the presence of *Hystrichokolpoma poculum* and *Hystrichosphaeropsis obscura* and absence of the high abundances of *Chiropteridium* spp., *Deflandrea* spp., and *Homotryblium* spp. This assemblage may be comparable EM3, middle-late Aquitanian biozone defined in this work of the Eastern Anatolia.

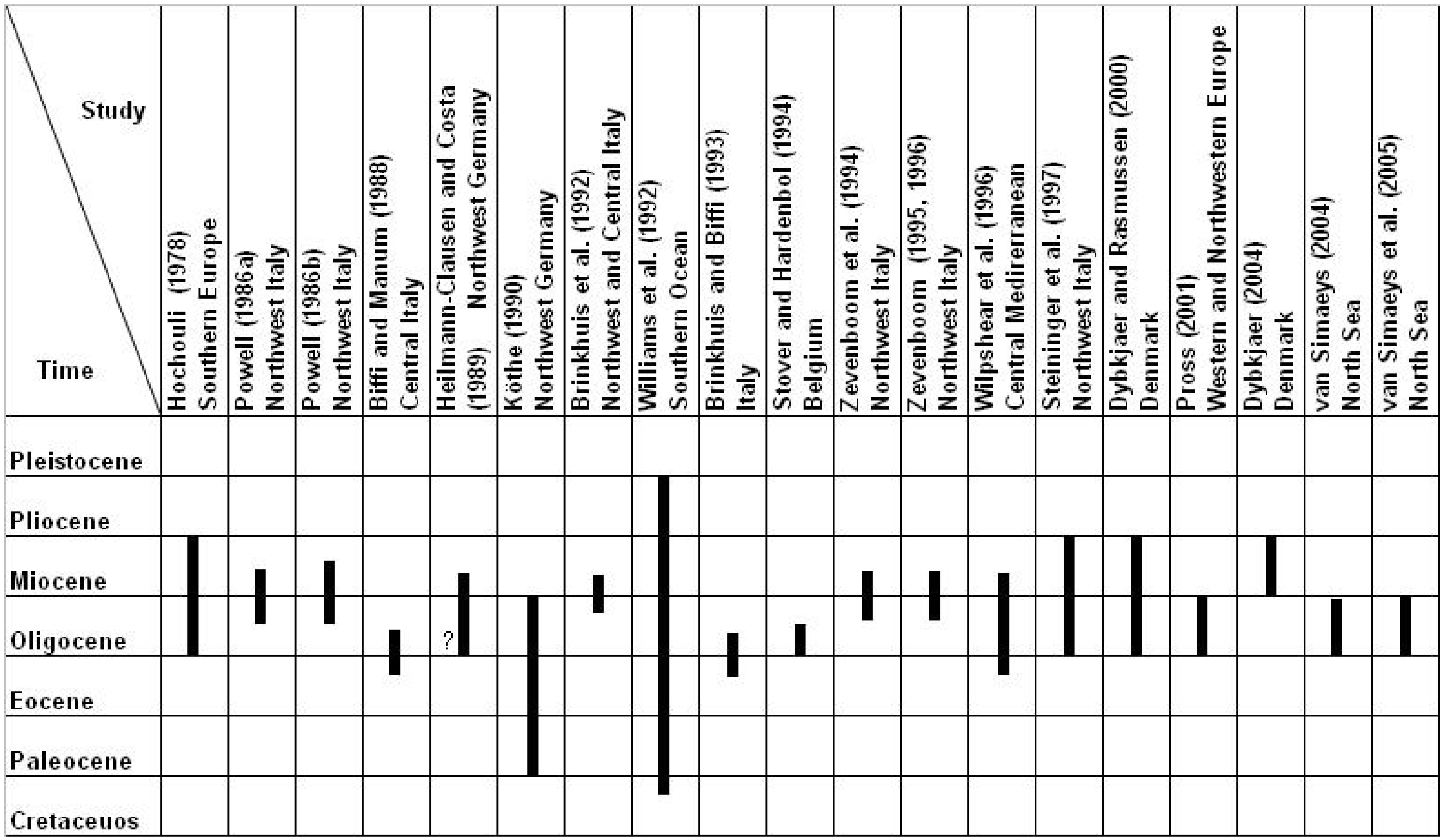
Köthe (1990) studied the Paleogene dinocysts of the northwest Germany. She reported an assemblage which can be comparable with D15 of Costa and Manum (1988) and characterized by the common occurrences of *Homotryblium plectilum*, *Membranophoridium aspinatum (*especially common in the lower part and becomes rare in the upper part), rare occurrences of *Chiropteridium* and absence of *Deflandrea phosphoritica* indicate a late Oligocene age corresponding to Nannoplankton Zone NP25. This assemblage may be comparable with sequences A and B, latest Chattian and/or early Aquitanian in age, of Dybkjaer (2004). Similar dinoflagellates have also been identified in the transitional zone (EM1) in the Eastern Anatolia and interpreted as early Miocene in age.

After the earlier studies of Powell (1986a and b) and Biffi and Manum (1988) on the dinoflagellate-based biostratigraphical studies in Oligocene-Miocene successions of Central Mediterranean, most detailed and well-calibrated dinoflagellate zonations have been started by the studies of Brinkhuis and his colleauges (e.g. Brinkhuis et al., (1992) for the latest Oligocene-earliest

Miocene and Brinkhuis and Biffi (1993) for the latest Eocene-earliest Oligocene) (Table 3). One of the most detailed studies on the high resolution dinoflagellate cyst stratigraphy was carried out by Brinkhuis et al. (1992) who have documented the dinoflagellate assemblages of the Oligocene-Miocene transition in Northwest and Central Italy. They have correlated their dinoflagellate cyst zonations with planktonic foraminifers, calcareous nannoplanktons and also with magnetostratigraphy. They have come up with the conclusion that Oligocene-Miocene boundary is related to a pronounced sea level fall in all studied sections. Two zones and four subzones in the uppermost Oligocene-lowermost Miocene sediments in the Marche Basin and one zone and two subzones in the Lower Miocene sediments in the Piedmont Basin have been distinguished by Brinkhuis et al. (1992). They have used FAD of *Hystrichosphaeropsis* cf. *obscura*, *Distatodinium apennicum*, *Ectosphaeropsis burdigaliensis*, *Caligodinium pychnum* and *Hystrichokolpoma pusilla* to correlate different sections in Piedmont Basin and total ranges of *Distatodinium biffii* and *Saturnodinium perforatum*, the FAD of *Hystrichosphaeropsis* cf. *obscura*, *Distatodinium apennicum*, *Ectosphaeropsis burdigaliensis*, *Caligodinium pychnum* and LAD of *Homotryblium* sp., cf. *H.oceanicum*, *Impagidinium dispertitum*, *Impagidinium brevisulcatum*, and *Hystrichokolpoma pusilla* to correlate different sections in Marche Basin. The First occurrence of *Hystrichosphaeropsis obscura* has also been used to detect EM3 *Hystrichosphaeropsis obscura* interval zone (middle-late Aquitanian) in this study. Even though Biffii and Manum (1988) have also studied the same interval and even same section at Casa di Tosi as Brinkhuis et al. (1992), they have not mentioned any *Hystrichosphaeropsis* cf. *obscura*, *Ectosphaeropsis burdigaliensis* and *Saturnodinium perforatum* occurrences in their study.

Due to the inappropriate lithologies (mostly limestones, carbonaceous sandstones with some silty marl intercalations in which palynomorphs occur sporadically) of the uppermost Aquitanian-Burdigalian sediments, most of the stratigraphically important dinoflagellates are missing (such as *Exochosphaeridium insigni*, *Sumatradinium druggii*, *Sumatradinium*

Table 3. List of the palynostratigraphic works used in this study for the correlation of the Oligocene-Miocene palynomorph assemblages in Europe.



*soucouyantiae*, *Cousteaudinium aubryae*) in Eastern Anatolia and therefore those intervals could not be correlated regionally.

Brinkhuis et al. (1992) have selected two successive quantitative events, which are consistent with the planktonic foraminifers, as biostratigraphic criteria for the Oligocene-Miocene boundary. These are the youngest high relative abundance (acme) of *Chriptoredium* species followed by the youngest acme of *Deflandrea* species. They suggested that middle parts of the *Chriptoredium* and *Deflandrea* acmes coincides with the FAD of *G. kugleri* and *G. dehiscens* respectively. Since the FAD of *G*. *kugleri* is corresponding to the lowermost Miocene, the youngest *Chriptoredium* acme may be used as a proxy for the Oligocene-Miocene transition. Biffi and Manum (1988), on the other hand, indicated distinct time-lag between those two sucsessive acmes and they placed Oligocene-Miocene boundary at the top of the *Deflandrea* acme. Palynological assemblages in the Eastern Anatolian Oligocene-Miocene sediments are consistent with the assemblages of Biffi and Manum (1988) in that last acme of *Deflandrea phosphoritica* occurred at the end of the Late Oligocene. Common occurrences of *Chriptoredium* might have been obtained as a result of trangressive events (Lucy Edwards, personal communication, 2005) and LAD of *Deflandrea phosphoritica* seems to be a reliable criterion for the detection of Oligocene-Miocene boundary. However, Brinkhuis et al. (1992) and Powell (1986a and 1986b) indicated that the Oligocene-Miocene transition is coincident with the youngest *Chriptoredium* acme which is corresponding to the FAD of *G. kugleri*. In other words, they have placed the youngest acme of *Chriptoredium* into the earliest Miocene which is also quite comparable with the biozonations established in this study for the Eastern Anatolia.

Brinkhuis et al. (1992) distinguished following dinoflagellate zones; *Distatodinium biffii* Interval Zone (Upper Oligocene-lowermost Miocene); the base of the youngest acme of *Deflandrea* spp., corresponding to P21 through N4 planktonic foraminifer zones and upper part of NP25 through NN1 calcareous nannoplankton zones. The youngest acme of *Deflandrea phosphoritica* has been used to define the top of the LO1 zone (Chattian) in this study. *Hystrichosphaeropsis* cf. *obscura* Interval Subzone (Upper Oligocene); the base of the youngest acme of *Chriptoredium* spp., corresponding to top P21 through top part of P22 planktonic foraminifer zones and upper part of NP25 calcareous nannoplankton zones. *Chriptoredium* Abundance Subzone (uppermost Oligocene-lowermost Miocene); interval from the base of the youngest acme of *Chriptoredium* spp., and the base of the youngest acme of *Deflandrea* spp., corresponding to top P22 through lowermost N4 planktonic foraminifer zones and top NP25 through lowermost NN1 calcareous nannoplankton zones. The *Chriptoredium* Abundance Subzone has also been identified outside the central Mediterranean. Benedek (1972) identified high abundances of *Chriptoredium* in the upper part of the NP25 Zone in West Germany. Ioakim (1979) has seen similar *Chriptoredium* spp., acme in Late Oligocene-Early Miocene *Chriptoredium lobospinosum* Zone from the northern North Sea. Peak occurrences (including the first common occurrence) of *Chriptoredium galea* and *Chriptoredium lobospinosum* have been detected in EM2 (early-middlle Aquitanian) zone in the Eastern Anatolia. *Ectosphaeropsis burdigaliensis* Interval Zone (Lower Miocene); the base of the youngest acme of *Deflandrea* spp., to the FAD of *Membranilarnacia* ?*picena*, corresponding to the basal N4 through N5 planktonic foraminifer zones and basal NN1 through NN2 calcareous nannoplankton zones. This zone may correspond to the EM1 to EM4 zones distinguished in this study. The *Deflandrea* Abundance Subzone (lowermost Miocene); interval from the base of the youngest acme of Deflandrea spp., to the FAD of *Distatodinium apennicum*, corresponding to the basal through middle part of the N4 planktonic foraminifer zones and middle part of NN1 calcareous nannoplankton zones.

Brinkhuis et al. (1992) mainly emphazised the consistency between the occurrence of the youngest *Chriptoredium* acme and the FAD of *G. kugleri* for Oligocene-Miocene transitions in all their studied sections. Similar relationship is also indicated for the youngest acme of *Deflandrea* spp., and *G.dehiscens dehiscens* in the Lower Miocene. In general, they claimed that typical Paleogene dinoflagellate cysts such as *Wetzeliella*, *Glaphyrocysta*, *Areoligera*, *Deflandrea*, and *Chriptoredium* gradually disappeared from Upper Oligocene to Lower Miocene and were never seen again in high abundances above the Oligocene-Miocene boundary. Similarly, Dybkjaer (2004) assigns a Late Oligocene age for her sequence A in Jylland, Denmark based on the presence of *Deflandrea phosphoritica* and the absence of the Lower Oligocene species such as *Wetzeliella gochtii*. As far as dinoflagellate assemblages of the Eastern Anatolia are concerned, *Chriptoredium* spp. commonly occur in Lower Miocene sediments but *Deflandrea* spp. (including *Deflandrea phosphoritica* complex) never passes into Early Miocene in that region.

Some of the biostratigraphically important dinoflagellate events reported by Williams et al. (1992) in the context of an ODP study in the NML (Northern Hemisphere mid-latitudes) and also recorded in the Eastern Anatolia Oligocene-Miocene sediments but occurred relatively earlier. For instance, LAD of *Wetzeliella gochtii* occurs in the latest Rupelian not in the middle Chattian (26.6 Ma), LO of *Deflandrea phosphoritica* occurs in the latest Chattian not in the middle Aquitanian (21.9 Ma), and LAD of *Cordosphaeridium cantharellus* occurs in the latest Aquitanian not in the early Burdigalian (19.5 Ma) as it is indicated by Williams et al. (1992). However, as it was reported by Stover et al. (1996), there is a disaggrement on the LAD of *Wetzeliella* and *Deflandrea*. Powell (1992) placed these events to the top of NP24 (Chattian) while Haq et al. (1987) assigned Late Oligocene age (NP25) for the same events. Costa and Manum (1988), in their study on dinoflagellate zonations for the Tertiary sediments of the northwest Europe (sections from England, Germany, France, Denmark, Belgium and Viking Graben of the North Sea) suggested wider ranges for the same LADs that occurred in their D14 zone corresponding to NP22, NP-23, and NP24. Powell later discussed that the top of D14 of Costa and Manum (1988) may correspond to NP25.

Stover and Hardenbol (1994) documented 37 dinoflagellate and acritarch taxa, which have their first and last occurrences in the Boom Composite Section, suggested as stratigraphically important and may be used in correlation studies of different sections belonging to the comparable ages. According to Stover and Hardenbol (1994), following taxa have ranges through Rupelian; *Achillodinium biformiodes*, *Areosphaeridium pectiniforme*, *Cordosphaeridium inodes*, *C*. *gracile*, *C*. *minimum*, *Membranophoridium aspinatum*, *Spiniferites pseudofurcatus*, *S. ramosus*, *Systematophora placacantha*, *Thalassiphora pelagica*, *Deflandrea phosphoritica* complex, *Wetzelialla symetrica* complex. *C*. *fibrospinosum*, *Homotryblium tenuispinosum*, *Wetzelialla articulata*, and *Fibrocysta axialis* have their tops in Rupelian whereas *Reticulosphaera actinocoronata* and *W*. *gochtii* show their first occurrences in Rupelian. Stover and Hardenbol (1994) suggested that an acritarch called *Ascostomocystis potane* is restricted to the Rupelian. In other words, both the first and the last occurrences of *A*.*potane* were in the Rupelian. *A*. *potane* has been recorded in EO1 and EO2 zones in this study and interpreted as Rupelian in age. FAD of *W*. *gochtii*, as it was indicated by Stover and Hardenbol (1994), also identified in EO2 zone (Rupelian) in the Eastern Anatolian sediments.

Zevenboom (1995) investigated the Upper Oligocene-Lower Miocene dinoflagellate biostratigraphy and paleoenvironment of the Lemme Section, Italy. (Dbi) Interval zone of Zevenboom (1995) was defined as the interval between the FAD of *Distatodinium biffii* to the base of the youngest acme of *Deflandrea* spp. and dated as Late Oligocene to latest Oligocene. This zone may correspond to Late Oligocene LO1 zone in this study based on high abundances of *Deflandrea* spp. (Ebu) Interval zone of Zevenboom (1995) was defined as the interval between the base of the youngest acme of *Deflandrea* spp. to the FAD of *Membranilarnacia* ?*picena* and dated as latest Late Oligocene to Early Miocene in age. This interval is represented by Aquitanian-aged EM1 to EM4 zones in this study. The base of the (Mpi) Interval zone of Zevenboom (1995) was defined by the FAD of *Membranilarnacia* ?*picena* but the top was not defined and dated as Early Miocene in age. EM5 zone corresponds to this zone and interpreted as Aquitanian in age in the Eastern Anatolia. Finally, (Hob) Interval zone of Zevenboom (1995) was defined as the interval between the FAD of *Hystrichosphaeropsis obscura* to the LAD of *Caligodinium pychnum* and dated as Early Miocene in age. Based on the FAD of *H*. *obscura*, it may correspond to EM3 zone, which is Aquitanian in age, in this study. Zevenboom (1995) also stated that two major sea level falls, coinciding relativelly cooler periods and comparable to the eustatic curve of Haq et al. (1988) and third order cycles of Exxon curve, occurred during the Oligocene-Miocene transition. This relative sea level fall in Oligocene-Miocene boundary might have been represented by EM1 zone in this study dominated by terrestrial palynomorphs, fresh water algae, and only a few dinoflagellates.

Similar to Powell (1986a and b) and Brinkhuis et al. (1992), Zevenboom (1996) also investigated the Late Oligocene-Early Miocene dinoflagellate cysts from the Lemne-Carrosi section, northwest Italy but different than the previous studies, he used some other microfossils, magnetostratigraphy and geochemistry to calibrate his dinocyst biozones. He distinguished three zones and five subzones as follows; The *Distatodinium biffii* (Dbi) interval zone (late Oligocene to latest Oligocene); interval between the FO of *Distatodinium biffii* and FO of *Ectosphaeropsis burdigaliensis* or base of the youngest acme of *Deflandrea* spp., corresponding to planktonic foraminifers P21 to upper part of P22 and nannoplankton NP 25 biozones. The *Hystrichosphaeropsis* cf. *obscura* (Hob) interval zone (Late Oligocene); interval between the FO of *Distatodinium biffii* to the base of the youngest acme of *Chiropteridium* spp., corresponding to planktonic foraminifers top of P21 to upper part of P22 and nannoplankton NP 25 biozones. The *Chiropteridium* spp. (Chi) abundance subzone (latest Oligocene); interval from the base of the youngest acme of *Chiropteridium* spp. to the FO of *Ectosphaeropsis burdigaliensis* or base of the youngest acme of *Deflandrea* spp., corresponding to planktonic foraminifers top of P22 to uppermost P22 and nannoplankton to of NP 25 to uppermost NN1 biozones. These three zones may correspond to the LO1 zone (Chattian) in this study based on the youngest acme of *Deflandrea phosphoritica*. The *Ectosphaeropsis burdigaliensis* (Ebu) interval zone (latest Late Oligocene to Early Miocene); interval from the FO of *Ectosphaeropsis burdigaliensis* or base of the youngest acme of *Deflandrea* spp. to the FO of *Membranilarnacia* ?*picena* corresponding to magnetic polarity subchronozones base of C6Cn2r to base of C6Ar. The *Deflandrea* spp. (Def) abundance subzone (latest Late Oligocene to earliest Early Miocene); interval from the FO of *Ectosphaeropsis burdigaliensis* or base of the youngest acme of *Deflandrea* spp. to the FO of *Distatodinium apennicum* corresponding to magnetic polarity subchronozones base of C6Cn2r to base of C6Aar1r. *Distatodinium apennicum* (Dap) interval subzone (Early Miocene); interval from the FO of *Distatodinium apennicum* to the FO of *Membranilarnacia* ?*picena* corresponding to magnetic polarity subchronozones C6Aar1r to base of C6Ar. These zones may correspond to the EO1 to EO4 zones (Aquitanian) in this study. The *Membranilarnacia* ?*picena* (Mpi) interval zone (Early Miocene); FO of *Membranilarnacia* ?*picena* defines the the base of the zone, top is undefined corresponding to magnetic polarity subchronozones C6Ar to base of C6An. This zone is detected as EM5 zone (latest Aquitanian) in this study. The *Hystrichokolpoma truncata* (Htr) interval subzone (Early Miocene); interval from the FO of *Membranilarnacia* ?*picena* to the FO of *Stoveracysta conerae* corresponding to magnetic polarity subchronozones C6Ar. This zone could not be detected in the Eastern Anatolia due to the inappropriate lithologies.

Steininger et al. (1997) defined the type section of Oligocene-Miocene boundary from the Lemme-Carrosio section in Northern Italy. The section is composed of poorly-sorted silts and believed to be stratigraphically complete (includes sediments extending from the upper part of NP25 nannoplankton zone to the middle part of NN2 nannoplankton zone). Most of the marker species, such as *Distatodinium apennicum*, *Stoveracysta conerae*, and *Hystrichokolpoma truncata*, detecting the boundary, on the other hand were neither recorded in Danish area by Dybkjaer (2004) nor in the Eastern Anatolia in this study probably due to unfavourable depositional environments. In the type area, the acme of *Chriptoredium* spp. occurs just below, and the acme of *Deflandrea* spp. occurs just above the Oligocene-Miocene boundary. No peak occurrences (acme) of neither *Chriptoredium* spp. nor *Deflandrea* spp. were recorded by Dybkjaer (2004) in the Danish area. Maximum abundances have been obtained during the HST as 7% of *Chriptoredium* spp. and 12% of *Deflandrea* spp. Therefore, Dybkjaer (2004) could not be able to propose detailed correlation of Oligocene-Miocene sediments in the Danish area and the type area due to the absence of biozonal marker species and the abundance variations of common species.

Dybkjaer and Rasmussen (2000) investigated palynology of the Oligocene-Miocene successions in the Lille Baelt area, Denmark. They suggested that, terrestrial palynomorphs dominated samples overlain by mostly dinoflagellate cysts dominated samples reflect a marine flooding. They claimed that the presence of *Homotryblium vallum* and *Deflandrea phosphoritica* indicates an age not younger than Aquitanian (the earliest Early Miocene). Dybkjaer and Rasmussen (2000) assigned a Middle Burdigalian age for the Ronshoved Section based on the presence of *Hystrichosphaeropsis obscura*, *Thallasiphora pelagica* and the absence of *Chiropteridium galea*. *H*. *obscura* and *C*. *galea* also exist in the Eastern Anatolian Lower Miocene sediments but the last occurrence of *Deflandrea phosphoritica* is slightly older in the Eastern Anatolia. It was recorded not in the the lowest Lower Miocene but in the uppermost Upper Oligocene.

Pross (2001) suggested that the LAD of wetzellioid dinoflagellates including *Wetzeliella symetrica* and *Wetzeliella gochtii* reflects strong diachronism in that younger LADs occurred in the Northwest European Tertiary Basin whereas older LADs occurred in the southern part of the Europe due to the seaway connection between the Tethys and Northwest European Basin. Northwest European basins were less affected by palaeoecological changes because of the northward direction of the Tethyan influence and, thus, have relatively younger last occurrences than the southern part of European basins. This connection might have caused palaeoenvironmental/palaeoceanographic changes resulting strong diachronism on wetzellioid diachronism (Pross, 2001). 4.5 Ma of time difference for *Wetzeliella symetrica* and 3.6 Ma of time difference for *Wetzeliella gochtii* has been indicated between last occurrences of above mentioned taxa in different regions of Europe. According to Batı and Sancay (submitted), *W*. *gochtii* recorded for the first time at the end of the Rupelian in Eastern Anatolia. Pross (2001) emphesized the paleoecological requirements such as sea surface temperature, salinity, nutrient supply, and the distance from the shoreline have a great effect on biostratigraphical potential of dinocysts. He discussed the complete ranges of some wetzellioid dinocysts as follows; *Wetzeliella symetrica* varies between the Early-Middle Eocene (33.45 Ma) to middle Chattian (NP 25, 26.1 Ma) and *Wetzeliella gochtii* between the early Rupelian (close to the NP 21 / NP 22 boundary, 32.8 Ma) to middle Chattian (26.6 Ma).

Dybkjaer (2004) used LO of *Thalassiphora pelagica* and FO of *Hystrichosphaeropsis obscura* in the TST to assign an early to middle Burdigalian age (see also Coccioni et al., 1997, and Hardenbol et al., 1998) for her sequence C in Jylland, Denmark. However, Stover et al. (1996) suggested that the LAD of *Thalassiphora pelagica* occur in the middle Chattian and the FAD of *Hystrichosphaeropsis obscura* occur in the middle-late Aquitanian. Therefore those events seem to be delayed in Dybkjaer's study. She explains those late FO's and LO's by the late Aquitanian-early Burdigalian hiatus and corresponding missing succession occurred below the sequence C and lagoonal/bay (unfavorable environment) conditions dominating during the parts of the TST in the same sequence. Sequence C of Dybkjaer (2004) is comparable with Lower Miocene sediments of the Eastern Anatolia. Dybkjaer (2004) indicated that the abrupt disappearence of *Glaphyrocysta*, *Deflandrea phosphoritica* and low diversity *Homotryblium*-dominated assemblage have been replaced by high diversity assemblage dominated by *Impletosphaeridium insolitum*, *Operculodinium centrocarpum, Spiniferites* spp., and *Systematophora placacantha* co-occurring with *Apteodinium* spp., *Hystrichocolpoma rigaudiae*, *Lingulodinium machaerophorum* and rare occurrences of *Homotryblium* spp.

Oligocene deposits are intensively studied in the southern North Sea Basins where both Rupelian (stiff clays along Rupel River in the northwestern part of Belgium) and Chattian (Doberg section in the north of Germany) unit-stratotype sections have been identified. Van Simaeys (2004) and Van Simaeys et al. (2005) has recently investigated the Rupelian and Chattian sediments in their type region in North Sea. They suggested that the FAD of *Wetzeliella gochtii*-complex (*Wetzeliella gochtii* and *Wetzeliella symmetrica*) occurred at 32.8 Ma, reported in North Sea Oligocene-2

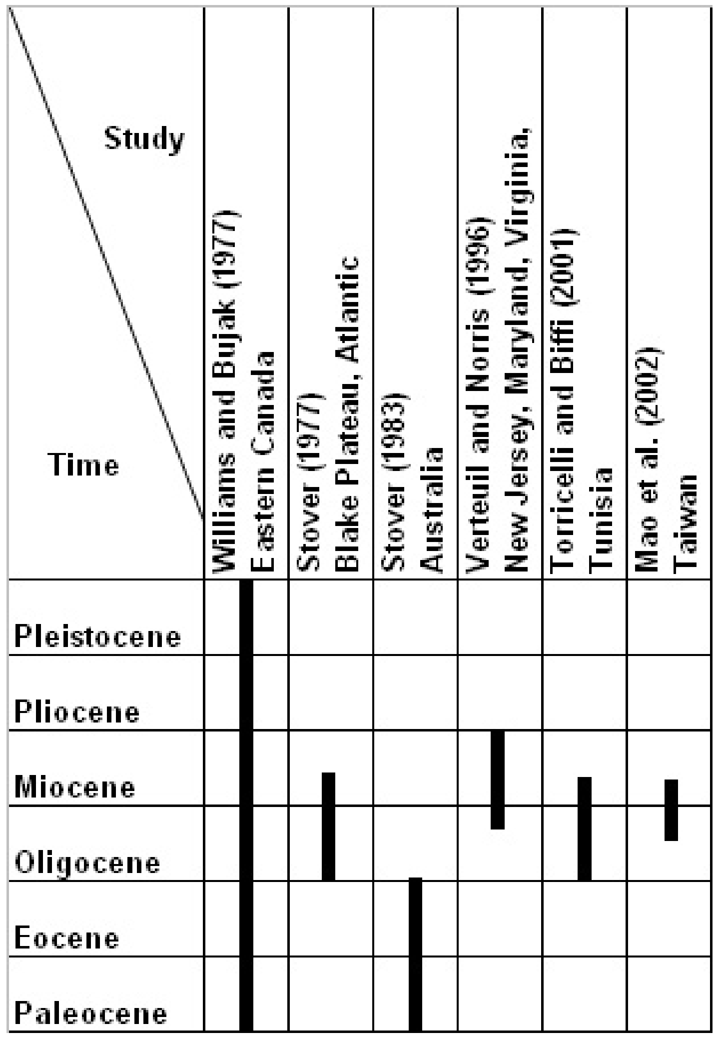
Biozone (NSO-2) and interpreted as latest Rupelian in age and related to NP21/NP22 transition. The last common occurrence of *Enneadocysta pectiniformis* complex defines the top of North Sea Oligocene-4a Subzone (NSO-4a) which is middle Rupelian in age. They have defined North Sea Oligocene-4b Subzone (NSO-4b), mid Rupelian in age, as an interval between the last common occurrence of *Enneadocysta pectiniformis* complex and the FAD of *Distatodinium biffii*. They have also reported that the FAD of *Distatodinium biffii* occurred approximately 27.9 Ma in Italy. The LAD of this taxon defines the top of Van Simaeys (2004)'s North Sea Oligocene-8 Biozone (NSO-8), Late Oligocene in age, and according to Williams et al. (2004), this event occurred at 24.2 Ma in low latitudes. Highest occurrences of *Achillodinium biformoides* have been identified at the base of the Chattian followed by *Deflandrea* spp. acme. Because of the latitudinal diferences, Van Simaeys (2004) and Van Simaeys et al. (2004) recorded FAD of *Membranilarnacia* ?*picena* and *Ectosphaeropsis burdigaliensis* at the top of Chattian in the North Sea, earlier than the Mediterranean where they occurred first time in the Early Miocene (e.g. Brinkhuis et al., 1992; Zevenboom et al., 1994). Williams et al. (2004) indicated that the LAD of *Enneadocysta pectiniformis* and *Achillodinium biformoides* occurred at 29.3 and 26.0 Ma, respectively whereas the LAD of *Distatodinium biffi* occurred later at 24.3 Ma for Nothern Hemisphere mid-latitudes. However, Van Simaeys (2004) and Van Simaeys et al. (2004) reported that *Distatodinium biffi* is not an exclusively Chattian species as it was reported by Wilpshaar et al. (1996) in central Mediterranean basins because it shows its first occurrence in the upper Rupelian in the North Sea. However, as far as the Eastern Anatolian palynomorph assemblages are concerned, FAD of *Distatodinium biffi* also occurred in the EO2 zone (late Rupelian) in the Eastern Anatolia coinciding with Van Simaeys's interpretation, but *E. pectiniformis* has been recorded throught the Oligocene, FAD and LAD of *Wetzeliella gochtii* in the middle and late Rupelian, respectively, and the FAD of *Membranilarnacia* ?*picena* recorded in the late Aquitanian.

Some dinoflagellate events reported by Van Simaeys (2004) in the North Sea basins have also been reported by different researchers in Mediterranean in the same chronologic order. For instance; Brinkhuis and Biffii (1993), recorded *Wetzeliella gochtii* for the first time in their *Reticulatosphaera actinocoronata* (Rac) Interval Zone in Italy. According to Wilpshaar et al. (1996), top of this zone occurs at 32.5 Ma. Wilpshaar et al. (1996) also reported that the LAD of *Enneadocysta pectiniformis* occurs well below the FAD of *Distatodinium biffii* in the central Mediterranean. However, even though the FAD of *Membranilarnacia*? *picana* occurs below the FAD of *Distatodinium biffii* in the North Sea, it is much higher than the FAD of *D. biffii* in Mediterranean (Wilpshaar et al., 1996).

3.10. Correlations of the palynomorph assemblages with other palynological studies from outside of Turkey and Europe

Even though some of the palynological studies have been carried out in quite long distances from Turkey (Table 4), they still seem to be comparable with this study. Williams and Bujak (1977) investigated the Cenozoic palynostratigraphy of offshore Eastern Canada. They have identified 12 assemblage zones ranging from Early Paleocene to Pleistocene and including over 200 dinoflagellates from 11 Scotian Shelf and 15 Grand Banks wells. Regarding to Late Oligocene, they suggested last occurrences of the following species; *Chriptoredium aspinatum*, *C. dispersum*, *C. lobospinosum*, *Deflandrea phosphoritica*, *D. spinulosa*, *Eocladopyxis peniculatum*, *Leptodinium incompositum*, *Phthanoperidinium comatum* and *Thalassiphora pelagica*. Williams and Bujak (1977) used last occurrences of *Apteodinium* sp., *Cordosphaeridium cantharellus*, *Distatodinium paradoxum* and *Polysphaeridium simplex* for Early Miocene, first occurrences of *Hystrichosphaeropsis obscura* and *Pterodinium circumsutum* and last occurrences of *Hemicystodinium zoharyi*, *Homotryblium floripes*, *Paleocystodinium golzowense* and *Pentadinium laticinctum* for Middle Miocene. Dinoflagellate events reported by these authors are quite similar to those of in this study. LAD of *Deflandrea*

Table 4. List of the palynostratigraphic works used in this study for the correlation of the Oligocene-Miocene palynomorph assemblages from outside of Turkey and Europe.




*phosphoritica* and *D. spinulosa* in the Late Oligocene, LAD of *Cordosphaeridium cantharellus* and FAD of *Hystrichosphaeropsis obscura* in the Early Miocene were also detected in the Eastern Anatolian Oligocene-Miocene sediments.

Stover (1977) studied Oligocene and Early Miocene dinoflagellates from Atlantic corehole 5/5B, Blake Plateau and distinguished four intervals as follows: *Phthanoperidinium* interval (Early Oligocene), Transition interval ("middle" Oligocene), *Pentadinium* interval ("middle" Oligocene to Early Miocene) and *Tuberculodinium* interval (Early Miocene). These intervals were dated by means of planktonic foraminifer assemblages. Studied uninterrupted sections represent an interval between Early Miocene *Catapsydrax dissimilis* Zone to Early Oligocene *Cassigerinella chiploensis-Pseudohastigerina micra* Zone. Top of the Early Oligocene interval is marked by the last occurrence of *Achillodinium biformoides*, *Areosphaeridium arcuatum*, *Cordosphaeridium fibrospinosum*, *Leptodinium incompositum*, *Phthanoperidinium comatum*, *P. eocenicum* and first occurrences of *Apteodinium australiense*, *Chiropteridium aspinatum*, *Deflandrea heterophlycta*, *Homotryblium vallum*, *Paleocystodinium golzowense* and *Wetzeliella asymmetrica incisa* and corresponds to the *Cassigerinella chiploensis-Pseudohastigerina micra* and *Globigerina ampliapertura* planktonic foraminifera zones. The lower part of the *Globorotalia opima opima* zone is represented by the transition interval and includes first occurrences of *Chriptoredium dispersum* and *Batiacasphaera micropapillata*. Most of the section studied by Stover (1977) was involved into *Pentadinium* interval, corresponding to the upper part of the *Globorotalia opima opima* Zone, whole of the *Globigerina ciperoensis* Zone and the lower part of the *Globorotalia kugleri* Zone, dated as "middle" Oligocene-Early Miocene. The first occurrence of *Hemicystodinium congregatum* and *Spiniferites membranaceus* determines the base of the interval while the last occurrence of *Chriptoredium aspinatum*, *Deflandrea phosphoritica* and *Wetzeliella asymmetrica incisa*, just below the first occurrences of *Batiacasphaera hirsuta* and *Tuberculodinium vancampoae*, limits the top of the interval. He suggested that several species have their last occurrences in this interval such as; *Homotryblium plectilum*, *Wetzeliella articulata*, *Riculacysta perforata* and *Thallasiphora pelagica*. The Early Miocene *Tuberculodinium* interval is distinguished above the last occurrences of *Deflandrea phosphoritica* and *Chriptoredium aspinatum* and generally characterized by *Tuberculodinium vancampoae* and *Apteodinium spiridoides* in high quantities. These results seem quite similar to this study in that LAD of *Achillodinium biformoides* identified in his *Phthanoperidinium* interval (Early Oligocene also recorded in the Rupelian in the Eastern Anatolia. Moreover, *Pentadinium* interval, dated as “middle” Oligocene to Early Miocene, of Stover (1977) may correspond to LO1 (Late Oligocene) zone in which *Deflandrea phosphoritica* occurred for the last time in this study. According to Stover (1977), rare occurrences of *Deflandrea phosphoritica* could be found together with *Chiropteridium galea* and *Homotryblium vallum* in the lowermost Miocene of the North Atlantic. However, reworking possibility of *Deflandrea phosphoritica* into the Lower Miocene sediments should be also taken into consideration. Additionally, high abundances of *Apteodinium spiridoides* have been detected in Lower Miocene sediments in the Eastern Anatolia as it has been reported in the *Tuberculodinium* interval (Early Miocene) of Stover (1977).

Stover (1977) also claimed that the species belonging to *Homotryblium* genera have an interesting distribution pattern throughout the planktic foraminifera zones in that *Homotryblium plectilum (*the oldest occurring species) is common in Middle Eocene (in *Orbulinoides beckmanni* and *Truncorotaloides rohri* Zones) but became abundant in the Early Oligocene (in the *Cassigerinella chipolensis*-*Pseudohastigerina micra* and *Globigerina ampliapertura* Zones). Transitional forms of *H. plectilum/vallum* occur in the *Cassigerinella chipolensis*-*Pseudohastigerina micra* Zone while low abundances of *H. vallum* occur in *Globigerina ampliapertura* Zone. All three *Homotryblium* species could have found in the whole *Globorotalia opima opima* Zone and the lower part of the *Globigerina ciperoensis* Zone. He argued that *Homotryblium plectilum* and *H. plectilum*/*vallum* became very rare and dissappear in the *Globigerina ciperoensis* Zone and lower part of the *Globorotalia kugleri* Zone respectively due to the high abundances of *Chriptoredium*. Finally, the only extant species *H. vallum* became increasingly common in the upper part of the *Globorotalia kugleri* Zone and the *Catapsydrax dissimilis* Zone. Similar evolutionary trend in *Homotryblium* also existed in the Eastern Anatolian Oligocene-Miocene sediments. *Homotryblium plectilum* occurs as the earliest representative of *Homotryblium* in the Rupelian. Transitional forms of *H. plectilum*/*vallum* seem to be recorded during the Chattian and *H. vallum* mostly dominates the Early Miocene *Homotryblium* species.

Stover (1983) investigated the morphological features of different *Deflandrea* species from the Paleocene and Eocene sediments in Australia. He suggested that the following features of *Deflandrea* could be used to assign relative age to the *Deflandrea*-bearing palynomorph assemblages: shape of the cysts (outline of the periblast), horn developments, amount of tabulation, archeophyle, sculpturing, position and size of endoblast (inner body) to periblast (outer body). He mainly observed following trends as the rocks gets younger; 1) Prominence of cingulum and sulcus and the clarity of the tabulation decreases. 2) Length/width ratio of the archeophyle decreases. 3) Horn development reduces and outline of the cysts becomes more rotund. 4) Endoblast occupies most of the pericoel (the space between endophragm and periphragm). 5) Sculpturing gets coarser. This criteria have been successfully applied to differentiate Eocene and Oligocene *Deflandrea* species in this study.

De Verteuil and Norris (1996) investigated the uppermost Oligocene-uppermost Miocene sediments from New Jersey, Maryland, Virginia and Delaware and identified 60 dinocyst horizons (with average duration of 1.8 Ma) calibrated by the timescale of Bergreen (1995). They have also calibrated dinocyst horizons with planktonic foraminifera and calcareous nannoplankton data to detect the chronostratigraphic position of the biozones. The oldest occurrence (FAD) of *Hystrichosphaeropsis obscura* and the youngest (LAD) of *Homotryblium vallum* and *Deflandrea phosphoritica* were reported in the DN1 zone (upper Upper Oligocene-lower Lower Miocene) of de Verteuil and Norris (1996). Following co-occuring species have also been identified for DN1; *Cordosphaeridium cantharellus*, *Hystrichokolpoma rigaudiae*, *Systematophora placacantha*, and *Chiropteridium galea*. They suggested the last common occurrence of *Chiropteridium galea* can be used as a very good indicator for the top of Zone DN1. This zone can be correlated with the base DO3b of Biffi and Mannum (1988) based on the highest occurrence of *Distatodinium biffii* as *Distatodinium paradoxum*. LAD of *Cordosphaeridium cantharellus* has been reported in the DN2 zone (lower Lower Mioocene-middle Lower Miocene) that is identified as an interval from the highest occurrence of *Chiropteridium galea* and the highest occurrence of *Exochosphaeridium insigni*. Co-occurring genera are *Apteodinium-Operculodinium*, *Spiniferites*, and *Systemathophora* in DN2. Even though they have not differentiated Late Oligocene and Early Miocene assemblages in their study, LAD of *Deflandrea phosphoritica* and FAD of *Hystrichosphaeropsis obscura* in their DN1 zone suggest that, this zone may comprise LO1 to EM3 zones defined in this study. Upper Oligocene to lower Lower Miocene sediments have been dominated by *Homotryblium* and *Chiropteridium* species in the North Atlantic (de Verteuil and Norris, 1996). They evaluated *Homotryblium vallum*, *Homotryblium floripes*, and *Homotryblium plectilum* as *Homotryblium* complex and suggested that the LAD of *Homotryblium* complex occurred in the lower Lower Miocene or just above but they may range into the middle Lower miocene in Europe. De Verteuil and Norris (1996) indicated that the LAD of *Cribroperidinium tenuitabulatum* occurred in the Zone DN2 (middle Lower Miocene) but it may range higher in the Mediterranean. They also suggested that the upper limit of *Apteodinium spiridoides* is in the top of DN4 (lower Middle Miocene). Differences between the chronostratigraphic positions of the same biostratigraphic events in different basins as indicated by de Verteuil and Norris (1996) may be related to the reworking at one or both sites and/or diachronity of a species' diversity. *Homotryblium* and *Chiropteridium* dominated Lower Miocene sediments have been also recorded in the Eastern Anatolia, but I could not have a chance to check LADs of *Cribroperidinium tenuitabulatum* and *Apteodinium spiridoides* due to the unfavourable depositional environments.

Torricelli and Biffi (2001) studied the palynostratigraphy of the Oligocene-Lower Miocene Numidian Flysch in five different section from the Northern part Tunisia. They reported that a dinoflagellate cyst zonation scheme proposed by Wilpshaar et al. (1996) for the central Mediterranean area has been succesfully defined in their samples. Most of the stratigraphically important dinoflagellate events identified by Torricelli and Biffi (2001) have also been recorded in the Eastern Anatolian Oligocene-

Miocene sediments. For instance, both FAD and LAD of *Wetzeliella gochtii*, FAD of *Tuberculodinium vancampoae,* and LAD of *Achillodinium biformoides* occurred in the Rupelian in their study. These events have also been identified in the EO1 to EO3 zones to which Rupelian age has been assigned in this study. Therefore, age assignments suggested by Torricelli and Biffi (2001) and this study for the same dinoflagellate events are quite consistent. According to Torricelli and Biffi (2001), the FAD of *Tuberculodinium vancampoae* and the LAD of *Wetzeliella gochtii* can be used as confirmatory events for the detection of Rac and Clo zones (Early Oligocene) of Brinkhuis and Biffi (1993) for the southern part of the Mediterranean. They have also reported that the FAD of *Membranilarnacia* ?*picena*, LAD of *Chiropteridium lobospinosum* and *Hystrichocolpoma pusillum* occurred in the Early Miocene in their study. These events have also been seen in the Eastern Anatolia in EM2 to EM5 zones, as it was reported by Torricelli and Biffi (2001), in the Early Miocene. On the other hand, even though the FAD of *Chiropteridium lobospinosum* occurs in the Late Oligocene in both studies a discrepancy seen at the time of the acme of *Chiropteridium lobospinosum* which was reported to be occurred in the Late Oligocene by Torricelli and Biffi (2001), but in the Early Miocene of the Eastern Anatolia in this study. However, since high abundances of *Chiropteridium* species might be related to transgressive events, their chronostratigraphic positions may vary from basin to basin.

Mao et al. (2002) investigated the Late Oligocene-Early Miocene dinoflagellate cysts of the Kuohsing area, central Taiwan. They distinguished two different dinocyst assemblages representing Late Oligocene and Early Miocene as follows; the Assemblage I is represented by *Cordosphaeridium gracile* and *Homotryblium tenuispinosum* accompanied by some other dinoflagellates such as *Cordosphaeridium minimum*, *Homotryblium abbreviatum*, *Chiropteridium lobospinosum* and indicated as possibly Late Oligocene in age. The Assemblage II, on the other hand, is characterized by the FADs of *Hystrichosphaeropsis obscura*, *Melitasphaeridium choanophorum*, and *Tuberculodinium vancampoae* and considered to be Early Miocene in age. FADs of *H*. *obscura* is identified in the Early Miocene of the Eastern Anatolia but *T. vancampoae* has also been recorded in Lower Oligocene sediments. Mao et al. (2002) compared his dinoflagellate cyst assemblages with other Oligocene-Miocene biozones (e.g. Stover, 1977; Costa and Downie, 1979; Edwards, 1984; Powell, 1986b; Manum et al., 1989; Brinkhuis et al., 1992; Bujak, 1984) by just using common species and most of the cases he faced some difficulties in correlation of different studies due to the absence of key species.

# CHAPTER 4

# PALEOCLIMATE, PALEOECOLOGY, AND PALEOENVIRONMENT

## 4.1. Paleoclimatological Reconstructions

Distribution of the present-day vegetation is dependent on the climatic conditions such as temperature and precipitation. Similarly, spore pollen derived from different vegetation types can be used as a proxy to reconstruct the climate of the past. For instance, ferns represent cold and arid upland conditions whereas palms mostly represent much warmer and humid climates. This is the general principle of the paleoclimatological analysis in palynology.

Terrestrial plants have some climatic requirements to survive. Therefore, they can commonly be used as a proxy in paleoclimatological studies. However, there is no accepted method to indicate paleoclimate data from the fossil plants yet. Two techniques have been suggested to be useful in such studies. First technique is leaf physionognomy approach, called “constructional morphology philosophy” proposed by Wolfe (1993) and known as “Climate-Leaf Analysis Multivariate Program” (CLAMP). This method reveals some climatic informations such as mean annual temperature, mean temperature of the coldest and the warmest month, and mean monthly precipitation from 25 different leaf physionognomies and leaf assemblages but the main limitation of the technique is that it can only be applied to the leaf floras which are not as common as spores and pollen. Mosbrugger and Utescher (1997) also noted that the climatic interactions of the leaf physionognomy is not necessarily the same in different regions.

Coexistence approach has been proposed by Mosbrugger and Utescher (1997) for quantitative paleoclimatological reconstructions. This technique is based on a very simple principle that is fossil plants have similar climatic tolerances with their nearest living relatives. This approach is known as a “nearest living relatives philosophy”. The main purpose of the technique is to determine climatic ranges in which a large number of nearest living relatives of the identified fossil taxa can coexist. These climatic ranges are estimated to be the best approximation for the climatic conditions under which fossil taxon lived. Technique can be applied to whole Tertiary but produces adequate results especially for Oligocene and younger sediments. Accuracy of the technique gets better as the rocks get younger (because assigning of the nearest living relative to fossil taxa can be done more precisely) and as the number of the coexisting taxa taken into account are increased. Therefore, climatic tolerances of as many taxa as possible should be indicated for the reconstructions. Mosbrugger and Utescher (1997) suggested that the minimum of 10 taxa are necessary to obtain reasonable climatic reconstructions. Coexisting approach method is applied by means of a computer software called CLIMSTAT. The database called “Palaeoflora” behind the coexsiting approach techinuqe has more than 3000 Tertiary plant taxa and their climatic requirements (Bruch and Mosbrugger, 2002). Today, the number of the taxa indicated to the database have reached over 3500 taxa (Utescher, personal communication, 2005) and keep growing with the contributions from all over the world. Climatic information of the taxa used in the software have been gathered from the local meteorological stations which are believed to be representative of the whole area of distribution of the taxa (see also web site “www.palaeoflora.de” for detailed information). Spores and pollen, fruits, seeds, leaves and woods are indicated within the data base. According to Mosbrugger and Utescher (1997), even though spores and pollen are more abundant than others, fruits and seeds provide the best climatic information (the narrowest coexistence intervals or the highest climatic resolution). The main limitation of the technique is the nearest living relatives of the fossil plants have to be assigned.

According to Mosbrugger and Utescher (1997), the resolution of the technique, which is up to 1-2 °C in temperature-related parameters and 100-200 mm in mean annual precipitation, is quite satisfying. Since the method provides results as coexistince intervals, it is possible to define uncertainity ranges for each climatic parameters. They have compared their information with the data derived from the local meteorological stations and tested their results. Coexistence approach is only interested in the presence/absence of fossil taxa and does not take their relative abundances into consideration to minimize taphonomic effects caused by different transportation mechanism of the palynomorphs.

The basic assumption of the coexistence approach is that the climatological requirements of the fossil taxon are same or very similar to those of their nearest living relatives. For instance, let us assume three fossil plants as X, Y, Z and their nearest living relatives X', Y', Z' as it is illustrated in the Figure 28 and X', Y', Z' have following mean annual temperatures: 0-6 °C for X', 2-12 °C for Y', and (-2)-(-10) °C for Z'. The coexistence interval in which X', Y', Z' can be found together is 2-6 °C. Therefore, it is suggested that the fossil taxon X, Y, and Z have lived in a climate having mean annual temperatures of 2-6 °C. Based on this idea ten different climatic parameters listed below may be obtained from the coexisting approach method suggested by Mosbrugger and Utescher (1997):

| | |
|---|---|
| MAT | Mean Annual Temperature (°C) |
| WMT | Mean Temperature of the Warmest Month (°C) |
| CMT | Mean Temperature of the Coldest Month (°C) |
| RH | Mean Relative Humidity (%) |
| PE | Potential Evaporation (mm) |
| MAP | Mean Annual Precipitation (mm) |
| MMaP | Mean Maximum Montly Precipitation (mm) |
| MMiP | Mean Minimum Montly Precipitation (mm) |
| MWP | Mean Precipitation of the Warmest Month (mm) |
| AI | Aridity Index (MAP/PE) |

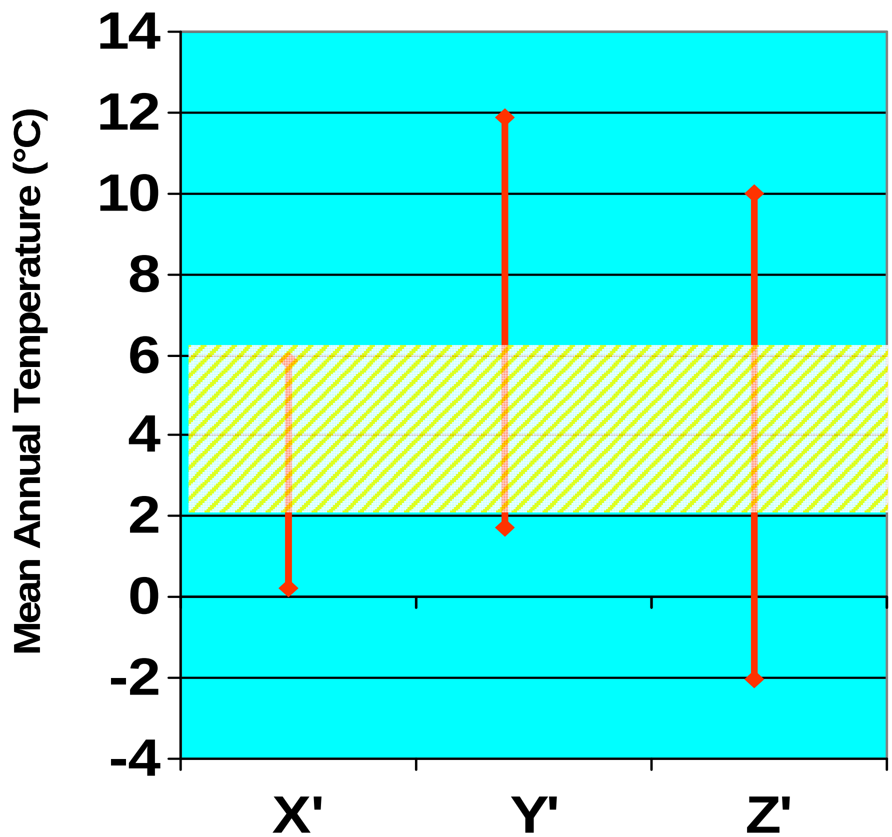



Figure 28. Schematic demonstration of the coexistence approach technique.

Main steps of the technique are as follows:

1. Identification of the fossil taxa (species level supplies more precise data than genus or family level).
2. Determination of nearest living relatives from the data base.
3. Selection of climatic parameter.
4. Determination of climatic tolerances for nearest living relatives from the data base.
5. Determination of the coexistence interval
6. Selection of new climatic parameter or complete the analysis.

Mosbrugger and Utescher (1997) suggested that the main problem of the coexistence approach technique is to detect the climatological requirements of the living plants. They claimed that the climatic tolerances of the plants can be determined by their distributional area which approximately correlates with the isolines of above listed climatic parameters. Therefore, data combined from different meteorological stations are indicated for the climatological tolerances of living plants.

In order to check the statistical significance of the technique, Mosbrugger and Utescher (1997) performed Monte Carlo simulation and proved that the coexistence approach technique is statistically highly significant (significance level is lower than 0.01%). They have also tested their technique on four different modern flora (two from Germany, one from USA and one from Croatia) and compared calculated coexistence intervals from software for all climatic parameters with those of derived from meteorological stations. They have seen that calculated values of the six parameters abbreviated as MAT, WMT, CMT, RH, PE, and MMaP have perfectly fit with those of gathered from meteorological stations. On the other hand, four parameters abbreviated as MAP, MmiP, MWP, and AI have less adequate reconstructions. This is interpreted as the precipitation-related parameters which are difficult to reconstruct and may vary in short distances. Finally, Mosbrugger and Utescher (1997) suggested that the coexistence approach method obtains precise information for mean annual temperature, temperature of the warmest and coldest month, relative humidity, potential evaporation, and mean maximum montly precipitation. Relatively less good but still acceptable estimates can be done on mean minimum montly precipitation and aridity index. Mean annual precipitation and mean precipitation of the warmest month are the least reliable reconstructions but still reflect the general trend and should be evaulated carefully.

Mosbrugger and Utescher (1997) suggested that the $\delta^{13}C$ values show similar climatic trend with calculated reconstructions from the software but it is not possible to convert $\delta^{13}C$ values into mean annual temperatures.

Even though the coexistence approache technique has mostly revealed promising results, Mosbrugger and Utescher (1997) argued that this technique is based on following assumptions which may cause wrong reconstructions: First, fossil taxon and its nearest living relative should be identified correctly. Second, the climatic tolerances of fossil taxon and its nearest living relative should be same or similar. Only a few exceptions from that argument have been detected. For instance, modern *Sequoia* and *Empetrum* lives in cool-temperate to cold conditions whereas fossil *Sequoia* and *Empetrum* in Tertiary occur relatively much warmer environments. Therefore, those taxa are identified as cold-outlier and taken out of the evaluation during the analysis. Similarly, there are some warm-outliers such as *Scindapsus*, *Parabaena*, and Zingiberaceae and have not been taken into consideration in coexistence approache analysis of Mosbrugger and Utescher (1997), either. Third, data derived from the meteorological stations in the distributional area of the living plants should be reliable and adequate. Therefore, misidentifications of fossil taxa or their nearest living relative, changing in climatic tolerances of the fosil taxa due to evolution, poor climatic information gathered from meteorological stations may cause inadequte paleoclimatic reconstructions.

As it has been mentioned before, temperature related parameters and the mean annual precipitation are indicated as the most accurate information derived from the Climsat software. Therefore, those parameters have a priority for the paleoclimatological reconstructions in this study. As a result of the analysis based on the coexistince approach technique following results have been indicated; the mean annual temparatures are in the range of 15.6 to 21.3 °C, mean temparatures of the coldest and the warmest month are 5.0 to 13.3 °C and 24.7 to 28.1 °C, respectively, and mean annual precipitation is 1122.0 to 1522.0 mm. Other relatively less precise parameters derived from the paleoclimatological analysis as follows; The exclusion of *Carya cordiformis* as an outlier leads to mean maximum montly precipitation (MmaP) values between 204.0 to 227.0 mm whereas the calculated coexistence interval for mean minimum montly precipitation (MMiP), ranges from 19.0 to 43.0 mm. The mean precipitation of the warmest month (MWP) interval, on the other hand, ranges from 79.0 to 125.0 mm by excluding *Ephedra* sp. as an outlier.

Table 5 shows the list of the fossil taxa and their nearest living relatives that have been indicated in paleoclimatological reconstrucitons of the Eastern Anatolia by CLIMSAT software. Coexisting taxa (the number of taxa coexisting within the ranges of each parameter) changes between 24 to 27 and never seen below 24 for all parameters. Since the technique requires at least 10 taxa for aquirate reconstructions, our interpretations on the paleoclimatological conditions of the Oligocene-Miocene sediments in the Eastern Anatolia should be quite promising.

According to Akgün et al. (2004), mean annual temperatures (MAT) range between 17,2 to 20,8 °C and the mean temperatures of the coldest month (CMT) were between 9,6 to 13,3 °C in the Oligocene of the Western Anatolia suggesting subtropical conditions. However, Climsat software results for the Oligocene sediments of the Eastern Anatolia revealed relatively cooler conditions in that the mean annual temperatures were between 15,6 to 21,3 °C and the mean temperatures of the coldest month (CMT) were between 5,0 to 13,3 °C. Therefore, temperate to subtropical conditions might have been dominating during the Oligocene in the Eastern Anatolia. Coexistence approach results indicate that even though mean annual temperatures are seen as quite similar, temperature related parameters were always lower in the Eastern Anatolia than those of in the Western Anatolia during the Oligocene just like how it is today. As far as spore-pollen assemblages of both region are compared, similar results can also be obtained. Tropical and subtropical elements of *Engelhardtia*, warm temperate indicator of Fagaceae (e.g. *Quercus*), and warm and humid climate indicators such as *Tilia*, *Alnus*, *Carya* etc., recorded in Nortwestern and Western Anatolian Tertiary sediments (Batı, 1996; Akkiraz, 2000; Akkiraz and Akgün, in press), do not exist or are very rare (0.5-1 %) in the Eastern Anatolia. Moreover, pteridophytic spores (e.g. Polypodiaceae, Lygodiaceae, and Osmundaceae), indicative of warm and humid conditions, are also seen in low frequencies in the Eastern Anatolia. Instead, dry-cold indicators (Compositae, Gramineae, Chenopodiaceae, and Umbelliferae)

Table 5. List of fossil taxa and their nearest living relatives used in paleoclimatological reconstructions by CLIMSAT software.

| FOSSIL TAXA | NEAREST LIVING RELATIVES |
|---|---|
| *Cingulatisporites macrospecious* | Pteridaceae |
| *Corsinipollenites oculus noctis* | Onagraceae |
| *Dicolpopollis kalewensis* | *Palmae* |
| *Ephedra* sp. | *Ephedripites* sp. |
| *Inaperturopollenites hiatus* | Taxodiaceae |
| *Intratriporopollenites instructus* | *Tilia* sp. |
| *Laevigatosporites haardti* | Polypodiaceae |
| *Leiotriletes adriennis* | *Lygodium* sp. |
| *Leiotriletes microadriennis* | *Lygodium* sp. |
| *Momipites* sp. | *Engelhardtia* |
| *Monocolpopollenites tranquillus* | Palmae |
| *Monoporopollenites gramineoides* | Gramineae |
| *Periporopollenites multiporatus* | *Carpinus betulus, C. coraliniana* |
| *Pityosporites* labdacus | *Pinus silvestris* |
| *Polyporopollenites stellatus* | *Pterocarya* sp. |
| *Polyporopollenites undulosus* | *Ulmus* sp. |
| *Polyvestibulopollenites verus* | *Alnus* sp. |
| *Sparganiaceaepollenites neogenicus* | Sparganiaceae |
| *Subtriporopollenites simplex* | *Carya* |
| *Tetracolporopollenites* sp. | Sapotaceae |
| *Triatriopollenites coryphaeus* | *Engelhardtia* |
| *Triatriopollenites* sp. | Myricaceae |
| *Tricolporopollenites euphorii* | Araliaceae |
| *Verrucatosporites alienus* | Polypodiaceae |
| *Verrucatosporites favus* | Polypodiaceae |

are commonly occurring in most of the samples suggesting temperate to subtropical climates. Therefore, relatively cooler conditions might be considered for the Eastern Anatolia than those of for the Western Anatolia during the Oligocene. Both results obtained from cexistence approach technique and spore-pollen assemblages indicate that temperate to subtropical conditions were predominating during the Oligocene and these climatic conditions have not been changed drastically during the deposition of the Oligocene-Miocene sediments in the Eastern Anatolia.

Tectonism had a great importance on Tertiary deposition in the Eastern Anatolia. Because of the collision of Arabian and Laurasian plates in Middle Eocene (Yılmaz 1993), the Eastern Anatolia compressed, uplifted, converted into the positive areas and eroded after Late Eocene (Şengör, 1980; Şengör and Yılmaz, 1981). The erosion from this elevated region into the relatively depressed areas, caused a terrestrial and/or very shallow marine to transitional lithologies during Late Oligocene-Early Miocene. This uplifting trend might be the main reason of relatively cooler conditions in climate and intensive Eocene reworking during the deposition of the Oligocene-Miocene sediments. Another reason of cooler climatic conditions in the Eastern Anatolia might be an intensive volcanism. As it was indicated by Ediger (1990) and Axelrod (1981) high amounts of volcanic dust could be distributed in the stratosphere and due to the decreasing intensity of solar radiation in the lower athmosphere, relatively lower seasonal mean annual temperatures, colder climatical conditions and less precipitation might have been experienced.

### 4.2. Paleoecological Reconstructions

Paleoecological reconstructions of Oligocene-Miocene sediments have been investigated by means of marine dinoflagellate and acritarch assemblages, “so-called eco-groups” in this study.

Many paleoecological studies carried out on dinoflagellates because they are are very useful as paleoenvironmental indicators (e.g. Wall et al., 1977; Marret and Zonneveld, 2003). According to Dale (1996), modern dinoflagellates are very sensitive to ecological changes resulted that every single depositional environment has its characteristic dinoflagellate assemblage. Therefore, as the environmentally sensitive modern dinoflagellates, fossil dinoflagellates can be sucsessfully used to some extent in the paleoenvironmental and paleoclimatological reconstructions, too. Dale (1996) also reported that the cosmopolitan taxa are mostly long-ranging because of their tolerance to the environmental changes and, thus they are less stratigraphically important than the environmentally restricted taxa which are more sensitive to environmental changes and yield high-resolution biostratigraphy.

As it was reported by Stover and Hardenbol (1994), dinoflagellates yield promising information for stratigraphic correlations because they can be found both in neritic and deeper marine depositional conditions and are not affected by post-depositional decalcification processes like planktonic foraminifers and calcareous nannoplanktons. Dinoflagellates are very resistant to the chemical dissolution and can reach high abundances in both coastal/neritic, where calcareous nannoplanktons are so rare, and open-oceanic settings. Therefore, they supply valuable information about the depositional conditions of the past oceans such as productivity trends, sea surface temperature, and salinity Sluijs et al. (2005). Dinoflagellates may occur in all aquatic environments from fresh water to hypersaline conditions Dale (1996), under different climatic conditions ranging from arctic to temperate and tropical conditions and in different water depths ranging from inner neritic to outer neritic and oceanic conditions (Figure 29) (e.g. Harland, 1983; Stover et al., 1996). Taylor (1987) reported that approximately 90 % of the living dinoflagellates are marine while remaining 10 % is living in freshwater conditions. He also indicated that light, salinity, temperature, nutrient supply, upwelling, tidal influence, methods of feeding, pollution and grazing are major factors determining the growth and distribution of dinoflagellates. Salinity and water depth (bathymetry) tolerances of the dinoflagellates vary drastically from species to species. Distribution of the dinoflagellate cysts is mostly controlled by salinity, water temperature, nutrient, and watermass composition (Williams, 1977; Wall and Dale, 1974;

Ellegaard, 2000). Therefore, dinoflagellates are very good indicators of paleoecological conditions and may give important signals about the surface water temperature, coastal/oceanic trend (paleobathymetry), salinity, productivity (e.g. Wall et al., 1977; Köthe, 1990; Brinkhuis, 1994; Stover and Hardenbol, 1994; Dale, 1996; Powell et al., 1996; Marret and Zonneveld, 2003; Van Simaeys, 2004; Van Simaeys et al., 2004). However, even though dinoflagellates seem abundantly and well-diversified throughout the studied sections, their preservation is mostly poor to moderate in many samples due to the restricted marine conditions.

According to Stover and Williams (1982) dinoflagellates are very usefull in both biostratigraphical and paleoecological studies. They may inhabite in middle neritic to upper bathyal environments. Therefore, it is possible to correlate dinoflagellate assemblages with spore-pollen assemblages in the landward direction and planktonic foraminifera and nannoplankton assemblages in the seaward direction.

Dale (1983) emphasized that the cyst population is very important for paleoecological reconstructions in that it gives an idea about the paleoclimate, paleosalinity, and the paleoprovincialism. According to Davies et al. (1982) four kinds of dinoflagellate information may be used for paleoecological studies as follows; 1. Absolute abundances (number of dinoflagellates/unit of sediment), 2. Abundance of dinoflagellates/other groups of palynomorphs, 3. Dinoflagellate species diversity, 4. Abundance of selected, single dinoflagellate species.

Köthe (1990) suggested a paleoecological model for the Paleogene of the Northwest Germany. She used dinoflagellate associations (so called “eco-groups”) to determine transgressive-regressive cycles and then she correlated those cycles with the third order cycles of Haq et al. (1987). Köthe’s eco-group based paleoecological model has been applied to the Eastern Anatolian Oligocene-Miocene sediments in this study. Some particular taxa have been selected and following eco-groups have been distinguished for the paleoecological investigations of the Eastern Anatolian Oligocene-Miocene sediments. Relative abundances of the eco-groups

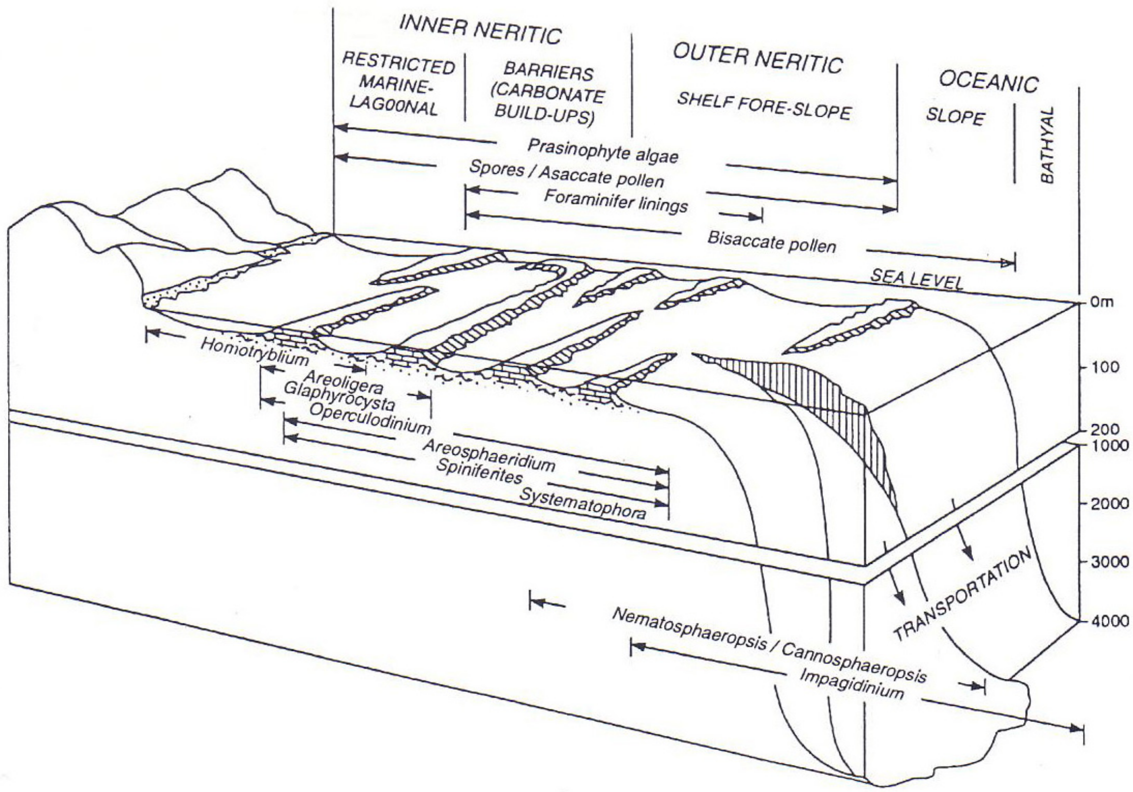



Figure 29. Distribution of marine and terrestrial palynomorphs on a continental shelf-slope profile (Stover et al. 1996; after Brinkhuis, 1992).

during the Oligocene and Miocene can be seen in Figures 30 and 31. Two sections (Ebulbahar and Kelereşdere sections) from the Hınıs-Muş-Van Basin where mostly marine deposition took place during Oligocene and Miocene have been choosen to illustrate changes in dinoflagellate assemblages in time.

1. *Chiropteridium* eco-group; dominated by *Chiropteridium*, but *Spiniferites*, *Glaphyrocysta*, *Enneadocysta pectiniformis*-complex, and *Membranophoridium* are also exist. Common occurrences of *Chiropteridium* and *Enneadocysta pectiniformis*-complex have been reported by transgressive deposits by Stover and Hardenbol (1994). Similarly *Glaphyrocysta* also reflects shallow marine conditions (Brinkhuis et al., 1992).

High abundance of *Chripteredium* spp. reflects high energy, marginal marine, near-shore conditions (e.g. Powell et al., 1996 and Zevenboom, 1996). Dybkjaer (2004) used relative increase in *Chripteredium* spp. abundance to define HST and believed to reflect progradation of the coastline. Lowest Miocene (early Aqutanian) sediments of the Eastern Anatolia were mostly dominated by *Chripteredium* eco-group suggesting that Early Miocene sedimentation took place in relatively shallow marine (high energy) conditions.

2. *Homotryblium* eco-group; (dominated by different species belonging to nominate taxon including (*H*. *plectilum*, *H*. *plectilum*/*vallum*, and *H*. *vallum*) and *Polysphaeridium zoharyi*, *Lingulodinium machaerophorum*, and *Thalassiphora pelagica*. It mainly represents restricted marine, inner neritic conditions and prefered warmer sea surface temperatures.

According to Brinkhuis (1994) and Williams and Bujak (1977), *Homotryblium* species become abundant in warm conditions. *Lingulodinium machaerophorum* prefers marginal marine, near-shore environments with

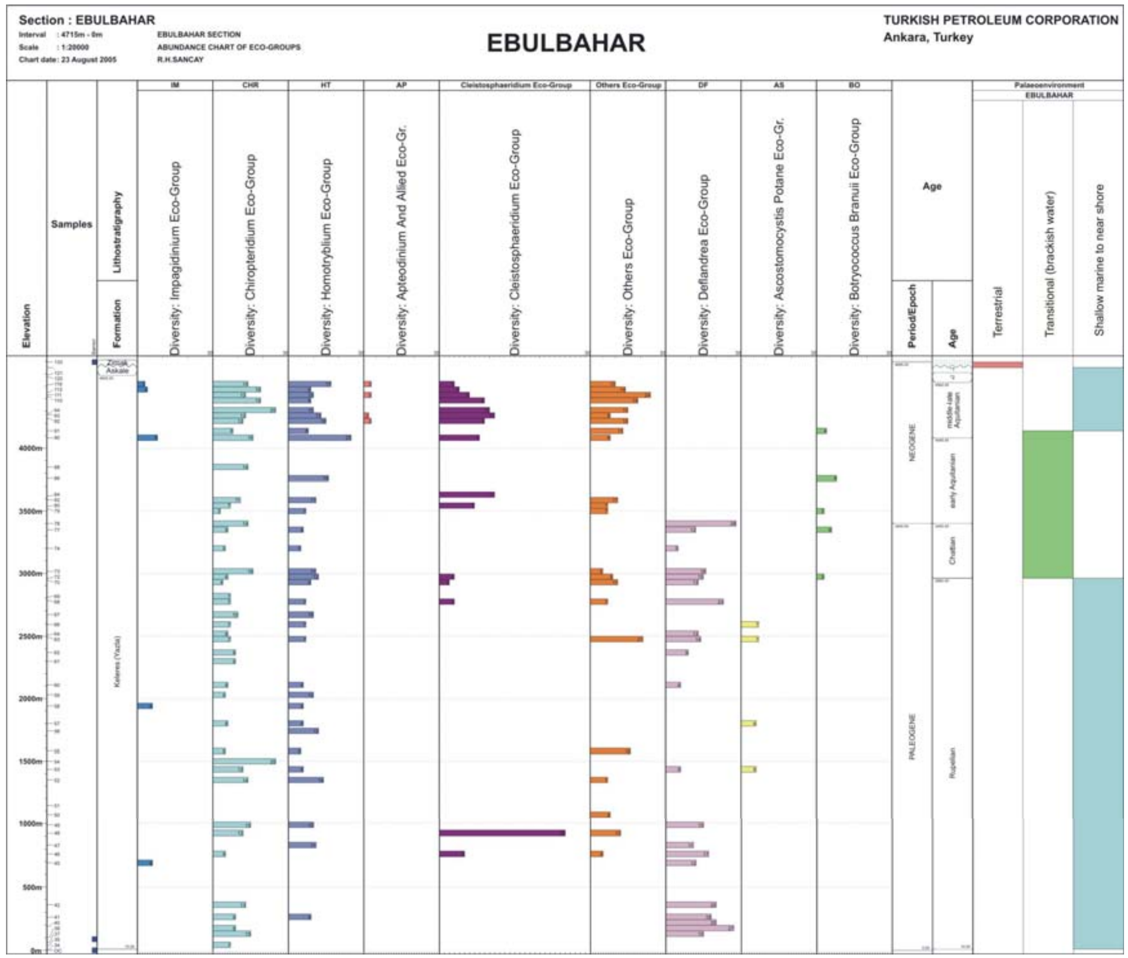



Figure 30. Relative abundances of dinoflagellate eco-groups in the Ebulbahar Section.

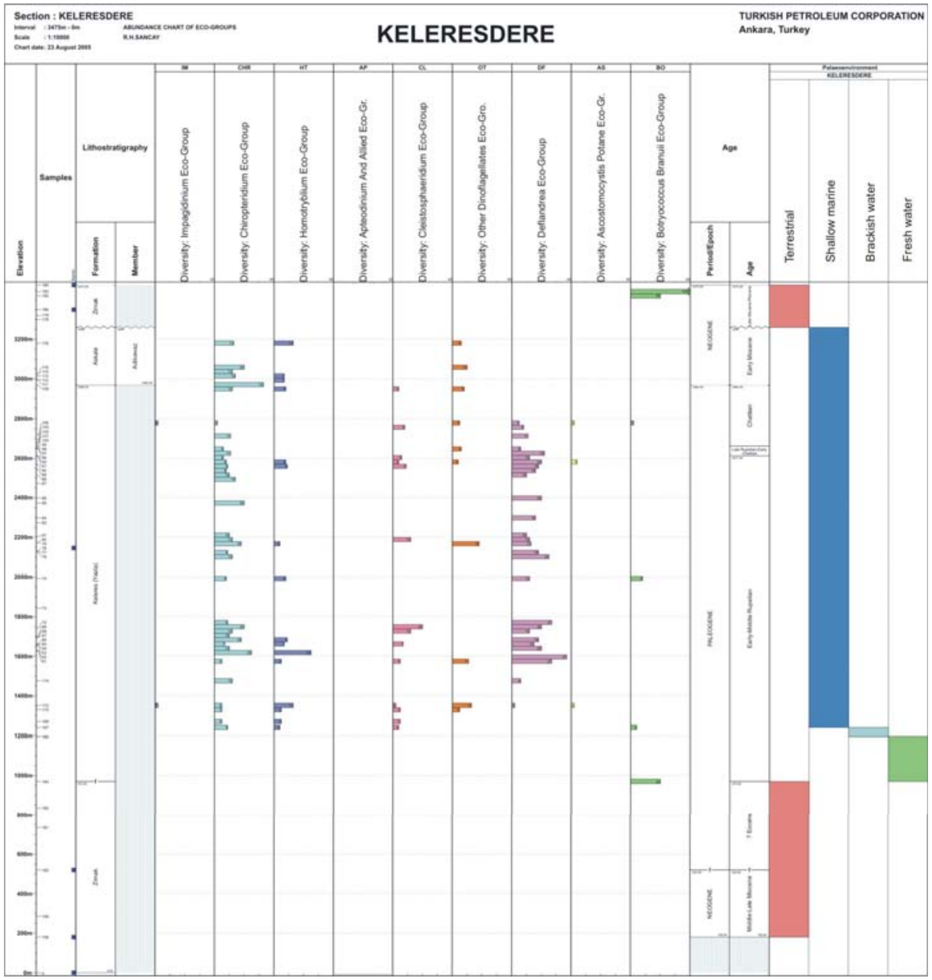



Figure 31. Relative abundances of dinoflagellate eco-groups in the Kelereşdere Section.

high nutrient content (Stover et al., 1996). Köthe (1990) reported that high occurrences of *Thalassiphora pelagica* may indicate low-oxygen, poorly-ventilated, and unaerobic sea floor conditions.

Dybkjaer (2004) investigated the variations in *Homotryblium*-cyst assemblages in different depositional environments in the uppermost Oligocene-Lower Miocene sediments in Jylland, Denmark. She reported that the high abundances of *Homotryblium* occurred at near-shore, marginal marine settings under the conditions with low-salinities.

Brinkhuis (1994) and de Verteuil and Norris (1996) suggested that *Homotryblium* spp. are tolerant to shallow marine conditions and high abundances of those species in HSH may also reflect initial progradation. They suggested that high abundances of *Homotryblium plectilum*, for instance, reflect most proximal/lowest salinity depositional conditions.

Van Simaeys (2004) reported that the high values of *Chiropteridium* eco-group corresponds to the low values of *Homotryblium* eco-group suggesting that these two eco-groups should have different paleoenvironmental tolerances. Moreover, as it was reported by Stover and Hardenbol (1994), Van Simaeys (2004) also recorded high abundances of *Chiropteridium* eco-group in transgressive settings. However, *Homotryblium* eco-group mostly dominate regressive deposits and prefers marginal marine, brackish water (even hypersaline), and lagoonal conditions. Van Simaeys (2004) interpreted that difference as the taxa identified in *Homotryblium* eco-group are much salinity tolerant than the those in *Chiropteridium* eco-group. The second most abundant eco-group seen in Lower Miocene sediments of the Eastern Anatolia is *Homotryblium* eco-group. Contrasting to the observation of Van Simaeys (2004), *Chiropteridium* eco-group and *Homotryblium* eco-group found together in high abundances in the Eastern Anatolian lower Aquitanian sediments again suggesting that marginal marine depositional conditions. Low abundances of *Thalassiphora pelagica* in these sediments also support high energy, high-oxygen, well-ventilated, and aerobic sea floor conditions.

Pross and Schmiedl (2002) tested distribution of *Homotryblium* spp. and *Thalassiphora pelagica* dominated intervals depending on the changing salinities. They observed that the high abundances of *Homotryblium* occur in drier periods with reduced run-off, increased evaporation and salinities while *Thalassiphora pelagica* prefers enhanced run-off and reduced salinities in the surface water. Lower Aquitanian sediments, rich in dinoflagellates belonging to *Homotryblium* eco-group, mostly have low abundances of terrestrial paynomorph and organic matter. As it has been indicated by Pross and Schmiedl (2002), this might have caused by drier periods and reduced run-off and suggests high salinity conditions. Köthe (1990) also recorded high abundances of *Homotryblium* spp. in high-salinity conditions from the Oligo-Miocene sediments in the Northwest Germany. However, Sluijs et al. (2005) mentioned acmes of *Homotryblium* spp. co-occurrence with a freshwater algae *Pediastum* spp. suggesting that even though *Homotryblium* spp. reflects hypersaline conditions, they can also tolerate extreme low salinities.

3. *Apteodinium* and allied eco-group; including *Apteodinium australiense, Apteodinium spiroides*, and *Cribroperidinium tenuitabulatum*.

The third most abundant dinoflagellate assemblage seen in the lower Aquitanian sediments are belonging to this eco-group. Their paleoecological tolerances are quite similar to those of *Chiropteridium* and *Homotryblium* eco-groups. According to Zevenboom (1994) *Apteodinium* spp. represents marginal marine conditions.

Zevenboom (1995) grouped following dinoflagellates, which are commonly seen in lowest Miocene sediments in the Eastern Anatolia, as inner neritic/marginal marine representatives; *Apteodinium* spp., *Spiniferites pseudofurcatus*, *Chiropteridium* spp., *Homotryblium* spp., *Dapsilidinium* spp., *Polysphaeridium* spp., *Systematophora* spp., *Lingulodinium* spp. According to Brinkhuis et al. (1992), decreasing abundances of these taxa may indicate rising sea level whereas increasing abundances mostly indicate relative fall in sea level.

4. *Deflandrea* eco-group; dominated by *Deflandrea phosphoritica*-complex (including *D. phosphoritica*, *D. spinulosa*, *D. leptodermata*, and *D. heterophlycta*) and *Wetzeliella*-complex (including *W. gochtii*, W. *symetrica*, W. *articulata* and W. cf. *ovalis*) and represents marginal marine, brackish marine, and nutrient rich conditions. Transportation of high terrestrial organic matter content to the basin by the rivers, should have been responsible from the high nutrient content and promoted the high abundances of the taxa identified in this eco-group.

Köthe (1990) indicated that *Deflandrea* and *Wetzeliella* are characteristic species of lagoonal, estuarine, brackish marine environments and reflect restricted marine conditions (Brinkhuis, 1994).

*Deflandrea* spp., possible heterotrophic peridinioid dinoflagellate (Brinkhuis et al., 1992), is reported mostly areas with high nutrient availability. Upwelling areas and river mouths are thought to be regions with high nutrients. Dybkjaer (2004) claimed that the progradation of the coastline during the HST may increase nutrient availability due to the increased river discharge.

High abundances of peridinoid dinoflagellates such as *Deflandrea* spp., and *Wetzeliella* spp., indicate enhanced coastal and neritic productivity/nutrient availability (e.g. Brinkhuis, 1994; Brinkhuis et al., 1992; Sluijs et al., 2005). Bujak, (1984) suggested that high phytoplankton productivities promote dinoflagellate assemblages dominated by peridiniacean species. Similarly, Sluijs et al. (2003), Brinkhuis (2003a and b) reported that the shallow marine heterotrophic dinoflagellates such as *Deflandrea* spp., may be related to deltaic settings and organic-rich sediments. In other words, peridinoid-cysts reflect phases of enhanced nutrients probably originated from the land or from the upwelling areas (Sluijs et al., 2005).

Harland (1983) suggested that the low gonyaulacoid/peridinoid ratio reflects significant freshwater input. On the other hand, Powell et al. (1992) suggested that the ratio between the peridinoid and gonyaulacoid cysts (P/G ratio) can be used as an indication for the paleo-upwelling. P-cysts predominates the assemblage as a result of the the upwellings. However, P/G ratio itself does not allow to understand the exact origin of the enhanced nutrient availability. It could be either related to upwelling or coastal run-off. If high nutrient content is related to high phytoplankton productivities, it can be observed during the analysis of palynofacies in which amorphous type of organic matter, believed to be originated from the algal remains (Tissot, 1984), dominates. Anoxic (oxygen-depleted) bottom conditions play an important role on the preservation of those amorphous mass. However, if the main mechanism is increased run-off, transportation of terrestrial organic matter by rivers, decreasing amount of amorphous type of organic matter could be seen during palynofacies analysis and may suggest oxic bottom conditions. Eastern Anatolian Oligocene sediments are mostly dominated by dinoflagellates belonging to *Deflandrea* eco-group (Figures 30 and 31). As it has been mentioned above, high abundances of *Deflandrea* spp. are related to high nutrient availability. Increased amount of terrestrial organic matter and palynomorph, very low abundances of marine-originated amorphous organic matter may reflect high terrestrial influx from the land. Therefore, lagoonal, estuarine, brackish water, and shallow marine environments affected by increased amount of run-off should have dominated during the Oligocene. Assemblages of *Deflandrea* eco-group have been replaced by assemblages of *Chiropteridium* and *Homotryblium* eco-groups at the early Aquitanian. This sudden change in the dinoflagellate composition might indicate completely new ecological conditions in that nutrient rich, lagoonal to shallow marine conditions have been replaced by more marine and high saline conditions related to rising sea level. The influence of terrestrial influx should not have been enough to affect dinoflagellate association of relatively deeper marine conditions in the Miocene.

Zevenboom (1996) also discussed the reason of high abundances of *Deflandrea* occurrences at very close to their last appearences and he suggested that nutrient-rich conditions may cause *Deflandrea* spp. to be found in high numbers. He claimed that these species may outcompete other groups of dinoflagellates if the amount of nutrients is more than “normal” marine conditions and this may even occur in the nutrient-depleted environments during downwelling.

5. *Cleistosphaeridium* eco-group; includes *Cleistosphaeridium*, *Dapsilidinium, Systematophora placacantha*. They mainly represent marginal marine to coastal depositional conditions and abundantly seen in most of the studied samples.

6. *Ascostomocystis potane* eco-group; dominated by an acritarch called *Ascostomocystis potane*. Stover and Hardenbol (1994) identified the nominate taxon in HST deposits of the Boom Clay Formation in Belgium. It became dominant under the innermost neritic conditions.

7. *Botryococcus braunii* eco-group; dominated by naminate taxon together with *Pediastum* spp., *Ovoidites ligneolus*, *Ovoidites parvus*, and represents fresh water, lacustrine, and fluvial conditions. High abundance of *Botryococcus braunii* eco-group may coincide with the increased fresh water influx (run-off) during the relative sea level falls.

8. *Impagidinium* sp. eco-group; Includes oceanic taxa such as *Impagidinium* sp. and *Nematosphaeropsis* sp. They represent open marine depositional conditions.

*Impagidinium* and *Nematosphaeropsis* have been reported as oceanic taxa (e.g. Mudie, 1992; Brinkhuis et al., 1992; Edwards, 1992; Dale, 1996). Their abundances are about 1-2 % and mostly found together with coastal/neritic cysts (Wall et al., 1977). However, according to Dale (1996), even only a few specimens of *Impagidinium* are enough to say deposition took place in oceanic waters. *Nematosphaeropsis* have prefered temperate conditions (Mudie et al., 1990) whereas *Impagidinium* mostly found in warm waters (Turon, 1984) except some arctic species such as *I. pallidum* and *I. velorum* (Mudie, 1992).

Characteristic oceanic dinoflagellate taxa such as *Nematosphaeropsis* and *Impagidinium* (Dale, 1996) do not exist or in very rare frequencies if they are present throught the Oligocene-Miocene sections in the Eastern Anatolia suggesting that deposition mostly took place in near shore-shallow marine depositional environments. Similarly, calcareous nannoplanktons and planktonic foraminifers are quite rare both quantitatively and qualitatively throughout the section reflecting marginal marine conditions (N. Akça, S. Kirici, and U. Işık, personel communication, 2005). These oceanic taxa have been recorded in upper Aquitanian sediments. Therefore, the late Aquitanian time has been interpreted as the period during which the most open marine depositional conditions were experienced from Late Eocene to Early Miocene in the Eastern Anatolia.

9. Others eco-group; including all other dinoflagellates that are not listed above such as *Heteraulacacysta* sp., *Hafniasphaera* sp., *Fibrocysta* sp., *Lejeunecysta* sp., *Membranilarnacea* ?*picena*, *Operculodinium* spp., *Hystrichokolpoma* spp., *Hystrichosphaeropsis obscura*, *Reticulatosphaera actinocoronata*, *Riculacysta perforata*, and S*elenopemphix nephroides*.

The eco-groups distinguished in the Eastern Anatolia have been also mentioned in some studies. For instance; Stover and Hardenbol (1994) distinguished following dinoflagellate eco-groups which are also recorded in this study; *Ascostomocystis potane* eco-group, *Deflandrea* eco-group, Wetzeliellaceae eco-group, *Apteodinium* and allied types eco-group, *Homotryblium*+*Thalassiphora* eco-group, *Cleistosphaeridium* eco-group, *Areosphaeridium pectiniforme* eco-group, *Chiropteridium* and allied types eco-group, others eco-group. According to Stover and Hardenbol (1994), most of these eco-groups are system tract tolerant with some exceptions which have slight preferences for some systems tracts. For instance, *Chiropteridium* eco-group and *Areosphaeridium pectiniforme* eco-group are very abundant in TST whereas *Deflandrea* eco-group mostly becomes abundant in the early HST.

Downie et al. (1971) distinguished four paleoenvironmentally important dinoflagellate associasions as follows; 1. *Spiniferites* association (includes *Achomosphaera*, *Cordosphaeridium*, *Hystrichosphaeridium*, *Spiniferites*), 2. *Areoligera* association (includes *Glaphyrocysta* and *Areoligera*), 3. *Micrhystridium* association (includes *Comasphaeridium* and *Micrhystridium*), 4. *Wetzeliella* association (includes *Deflandrea* and *Wetzeliella*). Both *Spiniferites* and *Areoligera* associations represent open marine conditions while *Micrhystridium* association reflects inner neritic and *Wetzeliella* association reflects lagoonal, estuarine to brackish marine depositional environments. Islam (1984) modified Downie et al. (1971)'s associations with a few additonal dinoflagellates. Similar to Downie et al. (1971), he suggested that *Spiniferites* group (*Achomosphaera*, *Cordosphaeridium*, *Hystrichosphaeridium*) represents open marine conditions (transgressive intervals). *Adnatosphaeridium*, *Areoligera*, and *Glaphyrocysta* reflect high energy environments (coarser-grained lithologies) and wetzelielloid group (*Deflandrea*, *Apectodinium*, *Charlesdowniea*, *Dracodinium* and *Wetzeliella*) reflect" lagoonal-estuarine to brackish marine conditions. Moreover, Islam (1984) also grouped *Homotryblium* morphotypes and he suggested that the *Homotryblium* species with long processes reflects open marine conditions whereas *Homotryblium* species with short processes represents inner neritic, estuarine to brackish water environments. Mudie (1986) reported *Nematosphaeropsis labyrinthus*, *Impagidinium* spp., *Operculodinium centrocarpum* and *Bitectatodinium tepikiense* as pelagic species.

Jaramillo and Oboh-Ikuenobe (2001) distinguished following ecological groups for the detection of paleobathymetry; Innermost neritic: *Homotryblium plectilum* and *Pediastrum*. Inner Neritic: *Ascostomocystis potane* and *Glaphyrocysta*-group. Middle Neritic: *Hystrichokolpoma rigaudiae*. Outer Neritic: *Impagidinium* and *Cribroperidinium tenuitabulatum*. Neritic: *Cleistosphaeridium* spp., *Enneadocysta*-group, *Spiniferites pseudofurcatus*, *Systematophora placacantha*, *Cordosphaeridium* spp., *Lingulodinium* spp., and *Pentadinium laticinctum*. They excluded *Deflandrea* spp., from those eco groups because their abundance is controlled not only by the paleobathymetry but also some other factors such as nutrient content associated with run-off changes.

Wrenn and Kokinos (1986) grouped *Brigantedinium* spp. and *Selenophemphix nephroides* as inner neritic, *Polysphaeridium zoharyi*, *Tuberculodinium vancampoae*, and *Spiniferites* spp. as inner neritic to outer neritic, and *Impagidinium* spp. and *Hystrichosphaeropsis obscura* as outer neritic to oceanic. The presence of *H. obscura* together with *Impagidinium* sp. in the upper Aquitanian sediments of the Eastern Anatolia also supports open marine to oceanic depositional conditions.

Dinoflagellate cysts also play an important role for bathymetrical studies. Morzadec-Kerfourn (1983) investigated dinoflagellate associations from different water depths in the Mediterranean Sea. They suggested that *Lingulodinium machaerophorum* association occurs in 10-30 m, *Operculodinium centocarpum-O. israelianum* association occurs in 30-50 m, *Spiniferites pachyderma* association occurs in 50-100 m, and *Leptodinium* association occurs in more than 100 m of water depths. Presence of *L. machaerophorum* together with *Deflandrea* eco-group in Oligocene sediments of the Eastern Anatolia is quite comperable with the shallow marine interpretation of Morzadec-Kerfourn (1983).

One of the most comprehensive ecological study based on modern organic-walled dinoflagellates was carried out by Marret and Zonneveld (2003). They have investigated geographical distribution and changing ecological parameters such as winter sea surface temperatures (SST), summer SST, sea surface salinity, and nutrient content of some selected taxa (Figure 32). Some of the explained dinoflagellates have also been recorded in the Eastern Anatolian sediments and their ecological properties are given by Marret and Zonneveld (2003) as follows; *Lingulodinium machaerophorum*, temperature range is between the 1.5 °C winter SST and 29.1 °C summer SST, 16.9 spring SSS, and 36.7 summer SSS, 0.1-0.7 μM phosphate and 0.1-7.8 μM nitrate. Marret and Zonneveld (2003) indicated that this taxon is very rare if the SST is below 10 °C and not present in nutrient-depleted environments. This taxon has been given as temperate to tropical, and coastal euryhaline species. *Polysphaeridium zoharyi*, temperature range is between the 14.5 °C winter SST and 28.0 °C summer SST, 16.2 spring SSS, and 36.6 summer SSS, reaches high abundances if approximately 0.3 μM of phosphate and 3.0 μM of nitrate exist. This taxon has been given as tropical to subtropical coastal euryhaline species. *Selenophemphix nephroides*, temperature range is between the 1.0°C winter SST and 29.6 °C summer SST, only exists if spring and summer SSS are exceeding 28.5, 0.1-1.0 μM phosphate and 0.0-22.8 μM nitrate. This taxon has been reported as a temperate to tropical coastal species. *Spiniferites mirabilis*, temperature range is between the 0.1 °C winter SST and 29.1 °C summer SST but mostly does not exist if the SST is below 12°C, only exists if spring and summer SSS are exceeding 28.5, 0.1-1.3 μM phosphate and 0.0-14.4 μM nitrate. This taxon has been given as temperate to tropical species. *Tuberculodinium vancampoae*, temperature range is between the 7.1 °C winter SST and 29.5 °C summer SST, but mostly does not exist if the winter SST is below 12.7 °C and summer SST is below 14.5 °C, 16.9 spring SSS, and 36.6 summer SSS, 0.1-0.5 μM phosphate and 0.1-3.3 μM nitrate. This taxon has been classified as a tropical to subtropical coastal species.

Dale (1996) suggested that even small changes in the sea surface temperatures between warmer-lower latitudes and cooler-higher latitudes may cause major changes in the dinoflagellate assemblages. He distinguished following biogeographic/climatic belts (Figure 32); polar (the coldest waters in the the highest latitudes including poles), sub-polar (cool water in high latitudes), temperate (warm waters in low latitudes), equatorial (the warmest waters in the lowest latitudes around the equator).

As it can be understood from the studies of Marret and Zonneveld (2003) and Dale (1996), some of the dinoflagellates identified in the Eastern Anatolia have some paleoecological and paleoclimatological restrictions. For instance; *Tuberculodinium vancampoae* and *Polysphaeridium zoharyi*, have been classified as subtropical to tropical, *Spiniferites mirabilis* has been known in temperate to subtropical conditions, *Selenophemphix nephroides* has been common in temperate to tropical conditions whereas

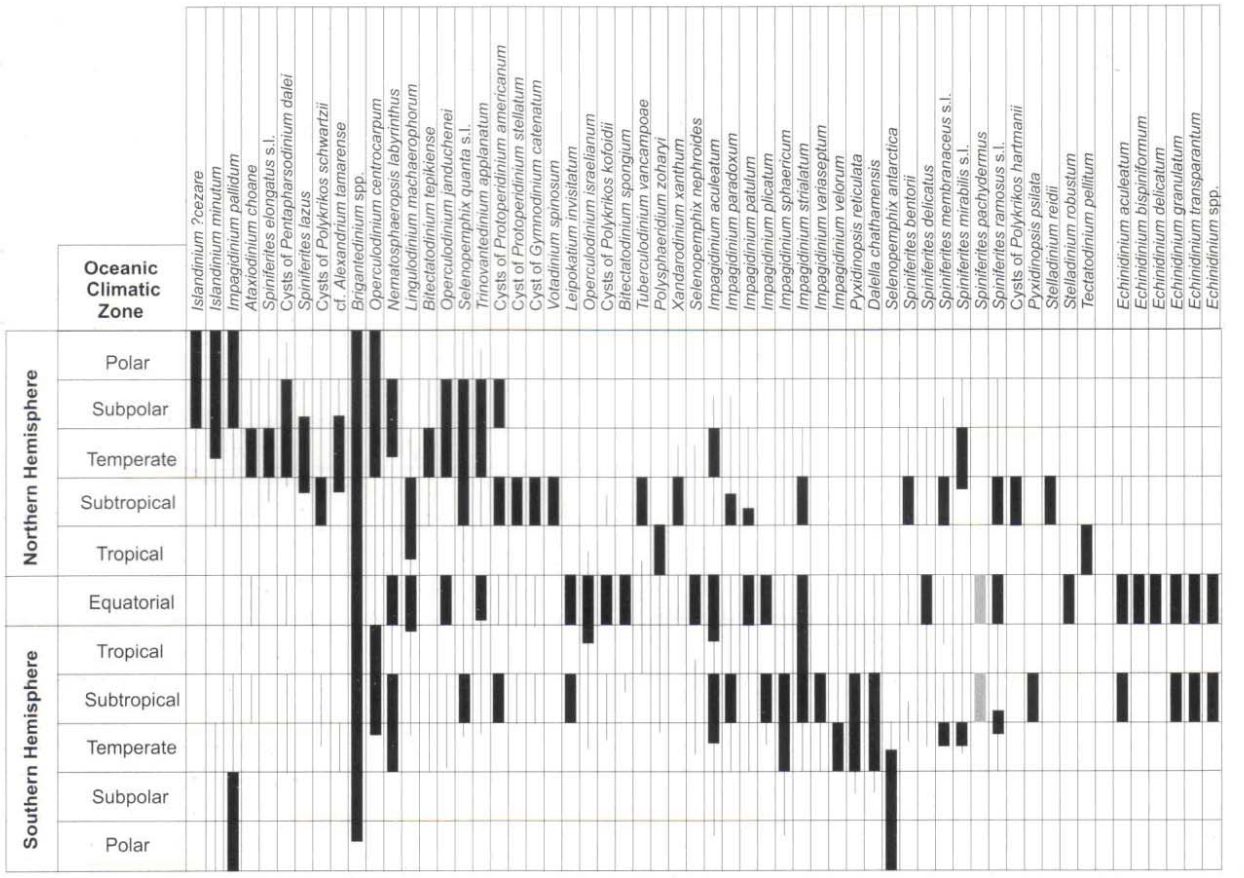



Figure 32. Biogeograhic distribution of dinoflagellates in different oceanic climatic zones (from Marret and Zonneveld (2003).

*Lingulodinium machaerophorum* has been classified as equatorial to temperate species and become abundant in the nutrient-rich environments by Dale (1996). Moreover, he argued that the presence of *Lingulodinium machaerophorum* in all interglacial sediments also supports that this taxon represents temperate or warmer waters. Edwards (1992) reported that *Polysphaeridium zoharyi*, *Tuberculodinium vancampoae*, and *Lingulodinium machaerophorum* have prefered warmer sea surface temperatures. Mao et al. (2002) also confirmed that *Polysphaeridium zoharyi* is a warm water indicator and lives under shallow marine-inner neritic and sub-normal saline conditions in low latitudes. He suggested that *Deflandrea* spp. are temperate to cold-water indicators and live in middle to high latitudes. Therefore, paleoecological conditions of *Deflandrea* eco-group dominated Oligocene period might be interpreted as warm-temperate to subtropical since it has also *Tuberculodinium vancampoae*, *Spiniferites mirabilis*, *Polysphaeridium zoharyi*, *Selenophemphix nephroides*, and *Lingulodinium machaerophorum*. These paleoecological reconstructions are quite consistent with the paleoclimatological reconstructions of Climsat which also suggest temperate to subtropical conditions for Oligocene and Miocene periods based on terrestrial spores and pollen.

As far as terrestrial palynomorphs are concerned, following ecological groups may be distinguished; montane elements restricted to the upland ares (e.g. *Pinus*, *Ulmus*, *Quercus*, Sapotaceae). Among which, *Pinus* grains are always overrepresented in all of the studied samples related to its wind-blown nature. They can be transported to long distances in large quantities by means of their air sacs. They mainly represent the mountainous background with those plants surrounding the depositional environments. Lowland-riparion elements (e.g. Taxodiaceae, Myricaceae, Fagaceae), and brackish water elements (e.g. Chenopodiaceae, Polypodiaceae, Schizeceae, Lygodiaceae) mainly represent forest associations in moisturized open areas. Finally fresh water elements (e.g. Sparganiaeceae, *Pediastrum*, *Botryococcus, Ovoidites*) represent the fluvial activity and fresh water swamps in the close vicinity.

## 4.3. Paleoenvironmental Reconstructions

### 4.3.1. Depositional Environments

As far as the depositional environment was concerned; information gathared from palynomorphs, and sedimentary organic matter suggests that Upper Eocene, Oligocene and Lower Miocene sediments were deposited under fresh and brackish water, shallow and relatively deeper marine conditions related to fluctuation of sea level in Hınıs-Muş-Van, Tekman, Tercan-Aşkale, and Pasinler-Horasan basins. Relatively deep marine deposition took place at the beginning of the Late Eocene replaced by shallowing-upward deposition towards the end of the Late Eocene. Rupelian deposition started under fresh water conditions and then continued in brackish water to shallow marine environments related to changes in sea level. Shallowing upward deposition during the Late Oligocene followed by the Early Miocene regional transgression until the end of the Middle Miocene. However, Lower Miocene sediments still represent shallow marine-near shore environments. Due to the withdraw of the sea, Upper Miocene-Pliocene sediments were deposited in terrestrial (lacustrine and fluvial) environments in Muş, Tekman, Tercan-Aşkale, and Pasinler-Horasan basins. However, lacustrine-terrestrial conditions have been predominating since Late Eocene in Bayburt-Kars Plateau.

Fresh water algae (*Pediastrum* spp., *Botryococus braunii*, *Ovoidites ligneolus*, *O. parvus*) have been identified at the base of Rupelian close to the Eocene-Oligocene boundary, at the end of Chattian, close to the Oligocene-Miocene boundary, and in the Upper Miocene-Pliocene (right above the unconformity surface). Absence of fresh water algae, and terrestrial palynomorph-dominated assemblage with some marine dinoflagellates suggest shallow marine depositional conditions during the Late Oligocene. However, fresh water algae were found together with marine dinoflagellates at the Oligocene-Miocene boundary suggest continuous deposition should have taken place under brackish water and restricted marine conditions without any depositional break in the latest Chattian-earliest Aquitanian.

Shallowing-upward nature of deposition during Late Oligocene might be responsible from the changes in depositional environment from shallow marine to restricted marine and brackish water conditions. Brackish water to restricted marine deposition at the Oligocene-Miocene boundary followed by again relatively deeper conditions in the Aquitanian. Shallowing in the early Burdigalian caused reefal limestone deposition in many localities in the Eastern Anatolia. Finally, the last deepening event occurred at the end of Burdigalian and ?early Langhian followed by completely terrestrial (lacustrine and fluvial) conditions since then in all sub-basins of the Eastern Anatolia.

### 4.3.2. Relative Sea Level Changes

Palynomorph and organic matter assemblages can be used for sequence stratigraphic interpretations. For instance, transgressive system tracts (TST) represent open marine depositional settings whereas highstand system tracts (HST) are represented by a gradual shallowing. TST are represented by the high abundance and diversity of dinoflagellates while they are both relatively lower during the HST Dybkjær (2004). Therefore, shift in palynomorph associations from dinoflagellate and marine organic matter-dominant assemblages to spore-pollen and terrestrial organic matter-dominant assemblages could be detected from TST to HST related to increased freshwater influx and the progradation of the coastline. Stover et al. (1996) pointed out that, since palynomorphs are originated from both terrestrial and marine organisms, they are the best suited fossil group in identifying systems tracts and correlating terrestrial, shallow marine and deep marine sediments. According to Stover et al. (1996), deposits related to lowstand system tracts (LST) may include intensive reworked palynomorphs. Powell (1992) suggested that greater diversity and higher abundances of dinoflagellates dominate the palynomorph assemblages related to transgressive surfaces which marks the base of TST. Stover et al. (1996) further suggested that TST are represented by an influx of new species and re-appearence of previously occurred species. Dinoflagellate diversity remains high in the lower part of the HST but gets lower close to the upper part of the HST where spore and pollen dominate the palynomorph assemblages. In general, the LST are represented by low dinoflagellate diversity and intensive reworking, the TST are represented by increased dinoflagellate diversity, the HST are represented by the maximum dinoflagellate diversity above the time of maximum flooding and gradual to marked decrease in diversity close to the upper part of the HST (Stover et al., 1996; Monteil, 1993; Habib et al., 1992). Moreover, Monteil (1993) indicated that the LADs and FADs of the selected species (he called the "sequential biomarkers") may be even used to detect the sequence boundaries and maximum flooding surfaces. Stover and Hardenbol (1994) reported that the LADs mostly occur in HST while FADs mostly occur in TST. They believed that this phenomenon may be related to the sensitivity of dinoflagellates to the transgressive-regressive cycles.

Stover and Hardenbol (1994) investigated stratigraphic distribution and relative abundances of dinoflagellates and depositional sequences of the Lower Oligocene (Rupelian) Boom Clay Formation in Belgium. They identified 26 base and 30 top occurrences of dinoflagellate and acritarch taxa during the deposition of the Boom Clay that covers about 6 Ma. They reported an abrupt increase of dinoflagellates in the TST (in the deepening-upward successions), and gradual decrease in the number of taxa in the middle and upper part of the HST (in the shallowing-upward successions). Most of the base (oldest) occurrences (FAD) (22 out of 26) have been identified in transgressive deposits in their paper whereas most of the top (youngest) occurrences (LAD) (19 out of 30) recorded in highstand deposits. Number of dinoflagellate taxa or number of specimens have been drastically reduced at or close to the downlap surfaces. They also reported that the appearance of new taxa is an abrupt event and occurred during the early transgression whereas disapperance (extinction) of taxa is gradual and mostly occurred during the late highstand. Similar to their study, most of the FADs have been recorded in TST whereas most of the LADs have been identified in HST in the Eastern Anatolia. For instance, *Wetzeliella gochtii* and *Achillodinium biformoides* occurred for the last time in the Rupelian in the early HST, *Deflandrea phosphoritica* and *Deflandrea spinulosa* occurred for the last time at the end of the Chattian in the late HST, and *Hystrichosphaeropsis obscura* and *Membranilarnacea ?picena* occurred for the first time in the late Aquitanian in TST.

*Pediastrum* and *Botryococcus* are colonial green algae that live in freshwater environments such as lakes and ponds (e.g. Batten and Grenfell, 1996). However, they can be found in the marine and transitional (brackish water conditions) successions as allochthonous material brought by rivers from fluvial and lacustrine environments (Evitt, 1963b; Brenac and Richards, 2001). According to Brenac and Richards (2001), high numbers of fresh water algae (*Pediastrum* and *Botryococcus*) and low numbers of marine microfossils in marine sediments correspond to periods of low relative sea level. They indicated that the maximum amount of *Pediastrum* in marine sediments have sequence stratigraphic importance in that they represent late HST and/or early LST. Similarly, number of *Pediastrum* recorded in the sediments deposited during the periods of early highstand system tracts are quite reduced. Brenac and Richards (2001), also identified system tracts with faunal composition in that transgressive system tracts is mainly represented by the abundant and diverse marine microfossils whereas increasing amount of fresh water algae such as *Pediastrum* and terrestrial palynomorphs coincide with the lowering of relative sea level corresponding to late highstand and/or early lowstand system tracts. Maximum flooding surfaces, on the other hand, are mainly characterized by the high percentages of marine-originated amorphous organic matter and the high abundances of outer neritic to oceanic dinoflagellate taxa (Jaramillo and Oboh-Ikuenobe, 2001). Under the light of things mentioned above, sediments belonging to uppermost Eocene-lowermost Rupelian and uppermost Chattian should have sequence stratigraphic emphasis due to having fresh water algae. These periods may represent lowering sea level conditions and might be interpreted as the late highstand and/or early lowstand system tracts in Hınıs-Muş-Van, Tekman, Tercan-Aşkale, and Pasinler-Horasan basins. Following those periods, lower Lower Miocene (Lower Aquitanian) might have been deposited during the late LST represented by gradual deepening and followed by TST in the late

Aquitanian during which the most open marine depositional conditions have been experienced in the studied interval (Figure 33). In addition to the high abundance of marine palynomorphs, marine-originated amorphous organic matter content is also more that 50 % in this level. Late HST and early LST deposits (Oligocene) are mostly dominated by *Deflandrea phosphoritica* complex whereas late LST and TST deposits (Lower Miocene) are mainly dominated by *Chiropteridium* spp., (mostly *Chiropteridium lobospinosum*) and *Homotryblium* spp., (mostly *Homotryblium plectilum* and *H*. *vallum*) respectively. TST deposits consisted of very rich dinoflagellate taxa. Early HST deposits are also very rich in dinoflagellate cysts but differ quantitatively. However, late HST deposits and early LST are distinguished from transgressive and early highstand deposits in having reduced numbers of palynomorph specimens and restricted species diversity. Shallowing-upward nature of the deposition resulted gradual decrease in the number of taxa towards the upper parts of the Oligocene in Muş, Tekman, Tercan-Aşkale and Pasinler-Horasan basins. The base of TST, recorded in the sample labeled as 94 in the Ebulbahar section (see Figure 7) represents the maximum flooding surface by having relatively less abundant and diverse marine dinoflagellates but high amounts of planktonic organisms (U.Işık, personal communication, 2005). According to Stover et al., (1996), during the time of maximum flooding, dinoflagellate diversity is reduced since they mostly live in coastal/neriti environments while planktonic foraminifera and calcareous nannoplankton assemblages are enriched.

Deep-sea benthic foraminiferal $\delta^{18}O$ records have been succesfully applied to studies regarding to the ice-sheet volumes at the poles and relative changes in sea level (e.g. Miller et al., 1985 and 1987; Zachos et al., 1999 and 2001). Increase in such records coincides with the time of glaciation, growth of ice-sheets, and subsequent fall in relative sea level that may be traced as major unconformities in the shallower settings. Greenhouse conditions of Eocene have been replaced by icehouse conditions in the beginning of the Oligocene (Prothero et al., 2003 and references therein). In general, two main glacial events and corresponding relative sea level falls have been recorded during the Oligocene (Pekar and

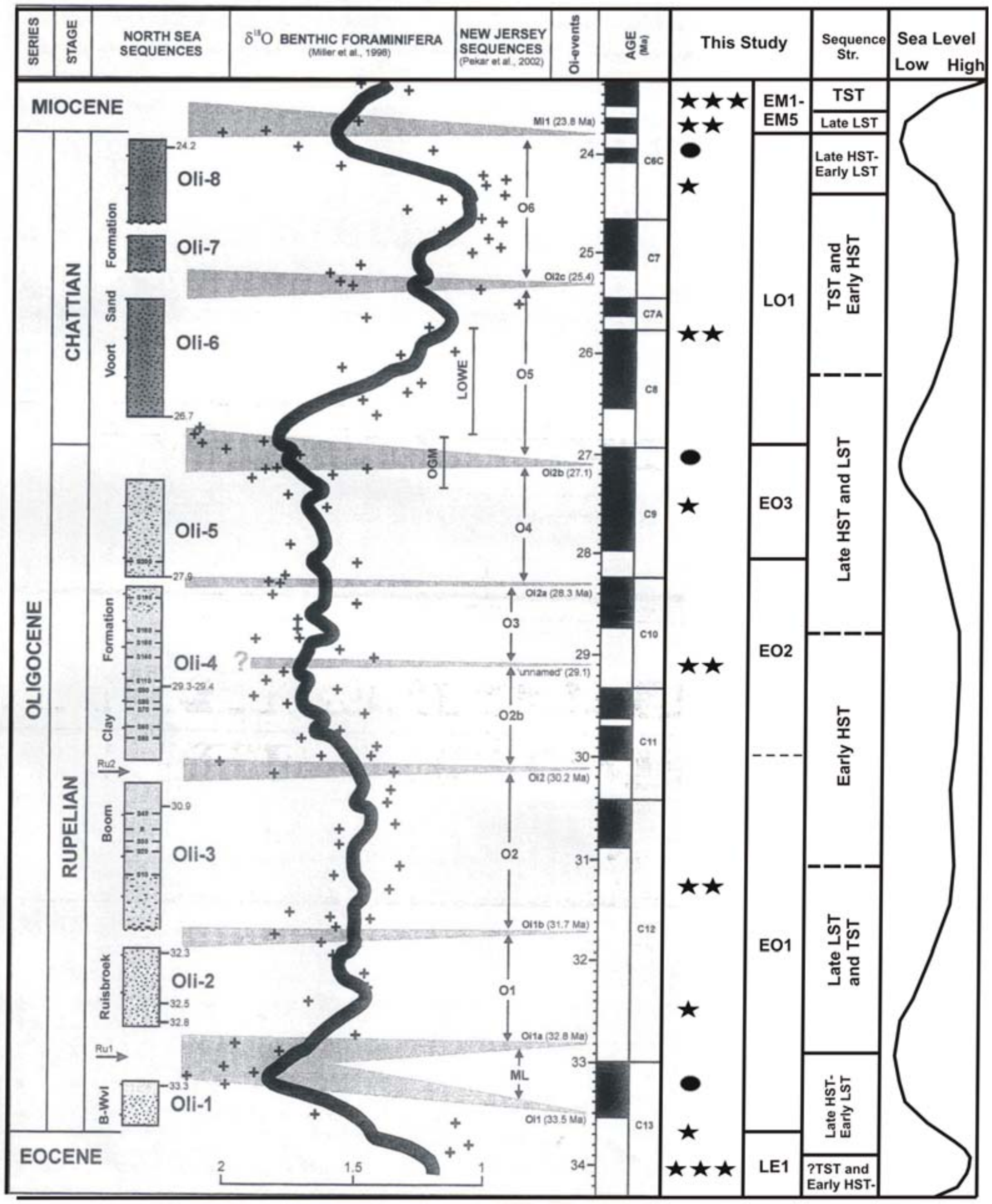



Figure 33. Relative changes in sea level (★ : dinoflagellates, ● : freshwater algae, modified from Van Simaeys, 2004).

Miller, 1996; Zachos et al., 1999 and 2001). One is called Oi1 event and occurred approximately at 33.3 Ma and the other one is called Oi2b event and occurred approximately at 27.1 Ma which is very close to the Rupelian-Chattian boundary. Van Simaeys (2004) recorded an arctic taxon *Svalbardella* at Rupelian-Chattian boundary coinciding with Oi2b event. He suggested “Oligocene Glacial Maximum (OGM)” term for this profound cooling rather than Oi2b event (Figure 33). According to Van Simaeys (2004), this episode was not a short-lived event and continued during 500 ka between 27.3 and 26.8 Ma. He claimed that this cooling episode and corresponding relative sea level fall are genetically related to the Rupelian-Chattian unconformity in the southern North Sea basins. OGM of Van Simaeys (2004) and relative sea level fall at the end of the Rupelian have followed by LOWE of Zachos et al. (2001) and relative sea level rise at the beginning of the Chattian (Figure 34). Van Simaeys (2004) suggested that early Chattian transgression is genetically related to Late Oligocene Warming Event of Zachos et al. (2001) and Rupelian-Chattian unconformity in the stratotype area is also genetically related to Oligocene Glacial Maximum (OGM) in southern North Sea basins. This cooling event, associated relative sea level fall, and the growth of Antarctic ice-sheets in the Oligocene has also been reported by Miller et al. (1991 and 1998) from the deep-sea benthic foraminiferal $\delta^{18}O$ records as Oi2b-event. Van Simaeys (2004) further indicated that this Oligocene cooling event occurred at the same chronostratigraphic position in the cental Mediterranean. As it was reported by Van Simaeys (2004), relative sea level fall related to OGM (approximately between 27.3 and 26.8 Ma) may caused subaerial exposure, erosion, and a break in sedimentation in marginal marine conditions. Then, transgressive deposits related to LOWE (approximately 26.0 Ma) unconformably overlie Rupelian sucsessions in southern North Sea basins. Shallowing at the end of the Rupelian and at the base of the Chattian in the Eastern Anatolia might have been caused by a major cooling event so called Oligocene Glacial Maximum (OGM of Van Simaeys 2004) and associated sea level fall at the end of the Rupelian. Eustatic sea level rise related to the Late Oligocene Warming Event (LOWE) of Zachos et al. (2001) occurred in the early Chattian might be responsible for the transgressive deposits conformably overlying Rupelian sediments in Eastern Anatolia. Similar transgressive deposits in the Late Oligocene have also been reported from Danish area by Dybkjaer (2004). Moreover, eustatic sea level fall indicated by Zachos et al. (2001) in the latest Chattian to early Aquitanian periods should be related to brackish water conditions in depositional environments following shallow marine conditions during the Chattian in Hınıs-Muş-Van, Tekman, Tercan-Aşkale, and Pasinler-Horasan basins. Very low diversity in dinoflagellates accompanied by a fresh water algae called *Botrococcus braunii* supports this interpretation. Zevenboom (1996) have reported two major cooling events and relative falls in sea level in the Lemme-Carrosio section in Italy during the Oligocene/Miocene transition. Since those events can be calibrated very well with Haq et al. (1988) third-order sea level cycles, they can be interpreted as global in nature and seem to be coinciding with the relative sea level fall indicated at Oligocene/Miocene boundary in this study. High abundances of marginal marine dinoflagellates such as *Homotryblium* spp. and increasing diversity in dinoflagellate in the overlying samples comparable with the early Aquitanian sea-level rise of Zachos et al. (2001) curve. Eustatic sae-level fall occurred in the late Aquitanian to early Burdigalian should have been represented by very thick succession of limestones, consisting mainly of benthonic foraminifers, overlying relatively deeper marine sediments of Aquitanian in Hınıs-Muş-Van, Tekman, Tercan-Aşkale and Pasinler-Horasan basins followed by again more marine conditions related to early to middle Burdigalian sea level rise documented by Zachos et al. (2001). In general, as it has also been reported by Dybkjær (2004) sequence developments seem to match with sea level rises (warmer periods) and sequnces boundaries, on the other hand, seem to match with relative sea level falls (colder periods). Relative sea level falls occurred at the base of Rupelian, end of Chattian, and latest Aquitanian (Haq et al., 1987 and 1988; Zachos et al., 1999 and 2001; Van Simaeys, 2004; Simaeys et al., 2004) might have been traced in the Hınıs-Muş-Van Basin especially in the Kelereşdere section which had experienced much shallower

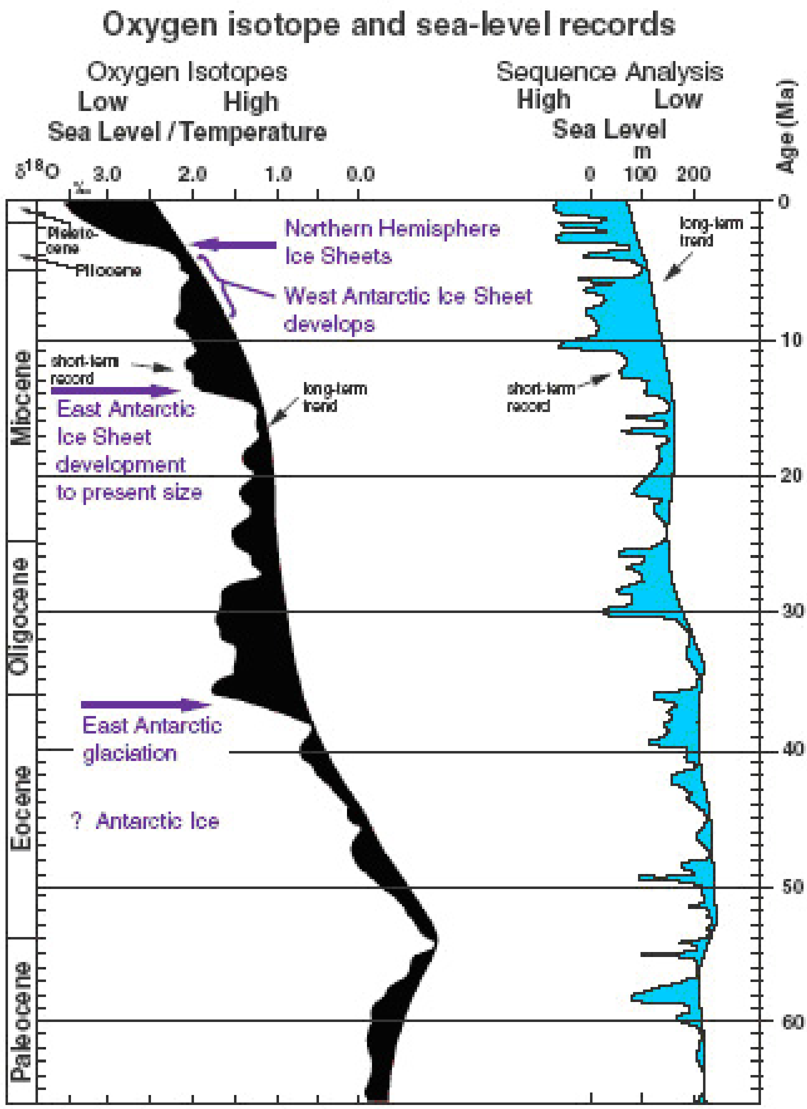



Figure 34. Oxygen isotope data reflecting ice volumes and changes in relative sea level (from Exon et al., 2001; after Barrett, 1994).

conditions than the Ebulbahar section during Tertiary. Very good correlation between the eustatic sea level changes in Zachos et al. (2001) curve and the palynological associations may indicate that the main driving mechanism was eustacy during the deposition of Oligocene-Miocene sediments in the Eastern Anatolia. However, as it has been reported in several studies (Şengör, 1980; Şaroğlu et al., 1980; Şaroğlu and Güner, 1981; Şengör and Yılmaz, 1981; Şaroğlu, 1985; Şaroğlu and Yılmaz, 1987 and 1991; Yılmaz et al., 1988), Eocene and Miocene periods were represented by major tectonic events in the Eastern Anatolia. Therefore, even though the main driving mechanism was eustacy during the formation of sequences, they had to be tectonically enhanced.

As it was indicated by Brinkhuis (1992a, b, and 1994; Stover et al., 1996) changes in composition and diversity of dinoflagellate assemblages might be related to third order depositional sequences. Every transgressive peak has resulted the first occurrence or recurrence of several dinoflagellate species. Relative abundances of palynomorphs (marine/terrestrial or dinoflagellate/spore-pollen) are related to transgressive-regressive cycles and can be comparable with third order sequences, coastal onlap curves and distances from shoreline (e.g. Stover et al., 1996; Reid, 1974; Lister and Batten, 1988; Dimter and Smelror, 1990; Brinkhuis and Zachariasse, 1988; Brinkhuis, 1994; Brinkhuis and Biffi, 1993). Sluijs et al. (2005) reports a very good correlation between the diversity of dinoflagellate cysts and the sea level curve of Haq et al. (1987) in that high diversity reflects high sea levels. They suggested that the diversity peaks of dinoflagellates occurred in the following periods; Middle Cretaceous, Albian (580 species), Late Cretaceous, Maastrichtian (570 species), Early Eocene (520 species). According to Stover et al., (1996), the acme of dinoflagellate cysts occurred in the Eocene by more than 500 species declined dramatically and some of the deflandreoid species such as *Wetzeliella* and *Deflandrea* became extinct in the Oligocene due to the climatic cooling occurred in the Late Eocene (Yancey et al., 2002). As far as the Eastern Anatolian dinoflagellate diversity is concerned, Upper Eocene, and Lower Miocene sediments are very rich in dinoflagellates. These periods are also in close relation with the transgressive intervals documented by means of oxygen isotope data (Zachos et al., 1996 and 2001).

Mao et al. (2002) proposed that spore-pollen to dinoflagellate (P/D) ratio can be used as a proxy for sea level fluctiations in that high P/D ratio refers falling sea level phase while low P/D refers an episode of rising in sea level. P/D ratio is getting higher towards the end of the Eocene and Oligocene whereas became lower in the Early Miocene in the Eastern

Anatolia coinciding with the regressive trend in former two periods and the transgressive events during the latter.

A regional marine transgression suggested by Demirtaşlı and Possini (1965), occurred at the beginning of the Miocene and the sea withdrew at the end of this epoch in their study carried out on the north of the Lake Van. This event could be interpreted as a continuation of Late Oligocene transgressive peak indicated by Zachos et al. (2001), Van Simaeys (2004), and Van Simaeys et al. (2004). As a result, high amounts of *Chriptoredium* spp. occur in the samples interpreted as Early Miocene in age in the studied sections. This high occurrence of *Chriptoredium* spp. should be related with the Early Miocene regional transgression indicated by Demirtaşlı and Pisoni (1965).

Demirtaşlı and Pisoni (1965) also reported that the lowest part of Adilcevaz limestone contains relatively arenitic Aquitanian limestones and these can be correlated with Muş and Van basins. The upper part of Adilcevaz limestone of Demirtaşlı and Pisoni (1965) is later named as the Burdigalian reefal limestone member of the Aşkale Formation by Şahintürk and Kasar (1980). Therefore the Aquitanian arenitic limestones indicated in Demirtaşlı and Pisoni's study correspond the lowermost part of Aşkale Formation in the Muş Basin. This information is completely correlatable with this study in that arenitic and lithic limestone layers of the lowermost part of the Aşkale Formation conformably overlie the sandstone-marl intercalations belonging to uppermost part of the Kelereş Formation in the Hınıs-Muş-Van Basin. There is no observation on a probable unconformity in the field. Therefore, transition between Aşkale and Kelereş formations and the boundary between the Oligocene and Miocene sediments seem to be conformable in Hınıs-Muş-Van Basin even though some local unconformities below the biostratigraphic resolution may be seen in much shallower and transitional to terrestrial parts of the region.

#### 4.3.3. Palynofacies Analysis

The term palynofacies has been introduced by Combaz (1964) to refer all acid-resistant organic matter, seen under the microscope, obtained from the sediment/sedimantary rock by palynological processing. Powell et al. (1990) modified this definition as an assemblage of palynoclast represents a distinct depositional environment. Different terms such as kerogen, macerals, palynological matter or and particulate organic matter are used for the organic content of palynofacies in different papers but they all refer exactly the same thing.

Jaramillo (1995) claimed that the differences in the percentages of the sedimentary organic matter constituents are related with the position of the depositional environments within the basin according to the paleoshoreline. For instance, amorphous dominated palynofacies mostly represent deep marine environments whereas terrestrially derived organic matter (woody and coaly) dominated palynofacies recall much shallower and near-shore conditions. This information should be always integrated by the information derived from the palynomorphs. In general, composition of the sedimentary organic matter can be successfully used in studies regarding depositional environments (Batten, 1996).

Burges (1974) distinguished following organic matter components with visual examination under the microscope; algal, amorphous, herbaceous, woody, and coaly. Modified classification of Burges (1974) has been applied to this study in that structureless, disseminated, and shapeless particules named as amorphous, spore, and pollen are evaluated as herbaceous, woody remains of land plants, plant tissue, and cuticles are grouped as woody, and opaque particules are mades as coaly type of organic matter. Some other alternative classifications of sedimantary organic matter have been listed in Figure 35. Masran and Pocock (1981) suggested six different categories for the organic matter (kerogen) constitutes as amorphous, resin, structured aqueous material, spore and pollen, structured terrestrial material, and charcoal. Teichmüller (1985) used standart terminologies of coal petrology for organic matter constitutes as variable alginite, liptinite, huminite, and inertinite. Hart et al. (1994) classified organic matter components based on their biological origin and preservation states as amorphous, protistoclast, phytoclast, sclerotoclast, and black debris. Tissot and Welte (1978), on the other hand, prefered Type I, II, III, and IV terms to classify different types of organic matter (kerogen) constituents. Finally, Tyson (1995) introduced on of the most comprehensive classifications which can also be used in paleoenvironmental reconstructions and physico-chemical characteristics of the facies. He distinguished three major groups as amorphous, palynomorphs (including phytoplanktons, sporomorph, and zoomorph), and phytoclasts. Phytoplanktons include dinoflagellates and algae. Lately, in order to prevent the big confusion in terminologies used in different classifications, Batten (1996) suggested a very comprehensive classification to combine different phrases used for palynological matter for easy communication among palynologists. He distinguished four groups as follows: 1) Palynomorphs (spore, pollen, fungal spore, dinoflagellate, acritarch, algae, foraminiferal linings, Chitinozoa, scolecodont, miscellaneous). 2) Structured Organic Matter includes phytoclasts (wood, charcoal, cuticles, bark and cork, plant tissue, tubes, flaments, and hairs, fungal hyphae) and zooclasts. 3) Unstructured (Structureless) Organic Matter (amorphous organic matter, gelified matter, resin and amber, solid bitumen. 4) Reworked Organic Matter.

Kerogen slides have been examined visually and percentages of the organic matter components have been documented during palynofacies analyses for all productive samples in this study (Appendix B). Since visual examinations are subjective to the studying person, percentage values should be evaulated with 2-3 % of possible error.

Palynofacies analyses in this study have been carried out by means of palynomorph assemblages and sedimentary organic matter. In general, palynomorph assemblages of Upper Eocene sediments mostly dominated by terrestrial palynomorphs (80-85 %) but frequencies of the marine dinoflagellates are also quite high (15-20 %). Abundances of dinoflagellates are getting reduced towards the end of the Eocene and base of the Rupelian and terrestrial palynomorphs and fresh water algae completely dominate the assemblages. Similarly, marine-derived amorphous organic matter content was reduced from 10-15 % in the Late Eocene to 2-5 % at the base of the Rupelian. Related to rising in sea level, marine dinoflagellates and amorphous organic matter seem to be increased towards the middle

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Amorphous (+ Resin) | Amorphous | | Amorphous | Amorphous (as secondary product) | Amorphous Resin | ? Resin | Amorphous | Variable | I–II |
| Acritarch | Phytoplanktons. | Palynomorphs | Algal | Protistoclast | Stuructured Aqueous | Marine Palynomorp | Algal | Alginite | I |
| Algae (prasinophyta-tasman. cholorococcale-pedias., botryc.) | | | | | | (Freswater) Algal | | | |
| Dinoflagellata | | | Palynomorph | | | Marine Palynomorph. | | | |
| Spore & pollen | Sporomorph | | | Phytoclast | Spore & Pollen | Terrestrial Palynomorph. | Herbaceous | Liptinite | II |
| Chitinozoa | Zoomorph | | ? | ? | ? | ? | ? | ? | ? |
| Scelocodont | | | ? | ? | ? | ? | ? | ? | ? |
| Microforaminifera | | | ? | ? | ? | Foraminiferal linings | ? | ? | ? |
| Fungal Remains (mostly F.spores) | Sporomorph | | ? | Sclerotoclast | Fungi | ? | ? | Inertinite | IV |
| Woody tissue of land plants | Phytoclasts | | Palynowafers | Phytoclast | Structured Terrestrial | Brown wood | Woody | Vitrinite / Huminite | III |
| Epidermal tissue of land plants (cuticles) | | | | | | Cuticle | Herbaceous | Liptinite | II |
| Non-woody, non-epidermal tissue of land plants | | | | | | ? | ? | ? | ? |
| Opaque & semi-opaque particles | | | | | Charcoal | Black wood. | Coaly | Inertinite | IV |
| Om types / Author | Tyson, 1995 | | Boulter, 1994 | Hart, etal 1994 | Masran & Pocock, 1981 | Parry, etal 1981 | Burges, 1974 | Teichmüller, 1985 COAL MACERALS | Tissot, welte 1978 CHEMICAL OM TYPES |

Figure 35. Comparison of organic matter classifications in different studies (from Tekin, 2002).

Rupelian and continued more or less consistent at the end of the Chattian. Terrestrial palynomorphs (spore, pollen, and fungal spores) started to dominate (up to 85-95 %) the assemblages towards the end of the Chattian in Hınıs-Muş-Van, Tekman, Tercan-Aşkale, and Pasinler-Horasan basins. Parallel to the palynomorph content, organic matter assemblages have been dominated by terrestrial (woody, coaly, and herbaceous) type of organic matter that indicates shallow marine conditions for the deposition during the Late Oligocene (Appendix B). Percentages of marine dinoflagellates vary from 5 % to 15 % related to fluctuating sea level conditions. Similar to marine palynomorphs, marine-amorphous organic matter content is in the range of 5-15 % in most the Upper Oligocene samples but reaches more than 40-50 % in the Aquitanian related to regional transgression. Dinoflagellate abundance also quite high (the highest in the sediments of Eocene to Pliocene) and reaches more than 50 % in the Aquitanian and suggests deeper marine depositional conditions in Muş, Tekman, Tercan-Aşkale, and Pasinler-Horasan basins. On the other hand, completely terrestrial palynomorphs and organic matter dominate the Eocene-Miocene sediments derived from the Bayburt-Kars Plateau. Terrestrial palynomorphs are represented by spore, pollen, fungal spore, and fresh water algae. Similarly, sedimentary organic matter assemblage is dominated by terrestrial-derived woody, coaly, and herbaceous particules. Amorphous organic matter content may reach up to 10 % in some of the samples. However they can also be seen in nonmarine environments caused by the biodegradation of cellular remains and products of that process under similar anoxic conditions (Batten, 1983). Main mechanism behind the formation of amorphous organic matter in terrestrial depositional conditions is the biological breakdown that was caused by bacteria and fungi of all organic particules.

#### 4.3.4. Paleogeographical Comments

The Eastern Anatolian Tertiary sub-basins were affected from the Mediterranean realm to the south-southeast and Paratethyan realm to the north-northeast. Carrying out a correlation study between these two realms is quite difficult. Jones and Simmons (1996) investigated the stratigraphy and paleogeography of the Oligocene-Holocene sediments from the Eastern Paratethys. They have also emphasized the difficulties in establishing a biostratigraphic zonations by means of planktonic foraminiferas and calcareous nannoplankton in Eastern Paratethys due to the isolated nature of the region. They suggested that due to the plate collisions in the Eocene, Tethyan Ocean began to close, the mountain chain that is extending from Alps to Himalayas and east-west trending sedimentary basins occurred. Because of the Miocene tectonism (uplifting) and eustatic shallowing, marginal to non-marine depositional environments predominate the region and connections to the world's oceans disappeared. Therefore, according to Jones and Simmons (1996), the correlation between the Mediterrenean and Paratethyan stages is rather difficult. They claimed that planktonic foraminiferas and calcareous nannoplankton may be used only periodically (in Maykopian, Maeotian and Kuyalnikian/Akchagylian) to calibrate global biostratigraphic zonations of Blow (1969) and Martini (1971). According to Jones and Simmons (1996) benthonic foraminiferas, ostracodes and terrestrially-derived palynomorphs can be succesfully used to define biostratigraphic zonations in the Eastern Paratethys. They suggested that brackish to reduced salinity (what they call "quasi-marine") conditions predominate in the Paratethyan Basin due to the restricted connections to the world's oceans. Jones and Simmons (1996) suggested that the base of the Tarkhanian stage of the Eastern Paratethys corresponding to the base of the Langhian stage of the Mediterranean and the base of the Badenian stage of Central Paratethys is defined by the first appearence of *Praeorbulina* (N8 Planktonic foraminifer Zone of Blow, 1969) and can be comparable with 16.5 Ma sea-level fall in Haq et al. (1988). They also suggested that the coarse clastics of the Chokrakian-Karaganian and Sarmatian stages of the Eastern Paratethys may be related to the 15.5 and 10.5 Ma sea-level falls in Haq et al. (1988) respectively.

Paleogeographic and palinspastic reconstructions of Steininger and Rögl (1984) from Late Oligocene to Pliocene of Mediterranean and Paratethys were one of the most comprehensive studies carried out in those regions. Mammals inferred in their study and helped a lot to reconstruct paleogeography of the regions because they reveal crucial information on the migration ways of the mammals between different continents, thus, time of connections and closures between world oceans. Changing connections of Mediterranean and Paratethys with world oceans have been also used in their study as an implication of transgressive-regressive cycles and seem comparable with the global sea level changes (Vail et al., 1977) or major tectonic phases of Alpine orogenesis (Schwan, 1980). Steininger and Rögl (1984) also suggested that, Mediterranean and Paratethys sea between the Eurasian and African plates were mainly affected by the changing connections with Atlantic and Indo-Pacific oceans in Cenozoic. They indicated that Eastern Mediterranean regions, where Muş, Hınıs, and Van basins were located, had a particular importance in acting not only as marine gateway to Indo-Pacific but also the most important land-bridge for mammals to migrate from Africa to Eurasia or vica versa in the Neogene. They have summarized the paleogeographic condition of Mediterranean and Paratethys as follows; Late Oligocene (Chattian/Aquitanian-Egerian-Caucasian, 25.0-23.0 Ma); A wide sea dominates the region between Africa, Turkey, and Eurasia with carbonate platforms. There was a connection between Indo-Pacific Ocean to the Eastern Mediterranean, Eastern and Central Paratethys, and Atlantic. According to Steininger and Rögl (1984), the connection from Indo-Pacific to Atlantic caused circum-equatorial current system, and resulted massive occurrence of larger foraminifera in both Mediterranean and Paratethys realms and prevented African-Eurasian mammal migration in the Late Oligocene. Late Oligocene time has been completed under a regressive regime. Even though their reconstructions are composed of Late Oligocene to Pliocene successions, their results seem quite consistent with this study. Shallow to deep marine environments were dominating a large area including Hınıs-Muş-Van, Tekman, Tercan-Aşkale, and Pasinler-Horasan basins during Late Eocene. Towards the end of the Eocene and early Rupelian transitional to fresh water environments (lacustrine) seem to be abundant related to lowering sea level conditions. Later, these regions have been occupied by shallow marine environments during the late Rupelian and Chattian, and as it was also reported by Steininger and Rögl (1984), a regressive (shallowing-upward deposition) regime resulted relatively shallowing marine depositional environments until the end of the Chattian followed by deeper marine environments at the end of the Aquitanian. On the other hand, completely terrestrial depositional environments (lacustrine to fluvial) dominate the Eocene-Miocene sediments in the Bayburt-Kars Plateau (Figure 36). Steininger and Rögl (1984) also placed an extensive continental area between the Eastern Mediterranean and Paratethys reaching from former Yugoslavia to Turkey in Late Oligocene.

Steininger and Rögl (1984) suggested that Early Miocene (Middle-Late Burdigalian, 20.0-17.0 Ma-Late Eggenburgian-Late Sakaraulian, 20.0-19.0 Ma); the time of collision of Africa and Eurasia resulted entensive regression. Marine connection between the Eastern Paratethys and Mesopotamian Trough closed. African-Eurasian mammal migration took place. For instance, African creodont predators such as *Hyaenaelurus* and primates such as *Pliopithecus* migrated to the Eurasia and suids and true carnivores were seen for the first time in Africa at this time (Ginsburg, 1979; Bruijn and Meulen, 1981). Finally, a very big land-locked sea with reduced salinities occurred. However Şengör and Yılmaz suggested that this collision took place in the Middle Miocene. Steininger and Rögl (1984) indicated that a major transgression reconnected Mediterranean, Paratethys, and Indo-Pacific Ocean in the Middle Miocene (Langhian-early Badenian-Tarkhanian 16.8-16.0 Ma). Continental island-shaped body occurred similar to the configuration in the Late Oligocene but no marine sedimentation took place in Greece, most of the former Yugoslavia and Turkey at this time. Whole Eastern Anatolia has been uplifted and the sea withdrew from the region at the end of the Middle Miocene as a result of this collision (Şengör et al., 1979 and Şengör, 1980). Therefore, completely terrestrial depositional conditions (lacustrine to fluvial) dominated in all Eastern Anatolian sub-basins since the end of the Middle Miocene.

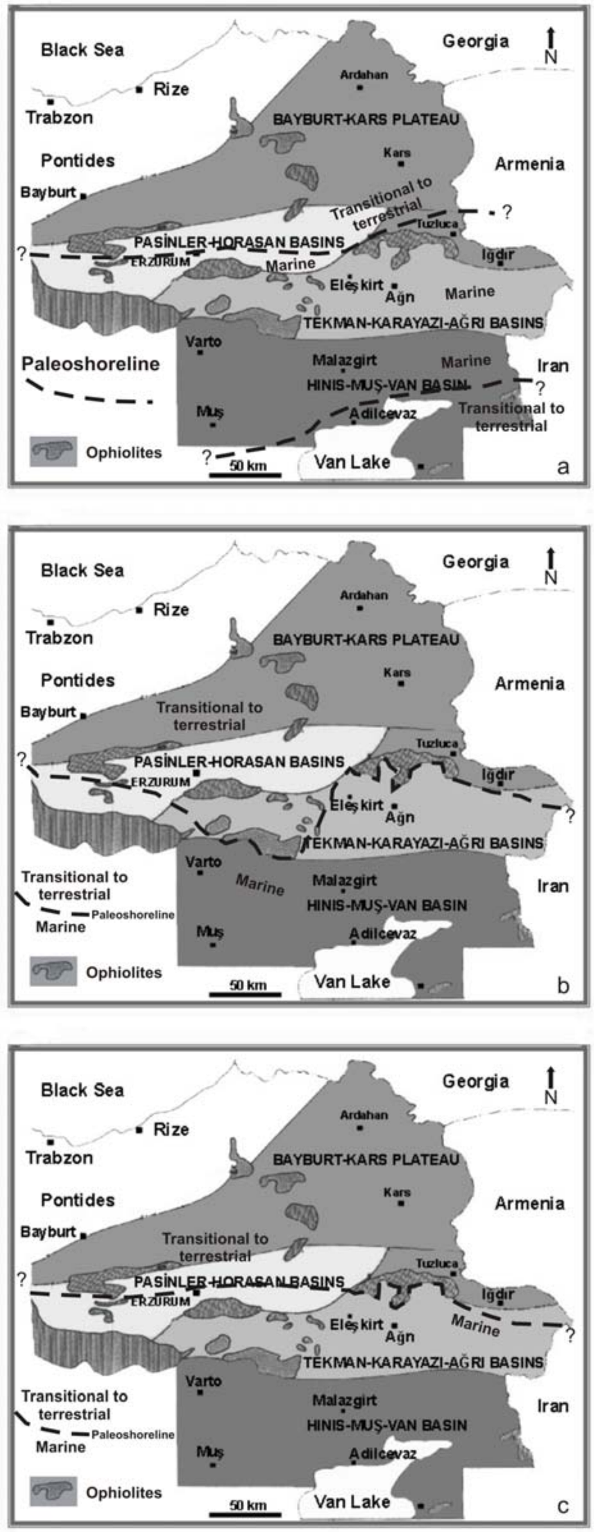



Figure 36. Paleogeographic map of the Eastern Anatolia, a: Late Eocene, b: Oligocene, c: Early Miocene (modified from Şahintürk et al., 1998b).

# CHAPTER 5

## CONCLUSIONS AND RECOMMENDATIONS

A total of 156 palynomorph species have been identified in this study composed of 43 pollen, 20 spores, 13 fungal spores, 70 dinoflagellates, 3 acritarchs, 2 organic-walled green algae, and 5 incertae sedis.

11 dinoflagellates, acritarchs, and pollen biozones have been identified in Upper Eocene to Pliocene sediments combined from Hınıs-Muş-Van, Tekman, Tercan-Aşkale, Pasinler-Horasan basins and the Bayburt-Kars Plateau in this study. Biostratigraphically important dinoflagellate/acritarch and pollen events calibrated by worldwide-defined dinoflagellates, planktonic foraminifers and calcareous nannoplanktons have been documented for the first time in this study for the Oligocene-Miocene sediments in the Eastern Anatolia. As it was given in detail in the biozonation part, FADs and LADs of some selected dinoflagellages and pollen have an importance to establish the biostratigraphic framework. FADs of Compositae (tubuliflorae-type), *Slowakipollis hipophaeoides*, *Mediocolpopollis compactus*, *Monoporopollenites gramineoides* and Umbelliferae at the base of Rupelian, FAD of *Wetzeliella gochtii* in the “middle” Rupelian, LAD of *Ascostomocystis potane* in the late Rupelian, LAD of *Wetzeliella gochtii* in the “latest” Rupelian, LAD of *Deflandrea* spp. in the latest Chattian, peak occurrences of *Chriptoredium* spp. in the early and late Aquitanian, FAD of *Hystrichosphaeropsis obscura*, followed by FAD of *Membranilarnacea* ?*picena* in the late Aquitanian should have particular emphasis for regional correlations.

Under the light of this study Miocene zonation of some palynomorphs have been fixed and stratigraphic ranges of the Compositae (tubuliflorae-type), small/less ornamented Umbelliferae and Gramineae pollen should be prolonged untill the base of Rupelian in the Eastern Anatolia.

Nine dinoflagellate and acritarch-based eco-groups have been defined representing different depositional conditions changing from coastal-marginal marine to oceanic-open marine in the studied samples.

As far as the depositional environments were concerned; information gathared from palynomorphs, and sedimentary organic matter suggest that Upper Eocene, Oligocene and Lower Miocene sediments were deposited under brackish water, shallow and relatively deeper marine conditions related to fluctuating sea level which was supported by relatively higher abundances of both marine dinoflagellates and amorphous organic matter. Relatively deeper marine deposition took place during the Late Eocene. Shallowing-upward deposition occurred during the Oligocene and followed by the Early Miocene regional transgression until the beginning of the Middle Miocene. However, Lower Miocene sediments still represent shallow marine-near shore environments. Due to the withdrawal of the sea, Upper Miocene-Pliocene sediments were deposited in terrestrial (lacustrine and fluvial) environments in Hınıs-Muş-Van, Tekman, Tercan-Aşkale, and Pasinler-Horasan basins. However, lacustrine-terrestrial conditions have been prodominating since Late Eocene in the Bayburt-Kars Plateau as indicated by completely land-derived palynomorphs and organic matter.

High abundances of *Deflandrea* spp., rare *Polysphaeridium zoharyi*, very rare occurrences of terrestrial warm indicators (such as *Carya*, *Tilia*, *Alnus* etc.) and high abundances of dry-cold indicators (Compositae, Gramineae, Chenopodiaceae, and Umbelliferae) all suggest cold sea surface temperatures with high nutrient contents, and temperate to subtropical climates in which mean annual temperatures varies between 15,6 to 21,3 °C, mean temparatures of the coldest and the warmest month are 5.0 to 13.3 °C and 24.7 to 28.1 °C, respectively, and mean annual precipitation is 1122.0 to 1522.0 mm. during the deposition of Oligocene-Miocene sediments in the Eastern Anatolia.

A Rupelian acritarch called *Ascostomocystis potane* has been recorded for the first time in Turkey. According to Stover and Hardenbol (1994), its first occurrence is near the bottom of the Rupelian and the last occurrence is at the top of middle Rupelian, in the calcareous nannoplankton zone NP23 of Martini (1971). However this taxon shows its highest occurrence at the base of NP24, in the latest Rupelian of Eastern Anatolian sediments.

In contrast to the earlier interpretations on the general stratigraphic settings of the Eastern Anatolia, presence of Rupelian successions may suggest that the relation between the Upper Eocene and Lower Oligocene sediments could have been comformable in some regions. Similarly, relation between the Oligocene and Miocene sediments seems to be conformable even though some local unconformities below the biostratigraphic resolution may be seen in much shallower and transitional to terrestrial parts of the region.

This study clearly documents that the Rupelian was the time of deposition rather than erosion, during which sedimentation started in fresh water environments and continued in shallow to deep marine environments in Hınıs-Muş-Van, Tekman, Tercan-Aşkale, and Pasinler-Horasan basins related to relative sea level fluctuations, whereas lacustrine-terrestrial conditions were prodominating in the Bayburt-Kars Plateau.

Although the number and distribution of the studied sections are not adequate, estimations made for the paleogeographic reconstruction of the Oligocene-Miocene sub-basins of the Eastern Anatolia point out that marine gateway was present during the Late Eocene and Oligocene times in the southern parts of the Eastern Anatolia bordering almost the northern margins of Hınıs-Muş-Van, Tekman, Tercan-Aşkale, and Pasinler-Horasan basins whereas the Bayburt-Kars Plateau was dominated by completely terrestrial environments. Shallowing of the sea towards the end of the Oligocene led withdrawal of the sea to the south-southwestern parts of the region creating extensive transitional to terrestrial depositional sites behind. Following the regional transgression of the sea in the Early Miocene extending up to the northern parts of Hınıs-Muş-Van, Tekman, Tercan-Aşkale, and Pasinler-Horasan basins, whole Eastern Anatolian sub-basins have been experienced completely terrestrial depositional conditions since Late Miocene. However, additional sections representing the all geography should be studied in the future for the detailed paleogeographic reconstructions of the Oligocene-Miocene sediments in the region.

Sea level curve established on the basis of the palynomorph assemblages in the Eastern Anatolian Oligocene-Miocene sediments seem to be comparable with the eustatic curve. However, the Eastern Anatolia was one of the most tectonically active regions of Turkey during this time. Therefore, even though the main driving mechanism in the formation of the depositional sequences was eustacy, they had to be tectonically enhanced.

Regularity of marl and sandstone intercalations in Eastern Anatolian Oligocene sediments may suggest long lasting and relatively stable depositional conditions. Changing from one lithology to other might be related to the level of energy at the sediment-water interface. Milankovitch cycles, climate or eustacy or both may play an important role on the formation of rhytmic marl-sandtone deposition.

Information will be gathered from mammals, and radiometric datings in the future works may also help to calibrate biozones documented in this study.

# REFERENCES

Akay, E., Erkan, E., and Ünay, E., 1989, Muş Tersiyer havzasının stratigrafisi, MTA Dergisi, 109: 59-76, Ankara.

Akgün, F. and Akyol, E., 1987, Akhisar (Çıtak) çevresi kömürlerinin palinolojik İncelemesi, Bulletin of the Geological Society of Turkey, 30: 35-50.

Akgün, F. and Akyol, E., 1992, Yukarıkaşıkara ve Yarıkkaya (Isparta) kömürlerinin karşılaştırmalı palinostratigrafisi ve paleoekolojisi. TAPG Bülletin, 4: (1), 129-139.

Akgün, F., Alişan, C., and Akyol, E., 1986, Soma Neojen stratigrafisine palinolojik bir yaklaşım. Bulletin of the Geological Society of Turkey, 29: 13-25.

Akgün, F., Olgun, E., Kuşçu, İ., Toprak, V., and Göncüoğlu, M. C., 1995, Orta Anadolu Kristalen Kompleksinin "Oligo-Miyosen" örtüsünün stratigrafisi, çökelme ortamı ve gerçek yaşına ilişkin yeni bulgular, TAPG Bulletin, 6: (6), 51-68.

Akgün, F., Akkiraz, M. S. and Örçen, S., 2004, Çardak-Tokça, Burdur ve İncesu Molas Havzalarındaki Kömürlü Tersiyer Tortullarının Palinostratigrafik Korelasyonu. Tübitak Proje No: 101Y133.

Akkiraz, M. S., 2000, Palynostratigraphy of the Oligo-Miocene Denizli Çardak Molasse Basin. M.Sc. Thesis, Dokuz Eylül University, İzmir-Turkey.

Akkiraz, M. S. and Akgün, F., 2005, Palynology and age of the Early Oligocene units in Çardak-Tokça Basin, Southwet Anatolia: Paleoecological implications. Geobios, (in press).

Akyol, E., 1964, Contribution a l'etude palynologique des charbons Tertiaires de la Turquie, MTA Bulletin, 63: 33-46.

Akyol, E., 1971, Microflore de l'Oligocene inferieur recoltee dans un sondage pres D'Avcıkoru, Şile-Istanbul. Pollen et Spores, 13: (1), 117-134.

Akyol, E., 1974, Laevigatosporites haardti (R. Pot. ve Ven. ) Th. ve tipi üzerinde bir biyometri araþtýrmasý. Bulletin of the Geological Society of Turkey, XVII: (1), 117-134.

Akyol, E. and Alişan, C., 1982, Miyosen'de palinolojik yaş saptamaları ve Soma örneği. Abstracts of the Geological Congress of Turkey-1982, 53-54.

Akyol, E. and Akgün, F., 1990, Bigadiç, Kestelek, Emet ve Kırka boratlı Neojen tortullarının palinolojisi. MTA Dergisi, 111: 165-173.

Akyol, E., and Akgün, F., 1992, Yukarıkaşıkara ve Yarıkaya (Isparta) kömürlerinin karşılaştırmalı palinostratigrafisi ve paleoekolojisi, TPJD Bulletin, .4: (1), 129-139.

Akyol, E. and Akgün, F., 1995, Age determinations on the Tertiary Trakya continental deposits. Symposium on the Geology of the Thrace Basin, May 30-June 3, 1995, Lüleburgaz-Kýrklareli (Abstracts), 28-29.

Alberti, G., 1959, Zur Kenntnis der Gattung *Deflandrea* Eisenack (Dinoflag.) in der Kreide und im Alttertiär Nord und Mitteldeutschlands, Mitteilungen aus dem Geologischen Staatsinstitut in Hamburg, 28: 93-105.

Alberti, G., 1961. Zur Kenntnis mesozoischer und alttertiärer Dinoflagellaten und Hystrichosphaerideen von Nord- und Mitteldeutschland sowie einigen anderen europäischen Gebieten. Palaeontographica, Abteilung A, 116: 1-58, pl. 1-12.

Alişan, C., 1981, Evciler çevresinin jeolojisi ve palinolojisi. Ege Üniversitesi Jeoloji Müh. Böl. Bitirme Projesi, (unpublished).

Alişan, C., 1984, Hazro İlçesi (Diyarbakır) dolayında Hazro ve Gomaniibrik forrmasyonlarının Alt Permiyen palinoflorası. Dokuz Eylül Üniv. Yüksek Lisans Tezi, (unpublished).

Allen, C. R., 1969, Active faulting in Northern Turkey, Contr. 1977, Div. Geol. Sciences, Calif. Inst. Tech., 32 p.

Alptekin, Ö., 1973, Focal mechanism of earthquakes in western Turkey and their tectonic implications: Ph.D. Thesis, New Mexico Institute of Mining and Technology, Socoror, New Mexico.

Altınlı, İ. E., 1966, Doğu ve Güneydoğu Anadolu'nun jeolojisi, MTA Dergisi, 66: 35-73, Ankara.

Angladai R., 1971, Sur la position du datum á Globigerinoides (Foraminiferida) la zone N 4 (Blow 1967) et la limite oligo-miocéne en Méditerraneé – C. R. Acad. Sci. Paris, 272: (D), 1067-1070.

Arpat, E., and Şaroğlu, F., 1972, Doğu Anadolu fayı ile ilgili bazı gözlemler ve düşünceler, MTA Dergisi, 78, 44-50.

Arslan, R., 1979, Kütahya-Tunçbilek sahasındaki sondaj örneklerinin palinoloji İncelemesi, Bulletin of the Geological Society of Turkey, 22: 135-140.

Artzner, D. G. and Dörhöfer, G., 1978, Taxonomic note: *Lejeunecysta* nom. Nov. Pro *Lejeunia* Gerlach 1961 emend. Lentin and Williams 1976-dinoflagellate cyst genus, Canadian Journal of Botany, 56: 1381-1382.

Axelrod, D. I., 1981, Role of volcanism in climate and evolution, Geol. Soc. Amer., Special Paper, 181: 1-59 p.

Aziz, A., 1971, Erzurum i46b4 ve i46c paftalarının detay jeolojisi ve petrol olanakları, MTA Rap. No: 5222, Ankara, (unpublished).

Barka, A., 1984, Erzincan havzasının bazı neotektonik özellikleri, KD Anadolu I. Ulusal Deprem Simpozyumu, 223-247, Erzurum.

Barreda, V. D., 1993, Late Oligocene?-Miocene pollen of the families Compositae, Malvaceae, and Polygonaceae from the Chenque Formation, Golfo San Jorge Basin, Southeastern Argentina, Palynology, 17: 169-186.

Barrett, P. J., 1994, Progress towards a Cenozoic Antarctic glacial history. Terra Antart., 1: 247–248.

Batı, Z., 1996, Palynostratigraphy and coal petrography of the Upper Oligocene lignites of the Northern Thrace Basin, NW Turkey, Ph.D. Thesis, Middle East Technical University.

Batı, Z., and Alişan, C., 1991, VIII. Bölge Murat Baseni'nde açılan Malazgirt-1 kuyusunda kesilen birimlerin Tersiyer palinostratigrafisi. TPAO Araştırma Merkezi Raporu, 1576, Ankara, (unpublished).

Batı, Z., Erk, S., and Akça, N., 1993, Trakya Havzası Tersiyer birimlerinin palinomorf, foraminifer ve nannoplankton biyostratigrafisi. TPAO Araştırma Merkezi rapor no. 1947, Ankara, (unpublished).

Batı, Z., and Sancay, R. H., (submitted), Rupelian: time of deposition or erosion (non-deposition) in Muş Basin, Eastern Anatolia, Turkey, Micropaleontology.

Batten, D. J., 1983, Identification of amorphous sedimentary organic matter by transmitted light microscopy, In: Brooks, J. (ed.), Petroleum geochemistry and exploration of Europe, Geological Society, London, Special Publication, 11: 275-287.

Batten, D. J., 1996, Palynofacies and paleoenvironmental interpretation, *in*: Jansonius, J. and McGregor, D. C., (ed.), Palynology: principles and applications, American Association of Stratigraphic Palynologists Foundation, 3: 1011-1064.

Batten, D. J., and Grenfell, H. R., 1996, Botryococcus, In: Jansonius, J. and McGregor, D. C., (ed.), Palynology: principles and applications, American Association of Stratigraphic Palynologists Foundation, 1: 205-215.

Benda, L., 1971a, Principles of the palynologic subdivision of the Turkish Neogene (Kainozoikum und Braunkohlen der Türkei. 3.). Newsl. Stratigr., 1: (3), 23-26.

Benda, L., 1971b, Grundzüge einer pollenanalytischen Gliederung des Türkischen Jungtertiars (Kainozoikum und Braunkohlen der Türkei. 4). Beih. geol. Jb., 113: (46), 46 p.

Benda, L., and Meulenkamp, J. E., 1979, Biostratigraphic Correlations in the Eastern Mediterranean Neogene. 5. Calibration of sporomorph associations, marine microfossils and mammal zones, marine and continental stages and the radiometric scale. Ann. Geol. Pays Hellen., VII$^{th}$ Internat. Congr. Medit. Neogene, Athens, 1: 61-70.

Benda, L., Meulenkamp, J. E., and Weerd, A. V. D., 1977, Biostratigraphic Correlations in the Eastern Mediterranean Neogene, Newsl. Stratigr., 6: (2), 117-130.

Benda, L., Jonkers, A. H., Meulenkamp, J. E., and Steffens, P., 1979, Biostratigraphic Correlations in the Eastern Mediterranean Neogene, Newsl. Stratigr., 8: (1), 61-69.

Benda, L., Meulenkamp, J. E., Schmidt, R. R, Steffens, P., and Zachariasse, J. W., 1977, Biostratigraphic correlations in the Eastern Mediterranean Neogene. 2. Correlation between sporomorph associations and marine microfossils from the Upper Oligocene-Lower Miocene of Turkey. Newsl. Stratigr., 6: (1), 1-22.

Benedek, P. N., 1972, Phytoplankton aus dem Mittel- und Oberoligozan von Tonisberg (Niederrheingebiet): Palaeontographica, B, 137: 1-71.

Benedek, P. N. and Gocht, H., 1981, *Thalassiphora pelagica* (Dinoflagellata, Tertiär): Electronenmikroskopische Unterschung und Gedanken zur Paläobiologie, Palaeontographica, Abt. B, 180, 39-64.

Benedek, P. N., Gocht, H., and Sarjeant, W. A. S., 1982, The dinoflagellate cyst genus *Pentadinium* Gerlach: a re-examination, Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 162, 265-285.

Berger, J. P., 1992, Correlative chart of the European Oligocene and Miocene: Application to the Swiss Molasse Basin. Eclogae Geol. Helv., 85: (3), 573-609.

Berggren, W. A., and Van Couvering, J. A., 1978, Biochronology, Amer. Assoc. Petrol. Geol. Stud. Geol., 6: 39-55.

Berggren, W. A., Kent, D. V., Swisher, III, C. C. and Aubry, M. P., 1995, A Revised Cenozoic Geochronology and Chronostratigraphy. SEPM Special Publication 54, 129-212.

Biffi, U., and Manum, S. B., 1988, Late Eocene-Early Miocene dinoflagellate cyst stratigraphy from the Marche Region (Central Italy), Bollettino della Societa Paleontologica Italiana, 27: (2), 163-212.

Bigazzi, G., Yeğingil, Z., Ercan, T., Oddone, M., and Özdoğan, M., 1996, The Pisa-Adana Joint Project of prehistoric obsidian artifacts: First results from Eastern Anatolia, In: Archaometry 94, Proceedings of the 29th Symposium of Archeometry, (Ed: Dimirici, S., Özer, A. M., Summers, G. D.), 521-528, Ankara.

Birgili, Ş., 1968, Muş Bölgesi 1/25000 ölçekli Karaköse J48-d3-d4 ve Muş K47 bb paftalarının detay petrol etüdü hakkında rapor, Maden Tetkik ve Arama Enstitüsü, Rapor No. İ707, Ankara, (unpublished).

Biolzi, M., 1983, Stable isotopic study of Oligocene-Miocene sediments from DSDP Site 354, Equatorial Atlantic. Marine Micropaleontology. 8: (2), 121-139.

Biolzi, M. M. E., 1985, The Oligocene/Miocene boundary in selected Atlantic, Mediterranean, and Paratethyan sections based on stratigraphic and stable isoevidence, Mem. Soc. Geol., 37: 303-307.

Blow, W. H., 1969, Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. In: Brönniman, R. and Renz, N.H. (eds.), Proceedings of the First International Conference on Planktonic Microfossils, Geneva 1967: 199-421.

Bold, H. C., Alexopoulos, C. D., and Delevoryas, T., 1980. Morphology of plants and fungi. Harper and Row, New York, 819 p.

Boulter, M. C. and Craig, D. L., 1979. A Middle Oligocene pollen and spore assemblage from the Bristol Channel. Review of Palaeobotany and Palynology, 28: 259-272.

Bozkuş, C., 1990, Oltu-Narman Tersiyer Havzası kuzeydoğusunun (Kömürlü) stratigrafisi, Türkiye Jeoloji Kurultayı Bülteni, 33: 47-56.

Bozkuş, C., 1993, Pasinler-Horasan (Erzurum) havzası doğusunun stratigrafisi, MTA Dergisi, 115: 43-51, Ankara.

Brenac, P., and Richards, K., 2001, *Pediastrum* as a guide fossil in sequence stratigraphy: In: Goodman, D. K., and Clarke, R. T. (eds.), Proceedings of the IX. International Palynological Congrees, Houston, Texas, U.S.A., 1996; American Association of Stratigraphic Palynologists Foundation, 239-241.

Brinkhuis, H., 1992, Late Eocene to Early Oligocene dinoflagellate cytfrom central and northeast Italy, Ph.D. Thesis, Utrecht University, 169 p.

Brinkhuis, H., 1994, Late Eocene to early Oligocene dinoflagellate cysts from the Priabonian type-area (northeast Italy); biostratigraphy and palaeoenvironmental interpretation. Palaeogeography, Palaeoclimatology, Palaeoecology, 107: 121-163.

Brinkhuis, H., and Zachariasse, W. J., 1988, Dinoflagellate cysts, sea level changes and planktonic foraminifers across the Cretaceous–Tertiary boundary at El Haria, northwest Tunisia. Mar. Micropaleontol., 13: 153-191.

Brinkhuis, H., and Biffi, U., 1993, Dinoflagellate cyst stratigraphy of the Eocene/Oligocene transition in central Italy. Marine Micropaleontology, 22: 131-183.

Brinkhuis, H., Powell, A. J. and Zevenboom, D., 1992, High-resolution dinoflagellate cyst stratigraphy of the Oligocene/Miocene transition interval in Northwest and central Italy. In: Head, M. J. and Wrenn, J. H. (eds), Neogene and Quaternary dinoflagellate cysts and acritarchs. American Association of Stratigraphic Palynologists Foundation, Salt Lake City, 219-258.

Brinkhuis, H., Munsterman, D. K., Sengers, S., Sluijs, A., Warnaar, J., and Williams, G. L., 2003a, Late Eocene to Quaternary dinoflagellate cysts from ODP Site 1168, Off western Tasmania. In: Exon, N.F., Kennett, J.P., Malone, M. (Eds.), Proceedings of the Ocean Drilling Program. Scientific Results, 189: 1-36. Available from World Wide Web: http://www-odp.tamu.edu/publications/189_SR/105/105.htm. [Cited 2003-10-28], College Station, TX.

Brinkhuis, H., Sengers, S., Sluijs, A., Warnaar, J., and Williams, G. L., 2003b, Latest Cretaceous to earliest Oligocene, and Quaternary dinoflagellate cysts from ODP Site 1172, East Tasman Plateau. In: Exon, N.F., Kennett, J.P., Malone, M. (Eds.), Proceedings of the Ocean Drilling

Program. Scientific Results, 189: 1-48. Available from World Wide Web: http://www-odp.tamu.edu/publications/189_SR/106/106.htm. [Cited 2003-10-31], College Station, TX.

Brosius, M., 1963, Plankton aus dem nordhessischenKasseler Meeressand (Oberoligozän), Zeitschrift der Deutschen geologischen Gesellschaft, 114: 32-56.

Bruch, A. A., and Mosbrugger, V., 2002, Paleoclimate versus vegetation reconstruction palynological investigations on the Oligocene sequence of the Sava Basin, Slovenia, Review of Paleobotany and Palynology, 122: 117-141.

Bruijn, H. de, and Van Der Meulen, A. J., 1981, The distribution of land mammals in the Mediterranean through the Neogene-is there a fit with the paleogeographic and paleoclimatologic reconstructions based on data from marine basins? Ann. Geol. Pays. Hellenique, tome hors serie, 4: 323-335.

Bujak, J. P., 1984, Cenozoic Dinoflagellate cysts and acritarchs from the Bering Sea and northern North Pacific. Micropaleontology, 30: 180-212 .

Bujak, J. P. and Davies, E. H., 1983, Modern and fossil Peridiniineae; AASP Contr. Series, 13, 203 p.

Bujak, J. P. and Matsuoka, K., 1986, Taxonomic re-allocation of Cenozoic dinoflagellate cysts from Japan and Bering Sea, Palynology, 10: 235-241.

Bujak, J. P., Downie, C., Eaton, G. L., and Williams, G. L., 1980, Taxonomoy of some Eocene dinoflagellate cyst species from southern England; *in* Bujak, J. P., Downie, C., Eaton, G. L., and Williams, G. L., Dinoflagellate cysts and acritarchs from the Eocene of southern England, The Paleontological Association, Special Papers in Paleontology, 24: 1-100.

Burgess, J. D., 1974, Microscopic examination of kerogens (Dispersed organic matter) in petroleum exploration, Geol. Soc. Am. Special Paper, 153: 19-30.

Chateauneuf, J. J., 1980, Palynostratigraphie et Paléoclimatologie de L'Éocéne Supérior et de L'Oligocéne du Bassin de Paris. Mém. B. R. G. M., 116: 1-360.

Combaz, A., 1964, Les Palinofacies, Revue de Micropaléontologie, 7: 205-218.

Cookson, I. C., 1965, Cretaceous and Tertiary microplankton from southeastern Australis, Proceedings of the Royal Society of Victoria, 78: 183-191.

Cookson, I. C. and Eisenack, A., 1958, Microplankton from Australian and New Guinea, Palaeontology, 2 (1): 243-261.

Cookson, I. C. and Eisenack, A., 1965, Microplankton from the Browns Creek Clays, SW. Victoria, Proceedings of the Royal Society of Victoria, 79, 119-131.

Cookson, I. C. and Eisenack, A., 1967, Some microplankton from the Paleocene Rivernook Bed, Victoria, Proceedings of the Royal Society of Victoria, 80 (2): 247-257.

Corsin, P. M. and Nakoman, E., 1967. Contribution a l'étude palynologique des formations tertiares du Bassin de Thrace. II.- Etude quantitative. Ann. Soc. Geol. du Nord., LXXXVII: (1), 39-53.

Corsin, P. M., Carette, J., Danze, J., and Laveine, J. P., 1962, Classification des spores et des pollen du Carbonifere au Lias. C. R. Acad. Sci. France, 25: 3062-3065.

Costa, L. I., and Downie, C., 1976, The distribution of the dinoflagellate *Wetzeliella* in the Paleogene of North-Western Europe, Palaeontology, 19: (Part 4), 591-614.

Costa, L. I., and Manum, S. B., 1988. The description of the interregional zonation of the Paleogene. In: Vinken, R. (Ed.), The Northwest European Tertiary Basin. Geologisches Jahrbuch, A100: 321-330.

Dale, B., 1983, Dinoflagellate resting cysts: "benthic plankton"; In: Fryxell, G. A., (ed.). Survival strategies of the algae; Canbridge University Press, Cambridge, 69-136.

Dale, B., 1996, Dinoflagellate cyst ecology; modelling and geological applications, In: Jansonius, J. and McGregor, D. C., (ed.), Palynology: principles and applications, American Association of Stratigraphic Palynologists Foundation, 3: 1249-1275.

Davey, R. J., and Williams, G. L., 1966a, The genera *Hystrichosphaera* and *Achomosphaera*, In: R.J. Davey et al. (Eds.): Studies on Mesozoic and Cainozoic dinoflagellate cysts, Bull. Of the British Museum (Natural History) Geology, Supplement 3: 4-7.

Davey, R. J. and Williams, G. L., 1966b, The genus *Hystrichosphaeridium* and its allies; *in* Davey, R.J., Downie, C., Sarjeant, W.A.S., and Williams, G.L., Studies on Mesozoic and Cainozoic dinoflagellate cysts, Bulletin of the Museum (Natural History) Geology, Supplement 3: 28-52.

Davey, R. J., Downie, C., Sarjeant, W. A. S., and, Williams, G. L., 1966, Fossil dinoflagellate cysts attributed to *Baltisphaeridium*; *in* Davey, R.J., Downie, C., Sarjeant, W. A. S., and Williams, G. L., Studies on Mesozoic and Cainozoic dinoflagellate cysts, Bulletin of the Museum (Natural History) Geology, Supplement 3: 157-175.

Davey, R. J., Downie, C., Sarjeant, W. A. S., and, Williams, G. L., 1969, Appendix to "Studies on Mesozoic and Cainozoic dinoflagellate cysts", Bulletin of the Museum (Natural History) Geology, Appendix to Supplement 3: 15-17.

Davies, E. H., Bujak, J. P., and Williams, G. L., 1982, The application of dinoflagellates to paleoenvironmental problems, Third North Americal Paleontological Convention, Proceedings, 1: 125-131.

Deflandre, G., 1935, Considérations biologiques sur les microorganisms d'origine planctonique conservés dans les silex de la craie, Bulletin biologique de la France et de la Belgique, 69: 213-244.

Deflandre, G., 1937, Microfossiles des silex crétacés. Deuxiéme partie. Flagellés *incertae sedis* Hystrichosphaeridés. Sarcodinés. Organismes divers, Annales de paleontology, 26, 51-103.

Deflandrea, D. and Cookson, I. C., 1955, Fossil microplankton from Australian Late Mesozoic and Tertiary sediments, Australian Journal of Marine and Freshwater Research, 6: 242-313.

Demirtaşlı, E, and Pisoni, C., 1965, The geology of Ahlat-Adilcevaz area (North of Lake Van), Bulletin of the Mineral Research and Exploratian Institute of Turkey, 64: 24-39.

Demirer, A., Batı, Z., Aköz, Ö., Özkan, R., İlleez, H. İ., and Uğur, F. A., 1996, Horasan-1 kuyusunun litostratigrafik, biyostratigrafik ve jeokimyasal değerlendirmesi, TPAO Araş. Gr. Rap. No. 2190, Ankara, (unpublished).

de Verteuil, L., and Norris, G., 1992, Miocene protoperidiniacean dinoflagellate cysts from the Maryland and Virginia coastal plain. *In* Head, M.J., and Wrenn, J.H. (Eds.), Neogene and Quaternary Dinoflagellate Cysts and Acritarchs. Am. Assoc. Stratigr. Palynol. Found., 391–430.

de Verteuil, L., and Norris, G., 1996, Miocene dinoflagellate stratigraphy and systematics of Maryland and Virginia: Micropaleontology, 42: Supplement, 172 p.

Dimter, A., and Smelror, M., 1990, Callovian (Middle Jurassic) marine microplankton from southwestern Germany, biostratigraphy and paleoenvironmental interpretations, Palaeogeography, Palaeoclimatology, Palaeoecology, 80: 173-195.

Dinçer, A., 1969, Muş K47-b3 paftasının jeolojisi, Maden Tetkik ve Arama Enstitüsü, Rapor No. 1997, (unpublished).

Dodge, J. D., 1989, Some revisions of the family Gonyaulacaceae (Dinophyceae) based on scanning electron microscope study, Botanica Marina, 32, 275-298.

Downie, C., Hussain, M. A., and Williams, G. L., 1971, Dinoflagellate cyst and acritarch associations in the Paleogene of southeast England. Geoscience and Man 3: 29–35.

Dörhöfer, G. and Davies, E. H., 1980, Evolution of archeophyle and tabulation in Rhaetogonyaulacinean dinoflagellate cysts, Royal Ontario Museum, Life Sciences Miscellaneous Publications: 91 p.

Drugg, W. S., 1970, Some new genera, species, and combinations of phytoplankton from the Lower Tertiary of the Gulf Coast, U.S.A., Proceedings of the North American Paleontological Convention, Chicago, 1969, Part G: 908-843.

Drugg, W. S. and Loeblich, A. R., Jr, 1967, Some Eocene and Oligocene phytoplankton from the Gulf Coast, U.S.A., Tulane Studies in Geology, 5: 181-194.

Drugg, W. A., and Stover, L. E., 1975, Stratigraphic Range Charts: Selected Cenozoic Dinoflagellates. American Association of Stratigraphic Palynologists, Contribution Series, 4: 73-77.

Dybkjær, K. and Rasmussen, E. S., 2000, Palynological dating of the Oligocene-Miocene successions in the Lille Bælt area, Denmark. Bulletin of the Geological Society of Denmark, 47: 87-103.

Dybkjær, K., 2004, Dinocyst stratigraphy and palynofacies studies used for refining a sequence stratigraphic model-uppermost Oligocene to lower Miocene, Jylland, Denmark. Review of Paleobotany and Palynology, 131: 201-249.

Eaton, G. L., 1971, A morphogenetic series of dinoflagellate cysts from the Bracklesham Beds of the Isle of Wight, Hampshire, England; in Farinacci, A. (ed.), Proceedings Second Planktonic Conference Rome 1970, Edizioni Technoscienza, Rome, 1: 355-379.

Eaton, G. L., 1976, Dinoflagellate cysts from the Bracklesham Beds (Eocene) of the Isle Wight, southern England, Bull. Of the British Museum (Natural History) Geology, 26: 227-332.

Ediger, V. Ş., 1981a, Fossil fungal and algal bodies from Thrace Basin, Turkey. Palaeontographica Abt. B, 179: (1-4), 87-102.

Ediger, V. Ş., 1981b, Some Tertiary dinoflagellate cysts from Thrace Basin, Turkey, and their usage in paleoenvironmental analysis. Revista Espanola de Micropaleontologia, 13: (1), 89-103.

Ediger, V. Ş., 1982, Kuleli-Babaeski Sırtı (KB Trakya)'nın Paleo-ortamsal incelemesi ve Kuzey Trakya Havzası'nın hidrokarbon potansiyelinin değerlendirilmesinde yeni bir yaklaşım. TPAO Report, 427, 194 p., Ankara, (unpublished).

Ediger, V. Ş., 1984, Some practical and theoretical considerations about palynological processing. Program and Abstracts, American Association of Stratigraphic Palynologists, 17 th Annual Meeting, 6 (Abstract).

Ediger, V. Ş., 1986a, Paleopalynological biostratigraphy, organic matter deposition and basin analysis of the Triassic- (?)Jurassic Richmont rift basin, Virginia, USA. The Pennsylvania State University, The Graduate School, Department of Geoscience, Ph. D. Thesis, 548 p. (unpublished).

Ediger, V. Ş., 1986b, Sieving techniques in palynological sample processing with special reference to the MRA system. Micropaleontology, 32: (3), 256-270).

Ediger, V. Ş., 1990, Palynology of coal-bearing Miocene sedimentary rocks associated with volcanics of the Biga Peninsula (NW Turkey) and the effect of volcanism on vegetation. N. Jb. Geol. Palaont. Abh., 180: (2), 259-277.

Ediger, V. Ş. and Batı, Z., 1988a, Morphological examination of Pediastrum (Chlorophyta) from the Tertiary strata of the Thrace Basin (NW Turkey). Pollen et Spores, 30: (2), 203-222.

Ediger, V. Ş. and Batı, Z., 1988b, Kuzey Trakya Havzası (KB Türkiye) Tersiyer birimlerinde gözlenen Pediastrum yeşil alginin morfolojik incelemesi. TPAO Report, 1265, 40 p., Ankara, (unpublished).

Ediger, V. Ş. and Alişan, C., 1989, Tertiary fungal and algal palynomorph biostratigraphy of the Northern Thrace Basin, Turkey. Review of Palaeobotany and Palynology, 58: 139-161.

Ediger, V. Ş., Batı, Z., and Alişan, C., 1990, Paleopalynology and Paleoecology of *Calamus*-like Disulcate Pollen Grains. Review of Palaeobotany and Palynology, 62, 97-105.

Edwards, L. E., 1984, Miocene dinocysts from Deep Sea Drilling Project Leg 81, Rockall Plateau, eastern North Atlantic Ocean. *In* Roberts, D.G., Schnitker, D., et al., Init. Repts. DSDP, 81: Washington (U.S. Govt. Printing Office), 581–594.

Edwards, L. E., 1992, New semiquantitative (paleo)temperature estimates using dinoflagellate cysts, an example from the North Atlantic Ocean, In: (M.J. Head and J.H. Wrenn, Eds). Neogene and Quaternary dinoflagellate cysts and acritarchs. Am. Ass. Strat. Paly., Foundation, Dallas, 69-87.

Ehrenberg, C. G., 1831. Animalia evertebrata. In: Hemprich, P.C. and Ehrenberg, C.G., Symbolae physicae, Pars zoologica, 10 pl.

Ehrenberg, C. G., 1838, Über das Massenverhältniss der jetzt lebenden Kiesel-Infusorien und über ein neues Infusorien-Conglomerat als Polirschiefer von Jastraba in Ungarn, Königliche Akademie der Wissenschaften zu Berlin, Abhandlungen, 1836: 109-135.

Eisenack, A., 1938, Die Phosphorithknollen de Bernstein-formation als Uberliefer Tertiares Plankton, Schr. Phys.-ökon, Geo Königsbg., 70: (2), 181-188.

Eisenack, A., 1954, Microfossilien aus Phosphoriten des samläändischen Ünteroligozns und über die Einheitlichkeit der Hystrichosphaerideen, Palaeontographica, Abt. A, 105: 49-95.

Eisenack, A., 1958, Mikroplankton aus dem norddeutschen Apt nebst ernigen Bemerkungen über fossile Dinoflagellaten, Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 106: 383-422.

Eisenack, A., 1963a, *Cordosphaeridium* d.g. *ex Hystrichosphaeridium*, Hystrichosphaeridea, Neues Jahrbuch für geologie und Paläontologie, Abhandlungen, 118: 260-265.

Eisenack, A., 1963b, Zur *Membranilarnax*-Frage, Neues Jahrbuch für geologie und Paläontologie, Monatshefte: 98-103.

Eisenack, A. and Gocht, H., 1960, Neue Namen für einige Hystrichosphären der Bernsteinformation Ostpreussens, Neues Jahrbuch für geologie und Paläontologie, Monatshefte: 511-518.

Ellegaard, M., 2000. Variations in dinoflagellate cyst morphology under conditions of changing salinity during the last 2000 years. Review of Palaeobotany and Palynology 109: 65– 81.

Elnaif, S., 1969, Muş kuzey sahasının petrol etüdü raporu (1/25000 ölçekli Erzurum J47-d4, Muş K47-a1,a3,a4,d2, K46-a3,b3,b4, K48-a4,d1 paftaları), Maden Tetkik ve Arama Enstitüsü, Rapor No. 4296, Ankara, (unpublished).

Elsik, W. C., 1968. Palynology of a Paleocene Rockdale Lignite Milam County, Texas I, II Morphology and Taxonomy. Pollen et Spores, 2: (10), 263-314, 3: (10), 599-664.

Elsik, W. C., 1981. Fungal palynomorphs. In: Palynology Short Course Notes. Lousiana State Univ., October 4-6, 1981, 242 p.

Elsik, W. C., Ediger, V.Ş., and Batı, Z., 1990. Fossil fungal spore: *Anatolinites* gen.nov. Palynology, 14: 91-103.

Elsik, W. C., and Jansonius, J., 1974. New genera of Paleogene fungal spores, Can. J. Bot., 52 (5): 953-958.

Ercan , T., Fujutani, T., Madsuda, T., Natsu, K., Tokel, S., and Todahide, U. 1990, Doğu ve GD Anadolu Neojen-Kuvaterner volkanitlerine ilişkin yeni jeokimyasal, radyometrik ve izotopik verilerin yorumu, MTA Dergisi, 110: 143-174, Ankara.

Erdoğan, T., 1966, Erzurum-Karayazı Bölgesi İ47-$c_2$, $c_3$, İ48-$d_4$ paftalarına ait jeolojik rapor: MTA Rapor., 4193, Ankara, (unpublished).

Erdoğan, T., and Soytürk, N., 1974, Tekman Baseni jeolojisi ve hidrokarbon imkanları, TPAO Arama Rap. No: 870, Ankara, (unpublished).

Erentöz, C., 1954, Aras havzasının jeolojisi, T.J.K. Bülteni, 5: 1-54.

Erinç, S., 1953, Doğu Anadolu coğrafyası, İst. Üniv. Coğrafya Ens. Yayını, 15.

Ertuğ, K., Batı, Z. and İlleez, İ., 1995. Dinoflagellate biostratigraphy of Oligo-Miocene deposits in the Tekman Basin and hydrocarbon potential of the Tertiary units, East Anatolia, Turkey. Turkish Speaking Countries 2$^{nd}$ Earth Sciences and Mining Conference, Ankara, Proceedings, 109-125.

Evitt, W. R., 1963a, a discussion and proposals concerning fossil dinoflagellates, hystrichospheres, and acritarchs, I, Proceedings of the Nat. Ac. Of Sc., Washington, 49: 158-164.

Evitt, W. R., 1963b, Occurrence of fresh water alga *Pediastrum* in Cretaceous marine sediments, Americal Journal of Science, 261: 890-893.

Exon, N. F., Kennett, J. P., and Malone, M. J., 2001, Proceedings of the Ocean Drilling Program, Initial Reports, Volume 189.

Fensome, R. A., Taylor, F. J. R., Norris, G., Sarjeant, W. A. S., Wharton, D. I., and Williams, G. L., 1993, A classification of living and fossil dinoflagellates. Micropaleontology Special Publication, Number 7, 351 p.

Gedik, A. , 1985, Tekman (Erzurum) havzasının jeolojisi ve petrol olanakları, MTA Dergisi, 95/96: 44-48, Ankara.

Gerhard, J. J. and Alişan, C.,1986. Palynostratigraphy, Paleoecology and visual organic geochemistry Turgutbey-2, Deðirmencik-3 and Pancarköy-1, Thrace Basin Turkey. TPAO Report, 983, 33 p. (unpublished), Ankara.

Gerlach, E., 1961, Mikrofossilien aus dem Oligozään und Miozän Nordwestdeutschlands, unter besonderer Berücksichtigung der Hystrichosphären und Dinoflagellaten, Neues Jahrbuch für geologie und Paläontologie, Abhandlungen, 112: 143-228.

Germeraad J. J., Hopping, G. A., and Muller, J., 1968, Palynology of Tertiary sediments from tropical areas. Review of Paleobotany and Palynology, 6: 189-348.

Ginsburg, L., 1979, Les migration de mammiferes cannassiers (Credontes + Carnivores) et le probleme des relations intercontinentales entre l'Europe et l'Afrique au Miocene inferieur. Ann. Geol. Pays. Hellenique, tome hors serie, 1: 461-466.

Gocht, H., 1960, Die Gattung *Chiropteridium* n. Gen. (Hystrichosphaeridea) im deutschen Oligozän, Paläontologische Zeitschrift, 34: 221-232.

Gocht, H., 1969, Formengemeinschaften alttertären Mikroplanktons aus Bohrproben des Erdölfeldes Meckelfeld bei Hamburg, Palaeontographica, Abt. B, 126: 1-100.

Goodman, D. K. and Witmer, R. J., 1985, Archeophyle variation and paratabulation in the dinoflagellate *Diphyes colligerum* (Deflandre and Cookson, 1955) Cookson, 1965, Palynology, 9: 61-83.

Gorin, G., 1975, Etude Palynostratigraphique Des sédiments paléogénes de la Grande Limagne. Bull. B. R. G. M., sect. I, 3, 147-181.

Göncüoğlu, M. C., and Turhan, N., 1983, Geology of the Bitlis Metamorphic belt, in: Tekeli, O., and Göncüoğlu, M. C. (eds.), Geology of the Taurus belt da., International Symposium, 237-244.

Habib, D., 1972, Dinoflagellate biostratigraphy, Leg 11, Deep Sea Drilling Project, Initial Reports, D.S.D.P., 11: 367-425.

Habib, D., Moshkovitz, S., and Kramer, C., 1992, Dinoflagellate and calcareous nannofossil response to sea-level change in Cretaceous–Tertiary boundary sections. Geology, 20: 165– 168.

Haeckel, E., 1894, Systematische Phylogenie. Entwurf eines natürlichen Systems der Organismen auf Grund ihre Stammegeschichte, I. Systematische Phylogenie der Protisten und Pflanzen.Berlin, Reimer, XV: 400 p.

Hansen, J. M., 1977, Dinoflagellate stratigraphy and echinoid distribution in Upper Maastrichtian and Danian deposits from Denmark, Geological Soc. Of Denmark, Bull. 26, 1-26.

Haq, B. U., Premoli-Silva, I. and Lohmann, G. P., 1987, Calcareous plankton paleobiogeographic evidence for major climatic fluctiation in the Early Cenozoic Atlantic Ocean. J. Geophys. Res., 82: (27), 3861-3876.

Haq, B. U., Hardenbol, J. and Vail, P. R., 1988, Mesozoic and Cenozoic chronostratigraphy and eustatic cycles. In:  Wilgus, C. K., Kendall, C.G. St. C., Posamentier, H.W., Ross, C.A. and Van Wagoner, J.C. (eds), Sea-level changes: an integrated approach. SEPM Special Publication 42, 71-180.

Harland, R., 1983, Distribution maps of Recent dinoflagellate cysts in bottom sediments from the North Atlantic Ocean and adjacent seas. *Paleontology*, 26: 321-387.

Hart, G. F., Pasley, M. A., and Gregory, W. A., 1994, Particulate organic matter, maceral facies models and applications to sequence stratigraphy, In: Sedimentation of organic particals (Ed: Traverse, A.), Chambridge Univ. Press., 337-390.

Havur, E., 1972, Erzurum İ47-$c_1$, $c_2$, $d_2$, $d_3$ paftalarının jeolojisi ve petrol imkanları: MTA Rapor., 4851, (unpublished), Ankara.

He Chengquan, 1991, Late Cretaceous-Early Tertiary microphytoplankton from the Western Tarim Basin in southern Xinjiang, China, Nanjing Inst. Of Geol. And Paleontology, Academia Sinica, 19, 143-192.

Head, M. J., and Norris, G., 1989, Palynology and dinocyst stratigraphy of the Eocene and Oligocene in ODP Leg 105, Hole 647A, Labrador Sea, Proceedings of the Ocean Drilling Program, Scientific Results, 105: 515-550.

Head, M. J., Norris, G., and Mudie, P. J., 1989, New species of dinocystsand a new species of acritarch from the Upper Miocene and Lowermost Pliocene, ODP Leg 105, Site 646, Labrador Sea, In: Srivastava, S. P., Arthur, M., c-Clement, B. et al., Proceedings of the Ocean Drilling Program, Scientific Results, 105: 453-466.

Heilmann-Clausen, C., and Costa, L. I., 1989, Dinoflagellate zonation of the Uppermost Paleocene? to Lower Miocene in the Wursterheide Research Well, NW Germany. Geologisches Jahrbuch *A,* 111: 431-521.

Helenes, J., 1984, Morphological analysis of Mesozoic-Cenozoic *Cribroperidinium* (Dinophyceae), and taxonomic implications, Palynology, 8: 107-137.

Hochuli, P. A., 1978, Palynological investigations of the Oligocene and Early Miocene of the Central and Western Paratethys, Institut für Palaontologie, Universitat Wien, Number 4, 1-132.

Hoorn, C., 1993, Marine incursions and the influence of Andean tectonics on the Miocene depositional history of northwestern Amazonia: results of a palynostratigraphic study. Palaeogeography, Palaeoclimatology, Palaeoecology, 105: 267-309.

Horowitz, A., 1992, Palynology of Arid Lands, Elsevier, Amsterdam, 546 p.

İbrahim, A. C., 1933, Sporenformen des Aegirhorizontes des Ruhrreviers, Diss. TH, Berlin.

"ICBN", 1983, Voss, E.G. et al. (Eds.). International Code of Botanical Nomenclature adopted by the 13th Int. Bot. Congr., Sydney, August, 1981. Bohn, Scheltema and Holkema, Utrecht, 1-472.

İlker, S., 1966, Erzurum Bölgesinde Erzurum i47c1, c4, d2, d3 paftalarının detay petrol etüdü hakkında rapor, MTA Rap. 4236, (unpublished), Ankara.

İlker, S., 1967, Erzurum-Muş Bölgesinde Karaköse j48a4, ve j48d1 paftalarının 1:25000 ölçekli detay petrol etüdü hakkında rapor, MTA Rap. 4177, (unpublished), Ankara.

Innocenti, F., Manetti, P., Mazzuoli, R., Pasquare, G., Radicati, F., and Villari, L., 1982a, Anatolia and NW Iran, In: Andesites (Ed:Thorpe, R. S.) Joh Wiley and Sons, 327-349.

Innocenti, F., Mazzuoli, R., Pasquare, G., Radicati, F., and Villari, L., 1982b, Tertiary and Quaternary volcanism of the Erzurum-Kars area (Eastern Turkey), Geochronological data and geodynamic evolution, Jour. of Volcan. And Geoth. Res., 13: 223-240.

İlhan, E., 1969, Çayırlı-Tercan-Erzurum-Pasinler havzaları ve çevresinin jeolojik durumu hakkında ilkel rapor, TPAO Arama Grubu Report No 470, Ankara.

İlker, S., 1966, Erzurum Bölgesinde Erzurum i47c1, c4, d2, d3 paftalarının detay petrol etüdü hakkında rapor, MTA Rap. 4236, Ankara, (unpublished).

Ioakim, C., 1979, Etude comparative des Dinoflagelles du Tertiaire inferieure de la Mar du Labrador et de la Mer du Nord, Universite Pierre et Marie Curie, Unpublished thesis, Paris, 203 p.

Islam, M. A., 1982, Archeophyle structure in the fossil dinoflagellate *Phthanoperidinium*, Rev. Of Paleobot. And Palynol., 36: 305-316.

Islam, M. A.,1983, Dinoflagellate cysts from the Eocene cliff sections of the Isle of Sheppey, southeast England, Revue de micropal., 25: 231-250.

Islam, M. A., 1984, A study of Early Eocene paleoenvironments in the Isle of Sheppey as determined from microplankton assemblage composition, Tertiary Research, 6: 11-21.

Jaramillo, C. A., 1995, Dinoflagellate cyst biostratigraphy and palynofacies of the Late Eocene-Early Oligocene in southern Mississippi and Alabama, U.S. Gulf Coast, M.S. Thesis, University of Missouri, Rolla, 97 p. (unpublished).

Jaramillo, C. A., and Oboh-Ikuenobe, F. E., 2001, sequence stratigraphy of the Pachuta-Marianna Interval (Upper Eocene-Lower Oligocene) in the U.S. Gulf Coast, In: Goodman, D. K., and Clarke, R. T. (eds.), Proceedings of the IX. International Palynological Congrees, Houston, Texas, U.S.A., 1996; American Association of Stratigraphic Palynologists Foundation, 263-276.

Jenkins, D., 1966, Planktonic foraminifera from the type Aquitanian-Burdigalian of France, Cushm. Found. Foram. Res., Contr. 17: 1-15.

Jones, R. W. and Simmons, M. D., 1996. A review of the stratigraphy of Eastern Paratethys (Oligocene-Holocene), Bull. Nat. Hist. Mus. Lond. (Geol.), 52: (1), 25-49.

Ke and Shi, 1978, Comittee name for the five authors who wrote the text cited in these references as Sung et al. (1978). The acronym was needed at the time to satisfy the restrictions in China on individual scientific recognition.

Kedves, M., 1960, Ėtudes palynologiques dans le bassin de Dorog. I, Pollen et Spores, 2 (1): 89-118.

Kedves, M., 1961, Ėtudes palynologiques dans le bassin de Dorog.II, Pollen et Spores, 3 (1): 101-153.

Kemp, E. M. and Harris, W. K., 1977. The palynology of Early Tertiary sediments, Ninetyeast Ridge, Indean Ocean. Spec. Papers in Palaeontology, 19: 1-70.

Keskin, M., Pearce, J. A., and Mitchel, J. G., 1998, Volcano-stratigraphy and geochemsitry of collision related volcanism on the Erzurum-Kars Plateau, NE Turkey, Jour. of Volc. and Geotherm. Res., 85: 355-404.

Ketin, İ., 1966, Anadolu’nun tektonik birlikleri, MTA Dergisi, 66: 23-24, Ankara.

Kıraner, F., 1957, Van Gölü Bölgesi, Muş kuzeyi petrol jeolojisi istikşaf etüdü, M.T.A. Rep., no. 2558 (unpublished).

Klement, K. W., 1960, Dinoflagellaten und Hystrichosphaerideen aus dem untern und mittleren Malm Sudwestdeutschlands, Palaeontographica, Abt. A, 114, 1-104.

Klump, B., 1953, Beitrag zur Kenntnis der Mikrofossilien des mittleren und oberen Eozän, Palaeontographica, Abt. A, 103, 377-406.

Koçyiğit, A., 1991, Changing stress orientation in progressive intercontinental deformation as indicated by the Neotectonics of the Ankara Region (NW Central Anatolia), Bull. Turk. Assoc. Petrol. Geol., 31: (1), 48-55.

Köthe, A., 1990. Paleogene dinoflagellates from Northwest Germany-Biostratigraphy and Paleoenvironment. Geologisches Jahrbuch A, 118: 3-111.

Krutzsch, W., 1959, Micropaläontologie (sporenpaläontologische) Unterschungen in der Braunkohle des Geiseltasles. I. Die Sporen und die Sporenartigen sowie die ehemals zu Sporites gestellten Formeinheiten der Sporae dispersae der mitteeozanen Braunkohle des mittleren Geiseltales (Tagebau Neumark-West i. W. S.), unter Berücksichtigung und Revision weiterer sporenformen aus der bisherigen Literatur, Geologie/Beih., 21/22, Berlin.

Krutzsch, W., 1962, Stratigraphisch bzw. Botanisch wihtige neue Sporen und Pollenformen aus dem deutschen Tertiär, Geologie, 11 (3): 265-307.

Krutzsch, W., 1963, Lieferg. 3., Sphagnaceoide und selaginellaceoide Sporenformen.

Krutzsch, W., 1970, Lieferung VII: Monoporate, monocolpate, longicolpate, und ephedroide (polyplicate) Pollenformen, 175 s.

Krutzsch, W. and Vanhoorne, R., 1977. Die pollenflora von Epinois und Loksbergen in Belgien. Palaeontographica Abt. B, 163: (1-4), 1-110.

Kurtman, F., and Akkuş, M. F., 1971, Doğu Anadolu'daki Ara Basenler ve Petrol Olanakları, 8. Dünya Petrol Kongresi (13-19 Haziran, 1971), Moskova.

Lahn, E., 1945, Anadolu'da Neojen ve 4. zaman volkanizması, Türk Coğrafya Dergisi, III: (VII-VIII), 37-49.

Lenoir, E. A., and Hart, G. F., 1988, Palynofacies of some Miocene sands from the Gulf of Mexico, offshore Louisiana, U.S.A., Palynology, 12: 151-165.

Lentin, J. K., and Williams, G. L., 1976, A monograph of fossil peridinioid dinoflagellate cysts, Bedford Inst. Of Oceanography, Report Series BI-R-75-16, 237 p.

Lentin, J. K., and Williams, G. L., 1993, Fossil Dinoflagellates: Index to Genera and Species 1993 Edition, Am. Assoc. Stratigr. Palynol. Contrib. Ser., 28: 855 p.

Lister, J. K., and Batten, D. J., 1988, Stratigraphic and paleoenvironmental distribution of Early Cretaceous dinoflagellate cysts in the Hurlands Farm Borehole, West Sussex, England, Palaeontographica, Abteilung B, 210: 8-89.

Lucas-Clark, J., 1987, Morphology of species of *Litosphaeridium* (Cretaceous, Dinophyceae), Palynology, 8: 165-193.

Maier, D., 1959, Planktonuntersuchungen in tertiären und quartären marinen Sedimenten. Ein Beitrag zur Systematik, Stratigraphie und Ökologie der Coccolithophorideen, Dinoflagellaten und Hystrichosphaerideen vom Oligozän bis zum Pleistozän, Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 107:278-340.

Mantell, G. A., 1850, A pictorial atlas of fossil remains, consisting of coloured illustrations selected from Parkinson's "Organic remains of a former world", and Artis's "Antediluvian phytology", Henry G. Bohn, London, xii+207 p.

Mantelll, G. A., 1854, The medals of Creation; or, First Lessons in Geology and the study of organic remains, Second edition, henry G. Bohn, london, 2 vols., 930 p.

Manum, S. B., 1976, Dinocysts in Tertiary Norwegian–Greenland Sea sediments (deep sea drilling project leg 38), with observations on palynomorphs and palynodebris in relation to environment. Deep Sea Drilling Project, Initial Reports, 38: 897-919.

Manum, S. B., Boulter, M. C., Gunnarsdottir, H., Ragnes, K., and Scholze, A., 1989, Eocene to Miocene palynology of the Norwegian Sea (ODP leg 104). In: Eldholm, O., Thiede, J., Taylor, E. (Eds.), Proceedings of the Ocean Drilling Program. Scientific Results, 104: 611-661.

Mao, S., Huang, C., and Lei, Z., 2002, Late Oligocene to early Miocene dinoflagellate cysts from the Kuohsing area, central Taiwan, Review of Palaeobotany and Palynology, 122: 77-98.

Marret, F., and Zonneveld, K. A. F., 2003, Atlas of organic-walled dinoflagellate cyst distribution, Review of Paleobotany and Palynology, 125: 1-200.

Martini, E., 1971, Standart Tertiary and Quaternary calcareous nannoplankton zonation. In: Farinacci, A. (ed), Proceedings of the second planktonic conference, Roma, 739-785.

Masran, Th. C., and Pocock, S. A. J., 1981, The classification of plant derived particulate organic matter in sedimentary rocks, In: Brooks, J. (Ed.), Organic Maturation Studies and Fossil Fuel Exploration, Academic Press, London, 145-147.

Matsuoka, 1983, Late Cenozoic dinoflagellates and acritarchs in the Niigata District, central Japan, Palaeontographica, Abt. B, v. 187: 89-154.

May, F. E., 1980, Dinoflagellate cysts of the Gymnodiniaceae, Peridiniaceae, and Gonyaulacaceae from the Upper Cretaceous Monmouth Group, Atlantic Highlands, New Jersey, Palaeontographica, Abt. B, 172: 10-116.

Meyer, B. L., 1956, Mikroflorishtische Untersuchungen an jungtertiären Braunkohlen im östlichen Bayern, Geol. Bavarica, 25: 100-128.

Mc Kenzie, D. P., 1976, The East Anatolian Fault, a major structure in eastern Turkey: Earth and Planetory Science Letters, 29: 189-193.

Miller, K. G., Aubry, M. P., Khan, M. J., Melillo, A. J., Kent, D. V., and Berggren, W. A., 1985, Oligocene-Miocene biostratigraphy, magnetostratigraphy and isotopic stratigraphy of the western North Atlantic. Geology, 13: 257-261.

Miller, K. G., Fairbanks, R. G. and Mountain, G. S., 1987. Tertiary oxygen isotope synthesis, sea level history, and continental margin erosion. Paleoceanography, 2: (1), 1-19.

Miller, K. G., Wright, J. D., and Fairbanks, R. G., 1991. Unlocking the Ice House: Oligocene-Miocene oxygen isotopes, eustasy and margin erosion. Journal of Geophysical Research, 96: 6829–6848.

Miller, K. G., Mountain, G. S., Browning, J. V., Kominz, M., Sugerman, P. J., Christie-Blick, N., Katz, M. E., and Wright, J. D., 1998. Cenozoic global sea level, sequences, and the New Jersey transect: results from coastal plain and continental slope drilling. Reviews of Geophysics, 36: 569– 601.

Montanari, A., Bice, D. M., Capo, R., Coccioni, R., Deino, A., DePaolo, D. J., Emmanuel, L., Monechi, S., Renard, M., and Zevenboom, D., 1997. Integrated stratigraphy of the Chattian to mid-Burdigalian pelagic sequence of the Contessa Valley (Gubbio, Italy). In Montanari, A., Odin, G.S. and Coccioni, R. (eds.) Miocene Stratigraphy: An integrated Approach. Developments in Palaeontology and Stratigraphy, Amsterdam, Elsevier, 15: 249-277

Monteil, E., 1993, Dinoflagellate cyst biozonation of the Tithonian and Berriasian of southeast France: correlation with the sequence stratigraphy, Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine, 17: 249-275.

Morgenroth, P., 1966, Mikrofossilien und Konkretionen des nordwesteuropäischen Untereozäns, Palaeontographica, Abt. B, 119: 1-53.

Morgenroth, P., 1968, Zur Kennthis der Dinoflagellaten und Hystrichosphaeridien des Danien, Geol. Jahrbuch, 86: 533-578.

Morzadec-Kerfourn, M. T., 1983. Intérêt des kystes de dinoflagellés pour l’etablissement de reconstition paléogéographique: example du Golfe de Gabés (Tunisie). Cah. Micropaléontol. 1983-1984: 15-22.

Mosbrugger V., and Utescher, T., 1997, The coexistence approach – a method for quantitative reconstructions of Tertiary terrestrial paleoclimate data using plant fossils. Palaeogeography, Palaeoclimatology, Palaeoecology, 134: 61-86.

MTA, 2002, 1/500.000 series of geological map of Turkey, Erzurum Quadrangle, compiled by N. Tarhan.

Mudie, P. J., 1992, Circum-Arctic Quaternary and Neogene Marine Palynofloras: Paleoecology and statistical analysis. In: (M.J. Head and J.H. Wrenn EDS.). Neogene and Quaternary dinoflagellate cysts and acritarchs. (M.J. Head and J.H. Wrenn, Eds). Am. Ass. Strat. Paly., Foundation, Dallas, 347-390.

Mudie, P. J., de Vernal, A., and Head, M. J., 1990, Neogene and recent palynostratigraphy of circum-arctic basins: results of ODP Leg 104. Norvegian Sea, Leg 105, Baffin Bay and DSDP Site 611, Irminger Sea. In: Geol. Hist. Of the Polar Oceans, Arctic versus Antarctic (U. Bleil and J. Thiede Eds.). NATO ASI ser. C, 308; Kluwer Acad. Publ. Dordrecht, Netherlands, 609-628.

Muller, J., 1981, Fossil pollen records of extant angiosperms. The Botanical Review, 47: 1-142.

Nagy, E., 1969, Palynological investigation of the Miocene in the Mecsek Mountains, May. All. Földt. Intez., 52 (2): 235-649.

Nakoman, E., 1964, Etude palynologique de quelques échantillons de lignite provenant du Bassin de Thrace (Turquie). Ann. Soc. Geol. du Nord. T., LXXIV: 289-303.

Nakoman, E., 1965, Description d'un nouveau genre de forme: *Corsinipolenites*, Ann. Soc. Geol. du Nord. T., LXXXV: 155-158.

Nakoman, E., 1966, Contribution a l'étude palynologique des formations tertiares du Bassin de Thrace. 1. -Etude qualitative. Ann. Soc. Geol. du Nord. T., LXXXVI: 65-107.

Nakoman, E., 1967, Etude palynologique des formations Tertiaires du bassin de Thrace. Lille Univ., Ph.D. Thesis, (unpublished).

Nakoman, E., 1968, Karlıova-Halifan linyitlerinin sporo-pollinik etüdleri, TJK Bült., 11: (1-2), 68-90.

Naumova, S. N., 1937, Spores and Pollen from the USSR, Tr. Sessii meshdunar geol., 17 (1): 353-364.

Neale, J. W., and Sarjeant, W. A. S., 1962, Microplankton from the Speeton Clay of Yorkshire, Geological Magazine, 99: 439-458.

Nicora, A., 1971, Biostratigrafia del limite Oligocene-Miocene nelle Langhe (Piemonte), Riv. Ital. Paleont. Strat., 77: 2, 154-262.

Örçen, S., 2001. Türkiye Miogypsinidae türleri ve Doğu Akdeniz'in Erken-Orta Miyosen denizel bağlantıları. Hacettepe Üniversitesi Yerbilimleri Uygulama ve Araştırma Merkezi Bülteni, 23: 159-166.

Özcan, A., 1967, Erzurum-Hınıs Bölgesinde Erzurum j47a3, a4 paftalarının detay petrol etüdü, MTA Rap. No: 4128, Ankara, (unpublished).

Özyeğin, G., 1968, Muş bölgesi 1:25000 ölçekli Erzurum j47d3, Muş j47a2 paftalarının detay petrol etüdü hakkında rapor, MTA Rap. No: 4129, Ankara, (unpublished).

Pascher, A., 1914. Über Flagellaten und Algen. Deutsche Botanische Gesellschaft, Berichte, 32: 136-160.

Pasquare, G., 1965, Erzurum G'nde Tercan ile Tekman arasındaki bölgenin Tersiyer volkanizması, MTA, (unpublished).

Pearce, J. A., Benderj, F., de Long, S. E., Kidd, W. S. F., Low, P. J., Güner, Y., Şaroğlu, F., Yılmaz, Y., Moorbath, S., and Mitchel, J. G., 1990, Genesis of collision volcanism in Eastern Anatolia, Turkey, Jour. Of Volc. Geotherm. Res., 44: 189-229.

Pekar, S., and Miller, K. G., 1996 New Jersey Oligocene 'icehouse' sequences (ODP Leg 150X) correlated with global delta$^{18}$O and Exxon eustatic records. Geology, 24: 567-570.

Perinçek, D., 1980, Arabistan kıtası kuzeyindeki tektonik evrimin kıta üzerinde çökelen istifteki etkileri, Türkiye 5. Petrol Kongresi bildirileri, 77-93.

Pflanz, G., 1956, Das Alter der Braunkohlen des Meißners, der Flöze 2 und 3 des Hirschbergs und eines benachbarten Kohlenlagers bei Laudenbach, Notizbl. Hess. L. Amt. Bodenforsch, 84: 232-244.

Pierce, R. L., 1961, Lower Upper Cretaceous Plant Microfossils from Minnesota, Univ. Of Minn. Geol. Surv. Bull., 42.

Potonié, R., 1931a. Pollenformen der miocänen Braunkohle (2 Mitteilung), Sits.-Ber. Ges. Naturf. Fr. Berlin, 1-3: 24-29.

Potonié, R., 1931b, Zur Mikroskopie der Braunkohlen, Tertiäre Blüntenstaubformen Braunkohle 30 (16): 325-333.

Potonié, R., 1931c, Pollenformen aus tertiäres Braunkohlen, Jb. Preuß. Geol. L.-Amt, 52:1-7.

Potonié, R., 1931d, Pollenformen der mioznen Braunkohle, 2. Mitt. Sitzber. Naturf. Fr. Berln, Jg. 1-3, 24-27.

Potonié, R., 1934, Zur Mikrobotanik des eozänen Humodils des Geiseltales, Arb. Inst. Paläobot. Petrogr. Brennsteine, Preubß. Geol. L.-Amt, 4: 25-125.

Potonié, R., 1951, Revision stratigraphisch wichtiger Sporomorphen des mitteleuropaischen Tertiärs, Palaeontographica Bd 91 B, 131-151.

Potonié, R., 1956, Synopsis der Gattungen der Sporae dispersae. Teil I: Sporites, Beihefte zum Geologischen Jahrbuch, 23, Hannover.

Potonié, R., 1958a, Synopsisder Gattungen der Sporae dispersae. II. Teil: Sporites (Nachträge), Saccites, Aletes, Praecolpates, Polyplicates, Monocolpates, Beihefte zum Geologischen Jahrbuch, 31, Hannover.

Potonié, R., 1958b, The taxonomy of fossil plants (inclusive Sporae dispersae) in the International Code of Botanical Nomenclature, Paleobotanist, 7: 37-42, Lucknow.

Potonié, R., 1960a, Sporologie der eozänen Kohle von Kalewa in Burma, Senckenbergiana Lethaea, 41: 451-481.

Potonié, R., 1960b, Synopsis der Gattungen der Sporae dispersae. V. Teil: Nachträge zu allen Gruppen (Turmae), Beih. Geol. Jb., 87: 222p.

Potonié, R., and Venitz, H., 1934, Zur Mikrobotanik des miozänen Humodils der niederrheinischen Bucht, Arb. Inst. Paläobot. Petrogr. Brennsteine, 5: 5-58.

Potonié, R., and Gelletich, J., 1933, Über die Pteridophytensporeneiner aozänen Braunkohle aus Dorog, Ungarn, Sitz. Ber. Ges. Naturforsch. Freunde, 33: 517-528.

Potonié, R., and Kremp, G., 1954, Die Gattungen der paläzoichen Sporae dispersae und ihre Stratigraphie, Geol. Jb., 69: 111-194.

Powell, A. J. , 1986a, Latest Paleogene and earliest Neogene dinoflagellate cysts from the Lemme Section, Northwest Italy. *In*: Wrenn, J.H., Duffield, S.L. and Stein, J.A. (eds.), Papers from the First Symposium on Neogene Dinoflagellate Cyst Biostratigraphy. American Association of Stratigraphic Palynologists Contributions Series, 17: 83–104.

Powell, A. J. , 1986b, A dinoflagellate cyst biozonation for the Late Oligocene to Middle Miocene succession of the Langhe Region, Northwest Italy. *In*: Wrenn, J.H., Duffield, S.L. and Stein, J.A. (eds.), Papers from the First Symposium on Neogene Dinoflagellate Cyst Biostratigraphy. American Association of Stratigraphic Palynologists Contributions Series, 17: 105–128.

Powell, A. J., 1992, Making the most of microfossils, Geoscientists, 2: (1), 12-16.

Powell, A. J., Dodge, J. D., and Lewis, J., 1990, Late Neogene to Pleistocene palynological facies of the Perunian continental margin upwelling, Leg 112, In: Suess E., Von Huene, R., et al., Proceedings of the Ocean Drilling Program, Scientific Results, 112: 297-321.

Powell, A. J., Dodge, J. D., and Lewis, J., 1992, The palynological expression of post-Paleogene upwelling: a review; In: Summerhayes, C. P., Prell, W. L., and Emeis, K. C., (eds.). Upwelling systems: evolution since the Early Miocene; Geological Society, Special Publication, 64: 215-226.

Powell, A. J., Brinkhuis, H., and Bujak, J. P., 1996, Upper Paleocene–Lower Eocene dinoflagellate cyst sequence biostratigraphy of southeast England. In: Knox, R.W.O.B., Corfield, R.M., Dunay, R.E. (Eds.), Correlation of the Early Paleogene in Northwest Europe. Geological Society Special Publication, 101: 145-183.

Pross, J., 2001, Dinoflagellate cyst biogeography and biostratigraphy as a tool for paleooceanographic reconstructions: An example from the Oligocene of western and nortwestern Europe, N. Jb. Geol. Paläont. Abh., 219(½): 207-219.

Pross, J., and Schmiedl, G., 2002, Early Oligocene dinoflagellate cysts from the Upper Rhine Graben (SW Germany): paleoenvironmental and paleoclimatic implications. Marine Micropaleontology, 45: 1-24.

Prothero, D. R., Iwany, L. C., and Nesbitt, E. A., 2003, From Greenhose to Icehouse, The Marine Eocene-Oligocene Transition, Columbia University Press, New York, 541 p.

Rathur, A. Q., 1965, Pasinler-Horasan (Erzurum) sahasına ait genel jeolojik rapor (H47-$c_3$, c4; H48-$c_4$, $d_3$, $d_4$; İ47-$b_1$, $d_2$, $b_3$, $b_4$; İ48-$a_1$, $a_2$, $b_1$), MTA Rap., 73, Ankara, (unpublished).

Rathur, A. Q., 1966, Pasinler- Horasan (Erzurum) sahasına ait genel jeolojik rapor, MTA Rap. No: 4168, Ankara, (unpublished).

Reid, P. C., 1974, Gonyaulacacean dinoflagellate cysts from the British Isles. Nova Hedwigia, 25: 579–637.

Richards, K., 2001, Palynology and sequence stratigraphy of Early Miocene-Late Oligocene deltaics in the Sihapas Group, Central Sumatra, Indonesia, In: Goodman, D. K., and Clarke, R. T. (eds.), Proceedings of the IX. International Palynological Congrees, Houston, Texas, U.S.A., 1996; American Association of Stratigraphic Palynologists Foundation, 253-262.

Rossignol, M., 1962, Analyse pollinique de sédiments marins Quaternaires en Israël. I: Sédiments Récents, Pollen et Spores, 3: 303-324.

Rossignol, M., 1964, Hystrichosphères du Quaternaire en Méditerranée orientale, dans les sédiments Plistocènes et les boues marines actuelles, Rev. de micropal., 7: 83-99.

Rouse, G. E., 1959, Upper Jurassic plant microfossils. Micropaleontology, 3: (5), 303-324.

Rouse, G. E., 1962, Plant microfossils from the Burrard Formation of Western British Columbia. Micropaleontology, 2: (8), 187-218.

Rudolph, K., 1935, Mikrofloristische Untersuchungen Tertiärer Ablagerungen im nördlichen Böhmen, Beih. Bot. Zbl., 54: 244-328, Paris.

Sakınç, M., 1982, Mollababa-Uruman (Muş ili) yöresinin jeolojisi, biostratigrafisi ve paleontolojisi, İstanbul Yerbilimleri Dergisi, Aralık, No. 3: (1-2), İstanbul.

Sancay, R. H., 2000, Palynology and Paleoecology of Late Eocene Manning Formation (Jackson Group) of the Lake Somerville Spillway of east – central Texas. MS Thesis, Texas A&M University, 189 p.

Sancay, R. H., Kirici, S., Alaygut, D., Çanga, B., Tekin, T., and Aköz, Ö., 2003, Muş-2 Kuyusu Litostratigrafik, Biyostratigrafik ve Jeokimyasal Değerlendirme Raporu. TPAO Araştırma Merkezi Raporu, 2831.

Sancay, R. H., Batı, Z., Işık, U., Kirici, S., and Akça, N., (submitted), Multidiciplinary biostratigraphy of Oligo-Miocene sediments in Muş Basin, Eastern Anatolia, Turkey, Turkish Journal of Earth Sciences.

Sancay, R. H., Batı, Z., Edwards, L. E., and Ertuğ, I. K., (in prep.), *Pentadinium galileoi* Sancay et al., sp. nov., a new dinoflagellate from Oligo-Miocene sediments of Eastern Anatolia, Turkey, Micropaleontology.

Sarjeant, W. A. S., 1970, The genus *Spiniferites* Mantell, 1850 (Dinophyceae), Grana, 10: 74-78.

Sarjeant, W. A. S., 1981, A rsetudy of some dinoflagellate cyst holotypes in the University of Kiel Collections. II. The Eocene holotypes of Barbara Klumpp (1953); with a revision of the genus *Cordosphaeridium* Eisenack, 1963, Meyniana, 33: 97-132.

Sarjeant, W. A. S., 1982, The dinoflagellate cysts of the Gonyaulacysta group: a morphological and taxonomic study, AASP, Contribution Series, 9, 80p.

Sarjeant, W. A. S., 1983, A restudy of some dinoflagellate cyst holotypes in the University of Kiel Collections. IV. The Oligocene and Miocene holotypes of Dorothea Maier (1959), Meyniana, 35: 85-137.

Sarjeant, W. A. S., 1984, Restudy of some dinoflagellate cysts from the Oligocene and Miocene of Germany, Journal of Micropaleontology, 3 (2): 73-94.

Sarjeant, W. A. S., 1985, The German Aptian dinoflagellate cysts of Eisenack (1958): a restudy, Rev. of Paleobot. And Palynol., 45: 47-106.

Savcı, H., Yöndem, F., Göncüoğlu, C., and Turhan, N., 1979, Bitlis-Mutki dolayının jeotektonik evrimi, 33. Türkiye jeoloji bilimsel ve teknik kurultayı bildiri özetleri, 113-114.

Schwan, W., 1980, Geodynamic peaks in alpinotype orogenesis and changes in ocean-floor spreading during Late Jurassic-Late Tertiary time. Amer. Ass. Petrol. Geol. Bull. 64: 359-373.

Seaward, A. C., 1914, Antarctic fossil plants. Natur. Hist. Rep. Brit. Antarct. Exped. 1910 Geol., 1 (1): 1-49.

Seymen, I., and Aydın, A., 1972, Bingöl deprem fayı ve bunun Kuzey Anadolu fay zonu ile ilişkisi, MTA Bült., 79: 1-8.

Sheffy, M. V., and Dilcher, D. L., 1971, Morphology and taxonomy of fungal spores, Palaeontographica, Abt. B, 133 (1-3): 34-51.

Sirel, E., 2003, Foraminiferal description and biostratigraphy of the Bartonian, Priabonian and Oligocene shallow water sediments of the southern and eastern Turkey, Revue de Paléobiology, 22: (1), 269-339 p.

Sluijs, A., Brinkhuis, H., Stickley, C. E., Warnaar, J., Williams, G. L., and Fuller, M., 2003, Dinoflagellate cysts from the Eocene/Oligocene transition in the Southern Ocean; results from ODP Leg 189. In: Exon, N.F., Kennett, J.P., Malone, M.J. (Eds.), Proceedings of the Ocean Drilling Program. Scientific Results vol. 189, pp. 1–42. Available from World Wide Web: http://www-odp.tamu.edu/publications/189_SR/104/104.htm. [Cited2003-10-22]. College Station, TX.

Sluijs, A., Pross, J., and Brinkhuis, H., 2005, From greenhouse to icehouse; organic-walled dinoflagellate cysts as paleoenvironmental indicators in the Paleogene, Earth Science Reviews, 68: 281-315.

Soytürk, N., 1973, Murat Baseni jeolojisi ve hidrokarbon olanakları, TPAO Arama Gr. Rap No: 791, Ankara, (unpublished).

Stancliffe, R. P. W., and Sarjeant, W. A. S., 1990, The complex chorate dinoflagellate cysts of the Bathonian to Oxfordian (Jurassic) of Skye, Scotland and southern Dorset, England, Journal of Micropaleontology, 10 (2): 185-202.

Steninger, F. F. and Rogl, F., 1984, Paleogeography and palinspastic reconstruction of the Neogene of the Mediterranean and Paratethys. In: J.E. Dixon and A.H.F. Robertson (Eds.), The geological evolution of the eastern Mediterranean. Geol. Soc. Amer. Spec. Publ., 17: 659-668.

Steininger, F. F., Aubry, M. P., Bergreen, W. A., Biolzi, M., Borsetti, A. M., Cartlidge, J. E., Cati F., Corfield, R., Gelati, R., Iaccarino, S., Napoleone, C., Ottner, F., Rogl, F., Roetzel, R., Spezzaferri, S., Tateo, F., Villa, G., and Zevenboom, D., 1997, The Global Stratotype Section and Point (GSSP) for the base of the Neogene, Episodes, 20: (1), 23-28.

Stover, L. E., 1973, Paleocene and Eocene species of *Deflandrea* (Dinophyceae) in Vicrorian Coastal and offshore basins, Australia, Spec. Publs. Geol. Soc. Aust., 4: 167-188.

Stover, L. E., 1977, Oligocene and early Miocene dinoflagellates from Atlantic corehole 5/5b, Blake Plateau. In: Elsik, W.C. (Ed.), Contributions of Stratigraphic Palynology. 1: Cenozoic Palynology. Contributions Series - American Association of Stratigraphic Palynologists, 5A: 66– 89.

Stover, L. E. and Evitt, W. R., 1978, Analyses of pre-Pleistocene organic-walled dinoflagellates, Stanford Univ. Publications, Geological Sciences, 15, 300 p.

Stover, L. E., and Hardenbol, J., 1994, Dinoflagellates and depositional sequences in the lower Oligocene (Rupelian) Boom Clay Formation, Belgium, Bulletin de la Société belge de Géologie, 102: (1-2), 5-77.

Stover, L. E., and Williams, G. L., 1982, Dinoflagellates, Third North American Paleontological Convention, Proceedings, 2: 525-533.

Stover, L. E., Brinkhuis, H., Damanssa, S. P., de Verteuil, L., Helby, R. J., Monteil, E., Patridge, A. D., Powell, A. J., Riding, J. B. , Smelror, M., and Williams, G. L., 1996, Mesozoic-Tertiary dinoflagellates, acritarchs and prasinophytes; In: Jansonius, J. and McGregor, D. C., (ed.), Palynology: principles and applications, American Association of Stratigraphic Palynologists Foundation, 2: 641-750.

Strauss, C. and Lund, J. J., 1992, A middle Miocene dinoflagellate cyst microflora from Papendorf near Hamburg, Germany. Mitteilungen Geologisch-Paläontologischen Institut der Universität Hamburg, 73: 159-189.

Sung, Z. C., Tsao, L., Zhou, H. Y., Guan, Z. T., and Wang, K. D., (cited as the acronym Ke and Shi), 1978, Early Tertiary spores and pollen grains from the coastal region of the Bohai, Academy of Petroleum Exploration and and Development, Planning Resources Ministry of Petroleum and Chemical Industry, Nanjinj Institute of Geology and Paleontology, and Chinese Academy of Science, Kexue Chubanshe, Peking, 177 p.

Sungurlu, O., 1967, Erzurum-Hınıs Bölgesi'nde 1/25000 ölçekli Erzurum J46-b3,b4 paftalarına ait jeolojik petrol etüdü raporu, Maden Tetkik ve Arama Enstitüsü, Rapor No. 4176, (unpublished).

Sungurlu, O., 1971, İ45a, İ45b, İ46a, İ46b, İ47a, İ47b, paftalarına ait 1/50000 lik jeoloji haritaları, TPAO, Ankara, (unpublished).

Sungurlu, O., 1972, Aşkale-Horasan-Olur arasının korelasyon tablosu, Harita No: 6255, TPAO, Ankara, (unpublished).

Şahintürk, Ö. 1992, Tercan-Çayırlı Basenleri'nin jeolojisi ve hidrokarbon olanakları, TPAO Arama Grubu Rap. No. 3070, Ankara, (unpublished).

Şahintürk, Ö., and Kasar, S., 1979, Tekman-Pasinler-Kağızman-Tuzluca Basenlerinin stratigrafik ve tektonik analizleri ile hidrokarbon olanakları, TPAO Arama Grubu Rapor No. 1346, Ankara, (unpublished).

Şahintürk, Ö., and Kasar, S., 1980, Tercan-Çayırlı Baseninin jeolojisi ve hidrokarbon olanakları, TPAO Arama Grubu Rapor No. 1446, Ankara, (unpublished).

Şahintürk, Ö., and Erdem, K., 2002, Muş Baseni hidrokarbon potansiyeli hakkında rapor, TPAO Arama Grubu Rapor No. 4325, Ankara, (unpublished).

Şahintürk, Ö., Şaroğlu, F., and Çaptuğ, A., 1998a, Erzurum-Aşkale-Pasinler-Horasan Baseni i45, i46, i47, i48, n45, n46, n47, n48 paftaları 1/100000 lik yayınlanmamış jeoloji haritaları, Ankara, (unpublished).

Şahintürk, Ö., Şaroğlu, F., and Çaptuğ, A., 1998b, Doğu Anadolu (Erzurum-Kars-D.Beyazıt-Ağrı) jeoloji gezisi el kitabı, TPAO Arama Grubu Rapor No. 4172, Ankara, (unpublished).

Şahintürk, Ö., Şaroğlu, F., Çaptuğ, A., Temel, Ö., İlleez, H. İ., and Tekin, T., 1997, Ağrı yöresinin jeolojisi ve hidrokarbon olanakları, TPAO Arama Grubu Rapor No. 3790, Ankara, (unpublished).

Şaroğlu, F., 1985, Doğu Anadolu'nun Neotektonik dönemde jeolojik ve yapısal evrimi, İ.Ü. Fen Bilimleri Enstitüsü, Ph.D. Thesis, (unpublished).

Şaroğlu, F., 1999, Neotektonik ve Türkiye'nin Neotektoniğinden örnekler, TPAO Arama Grubu, Ankara, 195 p.

Şaroğlu, F., and Güner, Y., 1981, Doğu Anadolu jeomorfolojik gelişimine etki eden öğeler: Jeomorfoloji, tektonizma, volkanik ilişkileri, TJK Bülteni, No. 4, Ankara, 39-50.

Şaroğlu, F., and Yılmaz,.Y., 1987, Doğu Anadolu'da neotectonik dönemdeki jeolojik evrim ve havza modelleri, MTA dergisi, Ankara, No.107, 73-94.

Şaroğlu, F., and Yılmaz, Y., 1991, Geology of the Karlıova Region: Intersection of the North Anatolian and East Anatolian Transform Fault, Bull. of Techincal University of Istanbul, 44: (3-4), 475-493.

Şaroğlu, F., Güner, Y., Kidd, W. S. F., and Şengör, A. M. C., 1980, Neotectonics of Eastern Turkey: New evidence for crustal shortening and thickening in a collision zone, EOS, 61/17: 360 p.

Şengör, A. M. C., 1979, The North Anatolian Transform Fault: Its age, offset and tectonic significance, Jour. of Geol. Soc., 136: 269-282.

Şengör, A. M. C., 1980, Türkiye'nin Neotektoniğinin esasları, TJK Konferans Serisi, No.2, Ankara.

Şengör, A. M. C., and Kidd, W. S. F., 1979, Post-collisional tectonics of the Turkish-Iranian plateau and a comparison with Tibet, Tectonophysics, 55: 361-376.

Şengör, A. M. C., and Yılmaz, Y., 1981, Tethyan evolution of Turkey: A plate Tectonic Approach, Tectonophysics, 75: 181-241.

Şengör, A. M. C., White, G. W., and Dewey, J. F., 1979, Tectonic evolution of the Bitlis suture, southeastern Turkey: Implications for the tectonic of eastern Mediterranean: Rapp. Comm. Int. Mer. Medit., 25/26-2a: 95-97.

Şengör, A. M. C., Yılmaz, Y., and Ketin, İ, 1980, Remnants of a pre-late Jurassic ocean in northern Turkey: fragments of of Permian-Triassic Paleo-Tethys. Geol. Soc. Am. Bull., 91: (Part I), 499-609.

Şengör, A. M. C., Görür, N., and Şaroğlu F., 1985, Strike-slip faulting and related basin formation in zones of tectoniz escape: Turkey is a case study, In: Biddle, T.R., Christie-Blick, N. (Eds.), Strike-slip deformation, Basin formation and Sedimentation, Soc. Econ. Paleontol. Min. Spec. Publ., 37: 227-264.

Şengüler, İ. and Toprak, S., 1991, Varto, Hınıs, Bulanık, Malazgirt yöresi linyitlerinin petrografik özellikleri, Türkiye Jeoloji Bülteni, 34: 15-22.

Tappan, H., 1980, The paleobiology of plant protists. Freeman, W.H. and Company, San Fransisco, 1028 p.

Taylor, F. J. R., 1980, On dinoflagellate evolution. BioSystems, 13: 65-108.

Taylor, F. J. R. (Ed.), 1987, The Biology of Dinoflagellates, Botanical Monographs vol. 21. Blackwell Scientific Publications, London, 785 p.

Tchalenko, J. S., 1977, A reconnaisace of the seismicity and tectonics of the northern border of the Arabian plate (Lake Van Region): Revule de Geographie Physique et de Geologie Dynamigqee XIX/2: 189-208.

Teichmüller, M., 1985, Organic petrology of source rocks, History and State of Art, Adv. in Org. Geochem., 10: 581-589.

Tekin, T., Alişan, C., Işık, U., Akça, N., Aras, M., and Günal, B., 2000, Aşkale-1 kuyusu sonuç raporu, TPAO Araştırma Grubu Rapor No: 2514, Ankara, (unpublished).

Tekin, T., 2002, Source rock potential and organic facies properties of the Oligo- Miocene deposits in the Pasinler-Horasan, Tercan-Aşkale basins (East Anatolia), Unpublished Ph.D. thesis, Middle East Technical University, 212 p.

Thiergart, F., 1937, Die Pollenflora der Niderlausitzer Braunkohle, besonders im Profil der grube Marga bei Senftenberg, Jb Preuβ. Geol. L.-Amt, 58: 282-351.

Thiergart, F., 1940, Die Mikropaläontologie als Pollenanalyse im Dienst der Braunkohlenforschung, Schr. Brennstoff-Geologie, 13.

Thomson, P. W. and Pflug, H., 1953, Pollen und sporen des Mitteleuropaischen Tertiars. Palaeontographica Abt. B, 91: (1-4), 1-138.

Tissot, B. P. 1984, Recent advances in petroleum geochemistry applied to hydrocarbon exploration. Bull. Am. Assoc. Pet. Geol., 20: 545-563.

Tissot, B., and Welte, D. H., 1978, Petroleum Formation and Occurrence, Springer-Verlag, New York, 538 p.

Tokel, S., 1966, Erzurum-Muş Bölgesi 1/25000 ölçekli Erzurum J46-c3, Erzurum J46-c4 paftalarına ait jeolojik rapor, Maden Tetkik ve Arama Enstitüsü, Rapor No. 4175, (unpublished).

Tokel, S., 1979, Erzurum-Kars yöresinde Neojen çöküntüsü ile ilgili volkanizmanın incelenmesi, KTÜ, Ph.D. Thesis, Trabzon, 107 p, (unpublished).

Tokel, S., 1984, Doğu Anadolu'daki kabuk deformasyon mekanizması ve genç volkanitlerin petrojenezi, TJK Ketin Simpozyumu Özel Sayısı, 121-129, Ankara.

Torricelli, S., and Biffi, U., 2001, Palynostratigraphy of the Numidian Flysch of northern Tunisia (Oligocene-early Miocene): Palynology, 25: 29-55.

Traverse, A., 1988, Paleopalynology. Allen and Unwin Ltd., USA, 600 p.

Turon, J. L., 1984, Le palynoplancton dans l'environnement actuel de l'Atlantique nordoriental. Evolution climatique et hydrologique depuis le dernier maximum glaciaire. Mem. Inst. Geol. Bassin Aquitaine, 17: 1-313.

Türkelli, N., Sandvol, E., Zor, E., Gok, R., Bekler, T., Al-Lazki, A., Karabulut, H., Kuleli, S., Eken, T., Gurbuz, C., Bayraktutan, S., Seber, D., Barazangi, M., 2003, "Seismogenic zones in Eastern Turkey", Geophys. Res. Lett., 30: (24).

Tyson, R. V., 1987, The genesis and palynofacies chracteristics of marine petroleum source rocks: In Marine Petroleum Source Rocks (Ed: Brooks, J., and Fleed, A. J.), Geological Soc. Spec. Publ. 26, Blackwell Scientific, 47-68,

Tyson, R. V., 1995, Sedimentary Organic Matter, Chapman and Hall, 615 p.

Uğur, M. Ş., 2000, Kağızman-Kars-Tuzluca-Iğdır civarının jeolojisi ve petrol olanakları, TPAO Arama Gr. Rap. No: 4137, Ankara, (unpublished).

Uysal, Ş., 1986, Muş Tersiyer havzasının stratigrafisi ve Üst Lütesiyenin varlığı: MTA Dergisi, 105-106, 69-74.

Ünal, A., 1970, Muş bölgesi 1:25000 ölçekli Erzurum J47-c4, Muş K47-b4, c1, c2 paftalarının detay petrol etüdü raporu, MTA Rap., 4754, Ankara, (unpublished).

Üngör, A., 1992, Pasinler ve dolayının jeolojisi ve hidrokarbon olanakları, TPAO Arama Gr. Rap. No: 3271, Ankara, (unpublished).

Ürgün, S., 1961, Muş-Nazik Gölü-Murat Nehri arasındaki sahanın detay jeolojisi, Maden Tetkik ve Arama Enstitüsü, Rapor No. 34, (unpublished).

Vail, P. R., Mitchum, R. M. Jr, and Thomson, S. III., 1977, Global cycles of relative changes of sea level. In: Seismic Stratigraphy and Global Changes of Sea Level. Amer. Assoc. Petrol. Geol. Mem., 26: 83-87.

Van der Hammen, T., 1954, El desarrollo de la flora Colombiana en los peridos geologicos, I. Maestrichtiano hasta Terciario mas inferior. Bol. Geol. Bogota, 1: (2), 49-106.

Van Simaeys, S., 2004, Stratigraphic and paleoenvironmental analysis of the Rupelian and Chattian in their type regions: Implications for Global Oligocene Chronostratigraphy. Ph.D. Thesis, Katholieke Universiteit Leuven-Belgium.

Van Simaeys, S., De Man, E., Vandenberghe, N., Brinkhuis, H., and Steubaut, E., 2004, Stratigraphic and palaeoenvironmental analysis of the Rupelian–Chattian transition in the type region: evidence from dinoflagellate cysts, foraminifera and calcareous nannofossils: Palaeogeography, Palaeoclimatology, Palaeoecology, 208: 31-58.

Van Simaeys, S., Munsterman, D., and Brinkhuis, H., 2005, Oligocene dinoflagellate cyst biostratigraphy of the southern North Sea Basin, Review of Paleobotany and Palynology, 134: 105-128.

Varma, C. P., and Rawat, M. S., 1963, A note on some diporate grains recovered from Tertiary horizons of India and their potential marker value, Grana Palynologia, 1 (4): 130-139.

Verloet, C. C., 1966, Stratigraphical and Micropaleontological data on the Tertiary of Southern Piemont (northern Italy): Utrecht, Scotanus and Jens, 88 p.

Wall, D., 1965, Modern hystrichospheres and dinoflagellate cysts from the Woods Hole region, Grana Palynologica, 6: 297-314.

Wall, D., 1967, Fossil microplankton in deep-sea cores from the Caribbean Sea, Paleontology, 10: 95-123.

Wall, D., and Dale, B., 1974, Dinoflagellates in late Quaternary deep-water sediments of Black Sea. In: Degens, E.T., Ross, D.A. (Eds.), The Black Sea—Geology, Chemistry and Biology. Memoir - American Association of Petroleum Geologists, 364– 380.

Wall, D., Dale, B., and Harada, K., 1973, Descriptions of new fossil dinoflagellates from the late Quaternary of the Black Sea. Micropaleontology 19: 18– 31.

Wall, D., Dale, B., Lohmann, G. P., and Smith, W. K., 1977, The enviromental and climatic distribution in modern öarine sediments from regions in the North nad South Atlantic oceans and adjacent seas. Marine Micropaleontology, 2: 121-200.

Weiler, H., 1956, Über einen Fund von Dinoflagellaten, Coccolithophoriden und Hystrichosphaerideen im Tertiär des Rheintales, Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 104: 129-147.

Wilkinson, G. C. and Boulter, M. C., 1980, Oligocene pollen and spores from the western part of the British Isles. Palaeontographica Abt. B, 175: (1-3), 27-83.

Wilkinson, G. C., Bazley, R. A. B., and Boulter, M. C., 1980, The geology and palynology of the Oligocene Lough Neagh Clays, Northern Ireland. J. geol. Soc. London, 137: 65-75.

Williams, G. L., 1975, Dinoflagellate and spore stratigraphy of the Mesozoic-Cenozoic, offshore eastern Canada. Geol. Surv. Can., Pap. 74-30; 2, 107-161.

Williams, G. L., 1977, Dinoflagellate cysts, their classification, biostratigraphy and palaeoecology. In: Ramsay, A.T.S. (Ed.), Oceanic Micropalaeontology. Academic Press, London, 1231–1325.

Williams, G. L., 1978, Palynological biostratigraphy, Deep Sea Drilling Project Sites 367 and 370; in Lancelot, Y., Seibold, E. et al., Initial Reports of the Deep Sea Drilling Project, XLI: 783-815.

Williams, G. L., and Brideaux, W. W., 1975, Palynological analyses of upper Mesozoic and Cenozoic rocks of the Grand Baks, Atlantic continental margin. Geol. Surv. Can. Bull. 236: 1-163.

Williams, G. L., and Bujak, J. P., 1977, Distribution patterns of some North Atlantic Cenozoic Dinoflagellate cysts, Marine Micropaleontology, 2: 223-233.

Williams, G. L., and Bujak, J. P., 1985, Mesozoic and Cenozoic dinoflagellates. In: Bolli, H.M., Saunders, J.B., and Perch-Nielsen, K. (Eds.), Plankton Stratigraphy: Cambridge (Cambridge Univ. Press), 847–964.

Williams, G. L. and Downie, C., 1966a, The genus *Hystrichokolpoma*; in Davey, R.J., Downie, C., Sarjeant, W.A.S., and Williams, G.L., Studies in

Mesozoic and Caniozoic dinoflagellate cysts, Bull. of the British Museum (Natural History) Geology, Supplement 3: 176-181.

Williams, G. L. and Downie, C., 1966b, Further dinoflagellate cysts from the London Clay; in Davey, R.J., Downie, C., Sarjeant, W.A.S., and Williams, G.L., Studies in Mesozoic and Caniozoic dinoflagellate cysts, Bull. of the British Museum (Natural History) Geology, Appendix to Supplement 3: 17.

Williams, G. L., Bujak, J. P., and Brinkhuis, H., 1999, Mesozoic-Cenosoic Dinoflagellate Cyst Course, Urbino, Italy, (unpublished).

Williams, G. L., Brinkhuis, H., Pearce, M. A., Fensome, R. A., and Weegink, J. W., 2004, Southern Ocean and global dinoflagellate cyst events compared; index events for the late Cretaceous–Neogene. In: Exon, N.F., Kennett, J.P., Malone, M.J. (Eds.), Proceedings of the Ocean Drilling Program. Scientific Results vol. 189, pp. 1 – 98. Available from World Wide Web: < http://www-odp.tamu.edu/publications/189_SR/107/107.htm>. [Cited 2004-04-09]. College Station, TX.

Wilpshaar, M., Santarelli, A., Brinkhuis, H., and Visscher, H., 1996, Dinoflagellate cysts and mid-Oligocene chronostratigraphy in the central Mediterranean region: Journal of the Geological Society of London, 153: Part 4, 553-561.

Wilson, G. J., 1967, Some species of Wetzeliella Eisenack (Dinophyceae) from New Zealand Eocene and Paleocene strata, New Zealand Journal of Botany, 5: 223-240.

Wolfe, J. A., 1993, A method of obtaining climatic parameters from leaf assemblages, United States Geological Survey Bulletin, 2040, 1-71.

Wolff, H., 1934, Microfossilien des pliozänen Humodils der Grube Freigericht bei Dettingen a. M. Und Vergleich mit älteren Schichten des Tertiars sowie posttertiären Ablagerungen, Arb. Inst. Paläobot. U. Petrogr. Brennsteine, 5: 55-88.

Wodehouse, R. P., 1933, Tertiary Pollen II. The Oil Shales of the Eocene Green River Formation, Bull. Torrey. Bot. Club, 60: 479-524.

Wrenn, J. H., 1988, Paleogene dinoflagellate cyst biostratigraphy of Seymour Island, Antarctica, 321-447 in Geological Society of America, Memoir, 169.

Wrenn, J. H., and Kokinos, J. P., 1986, Preliminary comments on Miocene through Pleistocene dinoflagellate cysts from De Soto Canyon, Gulf of Mexico, AASP Contribution Series No. 17: 169-225.

Yancey, T. E., Elsik, W. C., and Sancay, R. H., 2002, The palynological record of late Eocene climate change, northwest Gulf of Mexico. Chapter 14, in Prothero, D.R., Ivany, L.C., and Nesbitt, E.A., eds., From Greenhouse to Icehouse: The Marine Eocene-Oligocene Transition, New York: Columbia Univ. Press, 252-268.

Yılmaz, A., 1989, Kafkasyanın tektonik kuşakları ve bu kuşakların Kuzeydoğu Türkiye'deki uzantıları: Bir karşılaştırma, MTA Dergisi, No: 109, 89-106.

Yılmaz, Y., 1993, New evidence and model on the evaluation of the southeast Anatolian orogen, Geol. Soc. Am. Bull.,105: 251-271.

Yılmaz, Y., Şaroğlu, F., and Güner, Y., 1987, Initiation of the neomagmatism in East Anatolia, Tectonophysics, 134: 177-199.

Yılmaz, A., Terlemez, İ., and Uysal, Ş., 1988, Hınıs (Erzurum Güneydoğusu) dolaylarının bazı stratigrafik ve tektonik özellikleri, MTA Dergisi, No. 108, 38-56, Ankara.

Yılmaz, Y., Yiğitbaş, E., and Genç, S. C., 1993, Ophiolitic and metamorphic assemblages of SE Anatolia and their significance in the geological evolution of the orogenic belt, Tectonics, 2: 1280-1297.

Zachos, J. C., Opdyke, B. N., Quinn, T. M., Jones, C. E. and Halliday, A. N., 1999, Early Cenozoic glaciation, antarctic weathering, and seawater $^{87}Sr/^{86}SR$: is there a link? Chemical Geology, 161: 165-180.

Zachos, J. C., Pagani, M, Sloan, L., Thomas, E. and Billups, K., 2001, Trends, rhytms, and aberrations in global climate 65 Ma to present. Science, 292: 686-693.

Zevenboom, D., Brinkhuis, H., and Visscher, H., 1994, Dinoflagellate cysts palaeoenvironmental analysis of the Oligocene/Miocene transition in northwest and central Italy: Giornale di Geologia, 56: 1, 155-169.

Zevenboom, D., 1995, Dinoflagellate cysts ffrom the Mediterranean Late Oligocene and Miocene, PhD Thesis, Universiteit Utrecht, Utrecht-Netherlands, 221 p.

Zevenboom, D., 1996, Late Oligocene-early Miocene dinoflagellate cysts from the Lemme-Carrosio section (NW Italy); biostratigraphy and palaeoenvironmental interpretation: Giornale di Geologia, 58: 1-2, 81-93.

# APPENDIX A

A1-28. Digital images of the palynomorphs and explanations.

Scale bar represents 10 micron for all plates if it is not given in paranthesis.

PLATE 1

1. *Hystrichokolpoma pusillum* (Ebulbahar section, Sample No: 92)
2. *Hystrichokolpoma pusillum* (Ebulbahar section, Sample No: 92)
3. *Hystrichokolpoma pusillum* (Ebulbahar section, Sample No: 93)
4. *Hystrichokolpoma pusillum* (Ebulbahar section, Sample No: 93)
5. *Hystrichokolpoma pusillum* (Ebulbahar section, Sample No: 92)
6. *Hystrichokolpoma pusillum* (Ebulbahar section, Sample No: 92)
7. *Hystrichokolpoma pusillum* (Ebulbahar section, Sample No: 70)
8. *Hystrichokolpoma pusillum* (Ebulbahar section, Sample No: 70)
9. *Dapsilidinium pseudocolligerum* (Ebulbahar section, Sample No: 93)
10. *Dapsilidinium pseudocolligerum* (Ebulbahar section, Sample No: 93)
11. *Dapsilidinium* sp. (Ebulbahar section, Sample No: 92)
12. *Dapsilidinium* sp. (Ebulbahar section, Sample No: 92)
13. *Spiniferites* sp. (Ebulbahar section, Sample No: 92)
14. *Polysphaeridium* sp. (Ebulbahar section, Sample No: 70, 93)
15. *Polysphaeridium* sp. (Ebulbahar section, Sample No: 70, 93)
16. *Systematophora placacanthum* (Ebulbahar section, Sample No: 93)
17. *Cordosphaeridium inodes* (Ebulbahar section, Sample No: 92)
18. *Cleistosphaeridium* sp. (Ebulbahar section, Sample No: 91)
19. *Operculodinium* sp. (Ebulbahar section, Sample No: 111)
20. *Operculodinium* sp. (Kelereşdere section, Sample No: 106)

PLATE 1

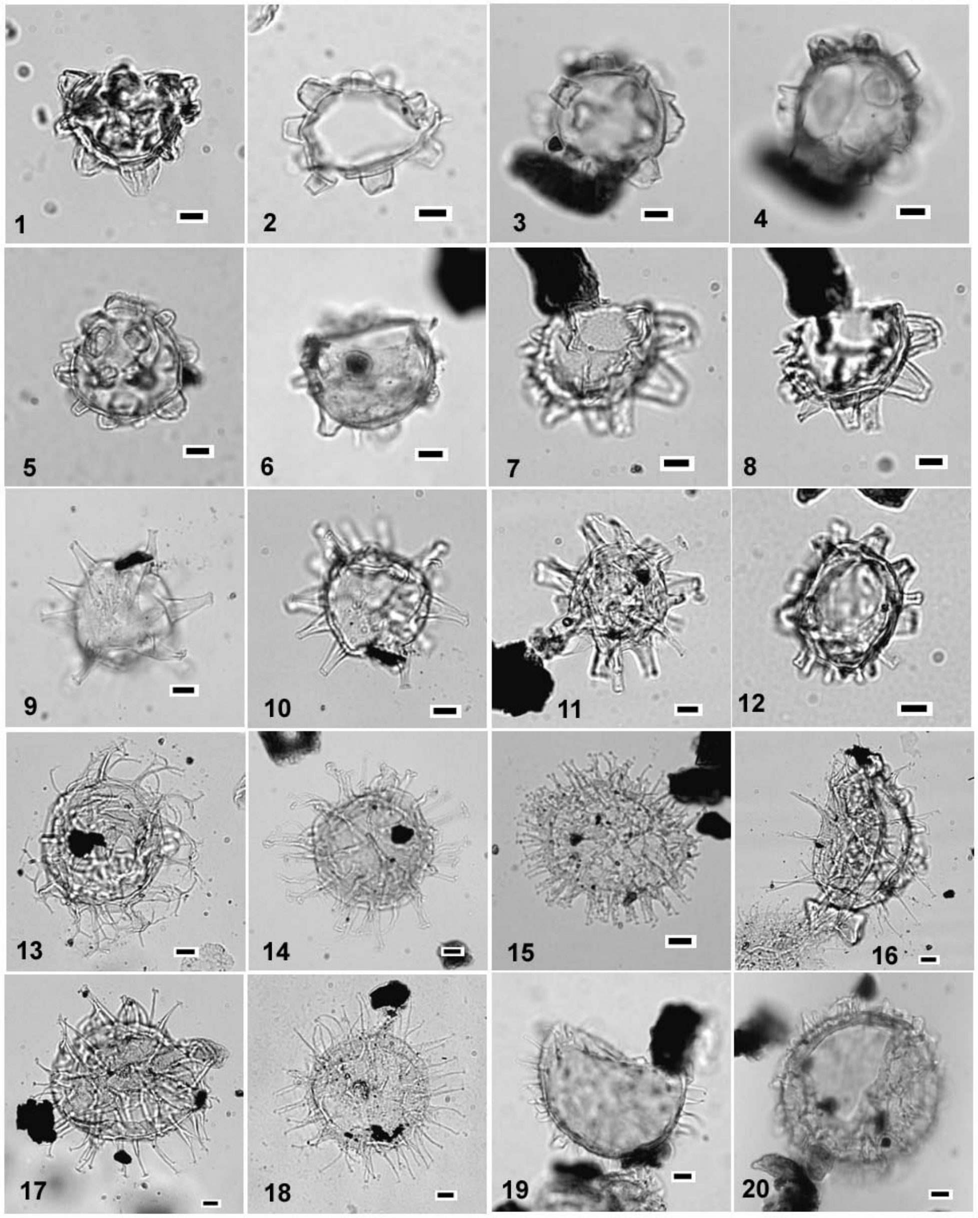


PLATE 2

1. *Membranilarnacea*? *picena* (Ebulbahar section, Sample No: 116)
2. *Membranilarnacea*? *picena* (Ebulbahar section, Sample No: 116)
3. *Membranilarnacea*? *picena* (Ebulbahar section, Sample No: 116)
4. *Membranilarnacea*? *picena* (Ebulbahar section, Sample No: 116)
5. *Membranilarnacea*? *picena* (Ebulbahar section, Sample No: 116)
6. *Membranilarnacea*? *picena* (Ebulbahar section, Sample No: 116)
7. *Hystrichosphaeropsis obscura* (Ebulbahar section, Sample No: 93)
8. *Hystrichosphaeropsis obscura* (Ebulbahar section, Sample No: 93)
9. *Systematophora placacanthum* (Ebulbahar section, Sample No: 116)
10. *Systematophora placacanthum* (Ebulbahar section, Sample No: 116)
11. *Systematophora placacanthum* (Ebulbahar section, Sample No: 116)
12. *Polysphaeridium zoharyi* (Ebulbahar section, Sample No: 70)
13. *Polysphaeridium zoharyi* (Ebulbahar section, Sample No: 70)
14. *Impagidinium* sp. (Ebulbahar section, Sample No: 93)
15. *Impagidinium* sp. (Ebulbahar section, Sample No: 111)
16. *Impagidinium* sp. (Ebulbahar section, Sample No: 116)
17. *Impagidinium* sp. (Ebulbahar section, Sample No: 116)
18. *Hystrichocolpoma* sp. (Çirişlitepe section, Sample No: 155)
19. *Cyclopsiella lusatica* (Ebulbahar section, Sample No: 93)
20. *Cyclopsiella lusatica* (Ebulbahar section, Sample No: 93)

PLATE 2

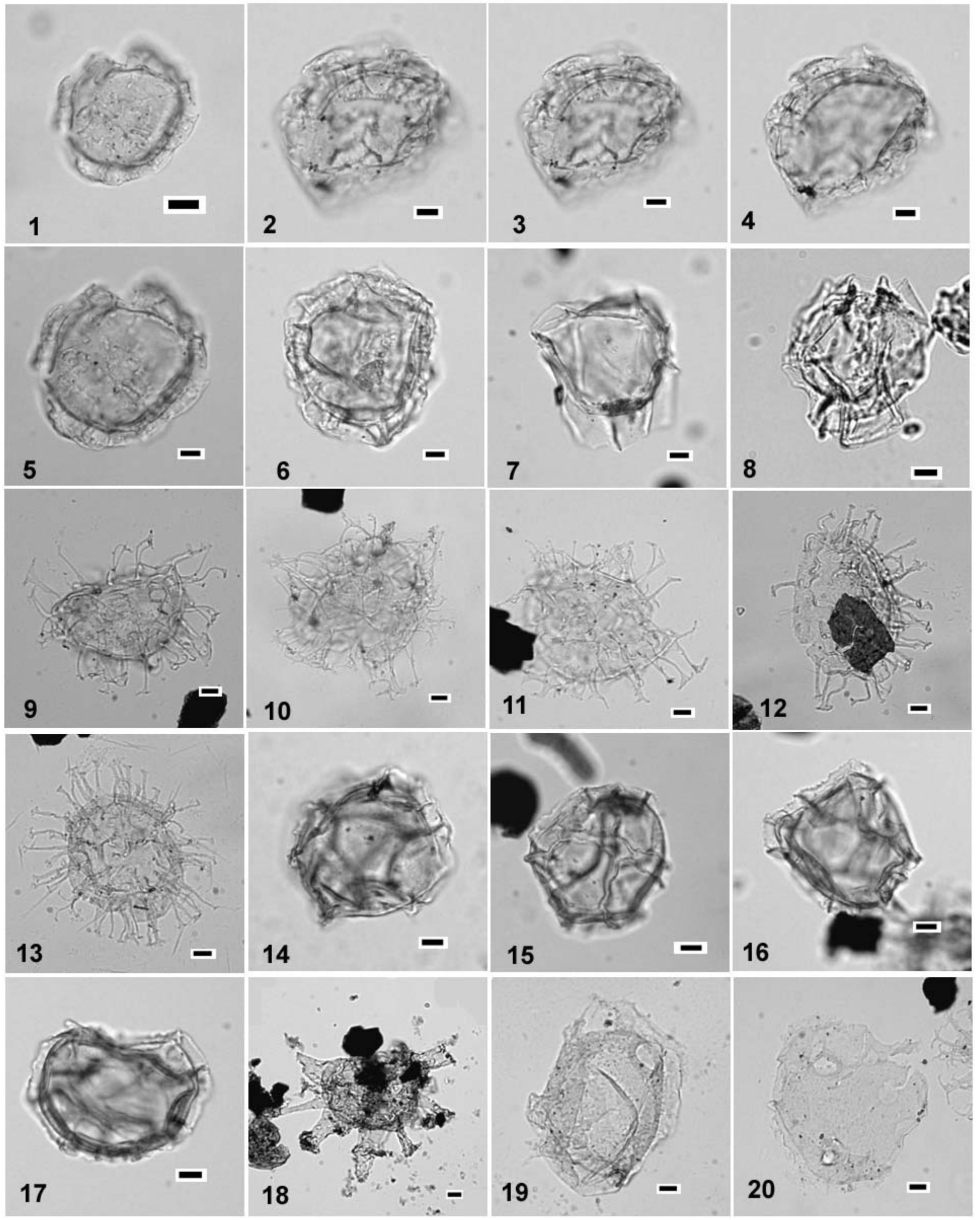


PLATE 3

1. *Homotryblium plectilum* (Ebulbahar section, Sample No: 72)
2. *Homotryblium plectilum/vallum* (transitional forms) (Ebulbahar section, Sample No: 93)
3. *Homotryblium plectilum* (Ebulbahar section, Sample No: 72)
4. *Homotryblium tenuispinosum* (Kelereşdere section, Sample No: 118)
5. *Homotryblium plectilum* (Ebulbahar section, Sample No: 93)
6. *Homotryblium plectilum/vallum* (transitional forms) (Ebulbahar section, Sample No: 93)
7. *Homotryblium plectilum/vallum* (transitional forms) (Ebulbahar section, Sample No: 93)
8. *Homotryblium plectilum* (Ebulbahar section, Sample No: 93)
9. *Homotryblium plectilum/vallum* (transitional forms) (Ebulbahar section, Sample No: 93)
10. *Homotryblium plectilum* (Kelereşdere section, Sample No: 115)
11. *Homotryblium plectilum* (Kelereşdere section, Sample No: 115)
12. *Homotryblium plectilum* (Kelereşdere section, Sample No: 115)
13. *Hystrichokolpoma rigaudiae* (Ebulbahar section, Sample No: 82)
14. *Hystrichokolpoma rigaudiae* (Ebulbahar section, Sample No: 111)
15. *Spiniferites mirabilis* (Ebulbahar section, Sample No: 92)
16. *Spiniferites mirabilis* (Ebulbahar section, Sample No: 116)
17. *Spiniferites pseudofurcatus* (Ebulbahar section, Sample No: 116)
18. *Spiniferites pseudofurcatus* (Ebulbahar section, Sample No: 116)
19. *Reticulatosphaera actinocoronata* (Ebulbahar section, Sample No: 111)
20. *Reticulatosphaera actinocoronata* (Ebulbahar section, Sample No: 116)

**PLATE 3**

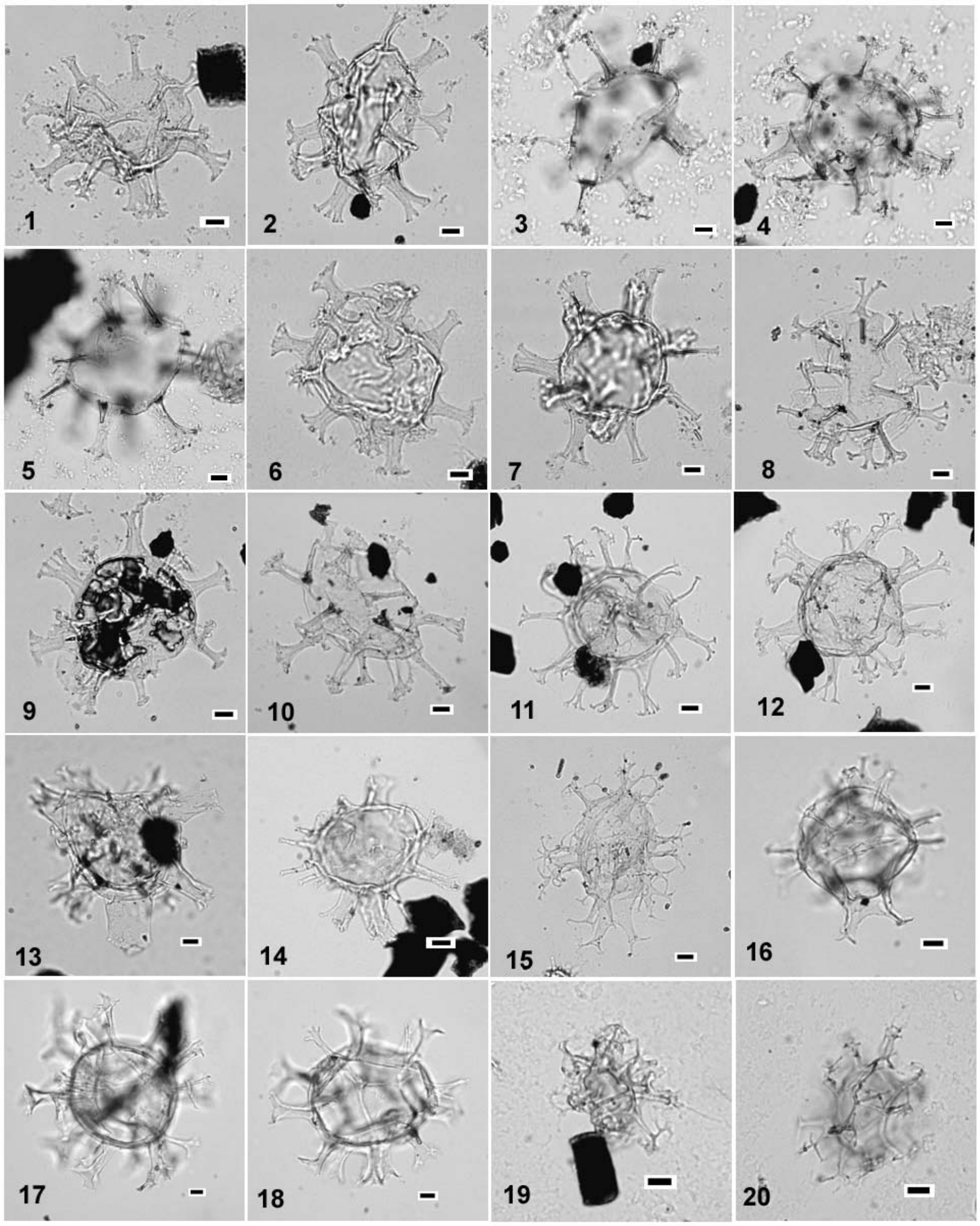


PLATE 4

1. *Ennaedocysta pectiniformis* complex (Ebulbahar section, Sample No: 93)
2. *Ennaedocysta pectiniformis* complex (Ebulbahar section, Sample No: 93)
3. *Ennaedocysta pectiniformis* complex (Ebulbahar section, Sample No: 111)
4. *Ennaedocysta pectiniformis* complex (Ebulbahar section, Sample No:111)
5. *Ennaedocysta pectiniformis* complex (Kelereşdere section, Sample No: 109)
6. *Ennaedocysta pectiniformis* complex (Kelereşdere section, Sample No: 109)
7. *Cordosphaeridium cantharellus* (Ebulbahar section, Sample No: 72)
8. *Cordosphaeridium cantharellus* (Ebulbahar section, Sample No: 91)
9. *Cordosphaeridium cantharellus* (Ebulbahar section, Sample No: 93)
10. *Cordosphaeridium cantharellus* (Kelereşdere section, Sample No: 92)
11. *Polysphaeridium zoharyi* (Ebulbahar section, Sample No: 93)
12. *Polysphaeridium zoharyi* (Ebulbahar section, Sample No: 93)
13. *Spiniferites mirabilis* (Ebulbahar section, Sample No: 93)
14. *Spiniferites mirabilis* (Ebulbahar section, Sample No: 93)
15. *Spiniferites* sp. (Ebulbahar section, Sample No: 93)
16. *Spiniferites mirabilis* (Ebulbahar section, Sample No: 93)
17. *Cribroperidinium tenuitabulatum* (Ebulbahar section, Sample No: 91)
18. *Cribroperidinium tenuitabulatum* (Ebulbahar section, Sample No: 93)
19. *Apteodinium* sp. (Ebulbahar section, Sample No: 92)
20. *Cribroperidinium tenuitabulatum* (Ebulbahar section, Sample No: 93)

**PLATE 4**

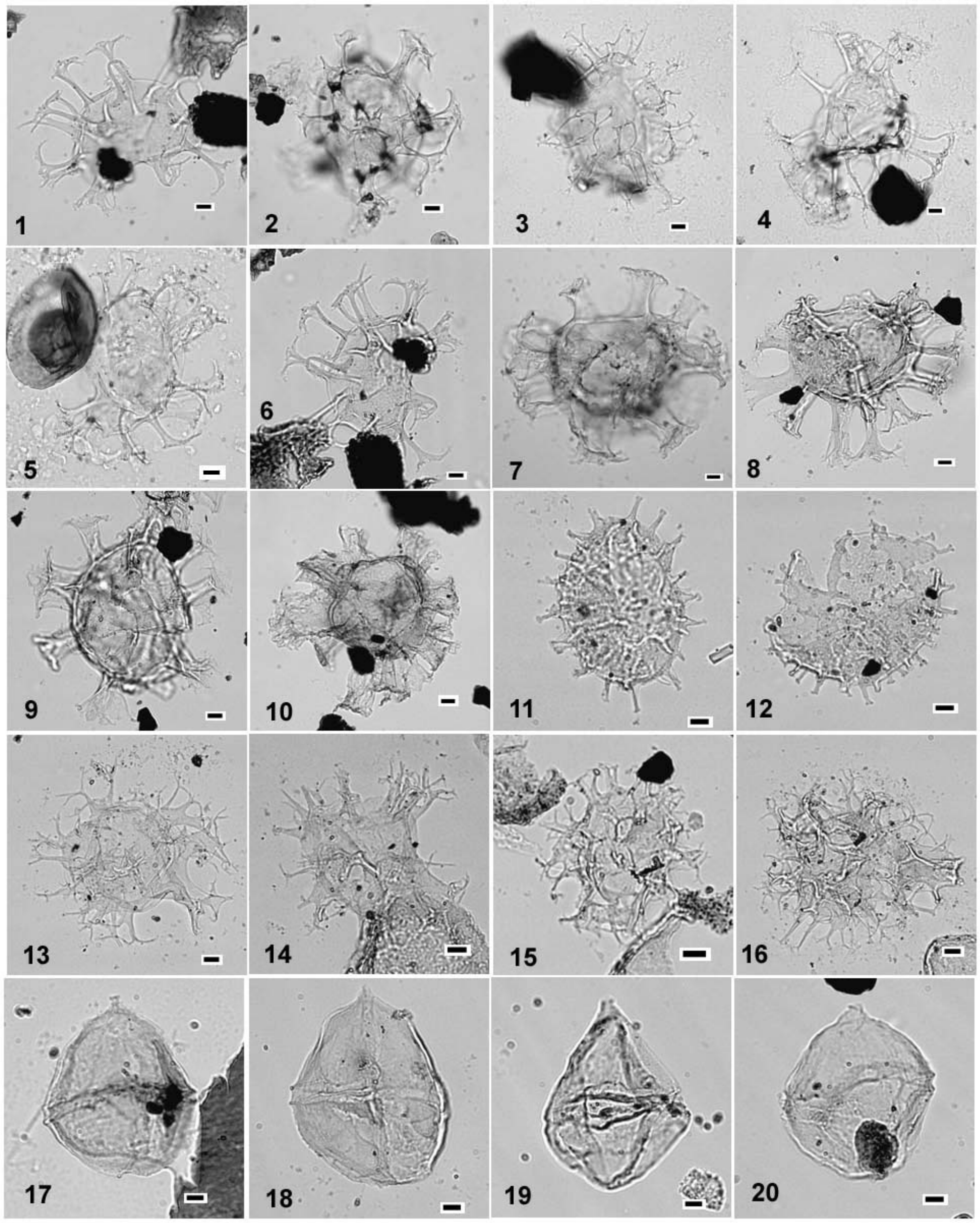


PLATE 5

1. *Thalassiphora pelagica* (Ebulbahar section, Sample No: 70)
2. *Thalassiphora pelagica* (Ebulbahar section, Sample No: 72)
3. *Thalassiphora pelagica* (Ebulbahar section, Sample No: 93)
4. *Thalassiphora pelagica* (Ebulbahar section, Sample No: 116)
5. *Thalassiphora pelagica* (Kelereşdere section, Sample No: 92)
6. *Deflandrea* sp. (Ebulbahar section, Sample No: 66)
7. *Deflandrea phosphoritica* (Ebulbahar section, Sample No: 72)
8. *Deflandrea* sp. (Ebulbahar section, Sample No: 72)
9. *Deflandrea* sp. (Ebulbahar section, Sample No: 72)
10. *Deflandrea* sp. (Ebulbahar section, Sample No: 72)
11. *Deflandrea leptodermata* (Ebulbahar section, Sample No: 70)
12. *Deflandrea* sp. (Ebulbahar section, Sample No: 72)
13. *Deflandrea phosphoritica* (Ebulbahar section, Sample No: 78)
14. *Deflandrea* sp. (Ebulbahar section, Sample No: 72)
15. *Tuberculodinium vancampoae* (Ebulbahar section, Sample No: 70)
16. *Tuberculodinium vancampoae* (Ebulbahar section, Sample No: 70)
17. *Tuberculodinium vancampoae* (Ebulbahar section, Sample No: 72)
18. *Tuberculodinium vancampoae* (Ebulbahar section, Sample No: 72)
19. *Distatodinium ellipticum* (Kelereşdere section, Sample No: 92)
20. *Distatodinium biffii* (Kelereşdere section, Sample No: 172)

**PLATE 5**

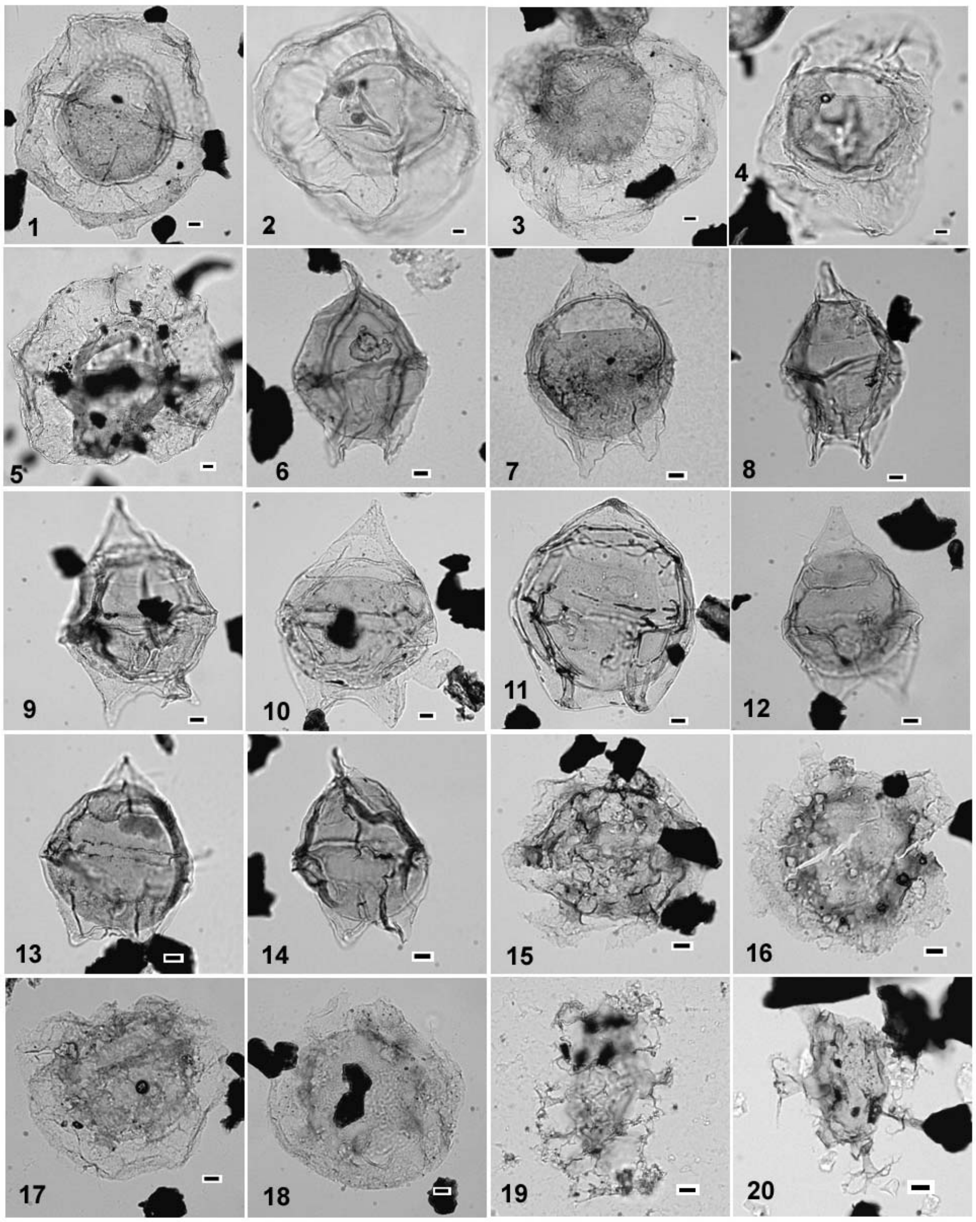


PLATE 6

1. *Wetzeliella gochtii* (Ebulbahar section, Sample No: 70)
2. *Wetzeliella* sp. (Ebulbahar section, Sample No: 70)
3. *Wetzeliella* sp. (Ebulbahar section, Sample No: 72)
4. *Wetzeliella* sp. (Ebulbahar section, Sample No: 92)
5. *Wetzeliella* sp. (Ebulbahar section, Sample No: 92)
6. *Wetzeliella* sp. (Ebulbahar section, Sample No: 72)
7. *Wetzeliella symmetrica* (Ebulbahar section, Sample No: 70)
8. *Wetzeliella* cf. o*valis* (Ebulbahar section, Sample No: 70)
9. *Wetzeliella articulata* (Ebulbahar section, Sample No: 72)
10. *Spiniferites* sp. (Ebulbahar section, Sample No: 72)
11. *Polysphaeridium zoharyi* (Ebulbahar section, Sample No: 93)
12. *Reticulatosphaera actinocoronata* (Ebulbahar section, Sample No: 116)
13. *Opeculodinium microtriainum* (Ebulbahar section, Sample No: 93)
14. *Riculacysta perforata* (Ebulbahar section, Sample No: 93)
15. *Riculacysta perforata* (Ebulbahar section, Sample No: 93)
16. *Operculodinium* sp. (Ebulbahar section, Sample No: 93)
17. *Operculodinium* sp. (Ebulbahar section, Sample No: 93)
18. *Operculodinium* sp. (Ebulbahar section, Sample No: 116)
19. *Operculodinium* sp. (Ebulbahar section, Sample No: 116)
20. *Operculodinium* sp. (Ebulbahar section, Sample No: 93)

**PLATE 6**

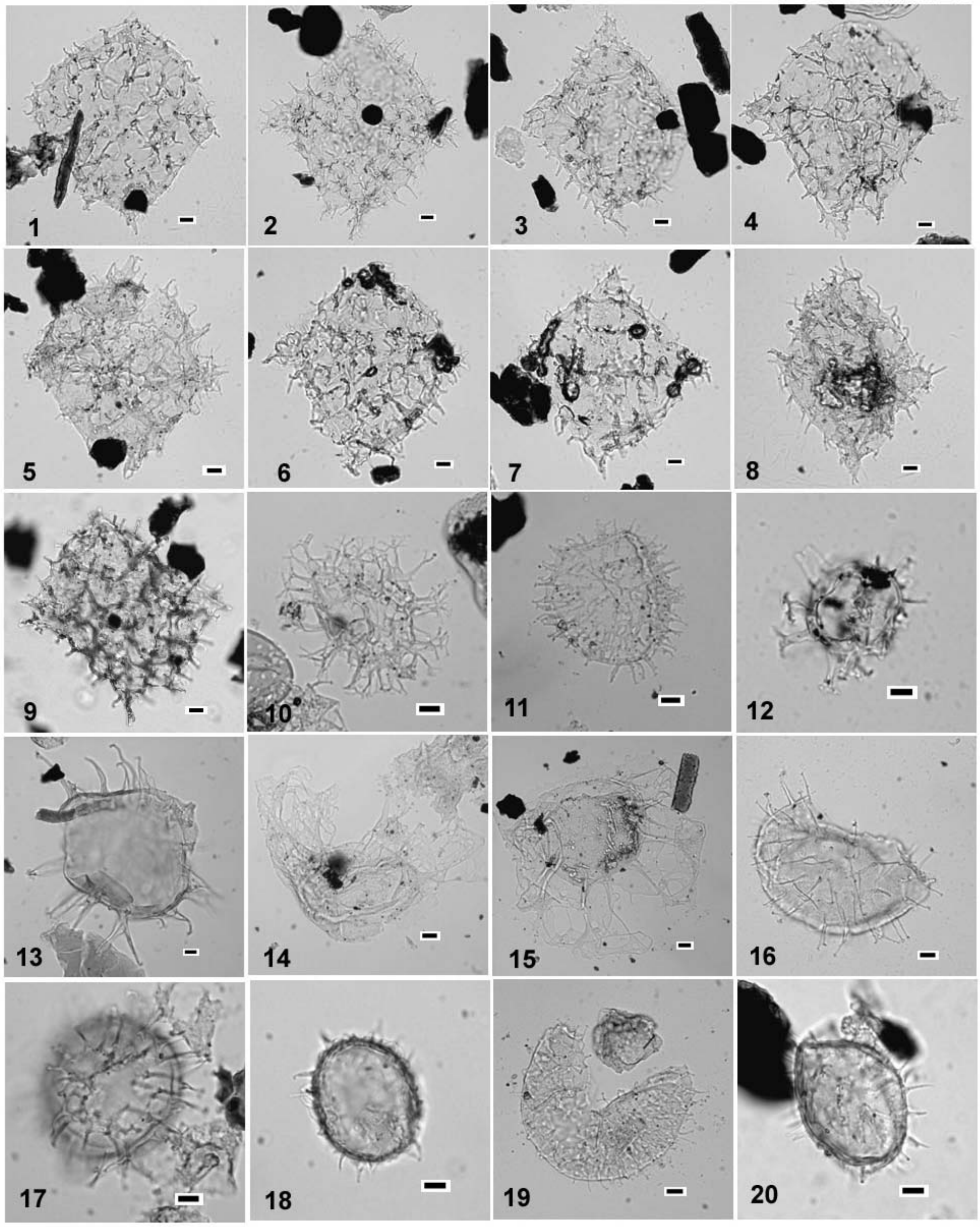


PLATE 7

1. *Fibrocysta* sp. (high focus) (Ebulbahar section, Sample No: 70)

2. *Fibrocysta* sp. (mid. Focus) (Ebulbahar section, Sample No: 70)

3. *Fibrocysta* sp. (low focus) (Ebulbahar section, Sample No: 70)

4. *Homotryblium oceanicum* (Ebulbahar section, Sample No: 93)

5. *Selenopemphix nephroides* (Ebulbahar section, Sample No: 70)

6. *Cordosphaeridium minimum* (Ebulbahar section, Sample No: 111)

7. *Hystrichokolpoma rigaudiae* (Ebulbahar section, Sample No: 112)

8. *Polysphaeridium zoharyi* (Ebulbahar section, Sample No: 93)

9. *Polysphaeridium zoharyi* (Ebulbahar section, Sample No: 93)

10. *Polysphaeridium zoharyi* (Ebulbahar section, Sample No: 111)

11. *Polysphaeridium zoharyi* (Ebulbahar section, Sample No: 111)

12. *Polysphaeridium zoharyi* (Ebulbahar section, Sample No: 111)

13. *Pentadinium* sp. (Ebulbahar section, Sample No: 72)

14. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)

15. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)

16. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)

17. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)

18. *Heteraulacacysta* sp. (Ebulbahar section, Sample No: 92)

19. unidentified chorate fragment (Ebulbahar section, Sample No: 70)

20. unidentified chorate fragment (Ebulbahar section, Sample No: 70)

PLATE 7

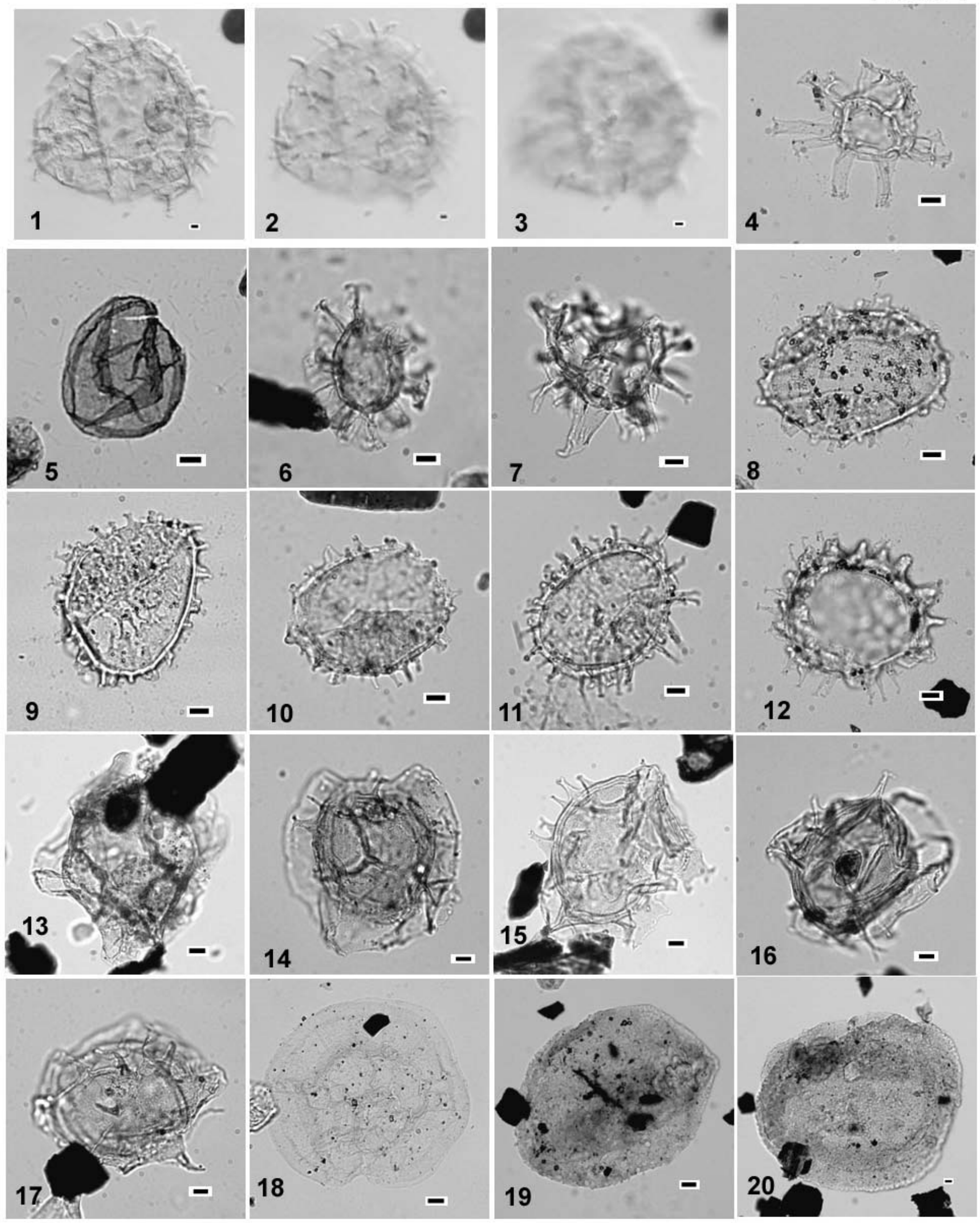


PLATE 8

1. *Lingulodinium machaerophorum* (Ebulbahar section, Sample No: 112)
2. *Lingulodinium machaerophorum* (Ebulbahar section, Sample No: 112)
3. *Chiropteridium galea* (Ebulbahar section, Sample No: 93)
4. *Chiropteridium galea* (Kelereşdere section, Sample No: 115)
5. *Chiropteridium lobospinosum* (Ebulbahar section, Sample No: 91)
6. *Chiropteridium lobospinosum* (Ebulbahar section, Sample No: 91)
7. *Chiropteridium lobospinosum* (Ebulbahar section, Sample No: 92)
8. *Chiropteridium lobospinosum* (Ebulbahar section, Sample No: 92)
9. *Chiropteridium lobospinosum* (Ebulbahar section, Sample No: 93)
10. *Chiropteridium lobospinosum* (Ebulbahar section, Sample No: 93)
11. *Chiropteridium lobospinosum* (Ebulbahar section, Sample No: 93)
12. *Chiropteridium lobospinosum* (Kelereşdere section, Sample No: 115)
13. *Chiropteridium lobospinosum* (Kelereşdere section, Sample No: 115)
14. *Cordosphaeridium* sp. (Ebulbahar section, Sample No: 93)
15. *Chiropteridium* sp. (Ebulbahar section, Sample No: 92)
16. *Chiropteridium* sp. (Ebulbahar section, Sample No: 92)
17. Chitinious foraminiferal linings (Kelereşdere section, Sample No: 92)
18. Chitinious foraminiferal linings (Kelereşdere section, Sample No: 106)
19. *Botryococcus braunii* (Ebulbahar section, Sample No: 77)
20. *Botryococcus braunii* (Kelereşdere section, Sample No: 106)

PLATE 8

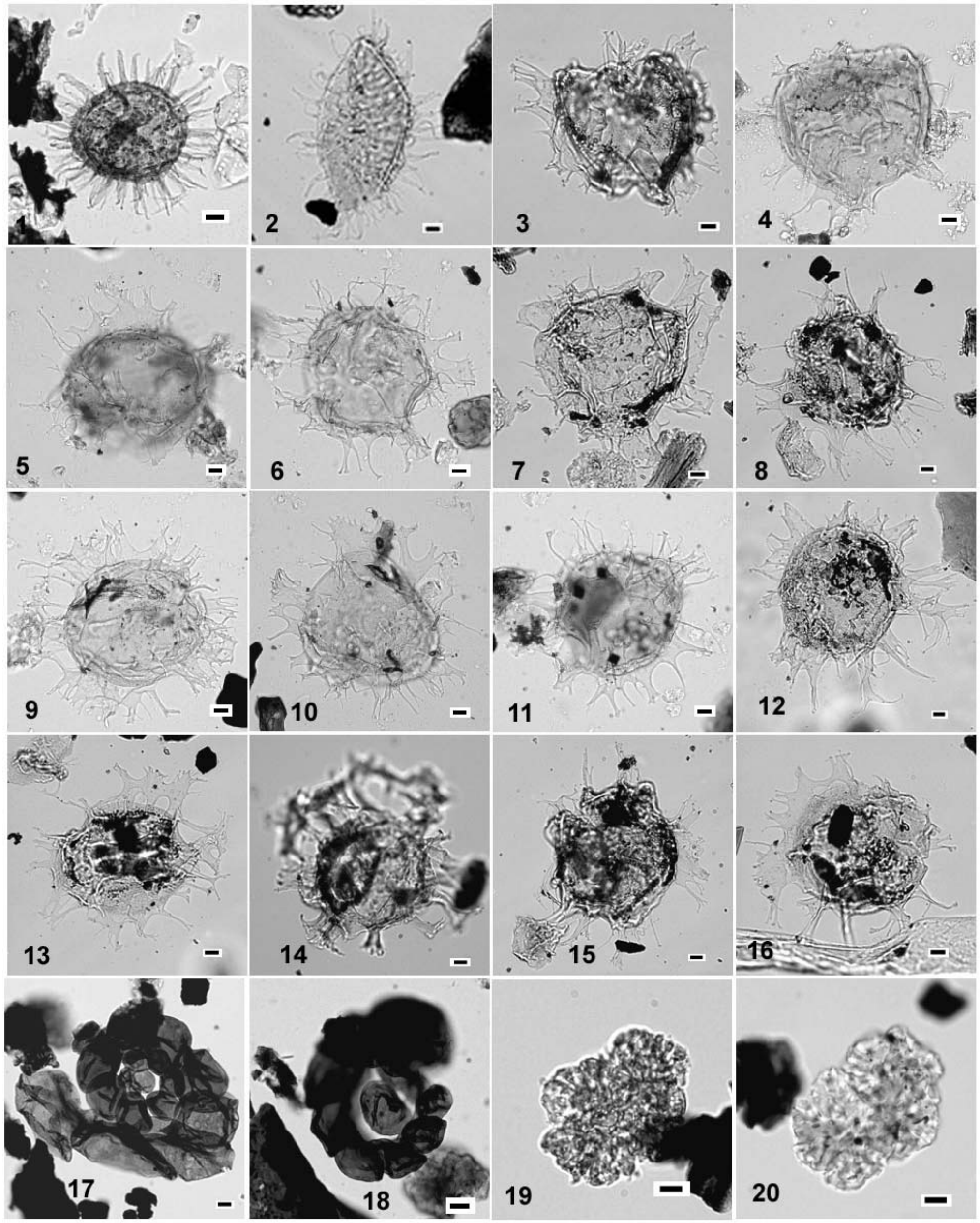


PLATE 9

1. *Wetzeliella gochtii* (Kelereşdere section, Sample No: 90)
2. *Wetzeliella* cf. *gochtii* (Ebulbahar section, Sample No: 70)
3. *Wetzeliella* sp. (Ebulbahar section, Sample No: 70)
4. *Wetzeliella articulata* (Ebulbahar section, Sample No: 70)
5. *Wetzeliella symmetrica* (Kelereşdere section, Sample No: 92)
6. *Wetzeliella* sp. (Ebulbahar section, Sample No: 72)
7. *Deflandrea* sp. (Kelereşdere section, Sample No: 61)
8. *Deflandrea phosphoritica* (Kelereşdere section, Sample No: 61)
9. *Deflandrea phosphoritica* (Ebulbahar section, Sample No: 36)
10. *Deflandrea phosphoritica* (Ebulbahar section, Sample No: 44)
11. *Deflandrea phosphoritica* (Kelereşdere section, Sample No: 61)
12. *Deflandrea phosphoritica* (Kelereşdere section, Sample No: 92)
13. *Deflandrea* cf. *leptodermata* (Ebulbahar section, Sample No: 70)
14. *Deflandrea leptodermata* (Kelereşdere section, Sample No: 61)
15. *Deflandrea spinulosa* (Kelereşdere section, Sample No: 92)
16. *Deflandrea spinulosa* (Ebulbahar section, Sample No: 72)
17. *Deflandrea* sp. (Ebulbahar section, Sample No: 72)
18. *Deflandrea* sp. (Kelereşdere section, Sample No: 61)
19. *Deflandrea* sp. (Kelereşdere section, Sample No: 66)
20. *Deflandrea* sp. (Kelereşdere section, Sample No: 61)

**PLATE 9**

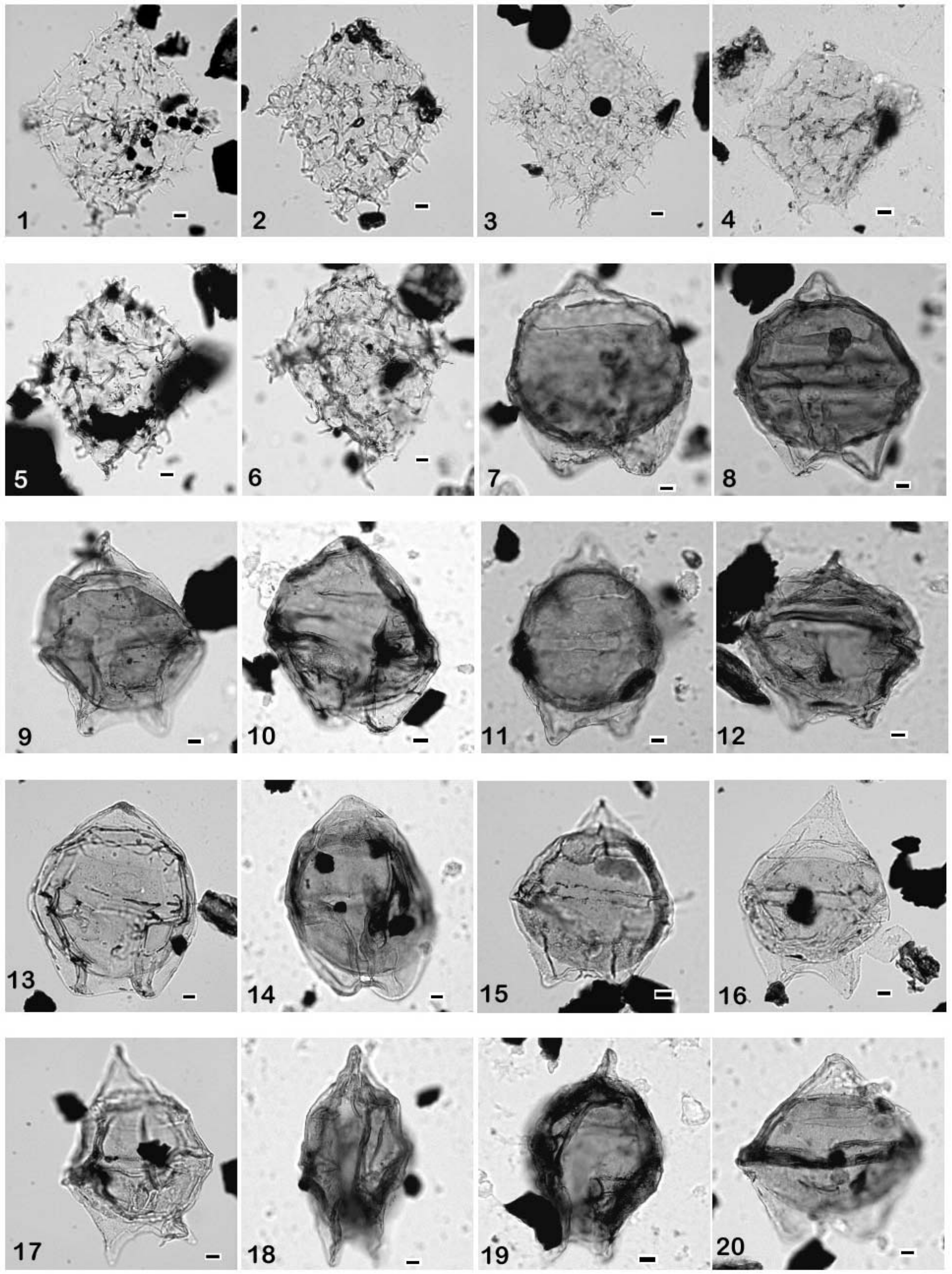


PLATE 10

1. *Deflandrea* sp. (Kelereşdere section, Sample No: 61)
2. *Deflandrea* sp. (Ebulbahar section, Sample No: 38)
3. *Deflandrea* sp. (Ebulbahar section, Sample No: 38)
4. *Spiniferites* sp. (Çirişlitepe section, Sample No: 155)
5. *Achomosphaera alcicornu* (Çirişlitepe section, Sample No: 155)
6. *Spiniferites* sp. (Çirişlitepe section, Sample No: 155)
7. *Areosphaeridium diktyoplokus* (Çirişlitepe section, Sample No: 155)
8. *Paleocystodinium golzowense* (Çirişlitepe section, Sample No: 155)
9. *Thalassiphora pelagica* (Ebulbahar section, Sample No: 72)
10. *Thalassiphora pelagica* (Ebulbahar section, Sample No: 72)
11. *Thalassiphora pelagica* (Kelereşdere section, Sample No: 92)
12. *Thalassiphora pelagica* (Ebulbahar section, Sample No: 70)
13. *Tuberculodinium vancampoae* (Ebulbahar section, Sample No: 70)
14. *Tuberculodinium vancampoae* (Ebulbahar section, Sample No: 72)
15. *Tuberculodinium vancampoae* (Ebulbahar section, Sample No: 72)
16. *Tuberculodinium vancampoae* (Ebulbahar section, Sample No: 70)
17. *Homotryblium plectilum* (Ebulbahar section, Sample No: 72)
18. *Homotryblium plectilum* (Ebulbahar section, Sample No: 72)
19. *Homotryblium plectilum* (Kelereşdere section, Sample No: 172)
20. *Homotryblium plectilum* (Kelereşdere section, Sample No: 172)

**PLATE 10**

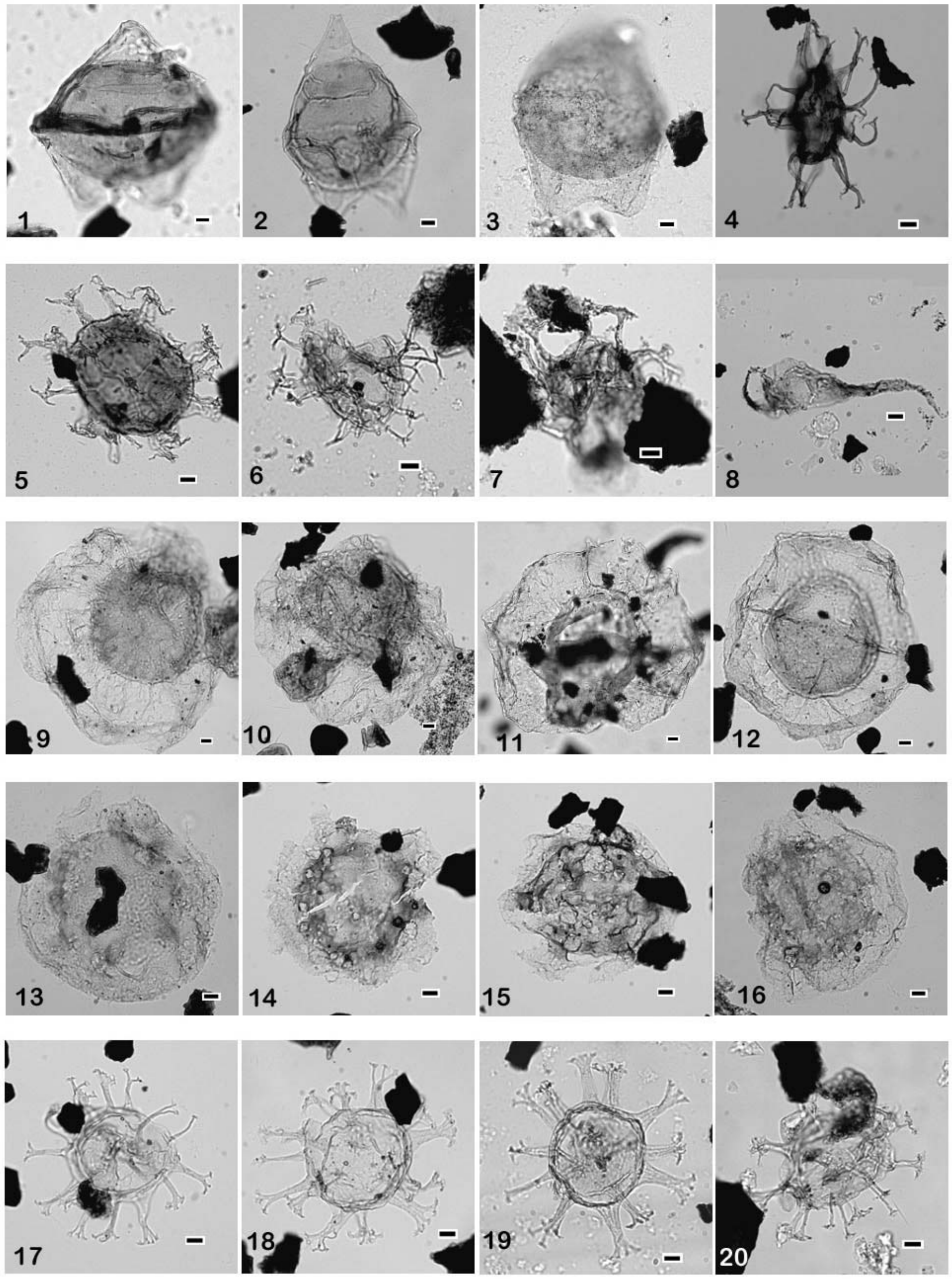


PLATE 11

1. *Pentadinium* sp. (Kelereşdere section, Sample No: 172)
2. *Pentadinium* sp. (Kelereşdere section, Sample No: 172)
3. *Pentadinium* sp. (Kelereşdere section, Sample No: 172)
4. *Pentadinium* sp. (Kelereşdere section, Sample No: 172)
5. *Pentadinium* sp. (Kelereşdere section, Sample No: 172)
6. *Pentadinium* sp. (Kelereşdere section, Sample No: 172)
7. *Pentadinium imaginatum* (Ebulbahar section, Sample No: 63)
8. *Pentadinium imaginatum* (Kelereşdere section, Sample No: 172)
9. *Achillodinium biformoides* (Kelereşdere section, Sample No: 172)
10. *Achillodinium biformoides* (Kelereşdere section, Sample No: 172)
11. *Achillodinium biformoides* (Kelereşdere section, Sample No: 172)
12. *Achillodinium biformoides* (Kelereşdere section, Sample No: 172)
13. *Membranophoridium aspinatum* (Kelereşdere section, Sample No: 172)
14. *Membranophoridium aspinatum* (Kelereşdere section, Sample No: 172)
15. *Membranophoridium aspinatum* (Kelereşdere section, Sample No: 172)
16. *Nematosphaeropsis* sp. (Ebulbahar section, Sample No: 45)
17. *Hystrichokolpoma rigaudiae* (low focus) (Kelereşdere section, Sample No: 172)
18. *Hystrichokolpoma rigaudiae* (low focus) (Kelereşdere section, Sample No: 172)
19. *Hystrichokolpoma* sp. (Kelereşdere section, Sample No: 172)
20. *Hystrichokolpoma rigaudiae* (Kelereşdere section, Sample No: 172)

**PLATE 11**

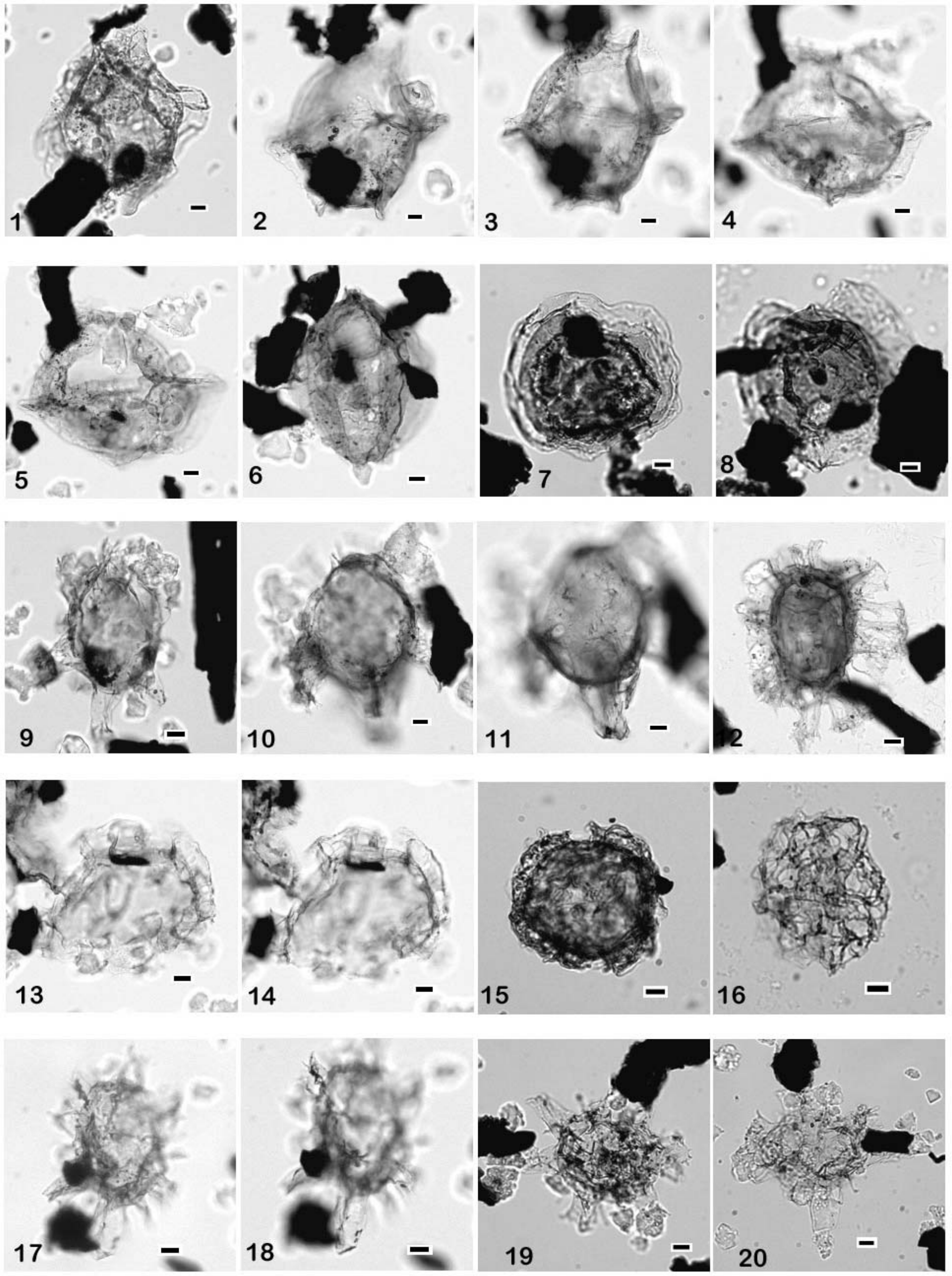


PLATE 12

1. *Hystrichokolpoma* sp. (Kelereşdere section, Sample No: 172)
2. *Hystrichokolpoma cinctum* (Ebulbahar section, Sample No: 68)
3. *Hystrichokolpoma cinctum* (Kelereşdere section, Sample No: 172)
4. *Reticulatosphaera actinocoronata* (Kelereşdere section, Sample No: 61)
5. *Lejeunecysta* sp. (Kelereşdere section, Sample No: 61)
6. *Lejeunecysta* sp. (Kelereşdere section, Sample No: 61)
7. *Lejeunecysta* sp. (Kelereşdere section, Sample No: 172)
8. cf. *Lejeunecysta* sp. (Ebulbahar section, Sample No: 46)
9. *Selenopemphix nephroides* (Kelereşdere section, Sample No: 172)
10. *Selenopemphix nephroides* (Kelereşdere section, Sample No: 172)
11. *Selenopemphix nephroides* (Ebulbahar section, Sample No: 70)
12. *Selenopemphix nephroides* (Kelereşdere section, Sample No: 172)
13. *Selenopemphix* sp. (Kelereşdere section, Sample No: 172)
14. *Distatodinium biffii* (Kelereşdere section, Sample No: 172)
15. *Distatodinium ellipticum* (Kelereşdere section, Sample No: 92)
16. *Lingulodinium machaerophorum* (Kelereşdere section, Sample No: 172)
17. *Lingulodinium machaerophorum* (Kelereşdere section, Sample No: 172)
18. *Lingulodinium machaerophorum* (Kelereşdere section, Sample No: 172)
19. *Lingulodinium machaerophorum* (Kelereşdere section, Sample No: 172)
20. Undetermined dinoflagellate (scale bar represents 50 microns) (Çirişlitepe section, Sample No: 155)

PLATE 12

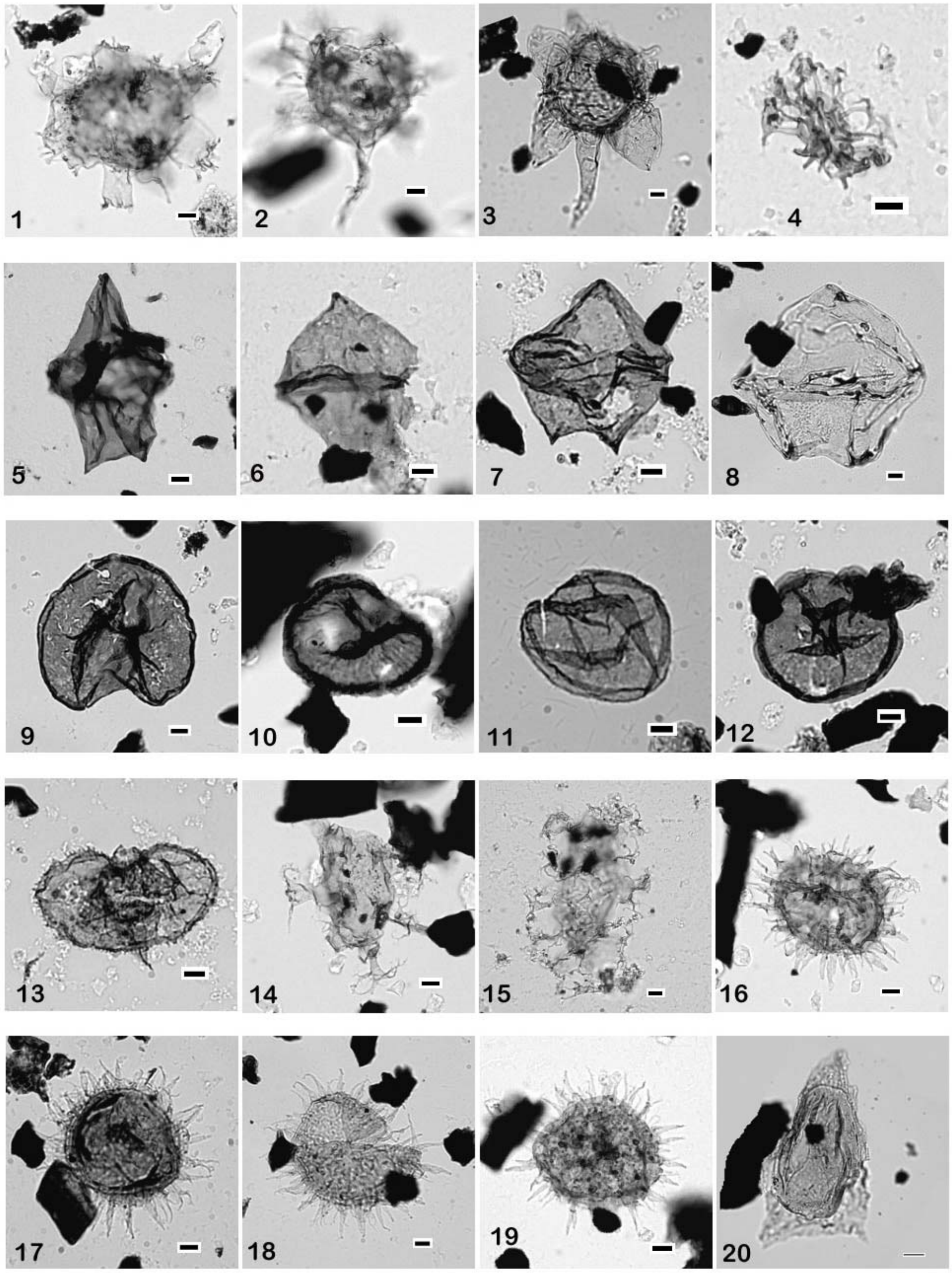


PLATE 13

1. *Glaphyrocysta* group (Kelereşdere section, Sample No: 172)
2. *Glaphyrocysta* group (Kelereşdere section, Sample No: 172)
3. *Glaphyrocysta* group (Kelereşdere section, Sample No: 172)
4. *Glaphyrocysta* group (Kelereşdere section, Sample No: 172)
5. *Ennaedocysta pectiniformis* complex (Kelereşdere section, Sample No: 61)
6. *Ennaedocysta pectiniformis* complex (Kelereşdere section, Sample No: 172)
7. *Systematophora* sp. (Kelereşdere section, Sample No: 172)
8. Undetermined dinoflagellate (Kelereşdere section, Sample No: 172)
9. *Dapsilidinium pseudocolligerum* (Kelereşdere section, Sample No: 172)
10. *Dapsilidinium pseudocolligerum* (Kelereşdere section, Sample No: 172)
11. *Polysphaeridium zoharyi* (Kelereşdere section, Sample No: 172)
12. *Polysphaeridium zoharyi* (Kelereşdere section, Sample No: 172)
13. *Polysphaeridium zoharyi* (Kelereşdere section, Sample No: 172)
14. *Polysphaeridium* sp. (Kelereşdere section, Sample No: 172)
15. *Opeculodinium microtriainum* (Ebulbahar section, Sample No: 63)
16. *Opeculodinium* sp. (Kelereşdere section, Sample No: 172)
17. *Opeculodinium* sp. (Kelereşdere section, Sample No: 172)
18. *Opeculodinium* sp. (Kelereşdere section, Sample No: 172)
19. *Opeculodinium* sp. (Kelereşdere section, Sample No: 172)
20. *Opeculodinium* sp. (Kelereşdere section, Sample No: 172)

PLATE 13

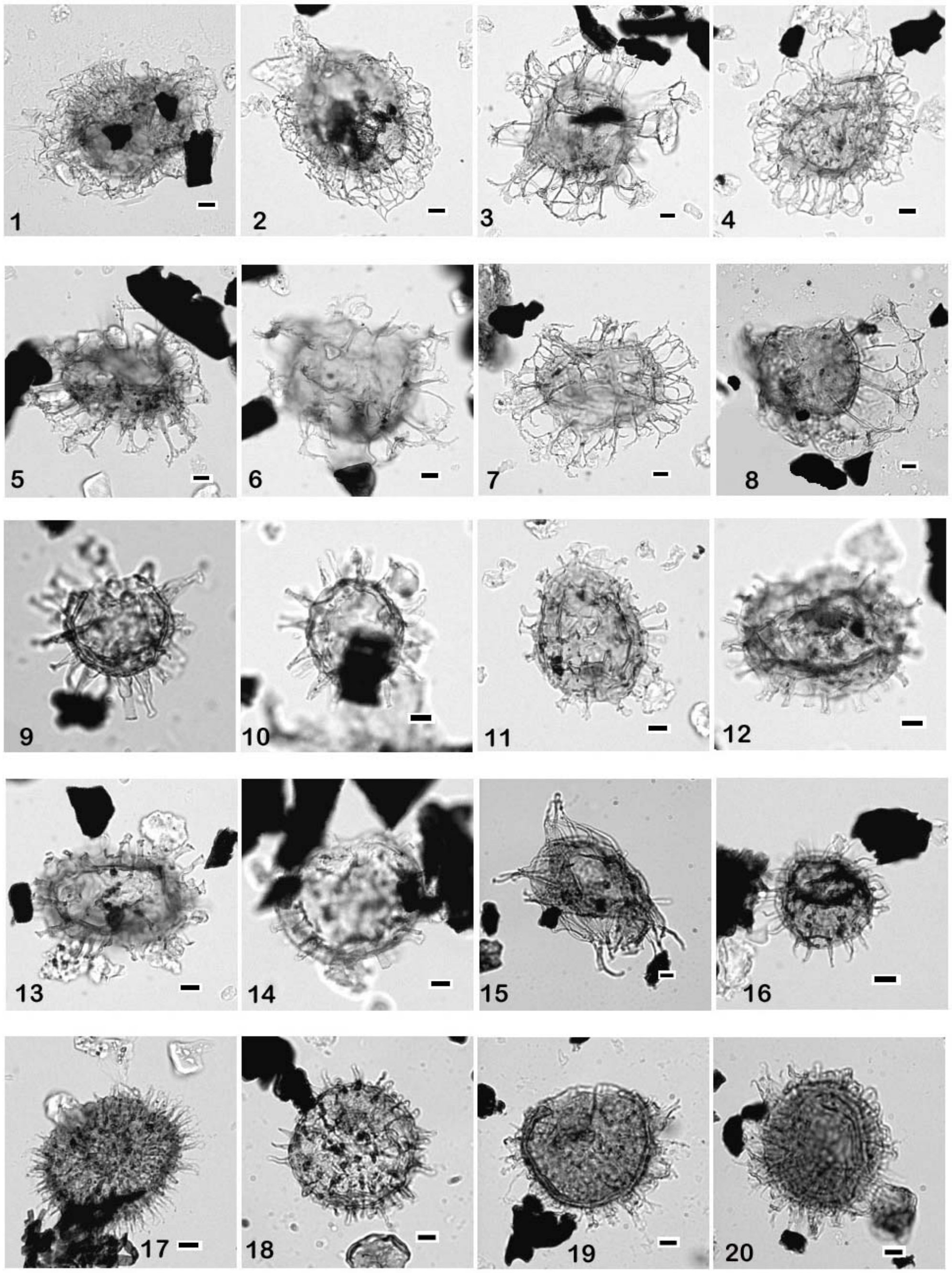


PLATE 14

1. *Cordosphaeridium cantharellus* (Kelereşdere section, Sample No: 172)
2. *Cordosphaeridium fibrospinosum* (Ebulbahar section, Sample No: 55)
3. *Cordosphaeridium fibrospinosum* (Kelereşdere section, Sample No: 172)
4. *Cordosphaeridium fibrospinosum* (Kelereşdere section, Sample No: 172)
5. *Cordosphaeridium fibrospinosum* (Kelereşdere section, Sample No: 172)
6. *Cordosphaeridium* cf. *fibrospinosum* (Ebulbahar section, Sample No: 55)
7. *Cordosphaeridium fibrospinosum* (Kelereşdere section, Sample No: 172)
8. *Cordosphaeridium fibrospinosum* (Kelereşdere section, Sample No: 172)
9. *Cordosphaeridium cantharellus* (Kelereşdere section, Sample No: 172)
10. *Cordosphaeridium fibrospinosum* (Kelereşdere section, Sample No: 172)
11. *Cordosphaeridium cantharellus* (Kelereşdere section, Sample No: 172)
12. *Cordosphaeridium cantharellus* (Kelereşdere section, Sample No: 172)
13. *Cordosphaeridium cantharellus* (Kelereşdere section, Sample No: 172)
14. *Cordosphaeridium cantharellus* (Ebulbahar section, Sample No: 79)
15. *Cordosphaeridium fibrospinosum* (Kelereşdere section, Sample No: 172)
16. *Cordosphaeridium* cf. *fibrospinosum* (Kelereşdere section, Sample No: 172)
17. *Cordosphaeridium fibrospinosum* (Kelereşdere section, Sample No: 172)
18. *Cordosphaeridium fibrospinosum* (Kelereşdere section, Sample No: 172)
19. *Cordosphaeridium* cf. *fibrospinosum* (Kelereşdere section, Sample No: 172)
20. *Hystrichokolpoma* sp. (Ebulbahar section, Sample No: 93)

PLATE 14

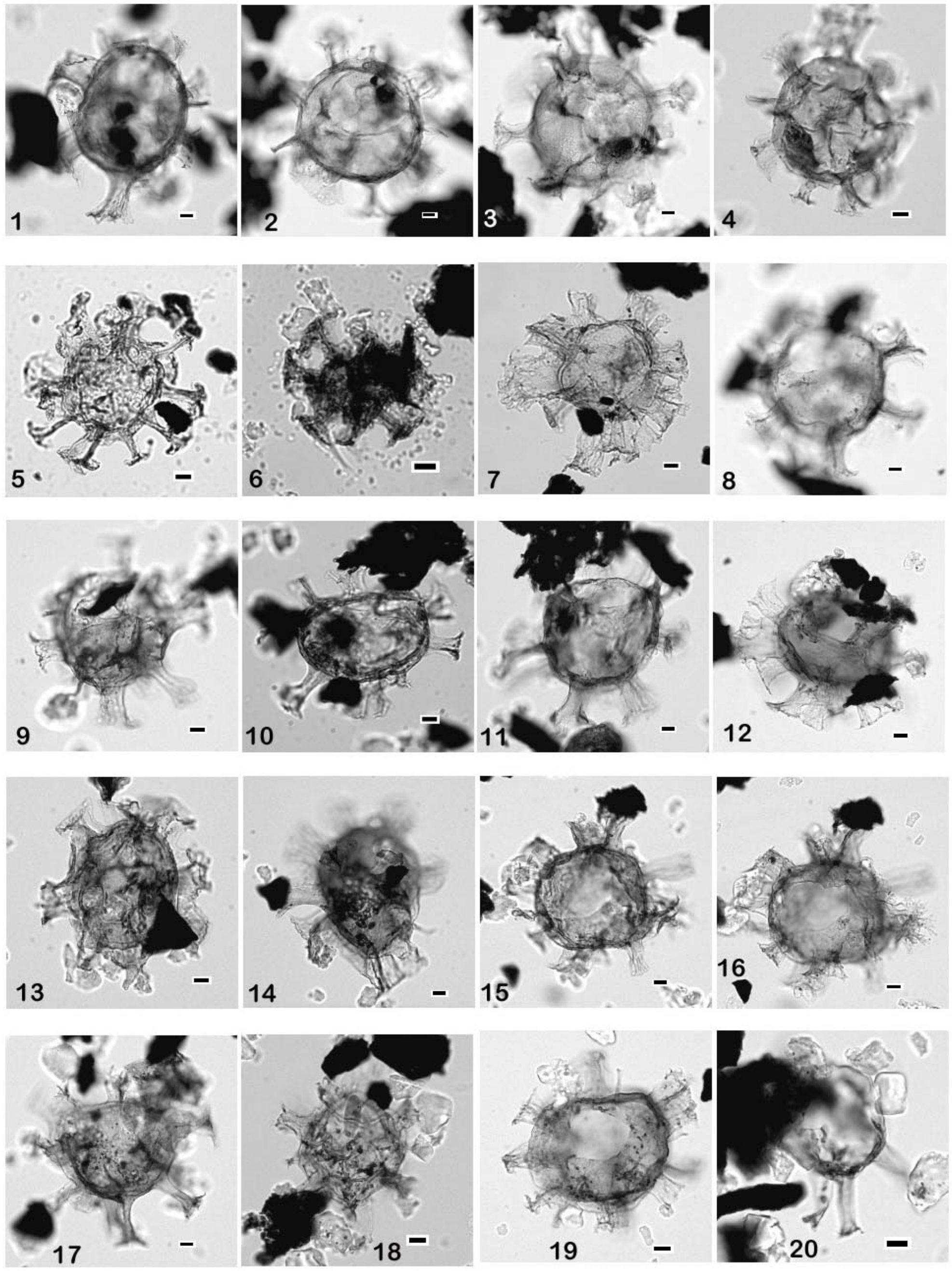


PLATE 15

1. *Hafniasphaera* sp. (Kelereşdere section, Sample No: 172)
2. *Hafniasphaera* sp. (Kelereşdere section, Sample No: 172)
3. *Hafniasphaera* sp. (Kelereşdere section, Sample No: 172)
4. *Hafniasphaera* sp. (Kelereşdere section, Sample No: 172)
5. *Hafniasphaera* sp. (Kelereşdere section, Sample No: 172)
6. *Artemisiocysta cladodichotoma* (Kelereşdere section, Sample No: 172)
7. *Artemisiocysta cladodichotoma* (Kelereşdere section, Sample No: 172)
8. *Artemisiocysta cladodichotoma* (Kelereşdere section, Sample No: 172)
9. *Spiniferites mirabilis* (Kelereşdere section, Sample No: 172)
10. *Spiniferites mirabilis* (Kelereşdere section, Sample No: 172)
11. *Spiniferites* sp. (Kelereşdere section, Sample No: 77)
12. *Spiniferites* sp. (Kelereşdere section, Sample No: 77)
13. *Spiniferites* sp. (Ebulbahar section, Sample No: 48)
14. *Spiniferites* sp. (Ebulbahar section, Sample No: 53)
15. *Spiniferites* sp. (Ebulbahar section, Sample No: 53)
16. *Spiniferites* sp. (Kelereşdere section, Sample No: 80)
17. *Systematophora placacantha* (Ebulbahar section, Sample No: 70)
18. *Systematophora placacantha* (Ebulbahar section, Sample No: 70)
19. *Systematophora placacantha* (Kelereşdere section, Sample No: 61)
20. *Heteraulacacysta* sp. (Kelereşdere section, Sample No: 172)

**PLATE 15**

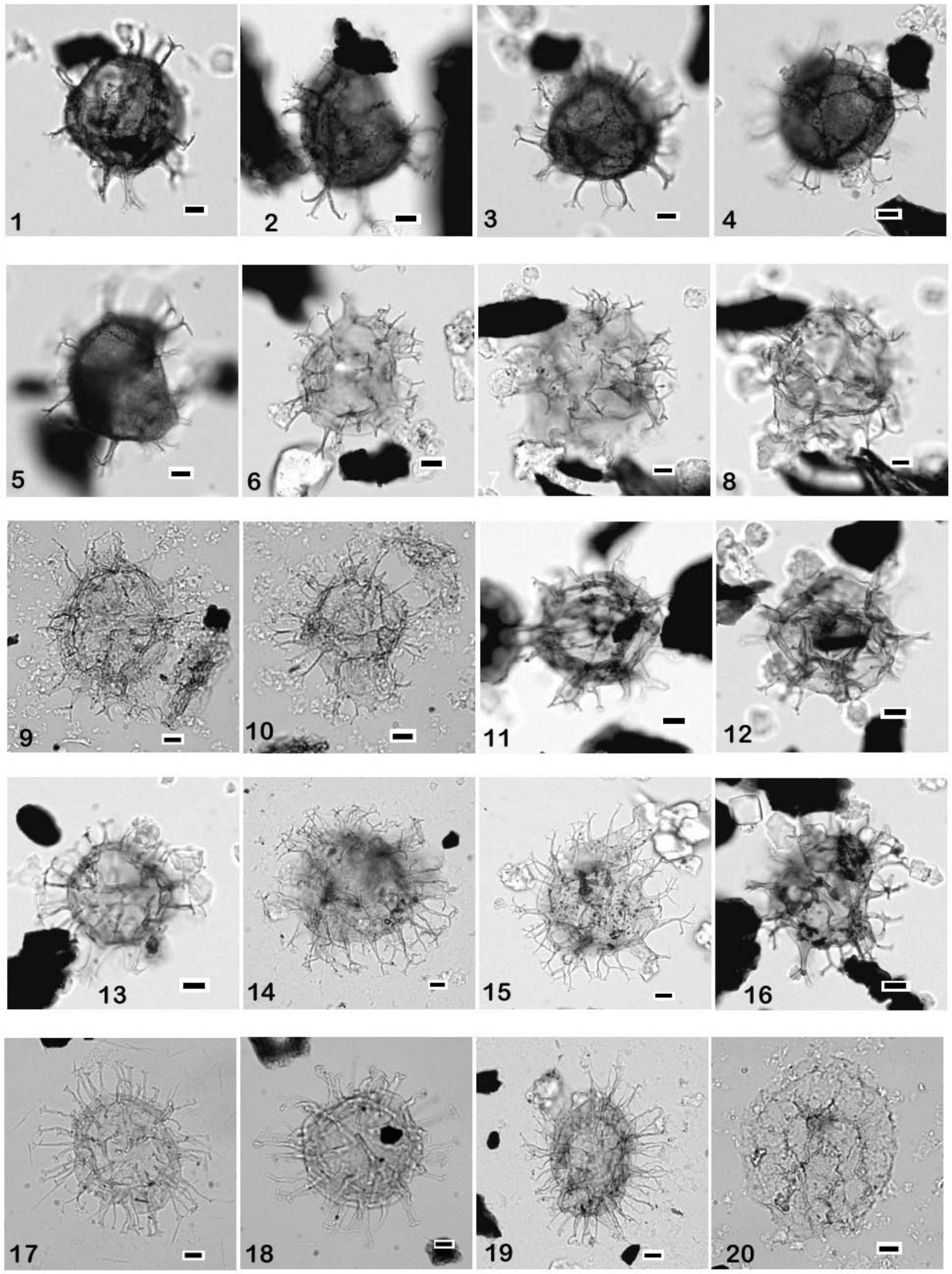


PLATE 16

1. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
2. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
3. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
4. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
5. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
6. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
7. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
8. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
9. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
10. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
11. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
12. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
13. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
14. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
15. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
16. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
17. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
18. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
19. *Ascostomocystis potane* (Kelereşdere section, Sample No: 172)
20. cf. *Ascostomocystis potane* (Ebulbahar section, Sample No: 38)

PLATE 16

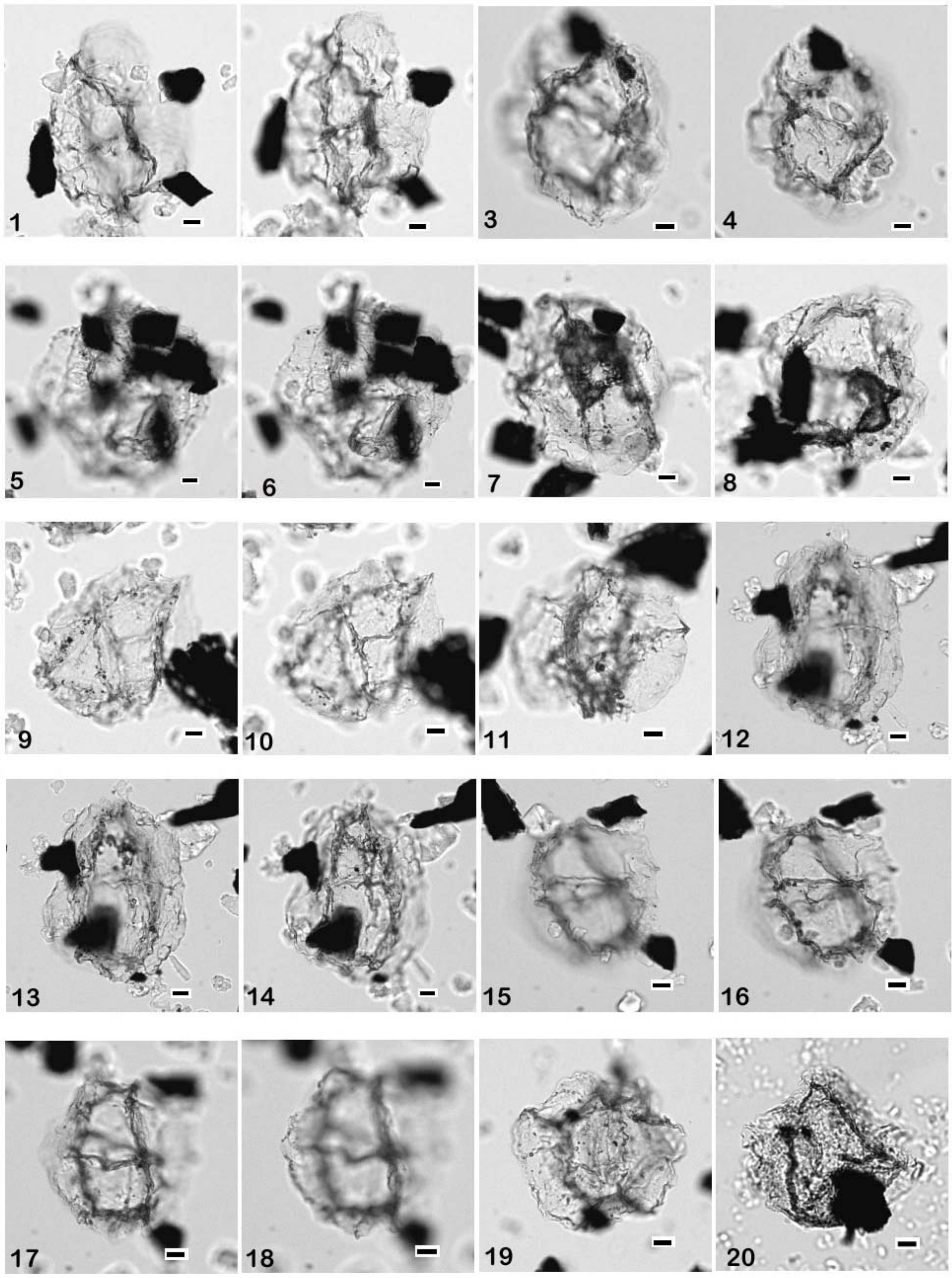


PLATE 17

1. *Wilsonidinium* sp. (Ebulbahar section, Sample No: 56)

2. *Brigantedinium* sp. (Ebulbahar section, Sample No: 72)

3. Undetermined dinoflagellate (Kelereşdere section, Sample No: 172)

4. Undetermined dinoflagellate (Kelereşdere section, Sample No: 172)

5. *Phthanoperidinium* sp. (Kelereşdere section, Sample No: 172)

6. *Phthanoperidinium multispinum* (Kelereşdere section, Sample No: 172)

7. *Phthanoperidinium multispinum* (Kelereşdere section, Sample No: 172)

8. Undetermined dinoflagellate (Kelereşdere section, Sample No: 172)

9. *Brigantedinium* sp. (Kelereşdere section, Sample No: 172)

10. *Brigantedinium* sp. (Kelereşdere section, Sample No: 172)

11. *Tasmanites* sp. (Ebulbahar section, Sample No: 90)

12. *Tasmanites* sp. (Kelereşdere section, Sample No: 172)

13. Chitinuous foraminiferal linings (Kelereşdere section, Sample No: 61)

14. Chitinuous foraminiferal linings (Kelereşdere section, Sample No: 172)

15. Scolecodont (Ebulbahar section, Sample No: 45)

16. Scolecodont (Kelereşdere section, Sample No: 172)

PLATE 17

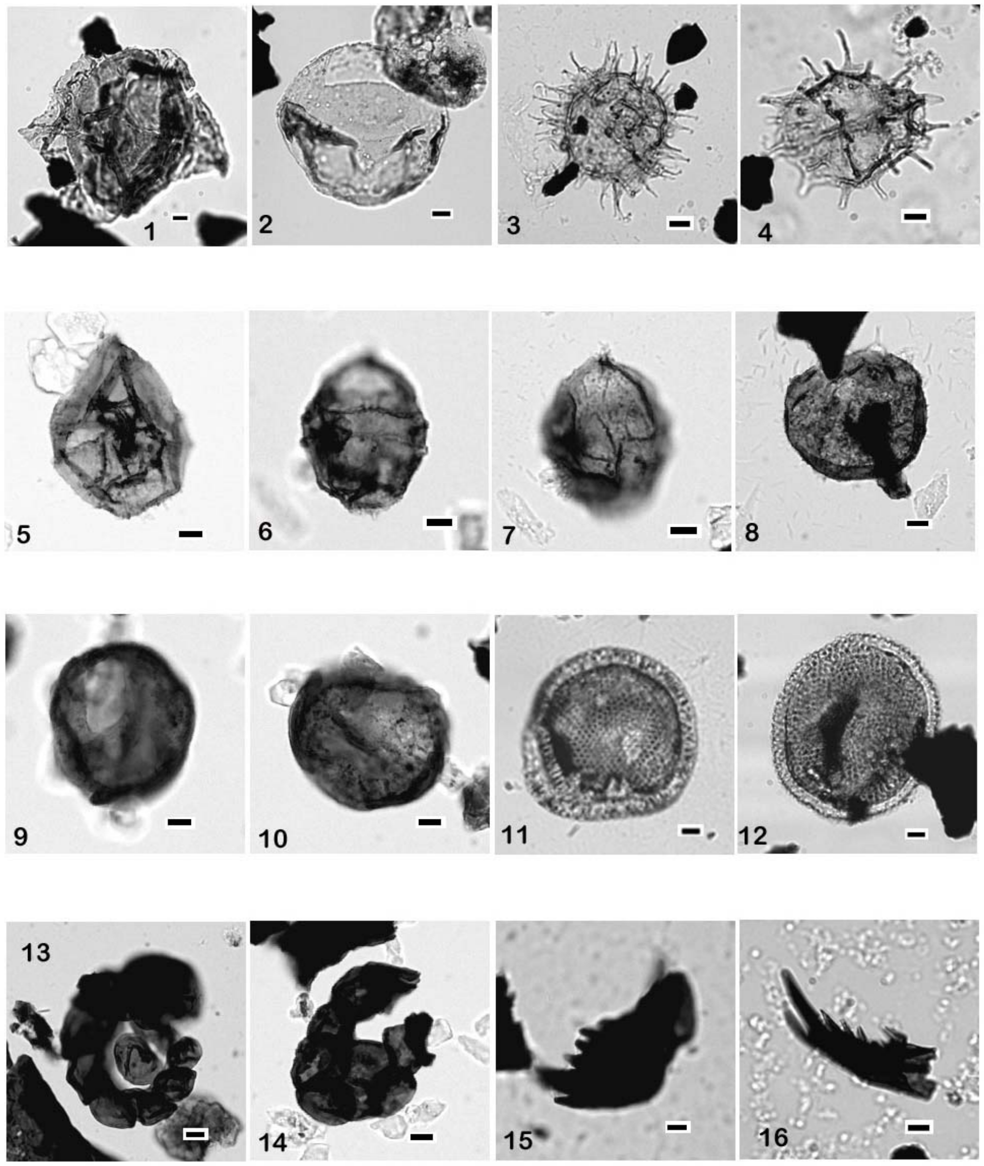


PLATE 18

1. *Wilsonidinium echinosuturatum* (Çirişlitepe section, Sample No: 155)
2. *Wilsonidinium echinosuturatum* (Çirişlitepe section, Sample No: 155)
3. *Wilsonidinium echinosuturatum* (Çirişlitepe section, Sample No: 155)
4. *Wilsonidinium echinosuturatum* (Çirişlitepe section, Sample No: 155)
5. *Wilsonidinium echinosuturatum* (Çirişlitepe section, Sample No: 155)
6. *Wilsonidinium echinosuturatum* (Çirişlitepe section, Sample No: 155)
7. *Wilsonidinium echinosuturatum* (Çirişlitepe section, Sample No: 155)
8. *Wilsonidinium tabulatum* (Çirişlitepe section, Sample No: 155)
9. *Wilsonidinium tabulatum* (Çirişlitepe section, Sample No: 155)
10. *Wilsonidinium tabulatum* (Çirişlitepe section, Sample No: 155)
11. *Wilsonidinium tabulatum* (Çirişlitepe section, Sample No: 155)
12. *Diphyes colligerum* (Çirişlitepe section, Sample No: 155)

**PLATE 18**

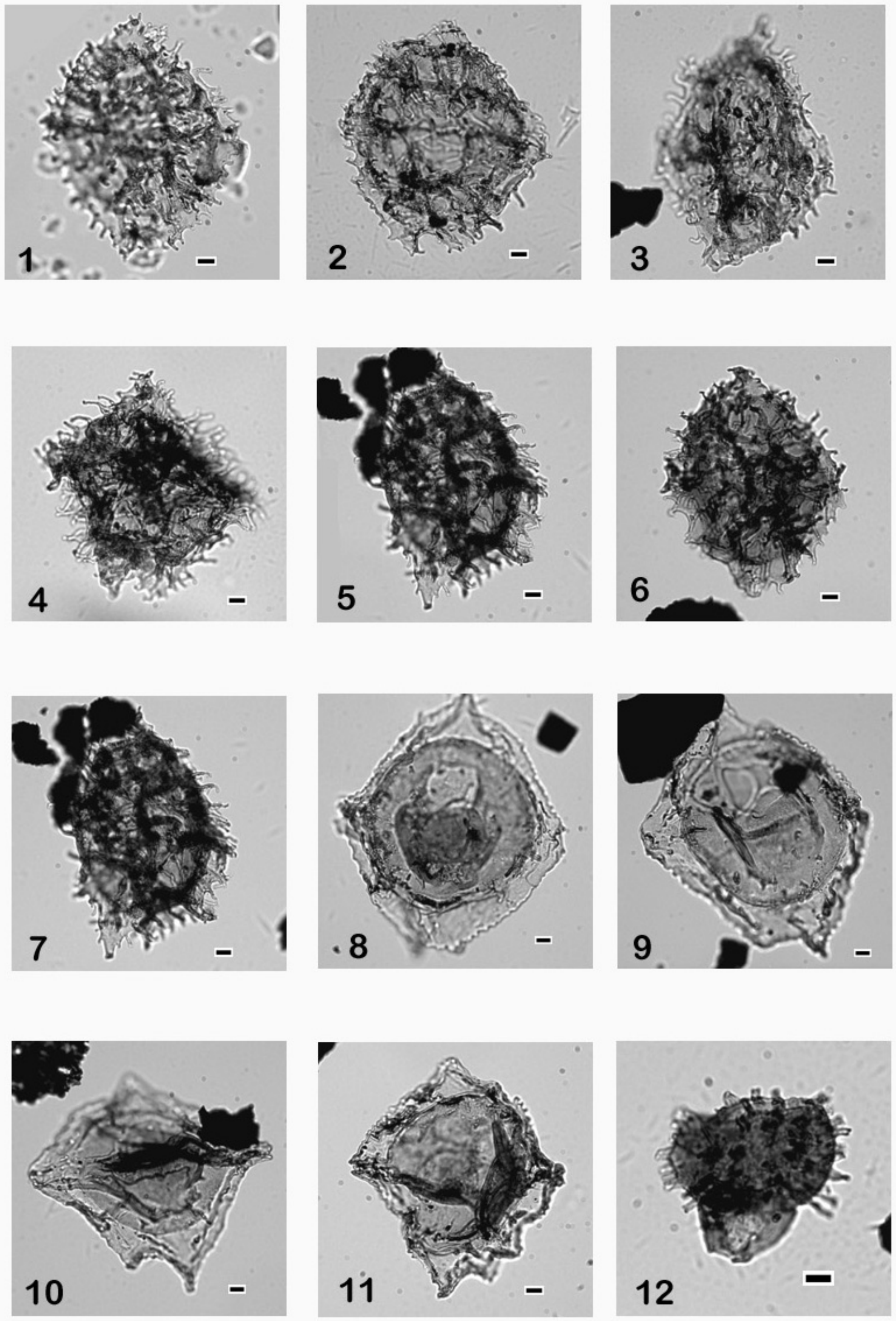


PLATE 19

1. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
2. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
3. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
4. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
5. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
6. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
7. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
8. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
9. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
10. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
11. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
12. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
13. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
14. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
15. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)
16. *Pentadinium galileoi* (Ebulbahar section, Sample No: 116)

PLATE 19

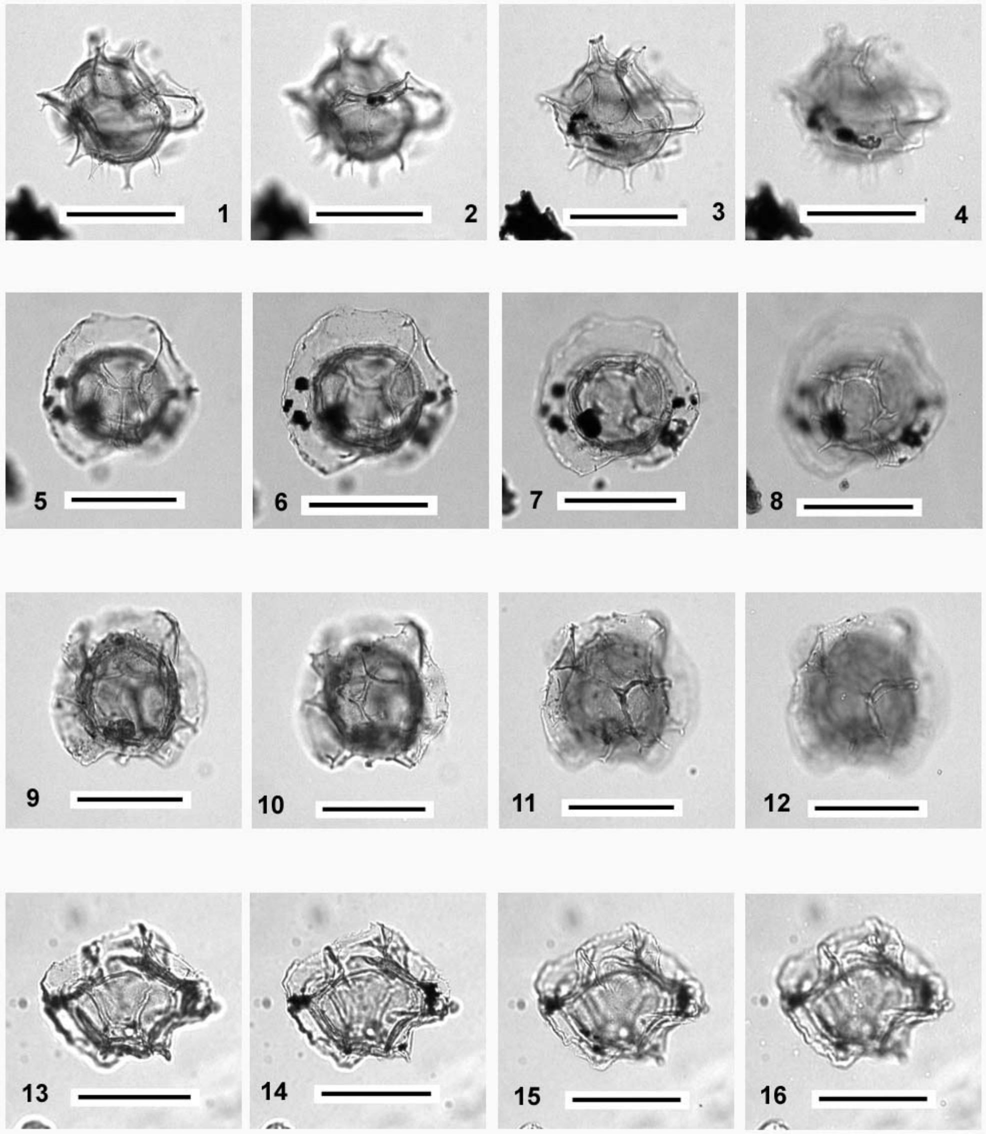


PLATE 20

1. *Batiacasphaera* sp. (Ebulbahar section, Sample No: 59)
2. *Deflandrea spinulosa* (Ebulbahar section, Sample No: 36)
3. *Deflandrea spinulosa* (Ebulbahar section, Sample No: 46)
4. *Cribroperidinium* sp. (Ebulbahar section, Sample No: 77)
5. *Pentadinium laticinctum* (Ebulbahar section, Sample No: 59)
6. *Tenua hystrix* (Pisyanlı-Çamlıca section, Sample No: 23)
7. *Distatodinium* sp. (Kelereşdere section, Sample No: 92)
8. *Pediastrum* sp. (Kelereşdere section, Sample No: 169)
9. *Pediastrum* sp. (Kelereşdere section, Sample No: 170)
10. *Pediastrum* sp. (Zırnak section, Sample No: 190)
11. *Pediastrum* sp. (Kükürtlü section, Sample No: 9)
12. *Ovoidites ligneolus* (Zırnak section, Sample No: 193)
13. *Ovoidites ligneolus* (Zırnak section, Sample No: 190)
14. *Ovoidites parvus* (Zırnak section, Sample No: 193)
15. *Ovoidites parvus* (Zırnak section, Sample No: 190)

PLATE 20

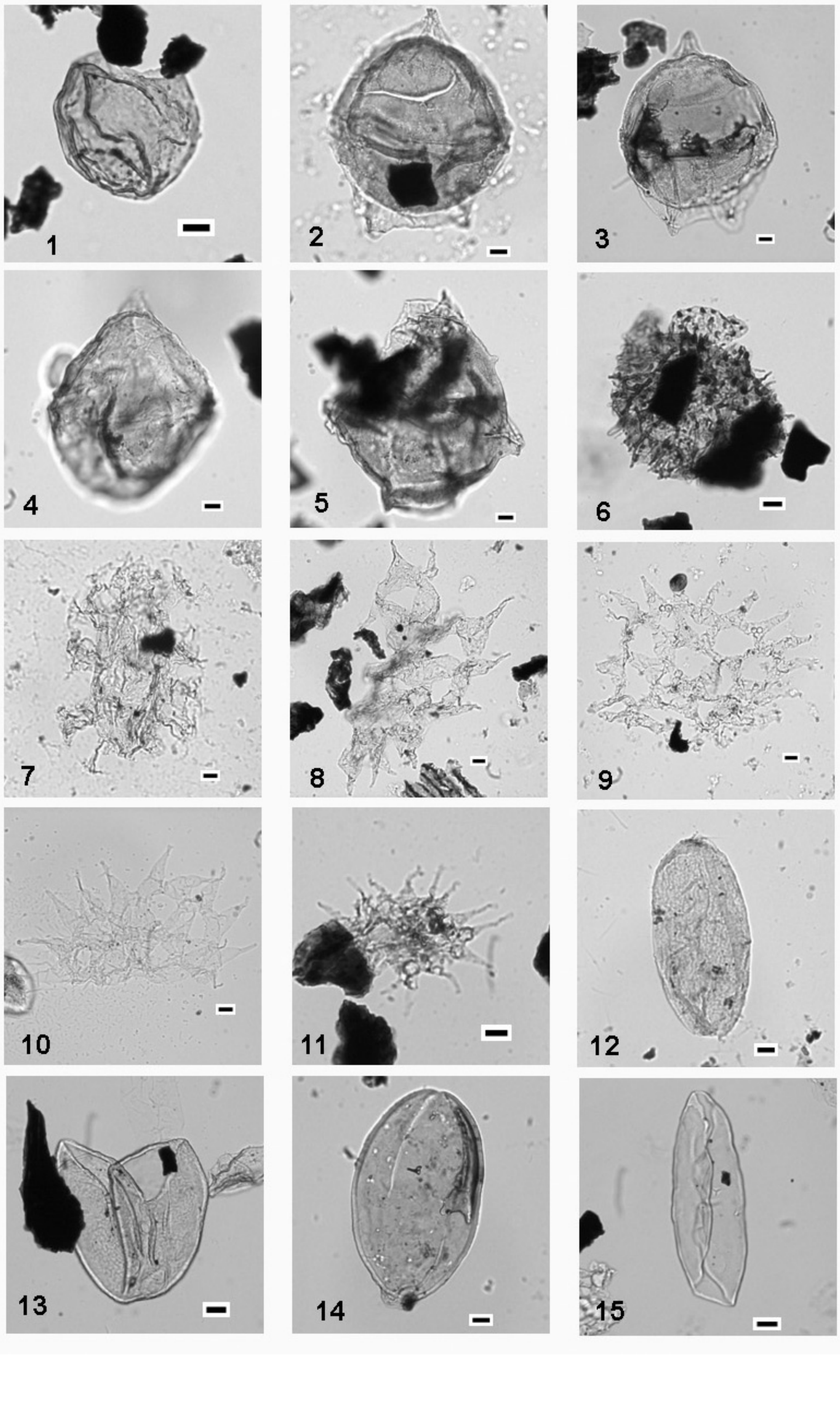


PLATE 21

1. *Pityosporites microalatus* (Kelereşdere section, Sample No: 172)
2. *Pityosporites libellus* (Ebulbahar section, Sample No: 66)
3. *Inaperturopollenites hiatus* (Kelereşdere section, Sample No: 172)
4. *Inaperturopollenites hiatus* (Kelereşdere section, Sample No: 172)
5. *Ephedripites* sp. (Kelereşdere section, Sample No: 61)
6. *Ephedripites* sp. (Kelereşdere section, Sample No: 65)
7. *Ephedripites* sp. (Kelereşdere section, Sample No: 65)
8. *Dicolpopollis* sp. (Ebulbahar section, Sample No: 70)
9. *Ilexpollenites* sp. (Kelereşdere section, Sample No: 172)
10. *Triatriopollenites excelsus* (Kelereşdere section, Sample No: 118)
11. *Slowakipollenites hipophäeoides* (Ebulbahar section, Sample No: 70)
12. *Slowakipollenites hipophäeoides* (Kelereşdere section, Sample No: 106)
13. *Corsinipollenites oculus noctis* (Ebulbahar section, Sample No: 57)
14. *Corsinipollenites oculus noctis* (Ebulbahar section, Sample No: 57)
15. *Mediocolpopollis compactus* (Kelereşdere section, Sample No: 172)
16. *Tricolporopollenites euphorii* (Kelereşdere section, Sample No: 172)
17. *Tricolporopollenites pseudocingulum* (Kelereşdere section, Sample No: 172)
18. *Tricolporopollenites pseudocingulum* (Kelereşdere section, Sample No: 172)
19. *Tricolporopollenites pseudocingulum* (Kelereşdere section, Sample No: 172)
20. *Tricolporopollenites* sp. (Kelereşdere section, Sample No: 172)

**PLATE 21**

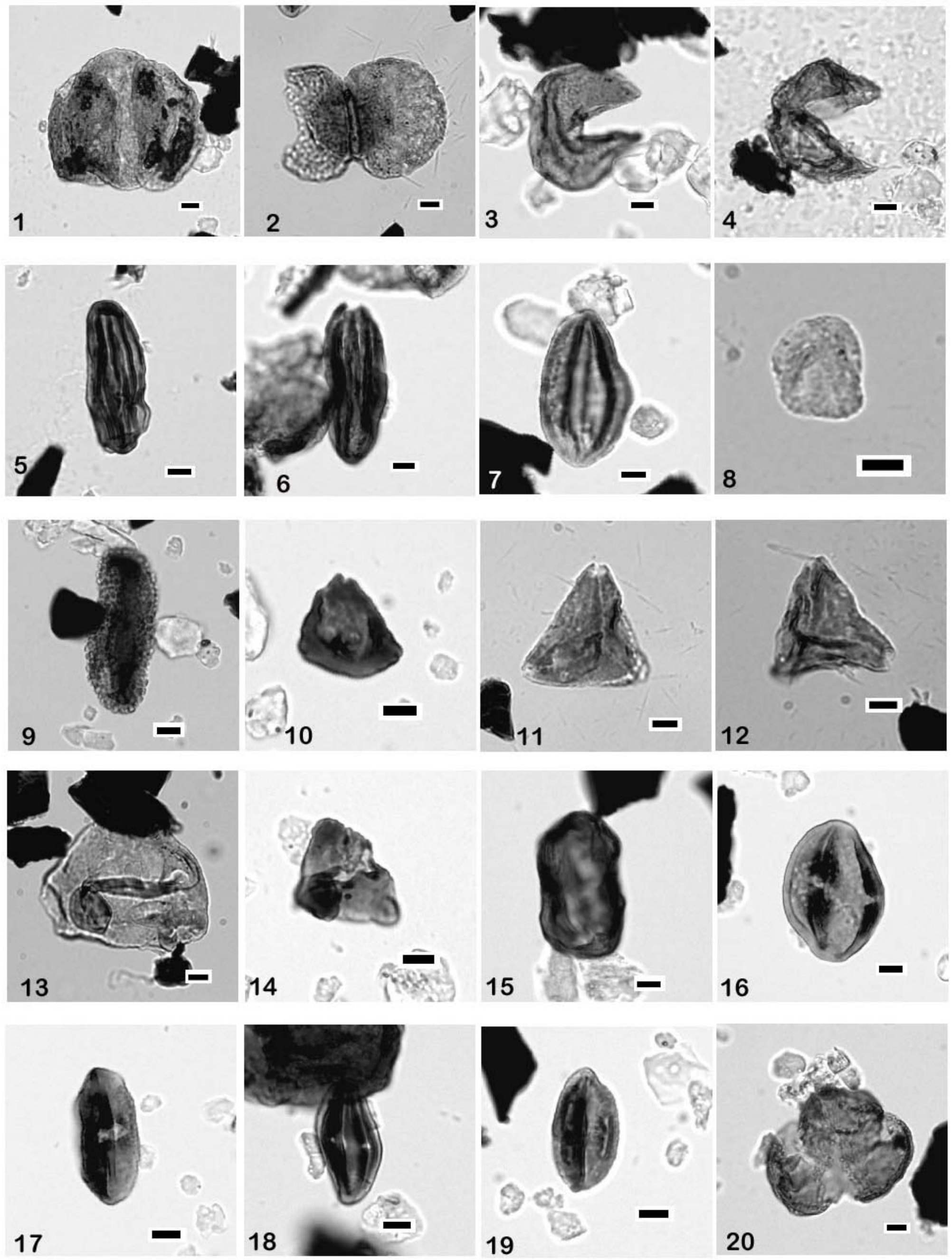


PLATE 22

1. *Pityosporites labdacus* (Ebulbahar section, Sample No: 52)
2. *Pityosporites labdacus* (Ebulbahar section, Sample No: 79)
3. *Pityosporites libellus* (Kelereşdere section, Sample No: 79)
4. *Inaperturopollenites dubius* (Kükürtlü section, Sample No: 40)
5. *Inaperturopollenites dubius* (Kükürtlü section, Sample No: 40)
6. *Inaperturopollenites polyformosus* (Kükürtlü section, Sample No: 40)
7. *Inaperturopollenites magnus* (Kelereşdere section, Sample No: 182)
8. *Monocolpopollenites tranquillus* (Kükürtlü section, Sample No: 40)
9. *Monocolpopollenites minus* (Kükürtlü section, Sample No: 40)
10. *Momipites* sp. (Kükürtlü section, Sample No: 40)
11. *Tricolpopollenites henrici* (Zırnak section, Sample No: 193)
12. *Tricolpopollenites henrici* (Ebulbahar section, Sample No: 93)
13. *Tricolporopollenites cingulum* (Ağgelin section, Sample No: 153)
14. *Tricolporopollenites cingulum* (Kelereşdere section, Sample No: 74)
15. *Tricolporopollenites cingulum* (Ebulbahar section, Sample No: 53)
16. *Tricolporopollenites cingulum* (Ebulbahar section, Sample No: 56)
17. *Tricolporopollenites pseudocingulum* (Ebulbahar section, Sample No: 44)
18. *Tricolporopollenites pseudocingulum* (Ebulbahar section, Sample No: 56)
19. *Tricolporopollenites cingulum* (Kükürtlü section, Sample No: 40)
20. *Tricolporopollenites euphorii* (Ağgelin section, Sample No: 153)

PLATE 22

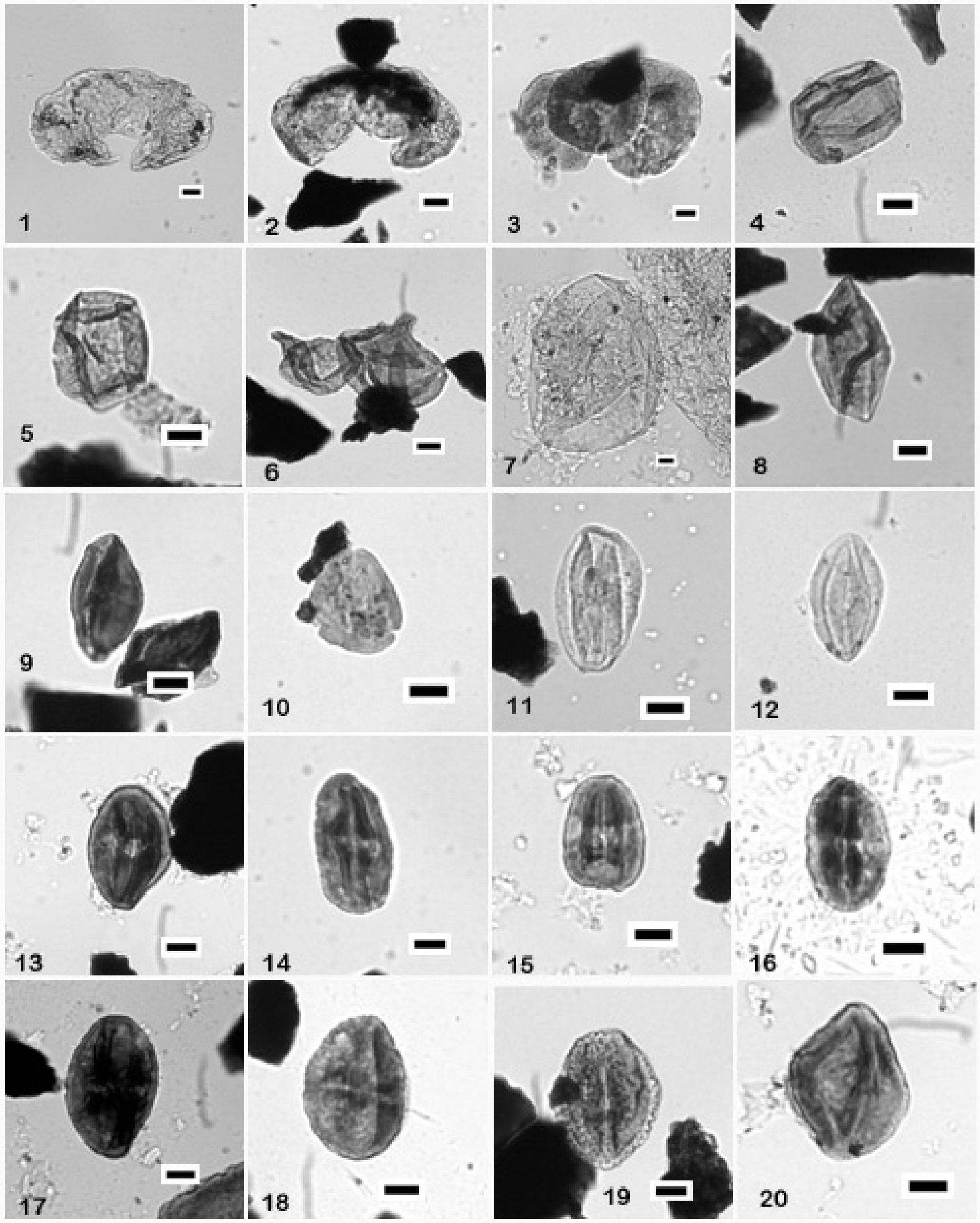


PLATE 23

1. *Zonalapollenites* sp. (Kelereşdere section, Sample No: 171)
2. *Monoporopollenites gramineoides* (Zırnak section, Sample No: 193)
3. *Monoporopollenites gramineoides* (Kelereşdere section, Sample No: 170)
4. *Monoporopollenites gramineoides* (Zırnak section, Sample No: 193)
5. *Sparganiaceapollenites neogenicus* (Kelereşdere section, Sample No: 169)
6. *Sparganiaceapollenites neogenicus* (Kelereşdere section, Sample No: 171)
7. *Sparganiaceapollenites neogenicus* (Kelereşdere section, Sample No: 170)
8. *Dicolpopollis kalewensis* (Kükürtlü section, Sample No: 40)
9. Umbelliferae (Zırnak section, Sample No: 190)
10. *Artemisia* sp. (Zırnak section, Sample No: 190)
11. Compositae (tubuliflorae-type) (Zırnak section, Sample No: 190)
12. Compositae (liguliflorae-type) (Kelereşdere section, Sample No: 159)
13. *Subtriporopollenites simplex* (Ebulbahar section, Sample No: 93)
14. *Boehlensipollis hohli* (Kelereşdere section, Sample No: 165)
15. *Mediocolpopollis compactus* (Ağgelin section, Sample No: 153)
16. *Intratriporopollenites instructus* (Ebulbahar section, Sample No: 56)
17. *Intratriporopollenites instructus* (Ağgelin section, Sample No: 153)
18. *Polyporopollenites stellatus* (Ebulbahar section, Sample No: 79)
19. *Polyporopollenites undulosus* (Zırnak section, Sample No: 193)
20. *Polyvestibulopollenites verus* (Kelereşdere section, Sample No: 171)

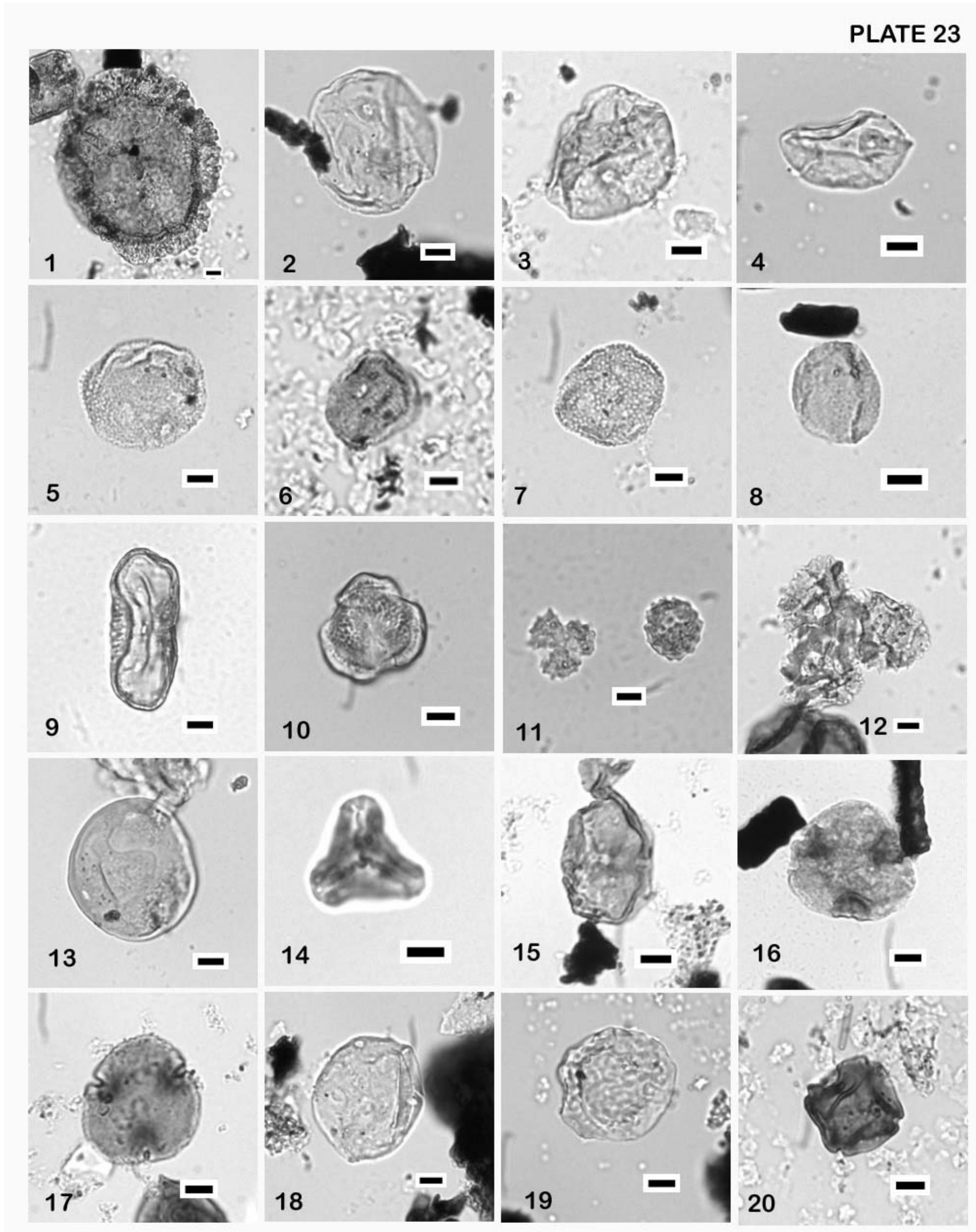


PLATE 23
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

PLATE 24

1. Compositae (tubuliflorae-type A) (Ebulbahar section, Sample No: 66)
2. Compositae (tubuliflorae-type A) (Ebulbahar section, Sample No: 66)
3. Compositae (tubuliflorae-type A) (Ebulbahar section, Sample No: 74)
4. Compositae (tubuliflorae-type A) (Ebulbahar section, Sample No: 74)
5. Compositae (tubuliflorae-type B) (Ebulbahar section, Sample No: 77)
6. Compositae (tubuliflorae-type A) (Ebulbahar section, Sample No: 77)
7. Compositae (tubuliflorae-type A) (Ebulbahar section, Sample No: 92)
8. Compositae (tubuliflorae-type B) (Kelereşdere section, Sample No: 92)
9. Compositae (tubuliflorae-type B) (Kelereşdere section, Sample No: 96)
10. Compositae (tubuliflorae-type B) (Kelereşdere section, Sample No: 96)
11. Compositae (tubuliflorae-type A) (Kelereşdere section, Sample No: 109)
12. Compositae (tubuliflorae-type B) (Kelereşdere section, Sample No: 115)
13. Compositae (tubuliflorae-type B) (Kelereşdere section, Sample No: 115)
14. Compositae (liguliflorae-type) (Kelereşdere section, Sample No: 159)
15. Compositae (liguliflorae-type) (Kelereşdere section, Sample No: 159)
16. Compositae-type pollen (Ebulbahar section, Sample No: 78)
17. Umbelliferae (Ebulbahar section, Sample No: 66)
18. Umbelliferae (Ebulbahar section, Sample No: 70)
19. Umbelliferae (Kelereşdere section, Sample No: 109)
20. *Monoporopollenites gramineoides* (Kelereşdere section, Sample No: 106)

PLATE 24

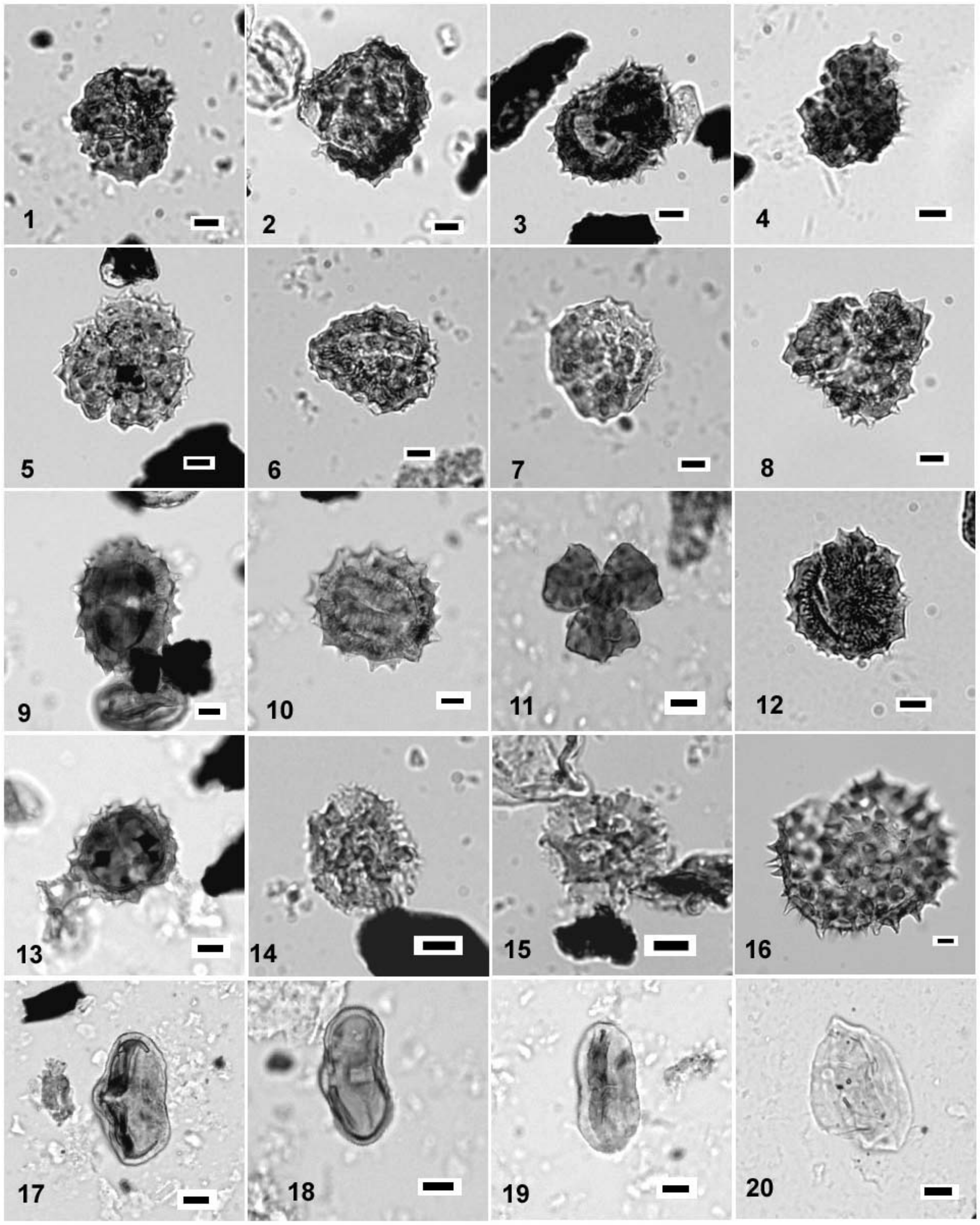


PLATE 25

1. *Tricolporopollenites* sp. (Kelereşdere section, Sample No: 172)
2. *Tricolporopollenites* sp. (Kelereşdere section, Sample No: 172)
3. Compositae (tubuliflorae-type B) (Kelereşdere section, Sample No: 172)
4. Compositae (tubuliflorae-type B) (Ebulbahar section, Sample No: 66)
5. Compositae (tubuliflorae-type B) (Kelereşdere section, Sample No: 172)
6. Compositae (tubuliflorae-type B) (Kelereşdere section, Sample No: 172)
7. Compositae-type pollen (Ebulbahar section, Sample No: 43)
8. Compositae-type pollen (Ebulbahar section, Sample No: 36)
9. *Tetracolporopollenites* sp. (Ebulbahar section, Sample No: 56)
10. *Tetracolporopollenites obscurus* (Ebulbahar section, Sample No: 59)
11. *Tetracolporopollenites manifestus* (Ağgelin section, Sample No: 153)
12. *Periporopollenites multiporatus* (Kelereşdere section, Sample No: 98)
13. *Polyporopollenites undulosus* (Kelereşdere section, Sample No: 109)
14. *Polyporopollenites undulosus* (Kelereşdere section, Sample No: 118)
15. *Polyadopollenites* sp. (Kelereşdere section, Sample No: 172)
16. *Retitriletes fragilis* (Ebulbahar section, Sample No: 57)

PLATE 25

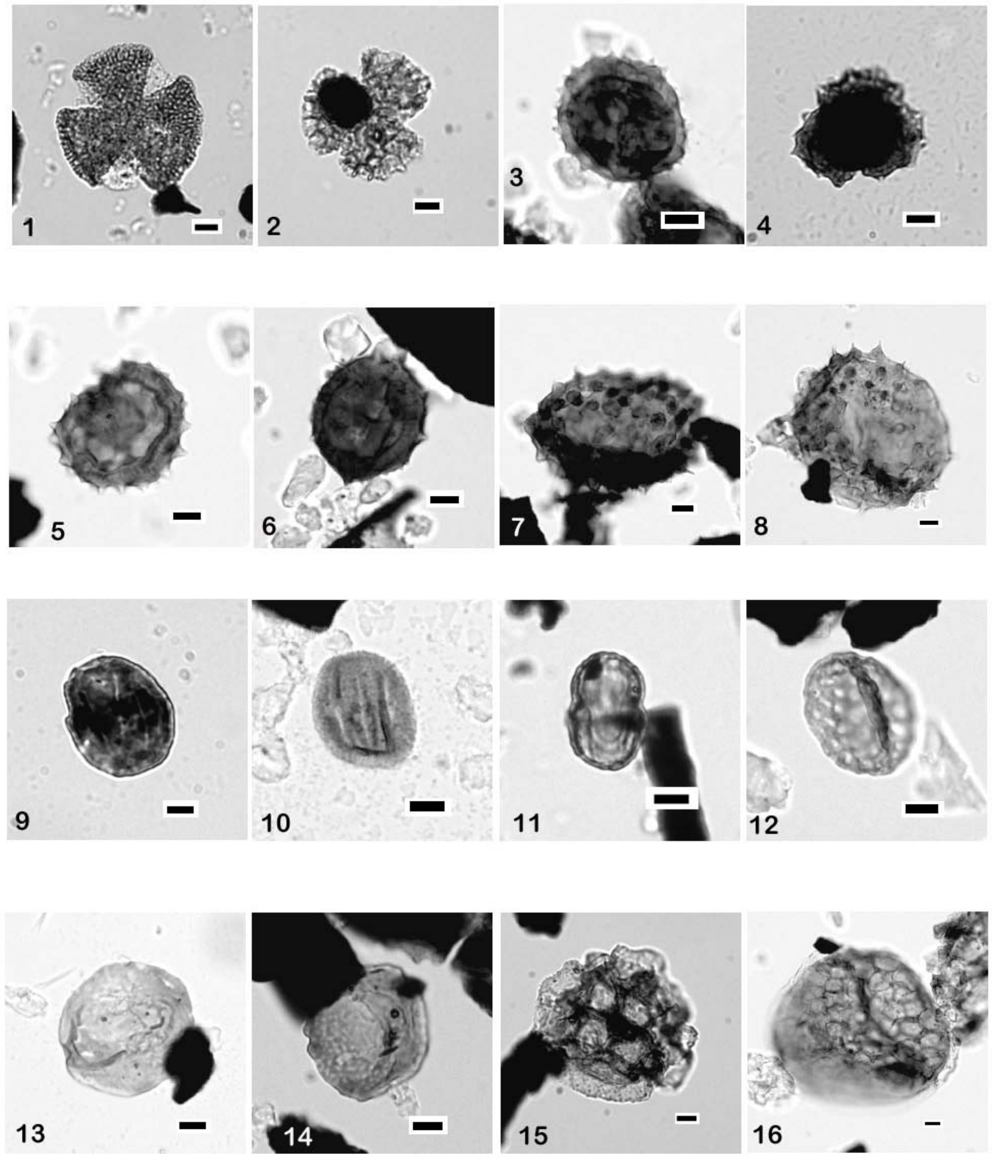


PLATE 26

1. *Monoporopollenites* sp. (Kelereşdere section, Sample No: 118)
2. *Slowakipollenites hipophäeoides* (Ebulbahar section, Sample No: 70)
3. *Slowakipollenites hipophäeoides* (Ebulbahar section, Sample No: 70)
4. *Slowakipollenites hipophäeoides* (Ebulbahar section, Sample No: 70)
5. *Slowakipollenites hipophäeoides* (Kelereşdere section, Sample No: 106)
6. *Mediocolpopollis compactus* (Kelereşdere section, Sample No: 92)
7. *Mediocolpopollis compactus* (Kelereşdere section, Sample No: 106)
8. *Dicolpopollis kalewensis* (Ebulbahar section, Sample No: 70)
9. *Verucatosporites favus* (Ebulbahar section, Sample No: 82)
10. *Subtriporopollenites simplex* (Kelereşdere section, Sample No: 109)
11. *Polyporopollenites undulosus* (Kelereşdere section, Sample No: 109)
12. *Periporopollenites multiporatus* (Ebulbahar section, Sample No: 74)
13. *Periporopollenites multiporatus* (Kelereşdere section, Sample No: 98)
14. *Polyvestibulopollenites verus* (Kelereşdere section, Sample No: 106)
15. Dipsacaceae (Kelereşdere section, Sample No: 106)
16. *Lusatisporites perinatus* (Kelereşdere section, Sample No: 92)
17. *Saxosporis* sp. (Ebulbahar section, Sample No: 116)
18. *Saxosporis* sp. (Kelereşdere section, Sample No: 109)
19. *Cicatricosisporites* sp. (Ebulbahar section, Sample No: 70)
20. *Echinatisporis longechinatus* (Ebulbahar section, Sample No: 86)

PLATE 26

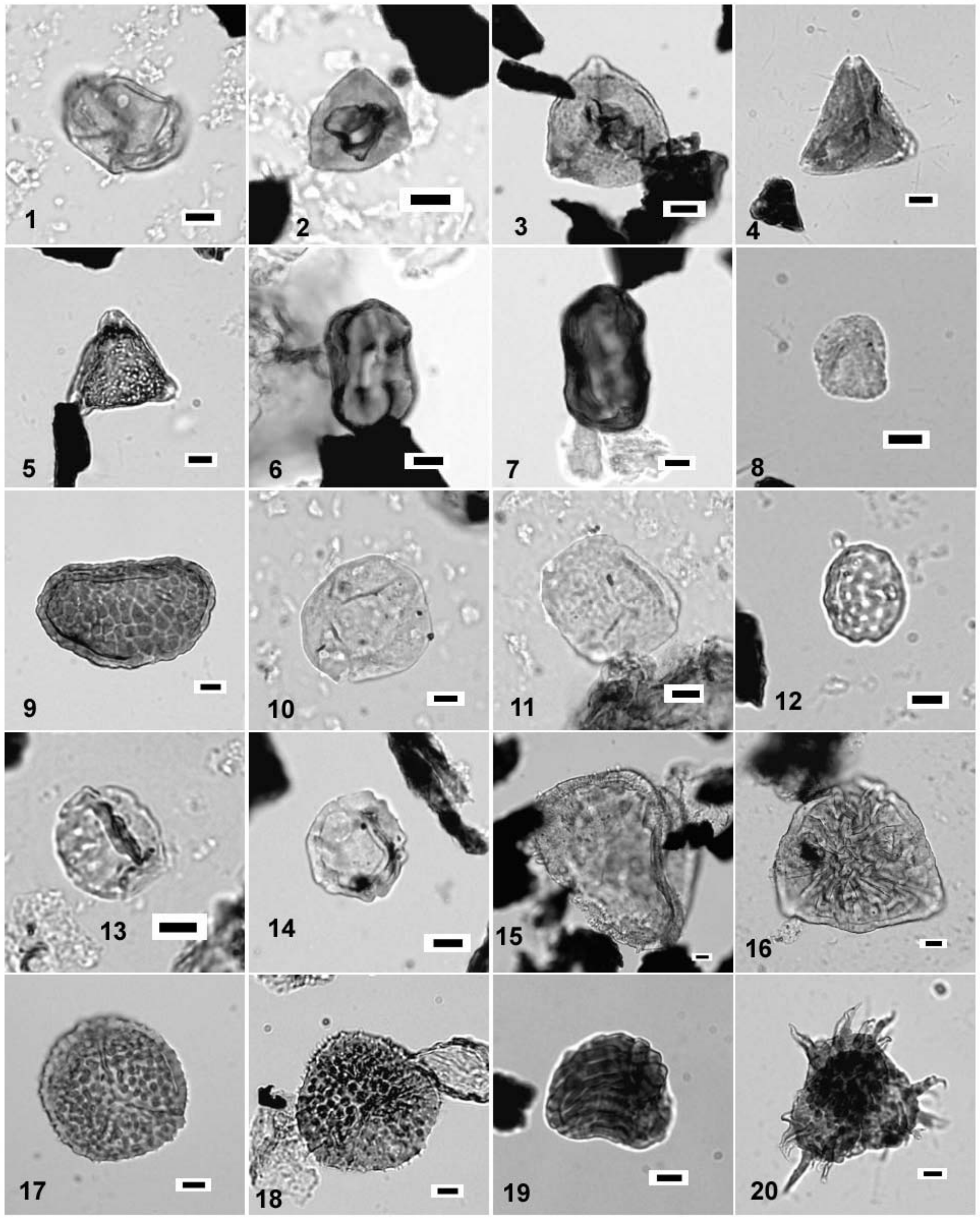


PLATE 27

1. *Periporopollenites stigmosus* (Zırnak section, Sample No: 190)
2. *Periporopollenites stigmosus* (Ebulbahar section, Sample No: 159)
3. *Periporopollenites stigmosus* (Ebulbahar section, Sample No: 42)
4. *Laevigatosporites haardti* (Kelereşdere section, Sample No: 159)
5. *Verrucatosporites favus* (Kükürtlü section, Sample No: 9)
6. *Verrucatosporites alienus* (Kelereşdere section, Sample No: 174)
7. *Verrucatosporites scutulum* (Kelereşdere section, Sample No: 169)
8. *Echinatosporites bifurcus* (Kelereşdere section, Sample No: 169)
9. *Echinatosporites bifurcus* (Kükürlü section, Sample No: 5)
10. *Echinatosporites bifurcus* (Kükürlü section, Sample No: 10)
11. *Leiotriletes adriennis* (Ebulbahar section, Sample No: 77)
12. *Leiotriletes adriennis* (Ebulbahar section, Sample No: 72)
13. *Leiotriletes microadriennis* (Pisyanlı-Çamlıca section, Sample No: 25)
14. *Leiotriletes adriennis* (Ebulbahar section, Sample No: 77)
15. *Leiotriletes microadriennis* (Ebulbahar section, Sample No: 70)
16. *Leiotriletes dorogensis* (Ebulbahar section, Sample No: 77)
17. *Baculatisporites primarius* (Kelereşdere section, Sample No: 169)
18. *Magnastriatisporites howardi* (Ebulbahar section, Sample No: 37)
19. Reworked trilet spor (Kelereşdere section, Sample No: 81)
20. Reworked trilet spor (Ebulbahar section, Sample No: 36)

PLATE 27

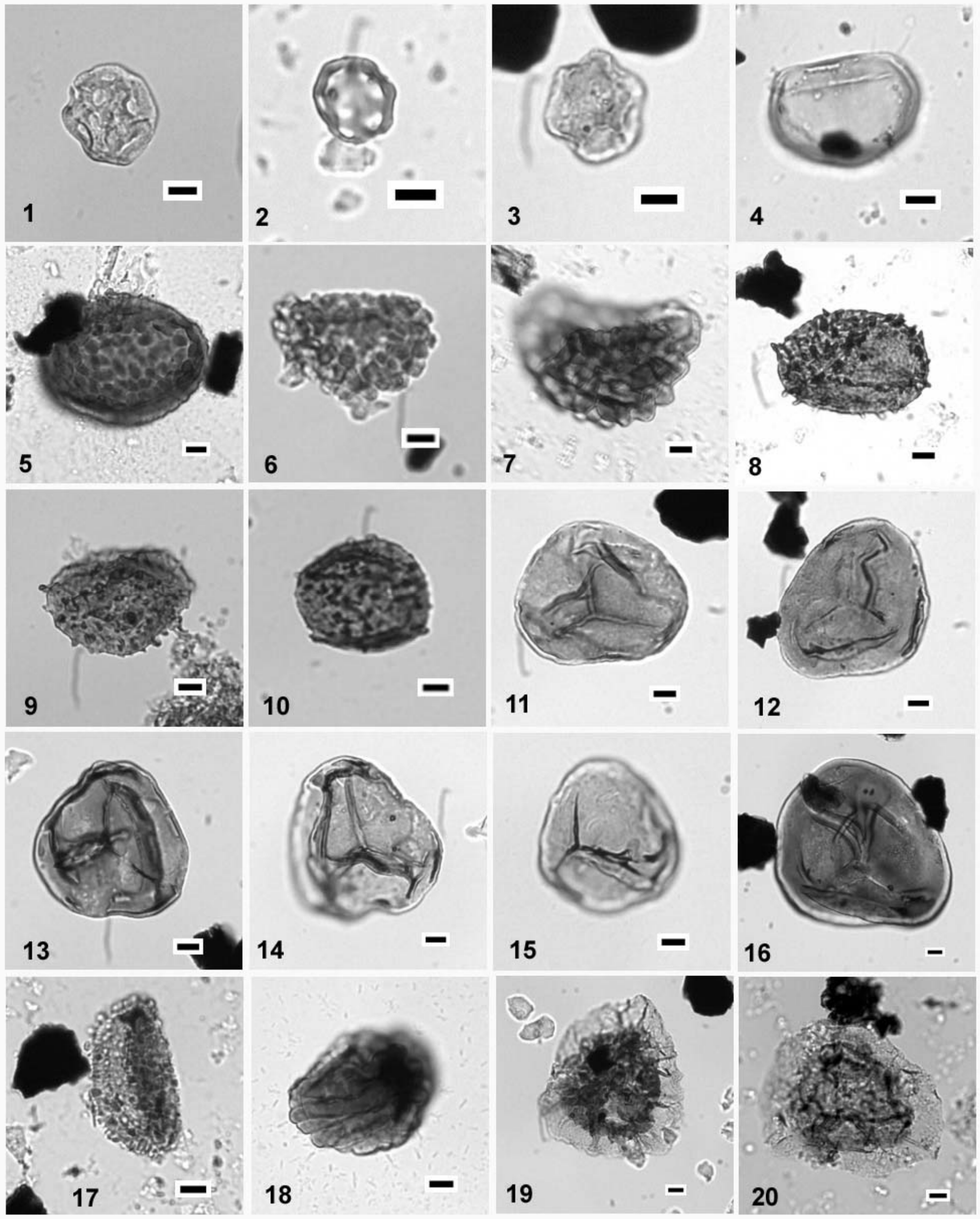


PLATE 28

1. *Cingulatisporites macrospeciosus* (Kelereşdere section, Sample No: 172)

2. *Cingulatisporites* sp. (Kelereşdere section, Sample No: 172)

3. *Trilites multivallatus* (Ebulbahar section, Sample No: 39)

4. *Lusatisporites perinatus* (Ebulbahar section, Sample No: 111)

5. *Leiotriletes microadriennis* (Kelereşdere section, Sample No: 118)

6. *Saxosporis* sp. (Ebulbahar section, Sample No: 93)

7. *Cicatricosisporites* sp. (Kelereşdere section, Sample No: 172)

8. *Cicatricosisporites* sp. (Ebulbahar section, Sample No: 66)

9. *Extratriporopollenites* sp. (Çirişlitepe section, Sample No: 155)

10. *Echinatisporis* sp. (Kelereşdere section, Sample No: 172)

11. *Appendicisporites* sp. (Kelereşdere section, Sample No: 172)

12. *Psilodisporites gunniae* (Kelereşdere section, Sample No: 172)

## PLATE 28

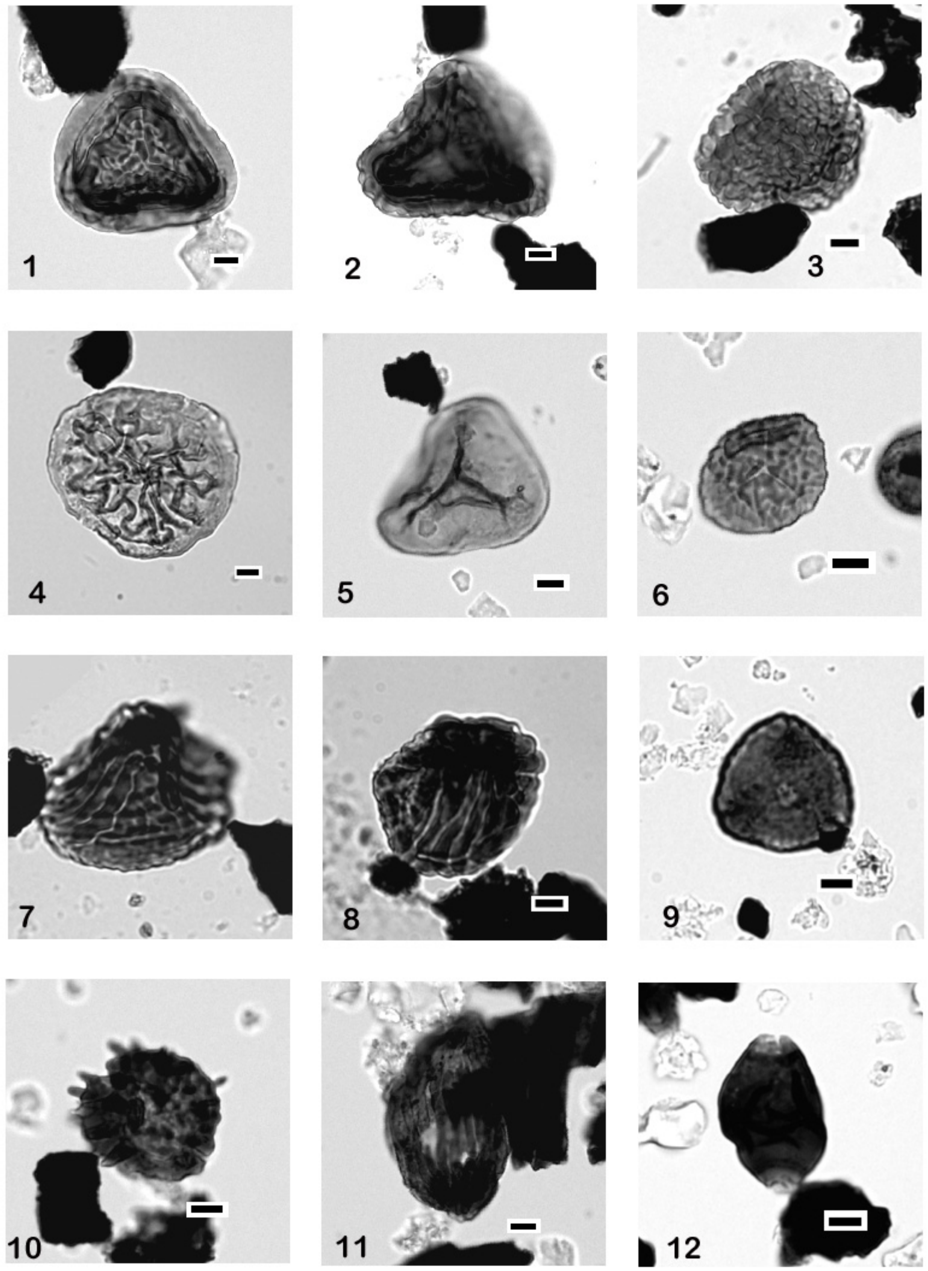
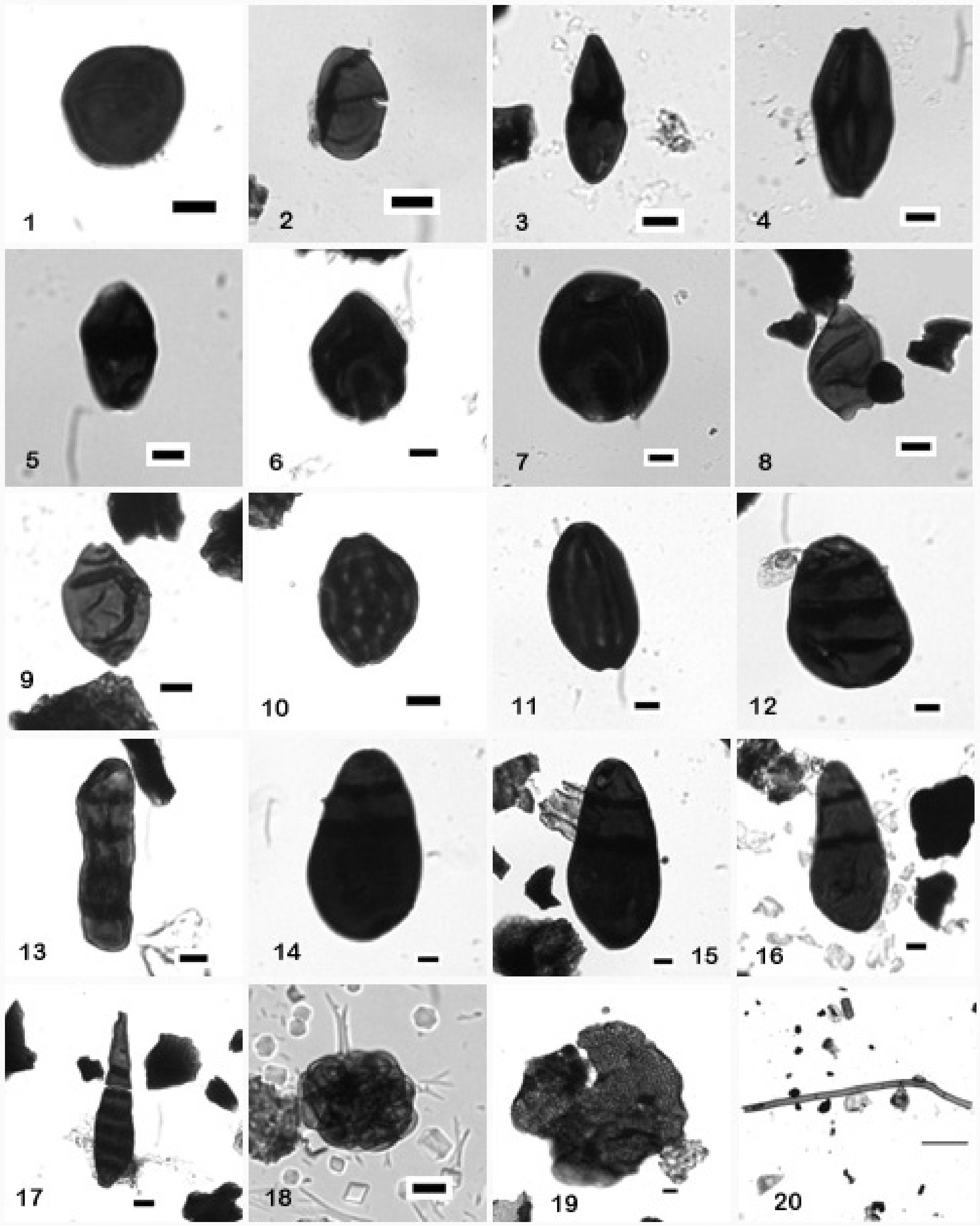


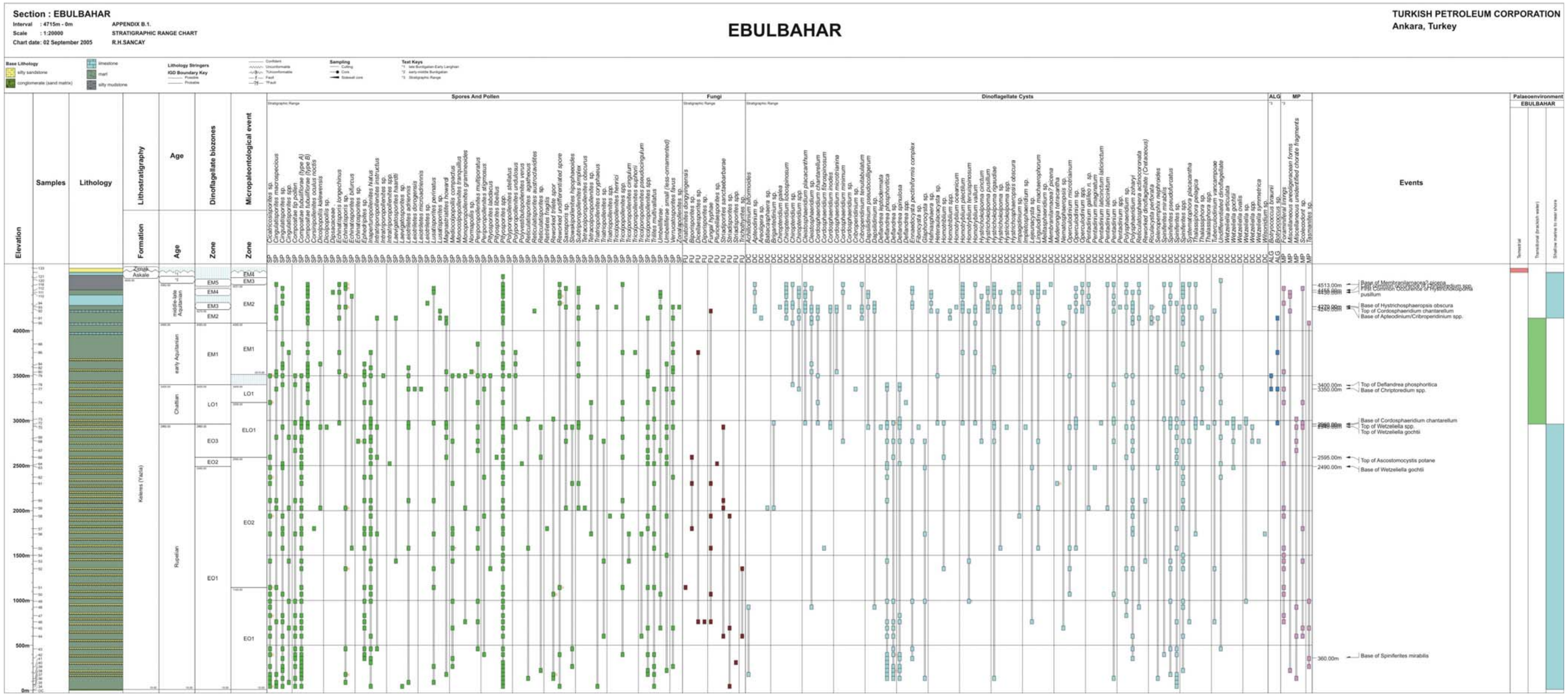
PLATE 29

1. *Inapertisporites rotundus* (Kükürtlü section, Sample No: 9)
2. *Dicellaesporites* sp. (Kömürlü section, Sample No: 40)
3. *Dicellaesporites* sp. (Ebulbahar section, Sample No: 46)
4. *Striadisporites* sp. (Kelereşdere section, Sample No: 170)
5. *Diporisporites* sp. (Pisyanlı-Çamlıca section, Sample No: 24)
6. *Biporisporites* sp. (Kötek section, Sample No: 132)
7. *Biporisporites* sp. (Kömürlü section, Sample No: 31)
8. *Psilodisporites gunniae* (Kömürlü section, Sample No: 40)
9. *Psilodisporites gunniae* (Kömürlü section, Sample No: 40)
10. *Striadisporites sanctaebarbarae* (Ebulbahar section, Sample No: 59)
11. *Striadisporites* sp. (Kükürtlü section, Sample No: 9)
12. *Pluricellaesporites* sp. (Kükürtlü section, Sample No: 9)
13. *Multicellaesporites* sp. (Kelereşdere section, Sample No: 165)
14. *Anatolinites dongyingensis* (Kükürtlü section, Sample No: 9)
15. *Anatolinites dongyingensis* (Kükürlü section, Sample No: 5)
16. *Anatolinites dongyingensis* (Kötek section, Sample No: 132)
17. *Multicellaesporites* sp. (Kömürlü section, Sample No: 40)
18. *Polyadosporites orbis* (Pisyanlı-Çamlıca section, Sample No: 24)
19. *Trichothyrites* sp. (Ebulbahar section, Sample No: 52)
20. Fungal hyphae (Ebulbahar section, Sample No: 92) (scale bar represents 100 microns).

PLATE 29

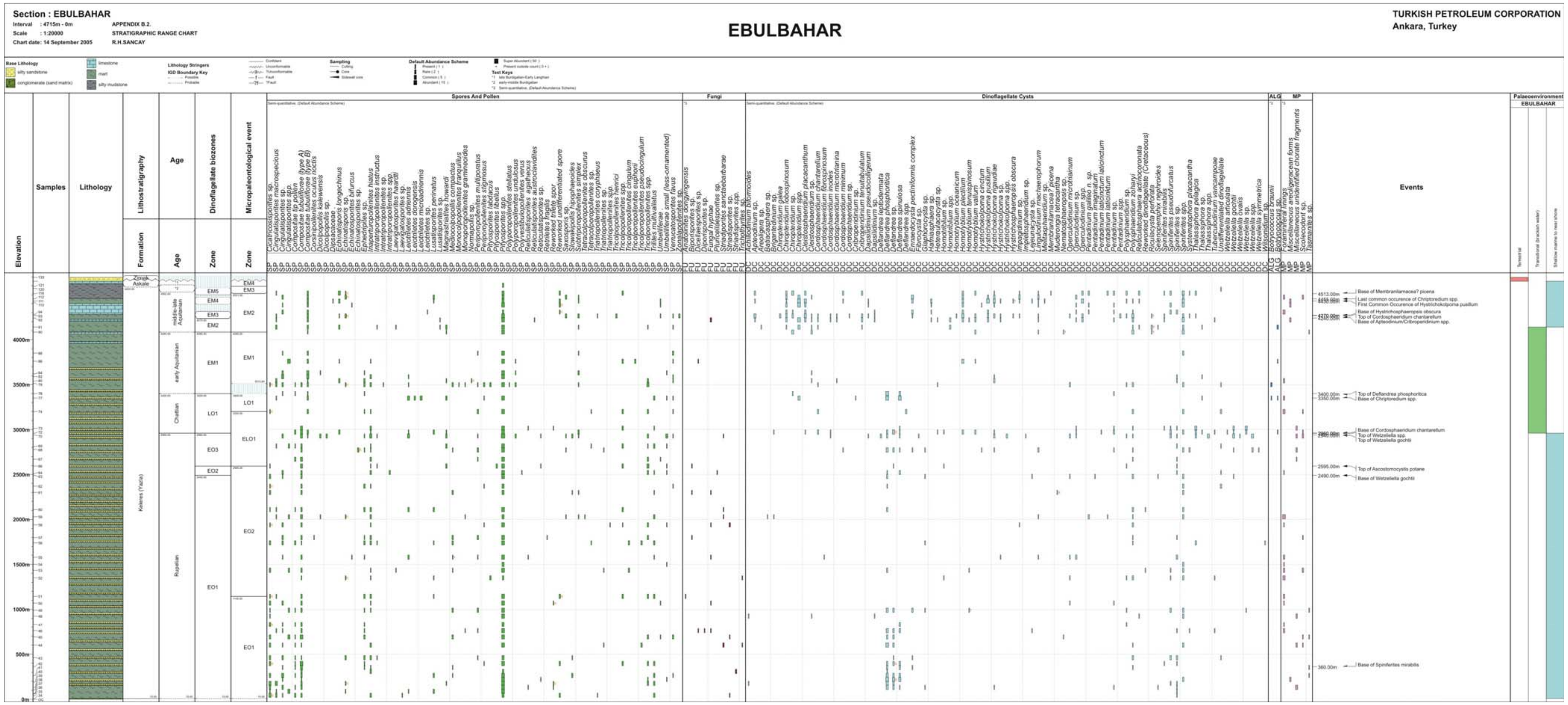


APPENDIX B



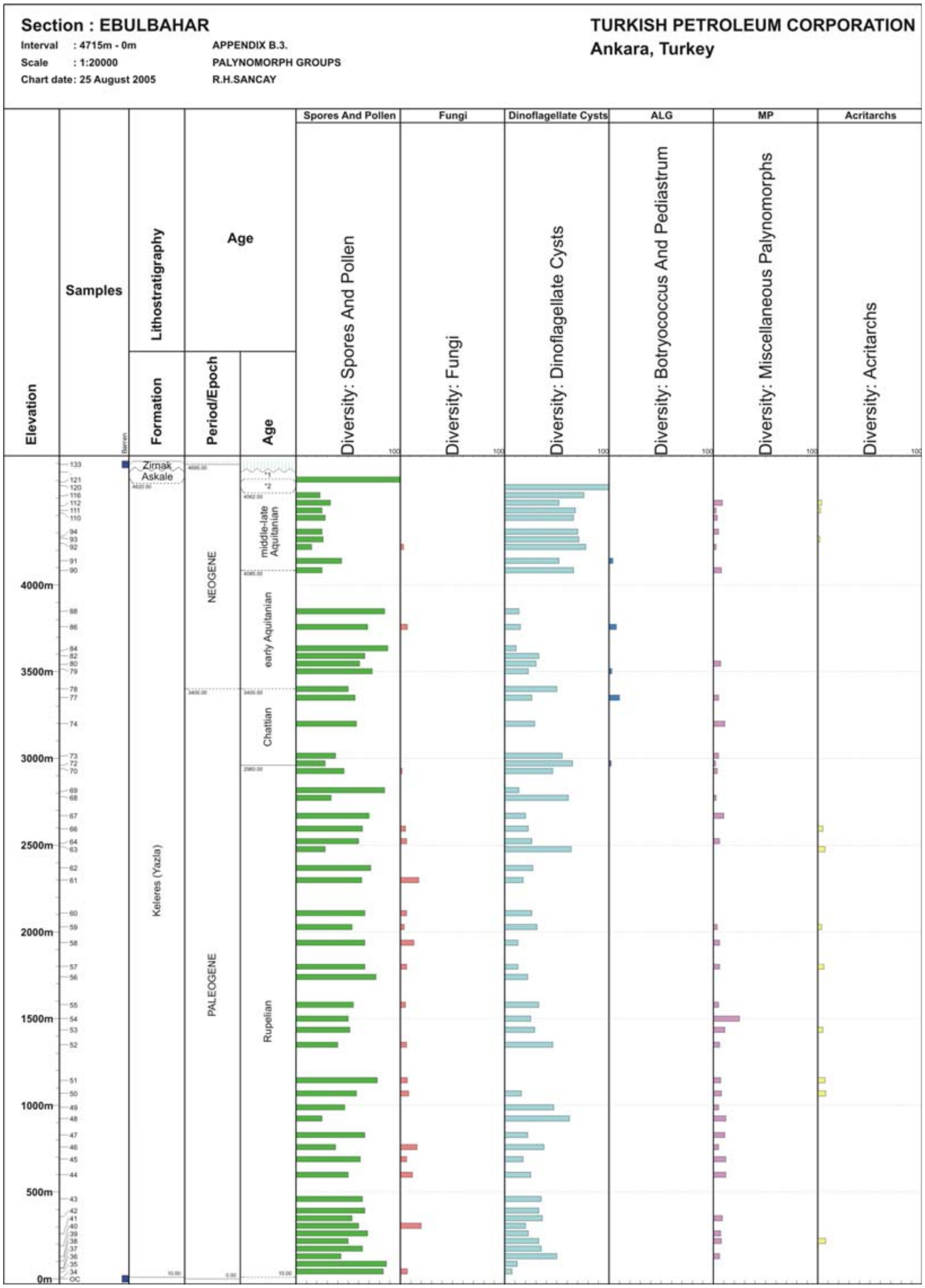

Appendix B.1. Stratigraphic Range Chart of the Palynomorphs in the Ebulbahar Section.

APPENDIX B



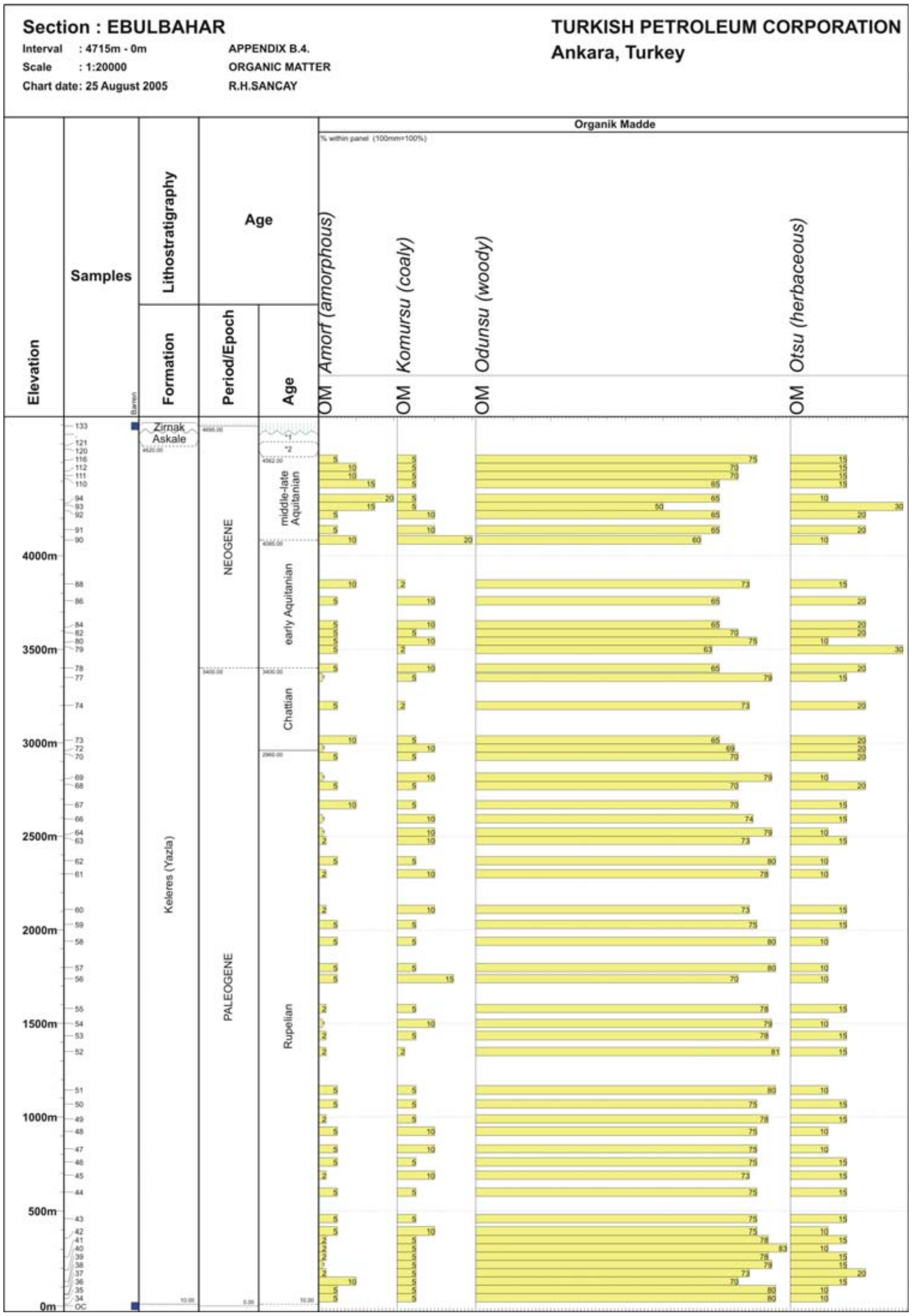
Appendix B.2. Abundance Chart of the palynomorphs in the Ebulbahar Section.

APPENDIX B



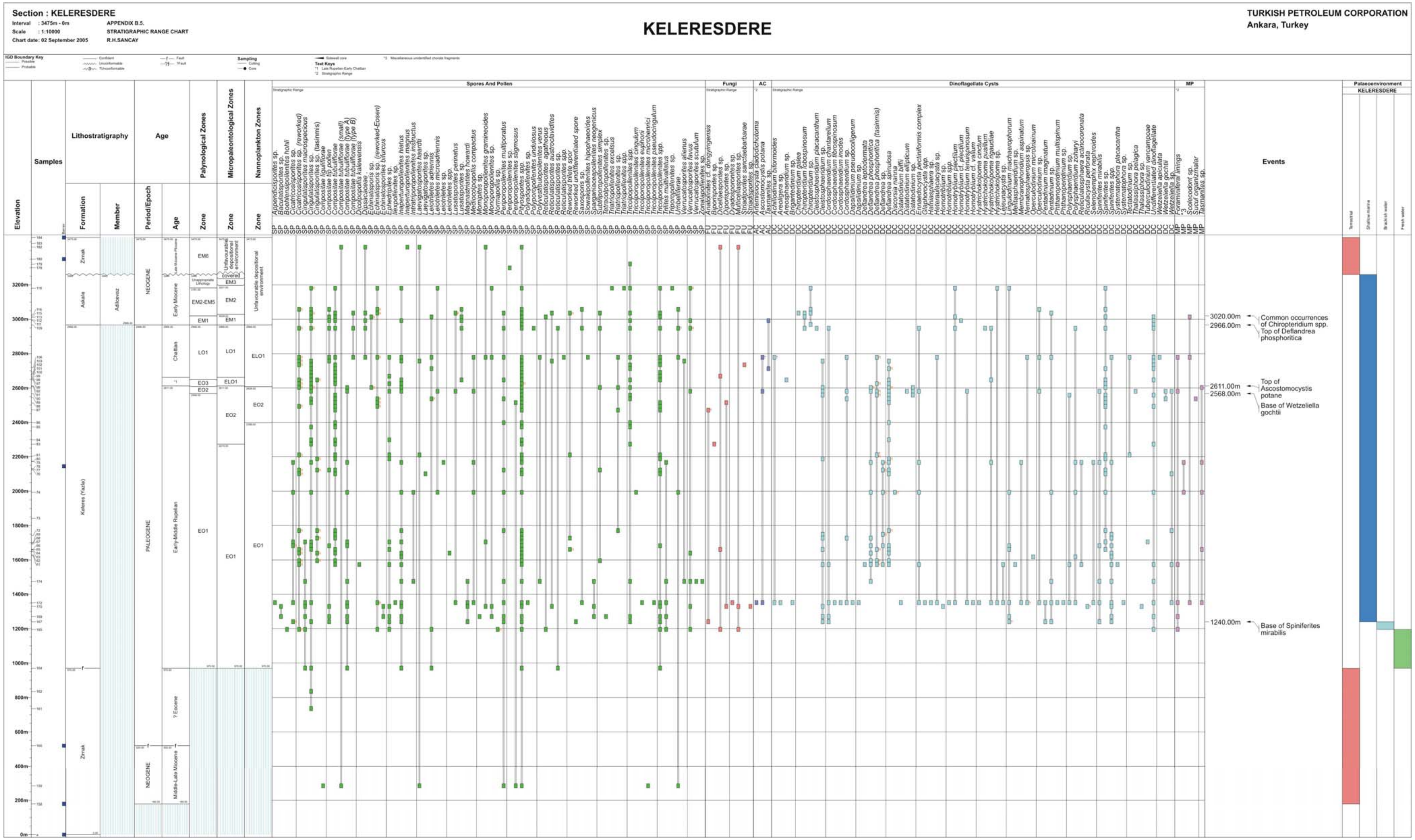

Appendix B.3. Relative abundances of the palynomorph groups in the Ebulbahar Section.

APPENDIX B



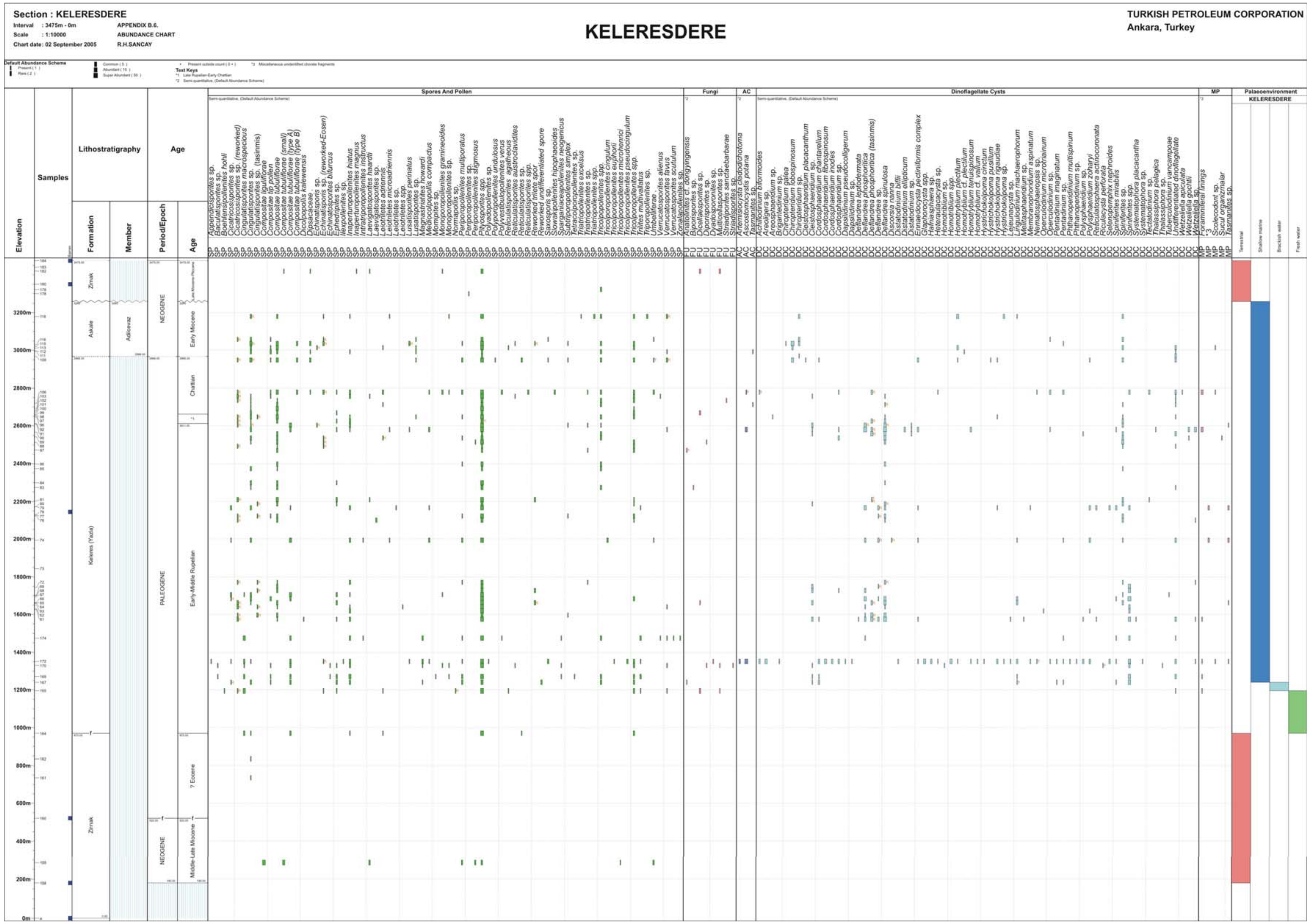

Appendix B.4. Percentages of the organic matter constituents in the Ebulbahar Section.

APPENDIX B



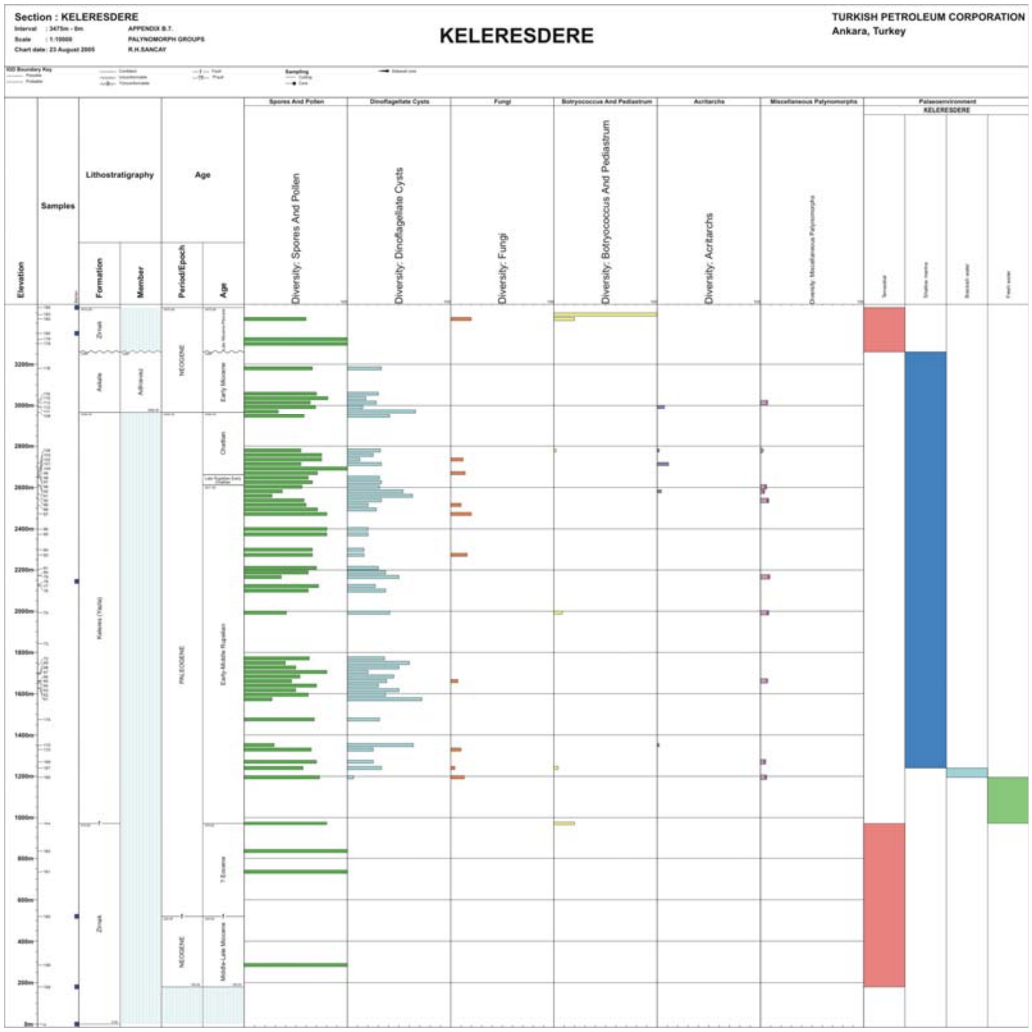

Appendix B.5. Stratigraphic Range Chart of the Palynomorphs in the Kelereşdere Section.

APPENDIX B



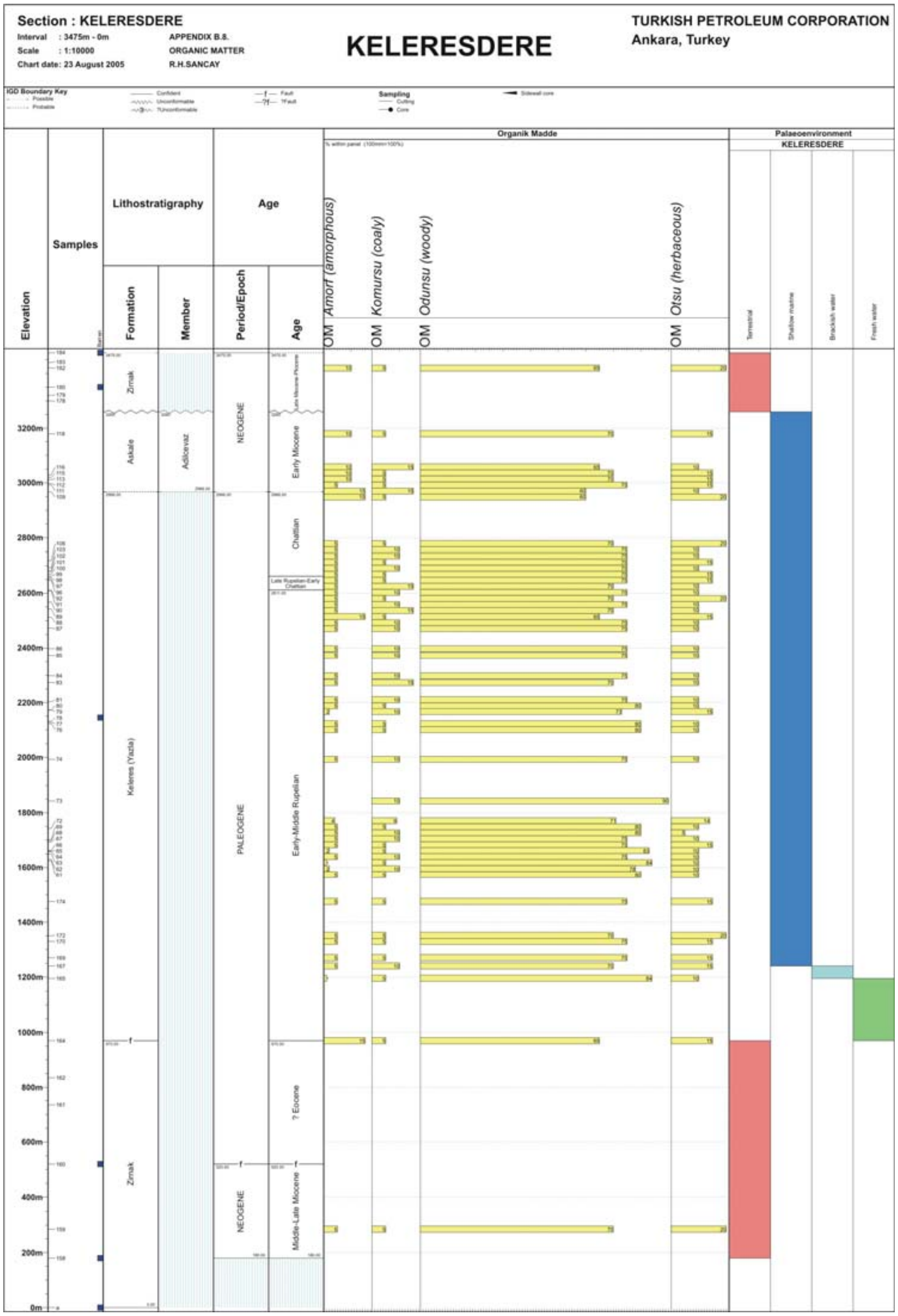
Appendix B.6. Abundance Chart of the palynomorphs in the Keleresdere Section.

APPENDIX B



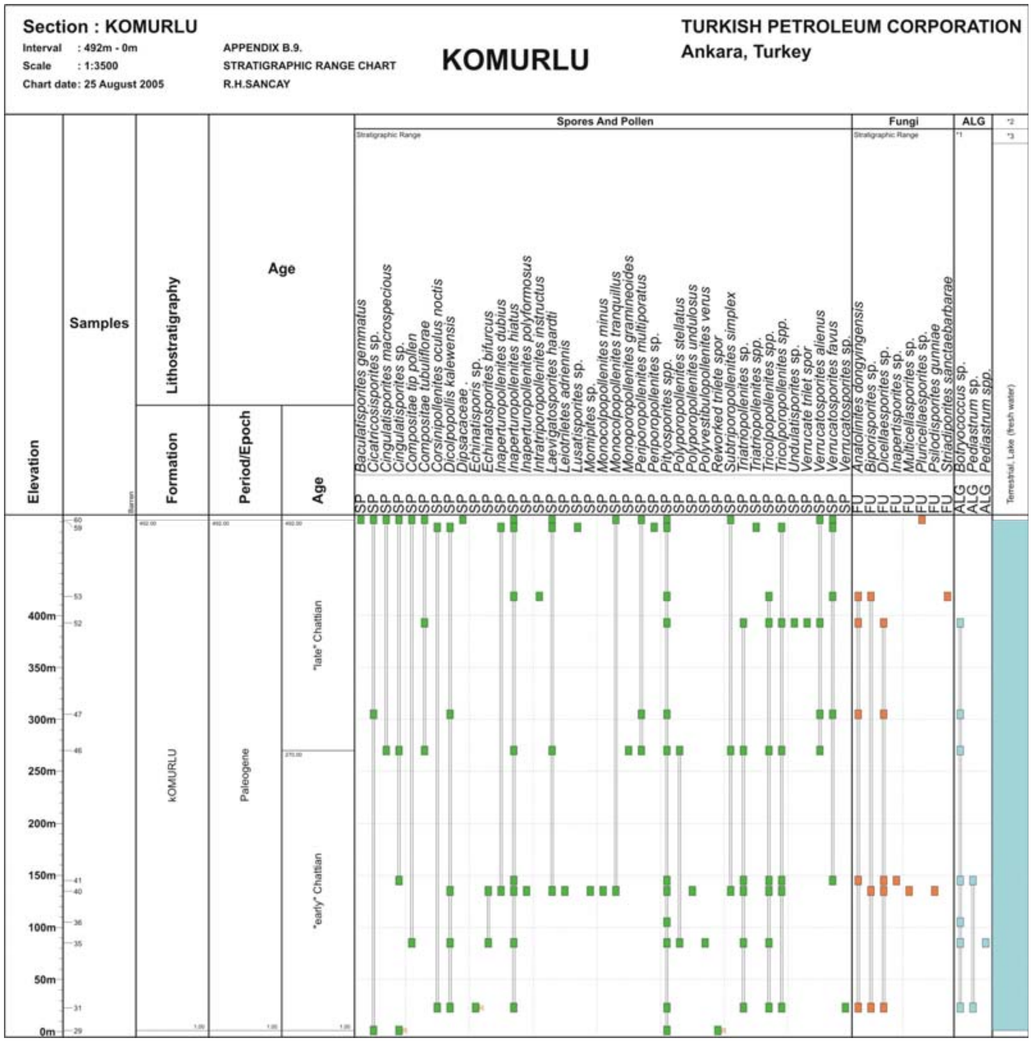

Appendix B.7. Relative abundances of the palynomorph groups in the Kelereşdere Section.

APPENDIXB



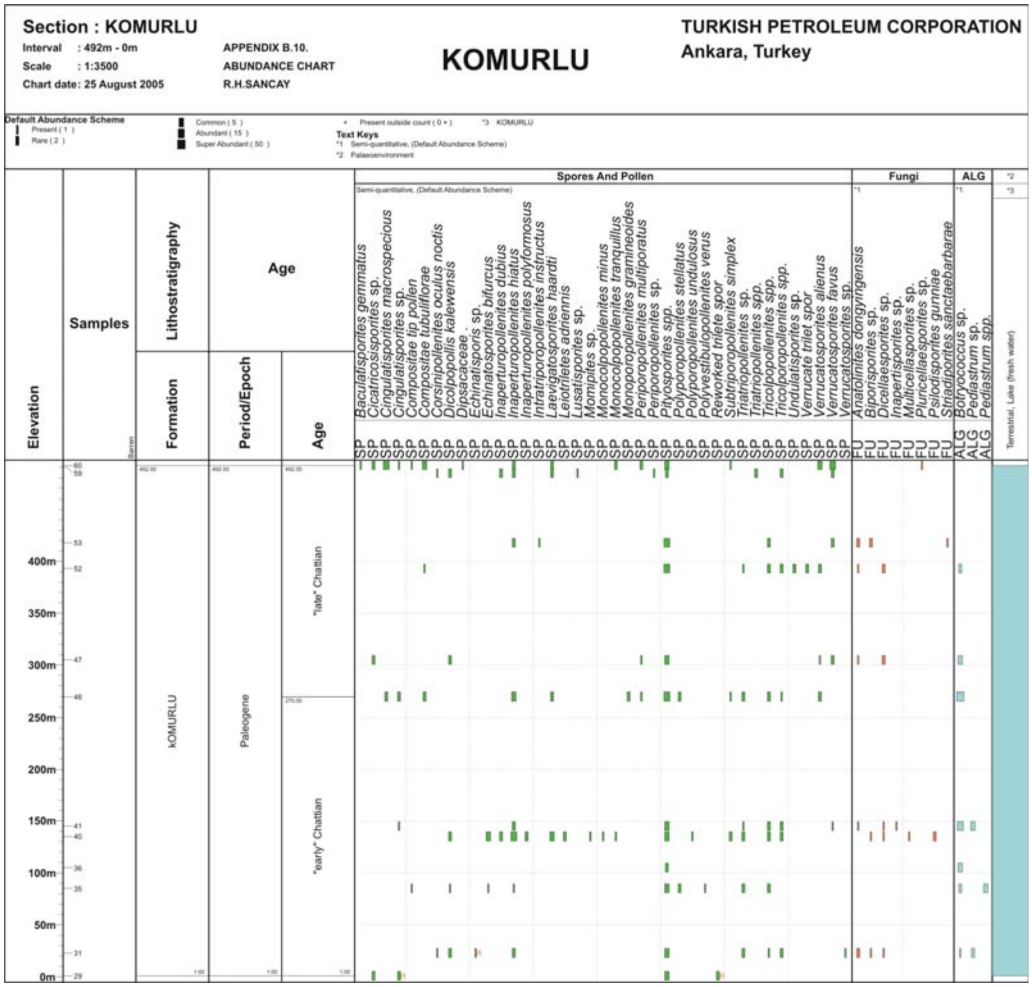

Appendix B.8. Percentages of the organic matter constituents in the Keleresdere Section.

APPENDIX B



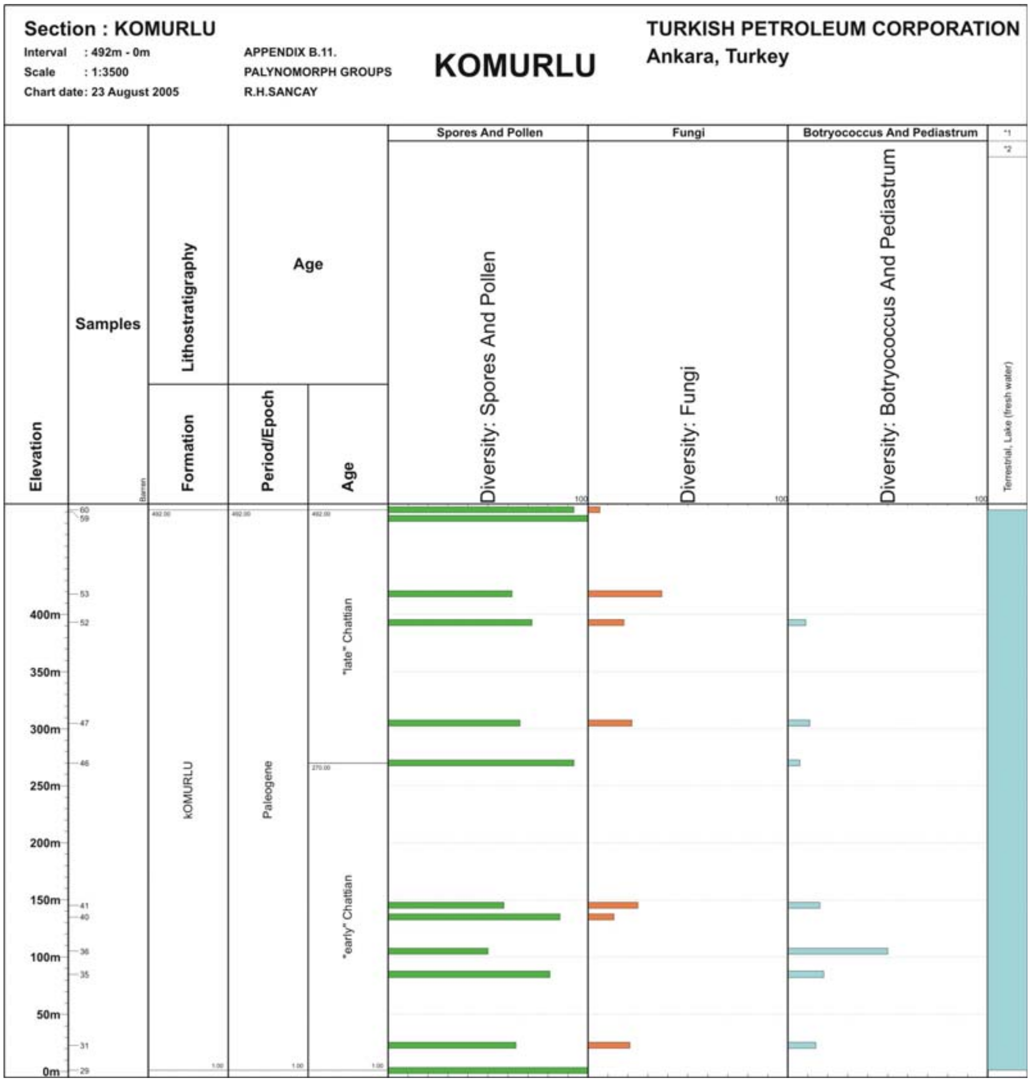

Appendix B.9. Stratigraphic Range Chart of the Palynomorphs in the Kömürlü Section.

APPENDIX B



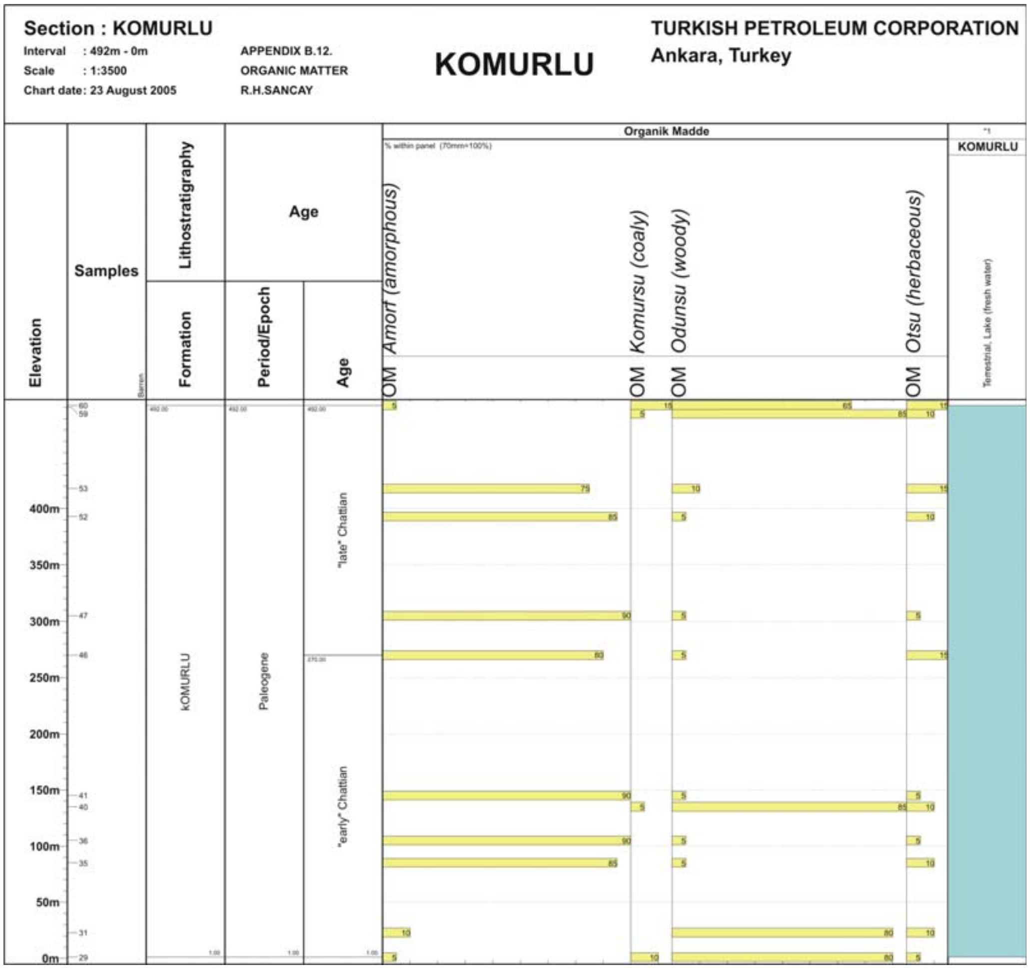

Appendix B.10. Abundance Chart of the palynomorphs in the Kömürlü Section.

APPENDIX B



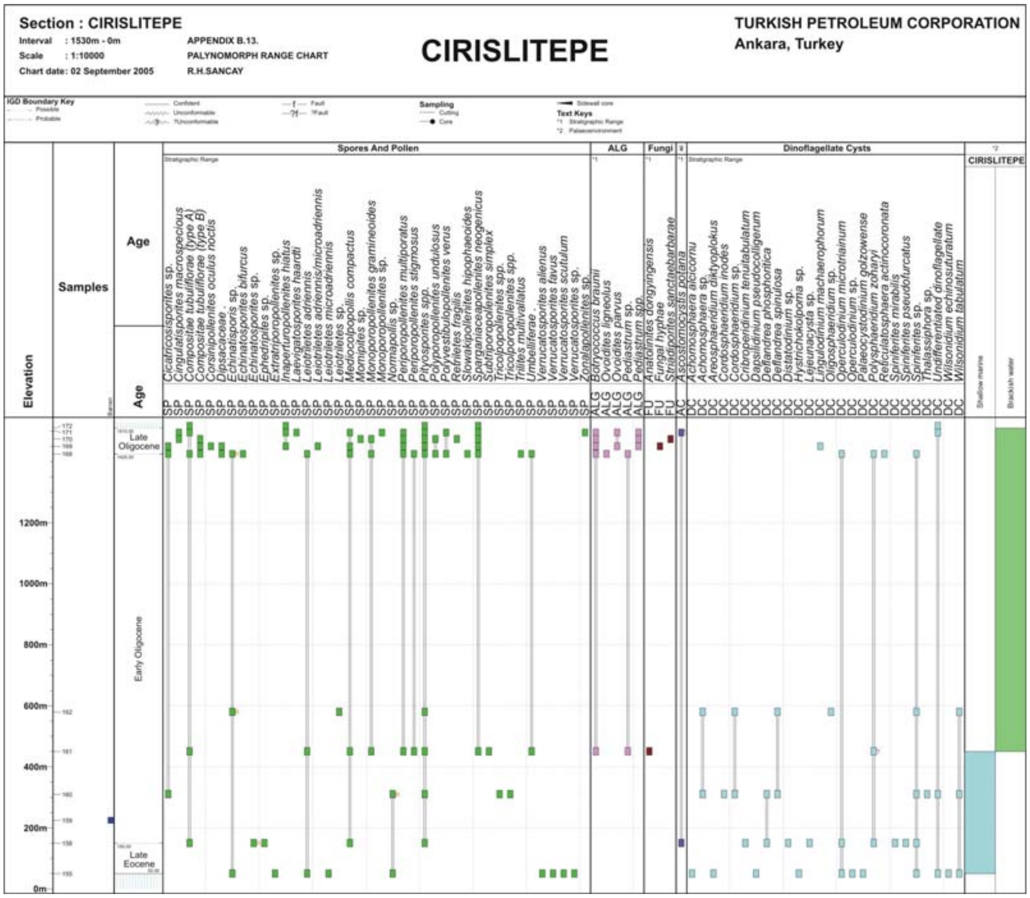

Appendix B.11. Relative abundances of the palynomorph groups in the Kömürlü Section.

APPENDIX B



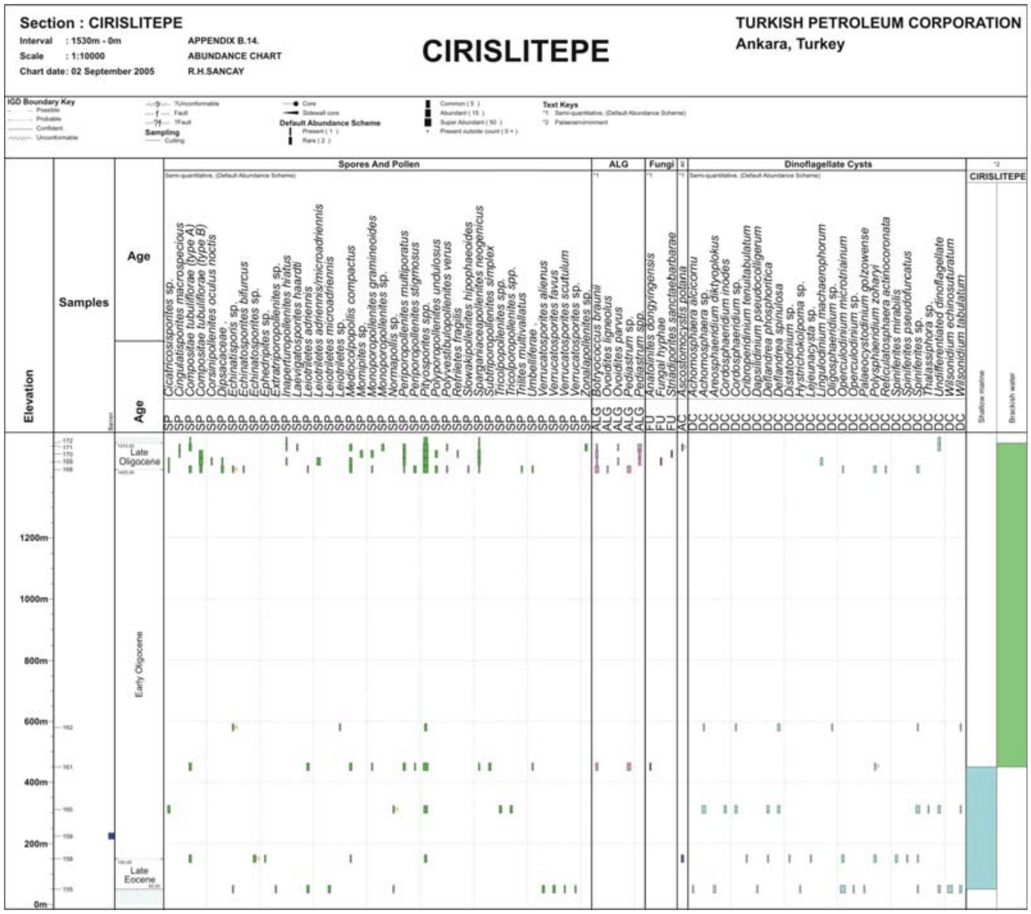

Appendix B.12. Percentages of the organic matter constituents in the Kömürlü Section.

APPENDIX B



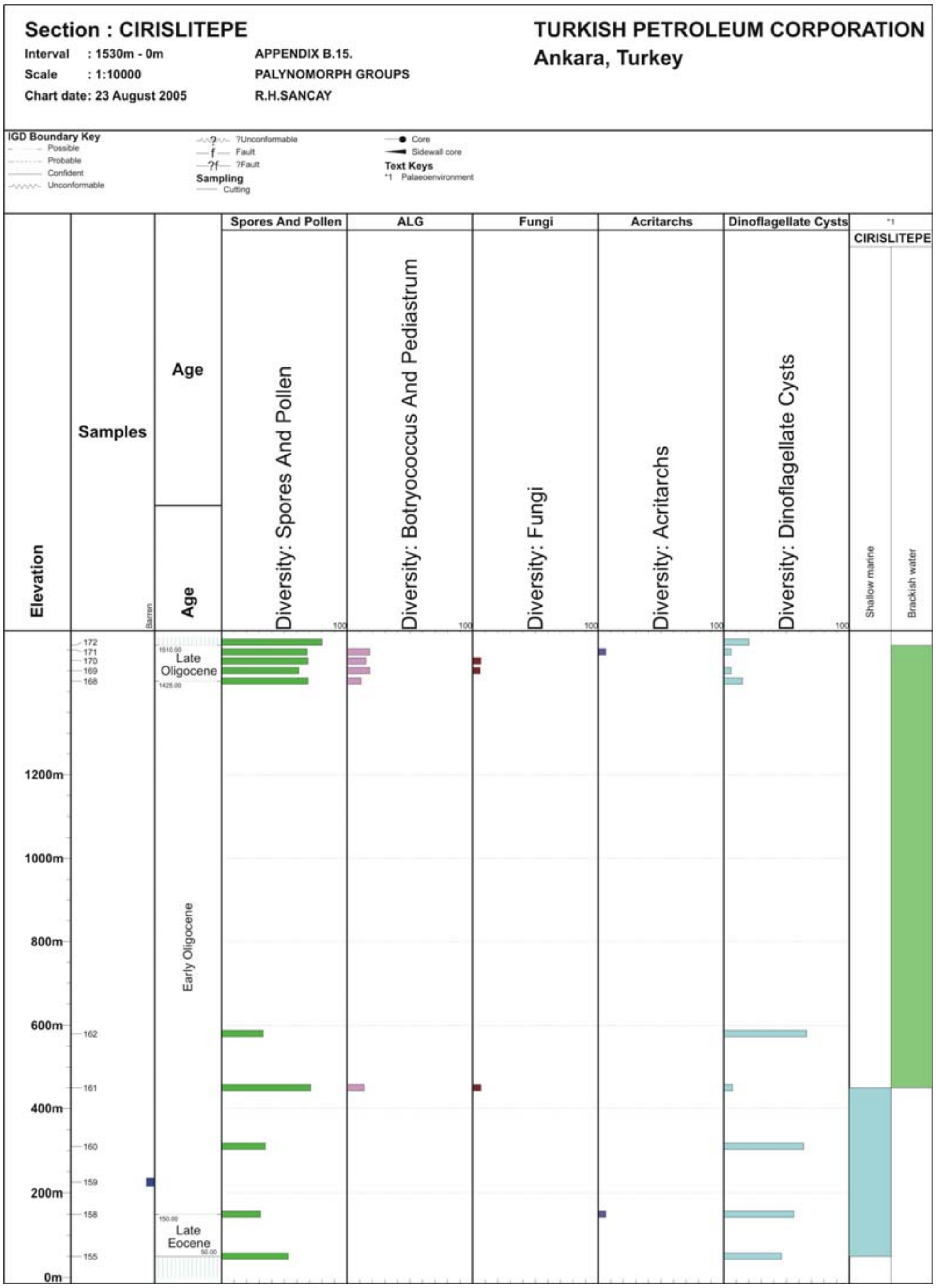
Appendix B.13. Stratigraphic Range Chart of the Palynomorphs in the Çirişlitepe Section.

APPENDIX B



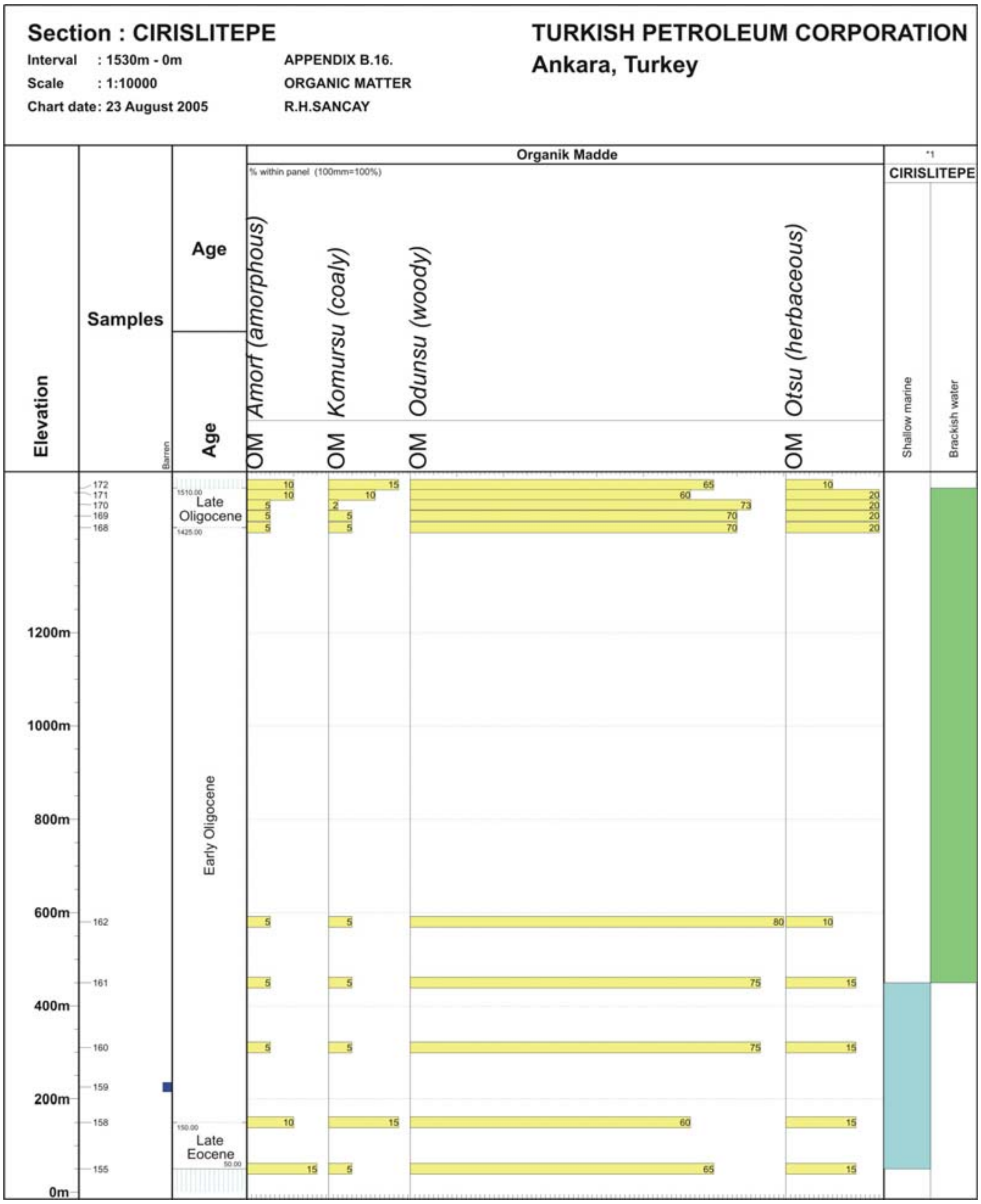

Appendix B.14. Abundance Chart of the palynomorphs in the Çirişlitepe Section.

APPENDIX B



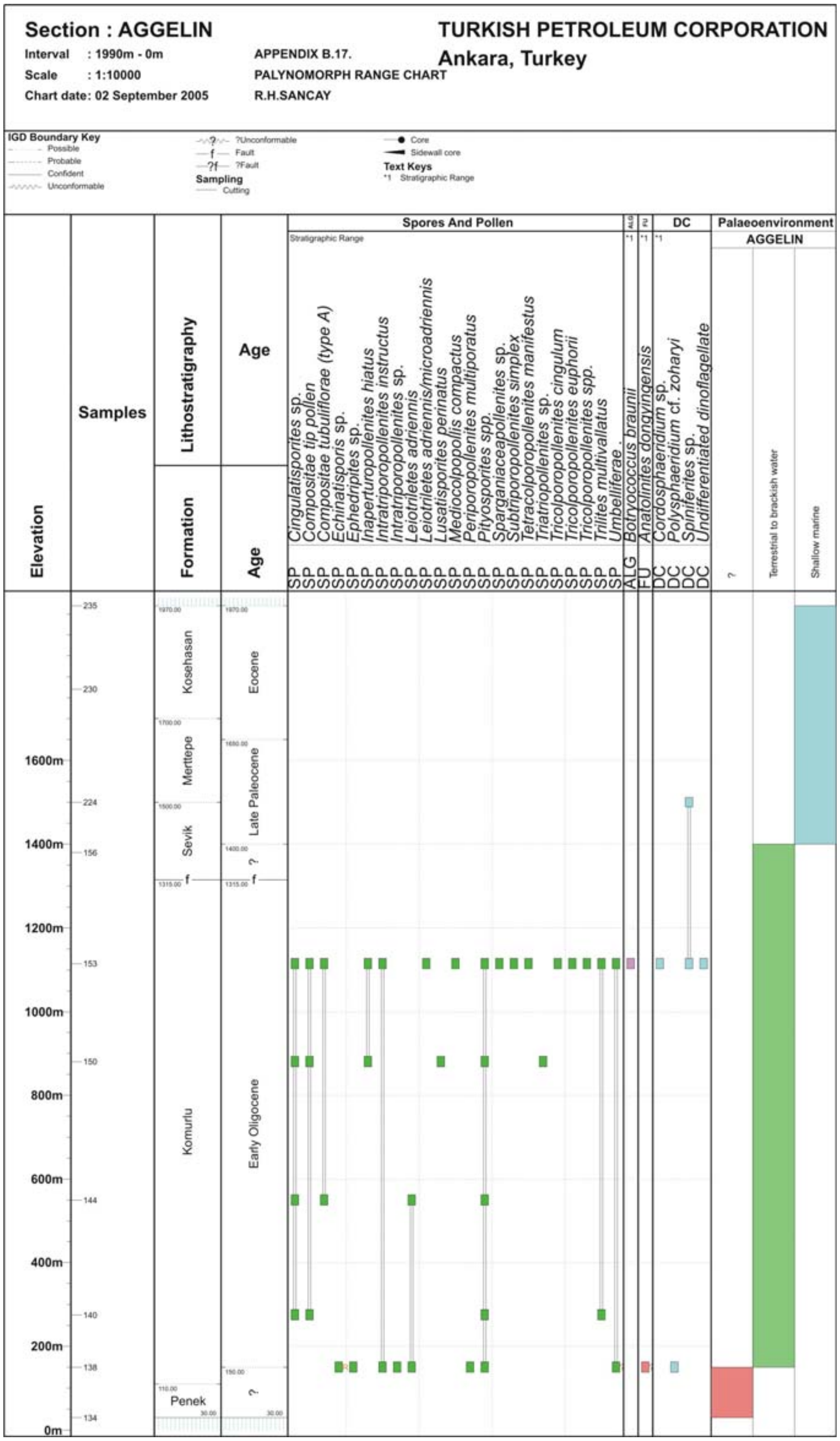

Appendix B.15. Relative abundances of the palynomorph groups in the Çirişlitepe Section.

APPENDIX B



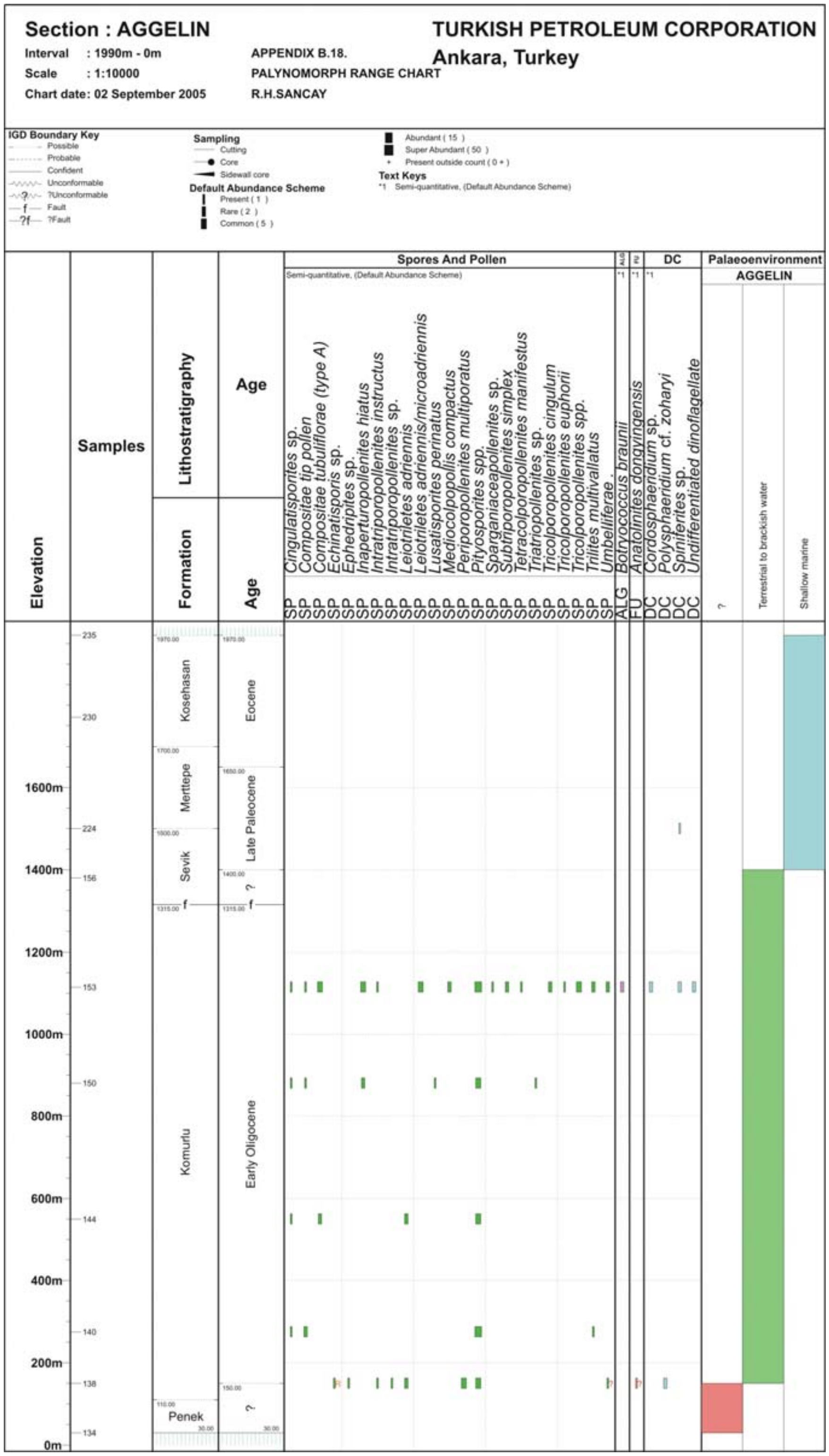

Appendix B.16. Percentages of the organic matter constituents in Çirişlitepe Section.

APPENDIX B



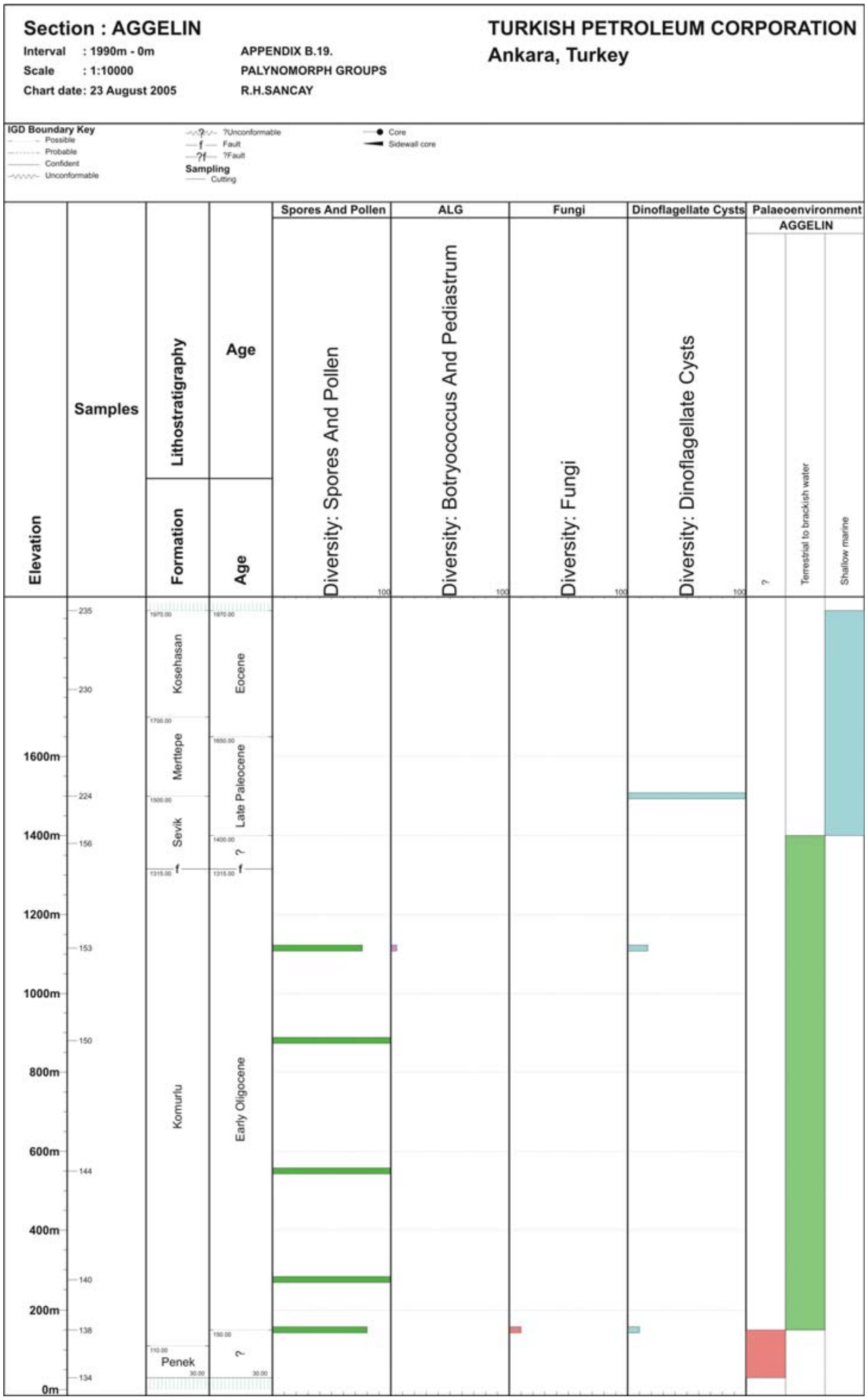

Appendix B.17. Stratigraphic Range Chart of the Palynomorphs in the Ağgelin Section.

APPENDIX B



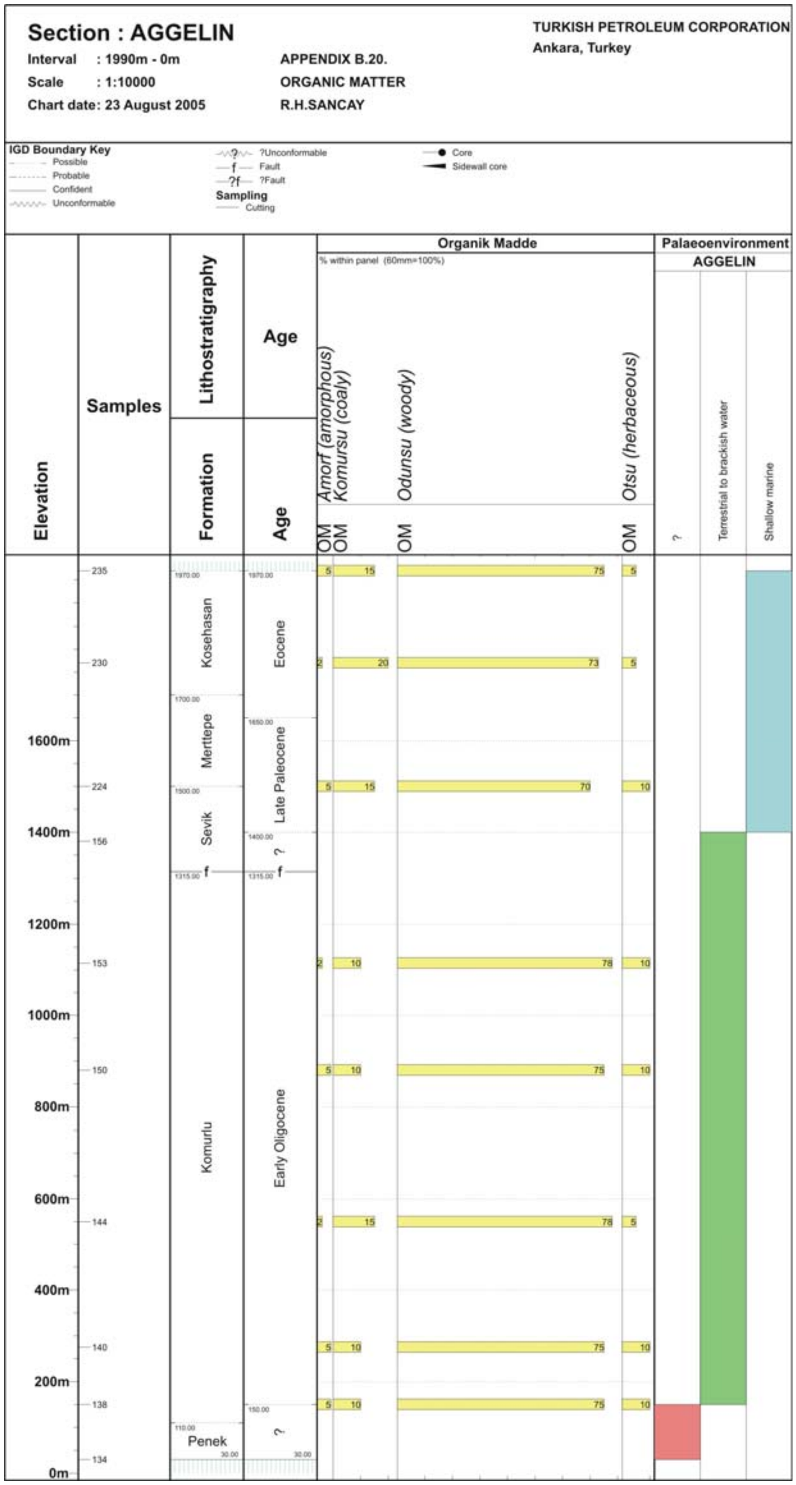

Appendix B.18. Abundance Chart of the palynomorphs in the Ağgelin Section.

APPENDIX B



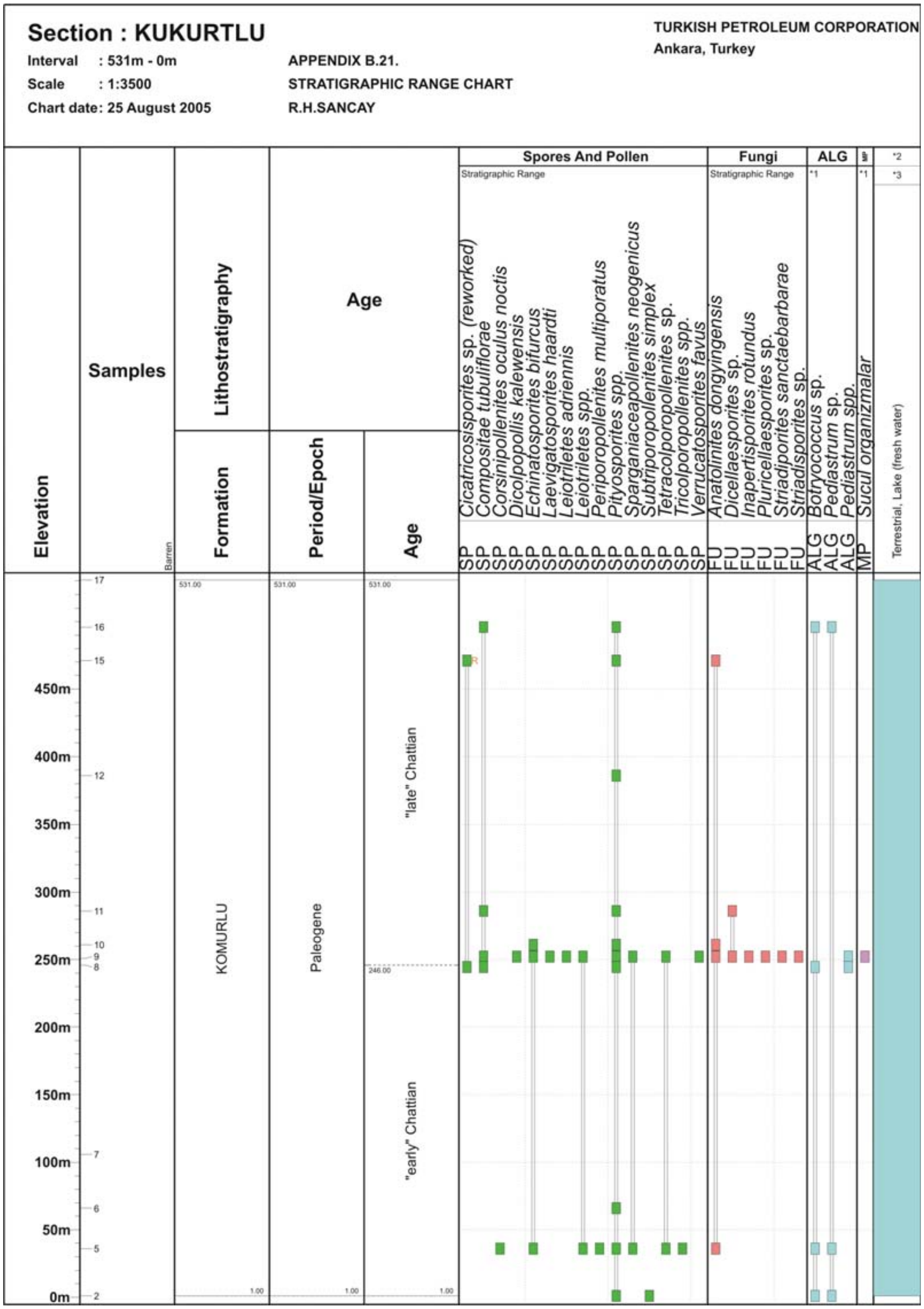

Appendix B.19. Relative abundances of the palynomorph groups in the Ağgelin Section.

APPENDIX B



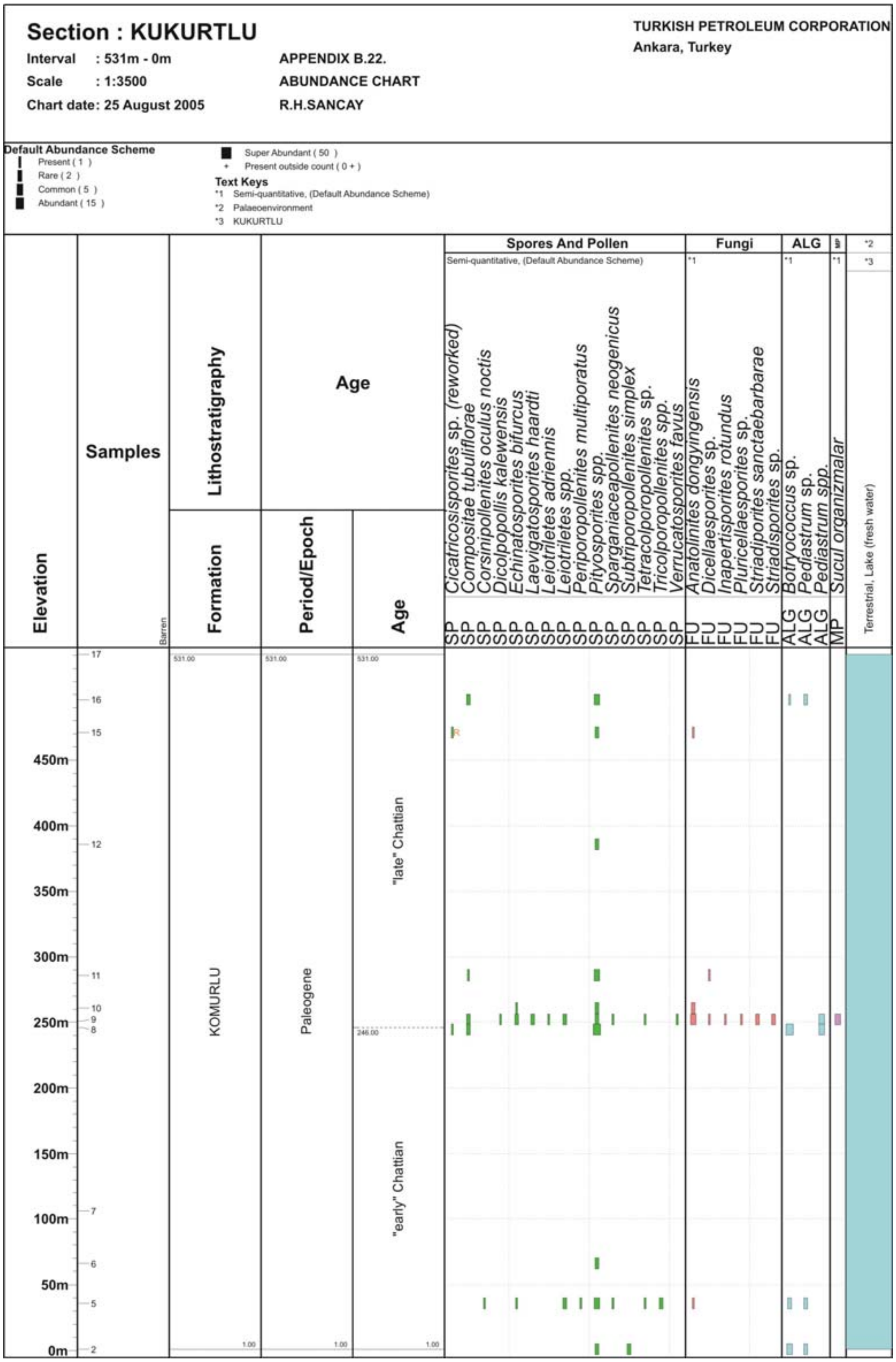

Appendix B.20. Percentages of the organic matter constituents in the Ağgelin Section.

APPENDIX B



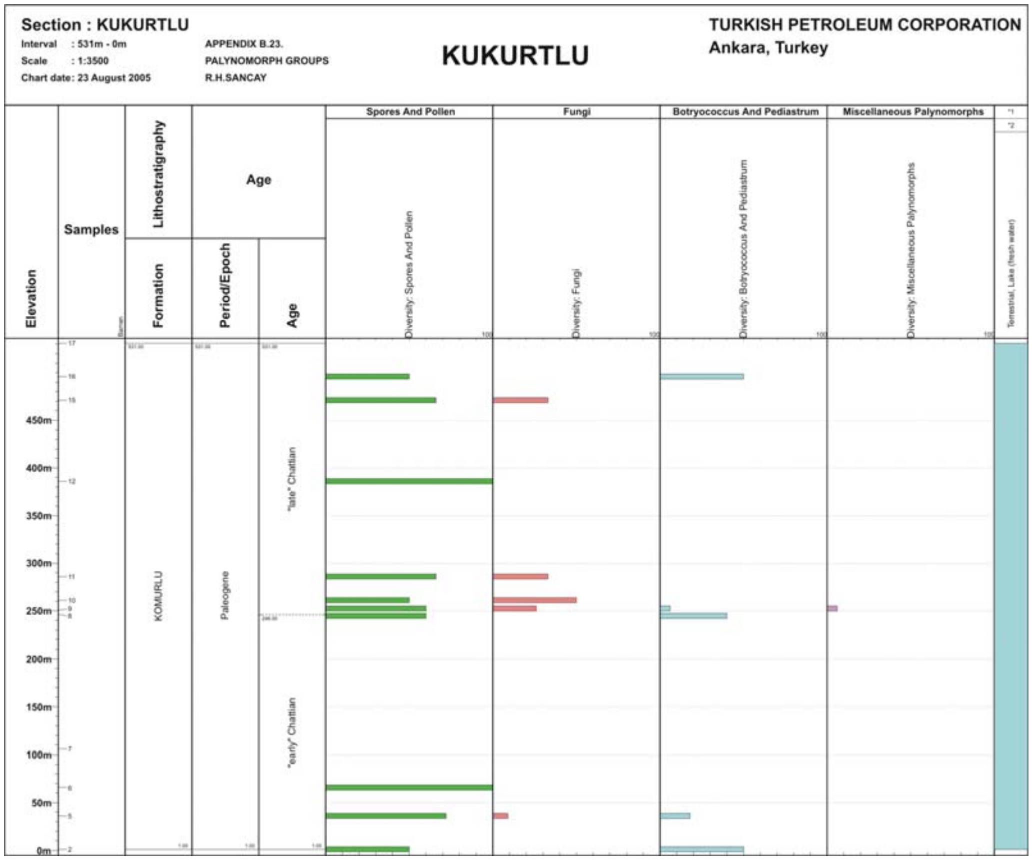

Appendix B.21. Stratigraphic Range Chart of the Palynomorphs in the Kükürtlü Section.

APPENDIX B



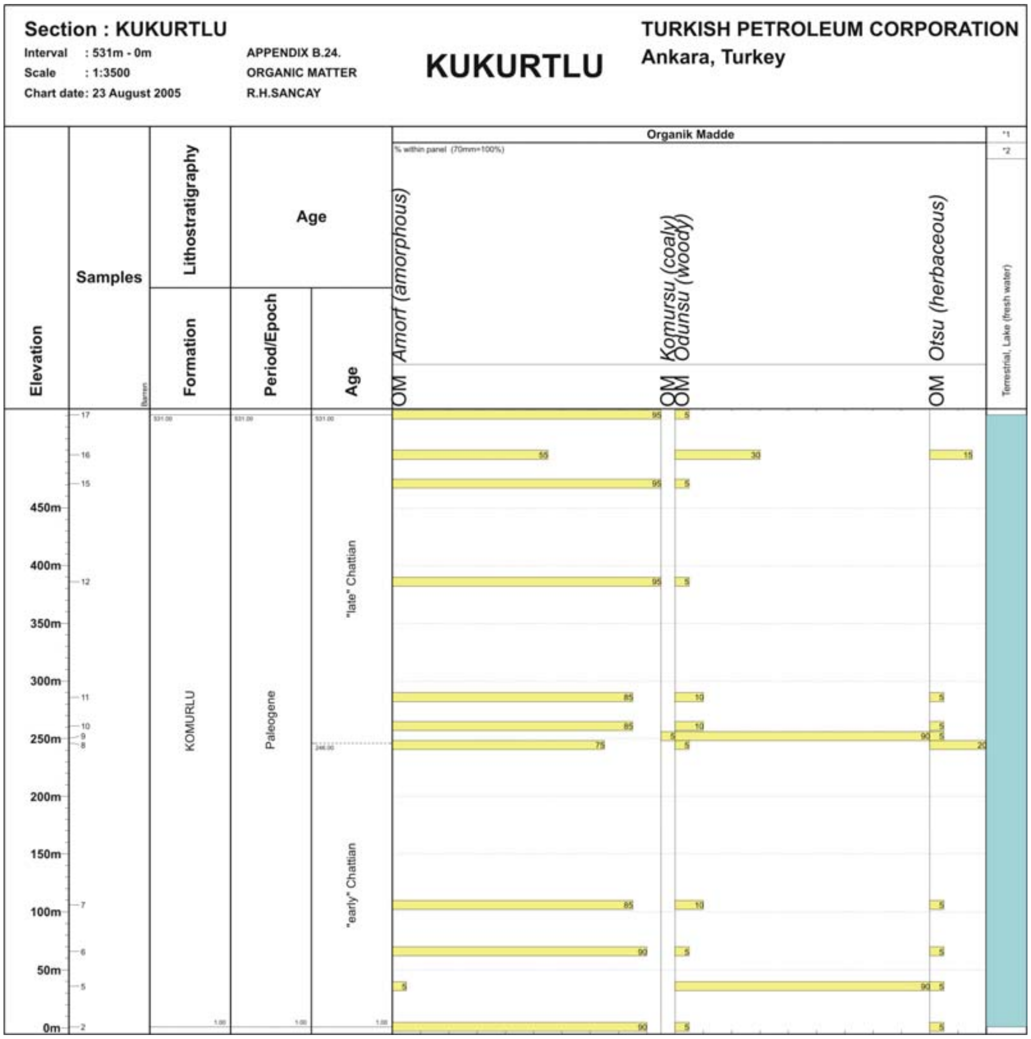

Appendix B.22. Abundance Chart of the palynomorphs in the Kükürtlü Section.

APPENDIX B



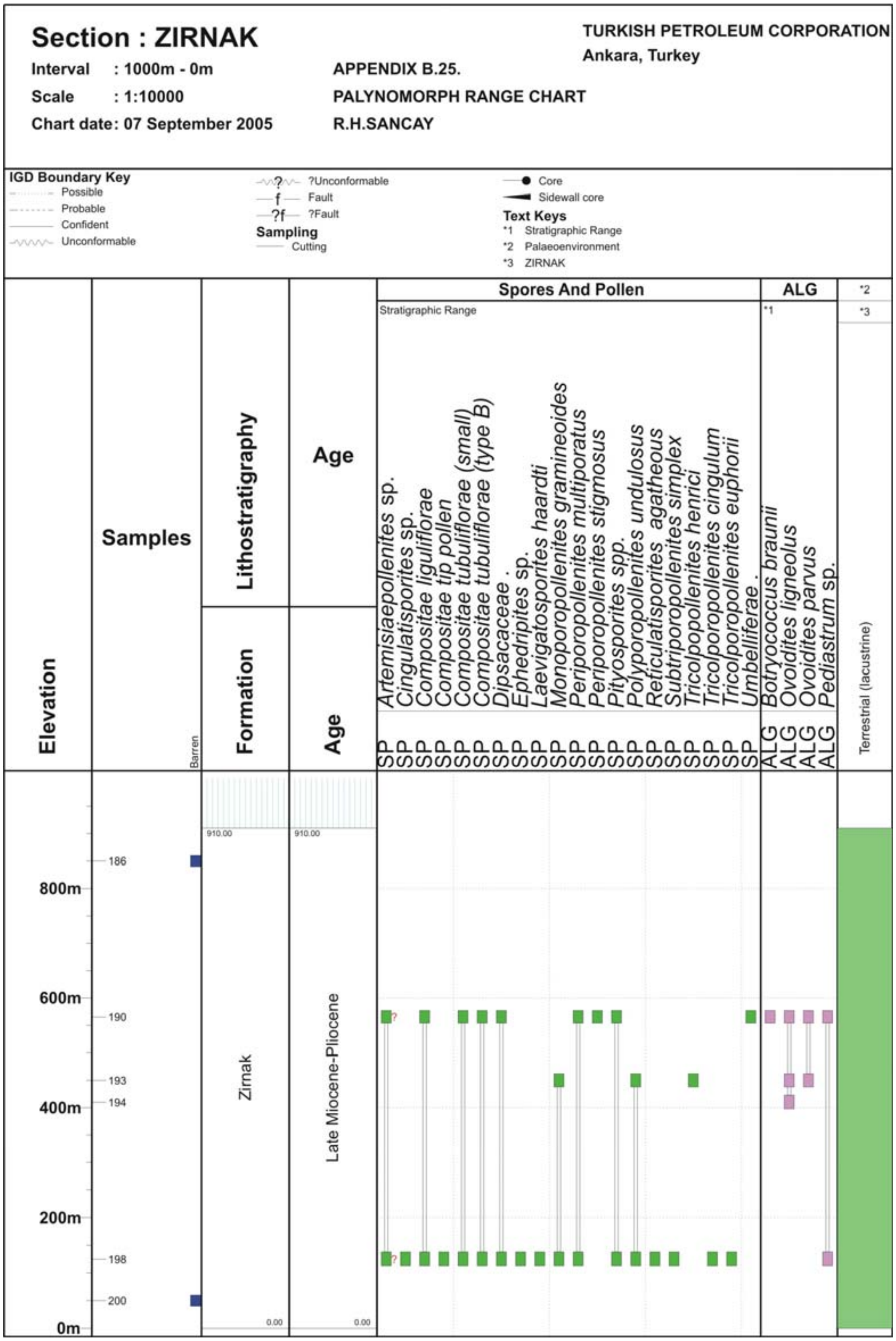

Appendix B.23. Relative abundances of the palynomorph groups in the Kükürtlü Section.

APPENDIX B



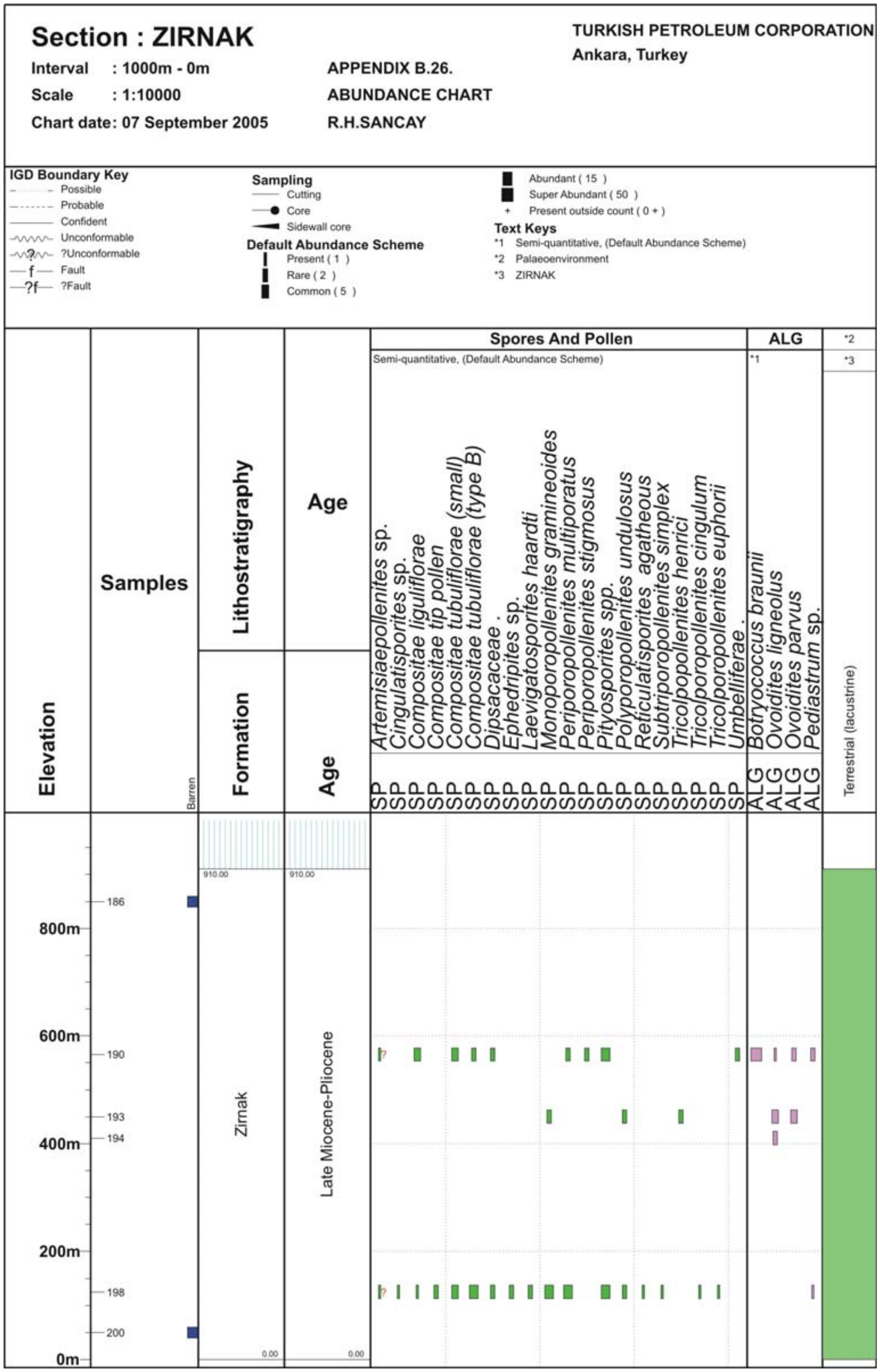

Appendix B.24. Percentages of the organic matter constituents in the Kükürtlü Section.

APPENDIX B

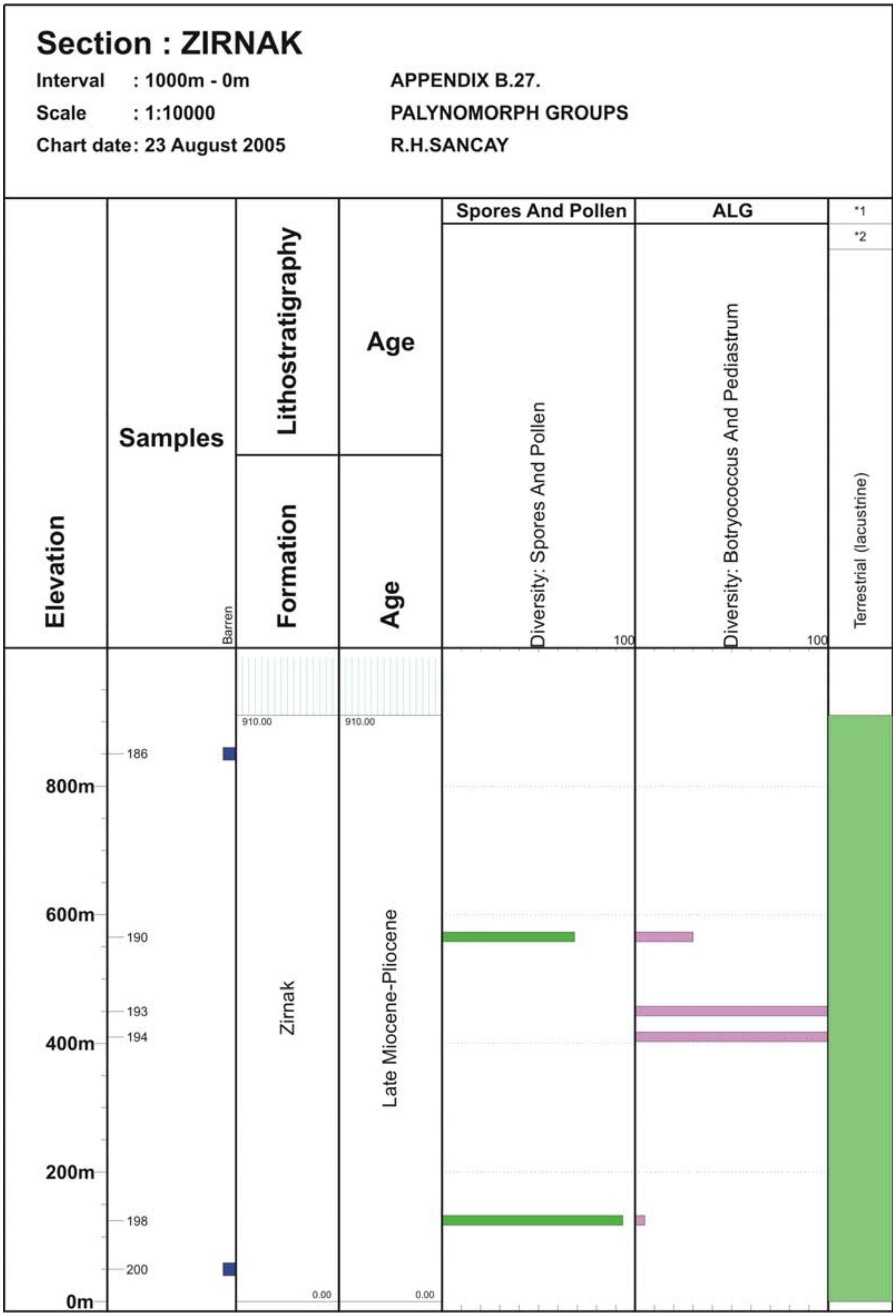



Appendix B.25. Stratigraphic Range Chart of the Palynomorphs in the Zırnak Section.

APPENDIX B

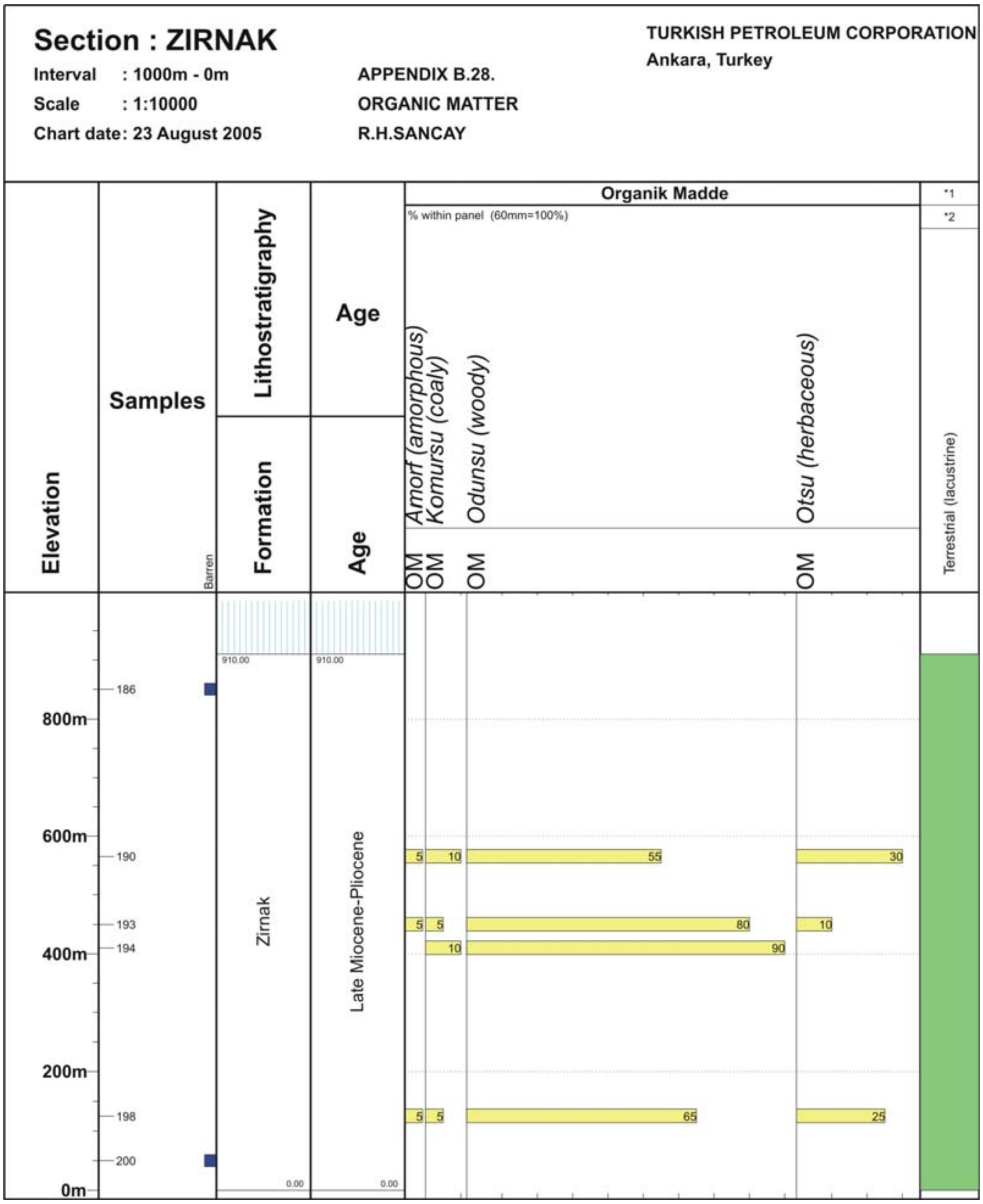



Appendix B.26. Abundance Chart of the palynomorphs in the Zırnak Section.



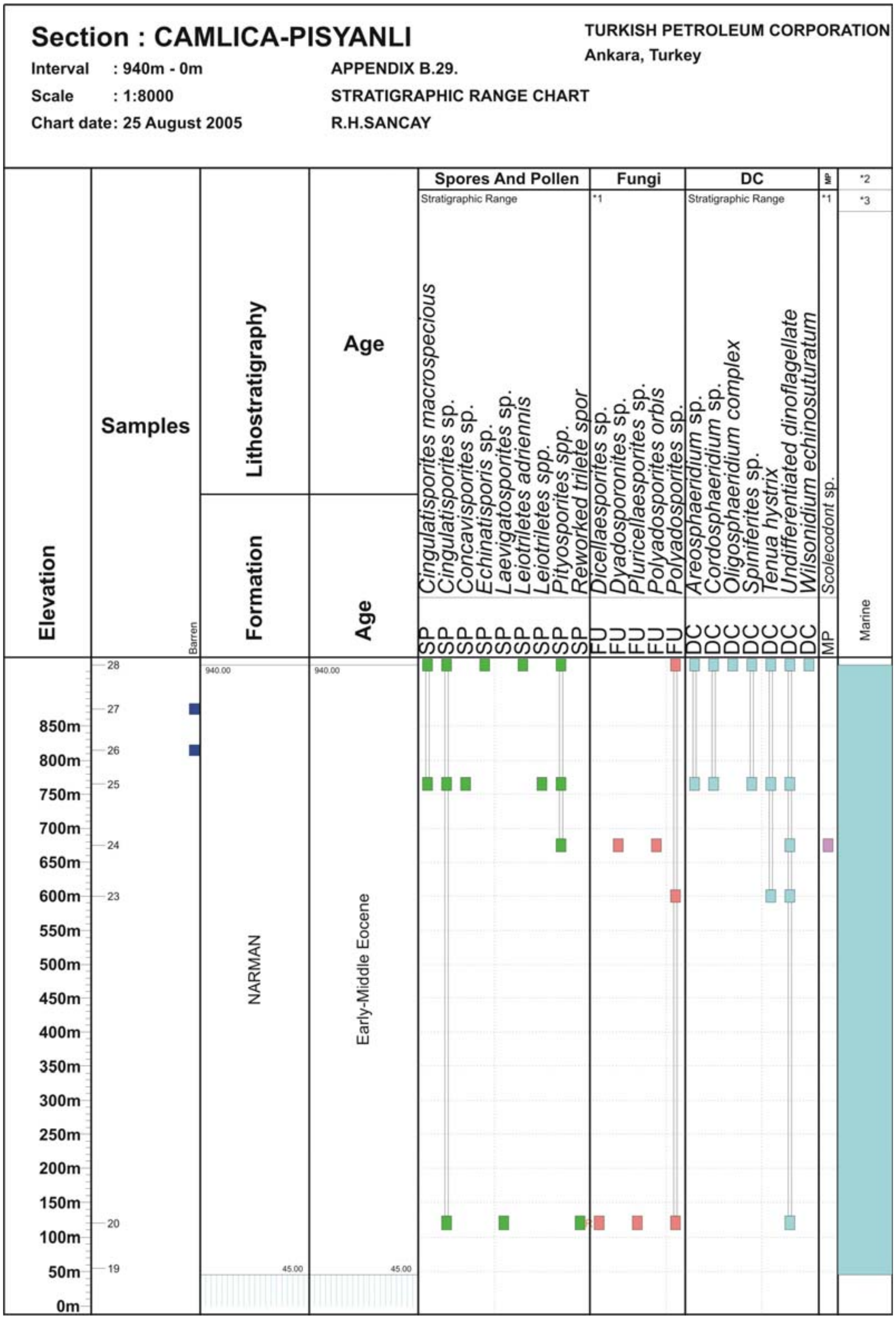

Appendix B.27. Relative abundances of the palynomorph groups in the Zırnak Section.

APPENDIX B



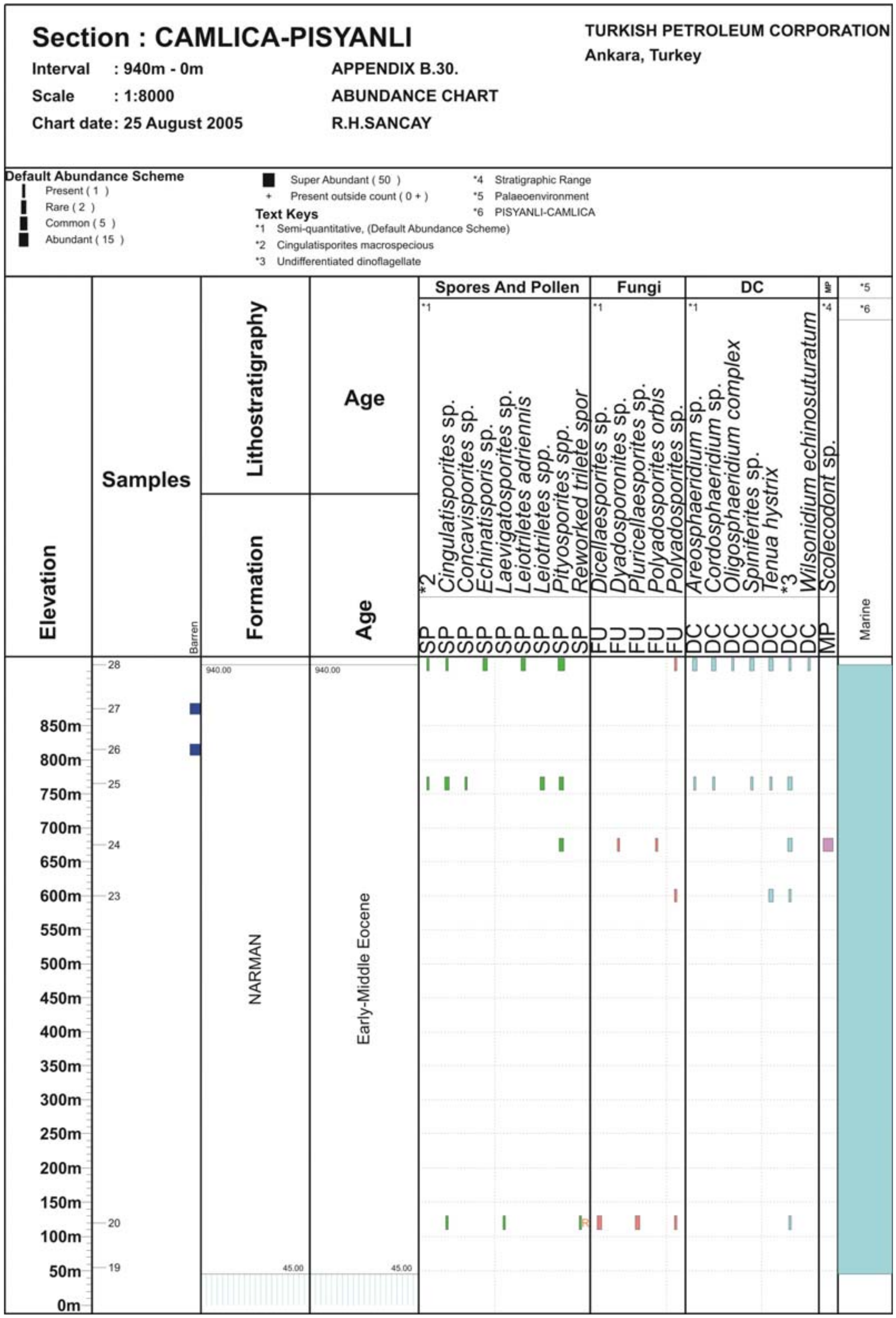
Appendix B.28. Percentages of the organic matter constituents in the Zırnak Section.

APPENDIX B



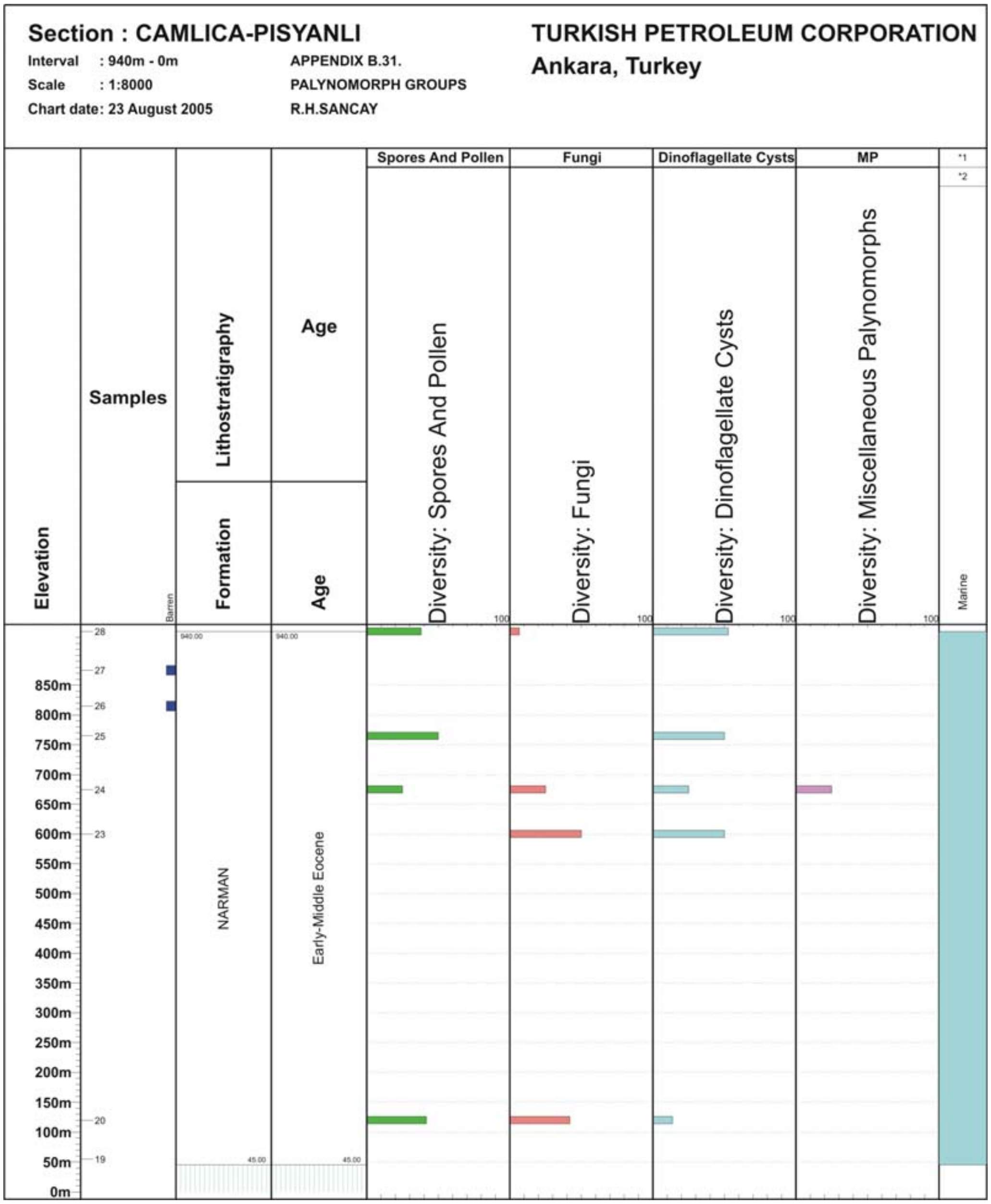

Appendix B.29. Stratigraphic Range Chart of the Palynomorphs in the Pisyanlı-Çamlıca Section.

APPENDIX B



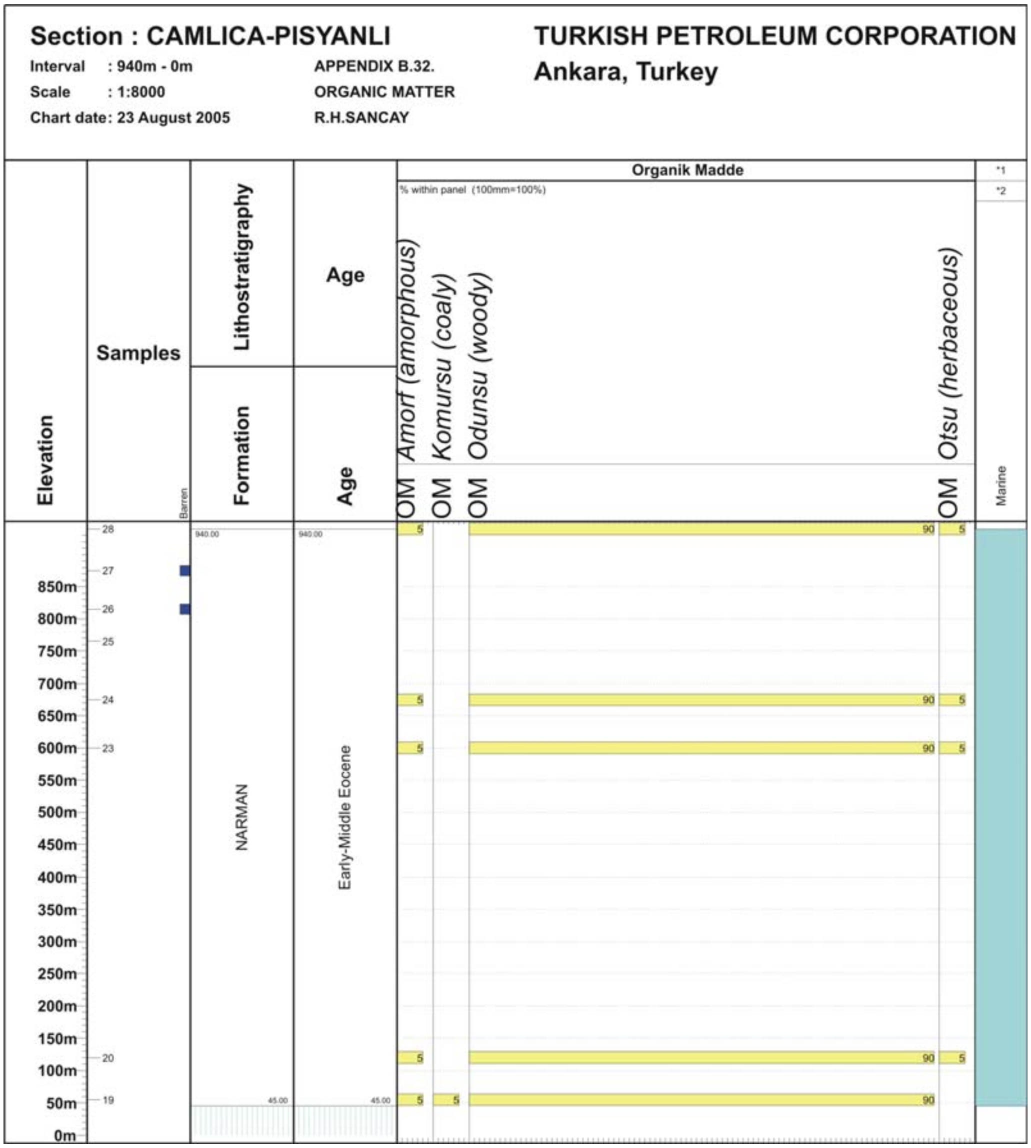
Appendix B.30. Abundance Chart of the palynomorphs in the Pisyanlı-Çamlıca Section.

APPENDIX B



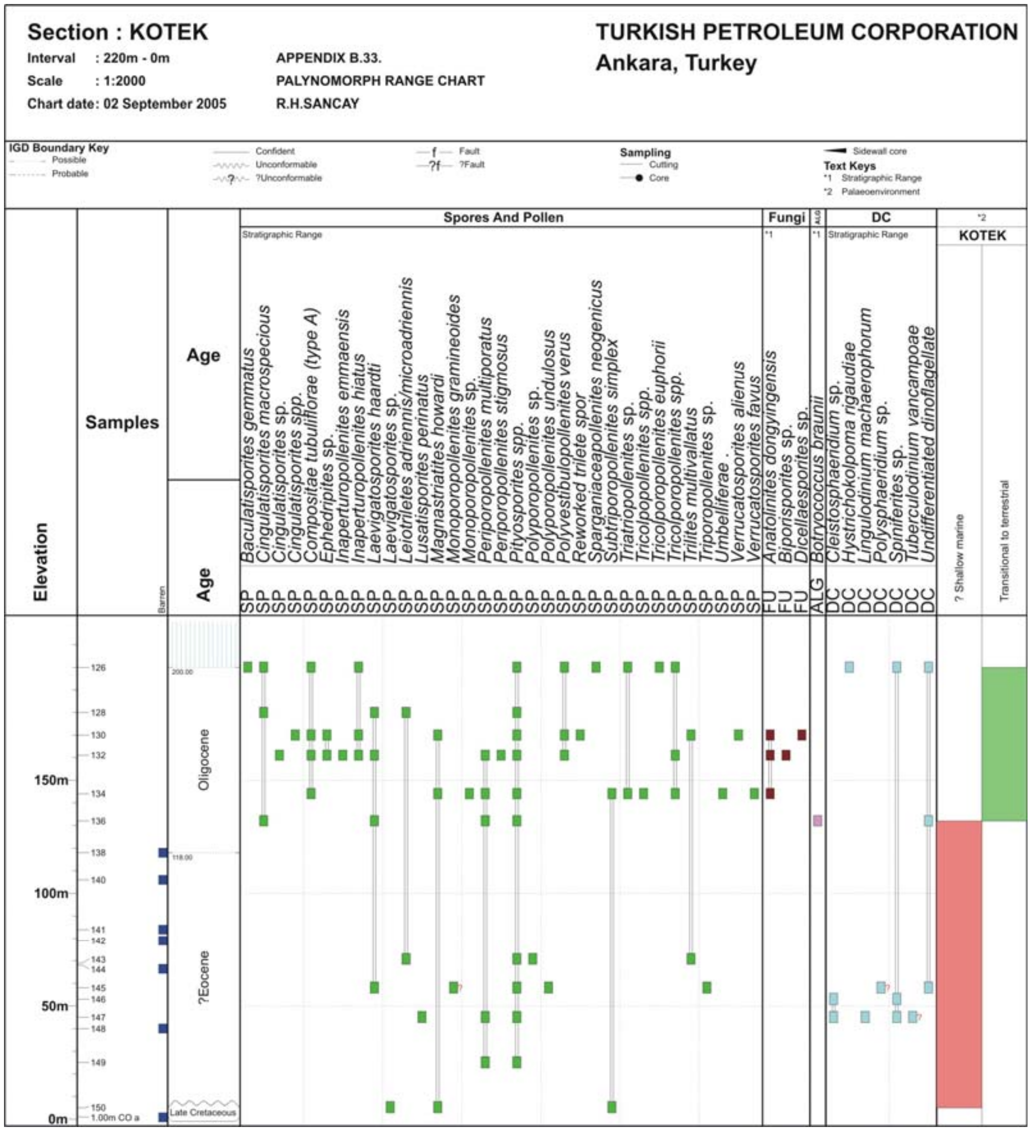

Appendix B.31. Relative abundances of the palynomorph groups in the Pisyanlı-Çamlıca Section.

APPENDIX B



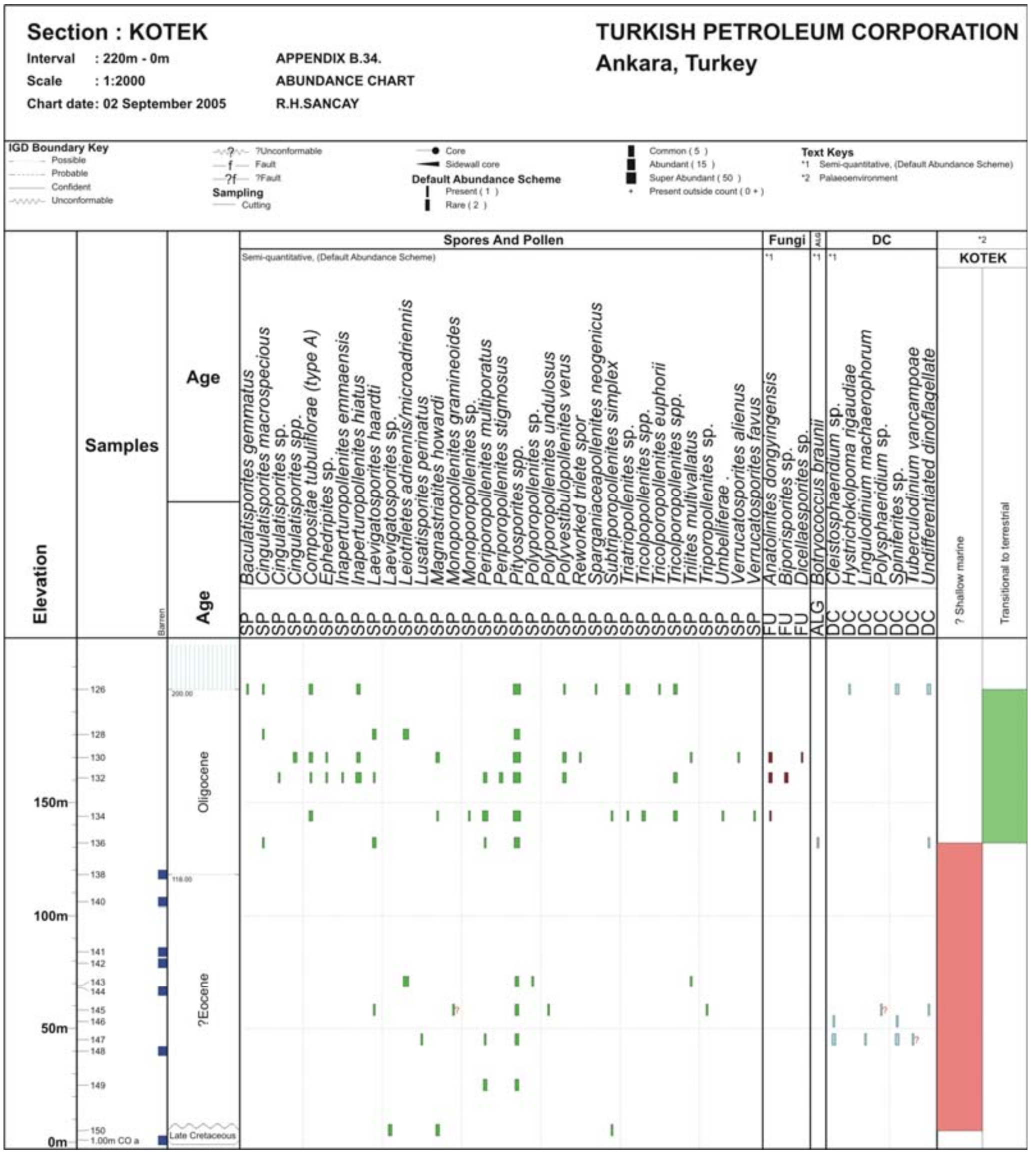

Appendix B.32. Percentages of the organic matter constituents in the Pisyanlı-Çamlıca Section.

APPENDIX B



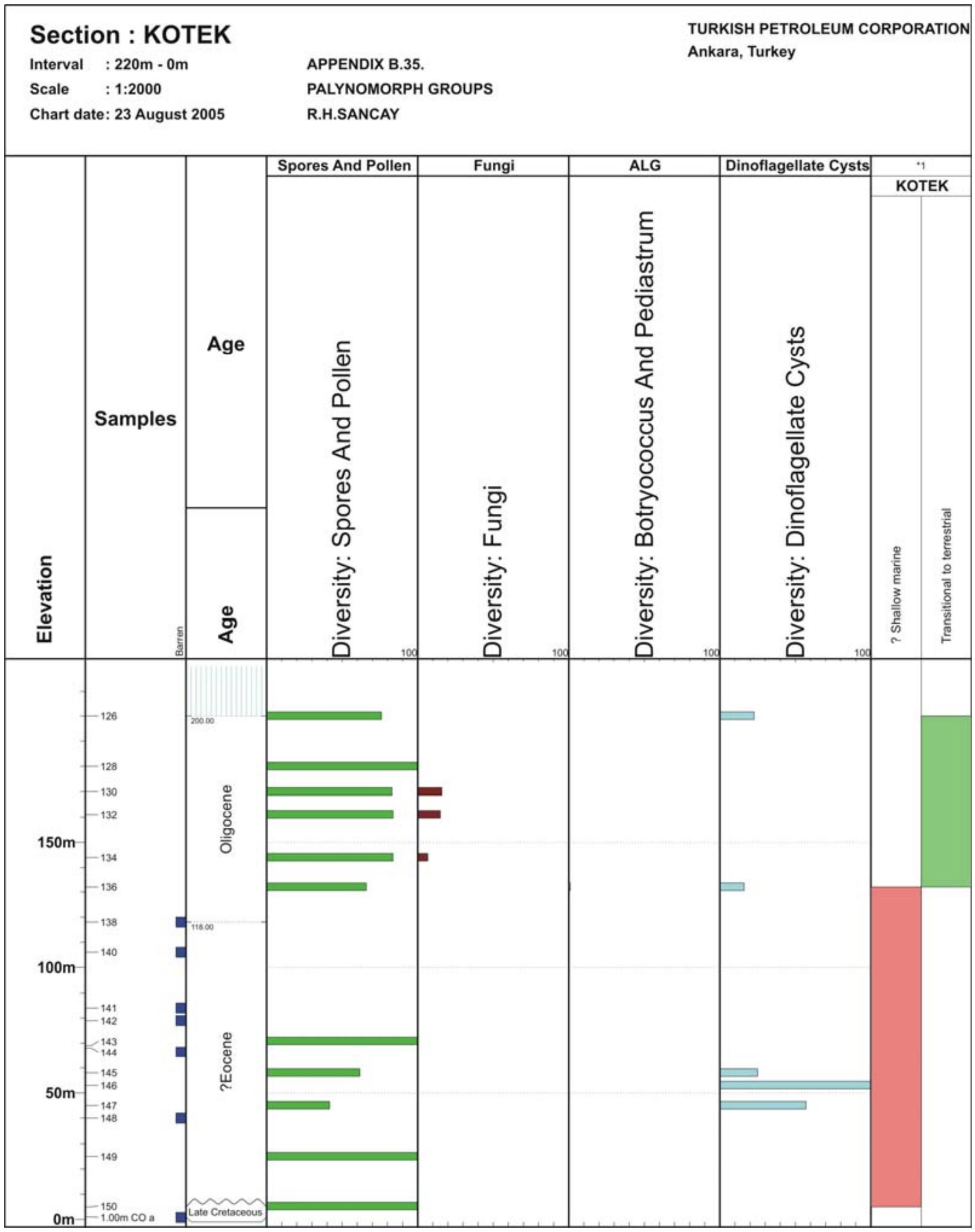

Appendix B.33. Stratigraphic Range Chart of the Palynomorphs in the Kötek Section.

APPENDIX B



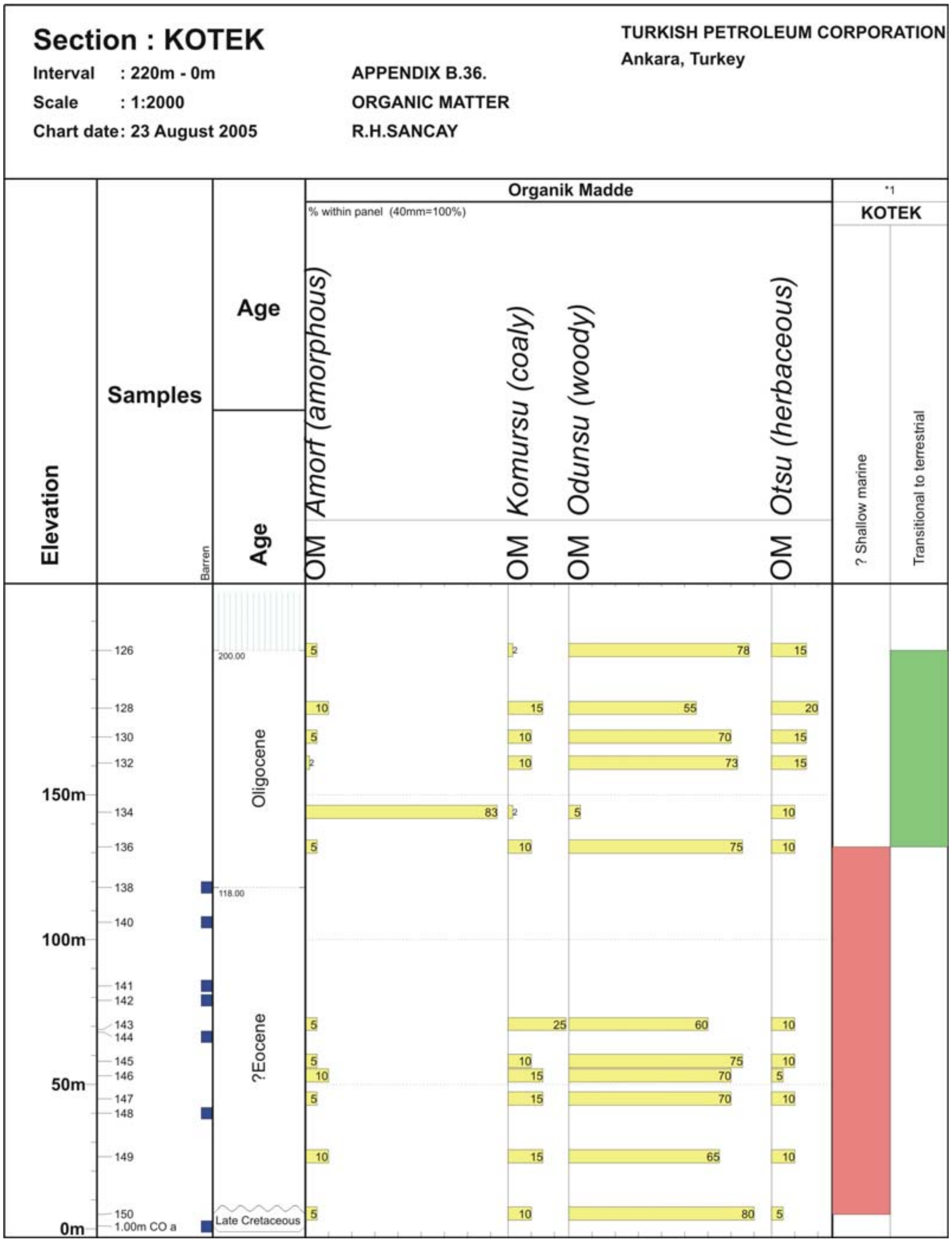

Appendix B.34. Abundance Chart of the palynomorphs in the Kötek Section.

APPENDIX B




Appendix B.35. Relative abundances of the palynomorph groups in the Kötek Section.

APPENDIX B




Appendix B.36. Percentages of the organic matter constituents in the Kötek Section.

APPENDIX C

| SECTION | SAMPLE NO | LITHOLOGY |
|---|---|---|
| Kükürtlü-2003 | 2 | Shale |
| Kükürtlü-2003 | 3 | Shale |
| Kükürtlü-2003 | 4 | Shale |
| Kükürtlü-2003 | 5 | Claystone |
| Kükürtlü-2003 | 6 | Carb. sandstone |
| Kükürtlü-2003 | 7 | Carb. sandstone |
| Kükürtlü-2003 | 8 | Claystone |
| Kükürtlü-2003 | 9 | Claystone |
| Kükürtlü-2003 | 10 | Shale |
| Kükürtlü-2003 | 11 | Shale |
| Kükürtlü-2003 | 12 | Shale |
| Kükürtlü-2003 | 13 | Shale |
| Kükürtlü-2003 | 14 | Marl |
| Kükürtlü-2003 | 15A | Marl |
| Kükürtlü-2003 | 16 | Marl |
| Kükürtlü-2003 | 17 | Marl |
| Pisyanlı-Çamlıca-2003 | 18 | Shale |
| Pisyanlı-Çamlıca-2003 | 19 | Shale |
| Pisyanlı-Çamlıca-2003 | 20 | Shale |
| Pisyanlı-Çamlıca-2003 | 21 | Shale |
| Pisyanlı-Çamlıca-2003 | 22 | Shale |
| Pisyanlı-Çamlıca-2003 | 23 | Shale |
| Pisyanlı-Çamlıca-2003 | 24 | Shale |
| Pisyanlı-Çamlıca-2003 | 25 | Shale |
| Pisyanlı-Çamlıca-2003 | 26 | Shale |
| Pisyanlı-Çamlıca-2003 | 27 | Shale |
| Pisyanlı-Çamlıca-2003 | 28 | Shale |
| Kömürlü-2003 | 29 | Silty marl |
| Kömürlü-2003 | 30 | Silty marl |
| Kömürlü-2003 | 31 | Shale |
| Kömürlü-2003 | 32 | Shale |
| Kömürlü-2003 | 33 | Shale |
| Kömürlü-2003 | 34 | Shale |
| Kömürlü-2003 | 35 | Shale |
| Kömürlü-2003 | 36 | Shale |
| Kömürlü-2003 | 37 | Marl |
| Kömürlü-2003 | 38 | Silty marl |
| Kömürlü-2003 | 39 | Shale |
| Kömürlü-2003 | 40 | Coal |
| Kömürlü-2003 | 41 | Shale |
| Kömürlü-2003 | 42 | Shale |

| SECTION | SAMPLE NO | LITHOLOGY |
|---|---|---|
| Kömürlü-2003 | 43 | Shale |
| Kömürlü-2003 | 44 | Shale |
| Kömürlü-2003 | 45 | Shale |
| Kömürlü-2003 | 46 | Shale |
| Kömürlü-2003 | 47 | Shale |
| Kömürlü-2003 | 48 | Marl |
| Kömürlü-2003 | 49 | Marl |
| Kömürlü-2003 | 50 | Marl |
| Kömürlü-2003 | 51 | Marl |
| Kömürlü-2003 | 52 | Marl |
| Kömürlü-2003 | 53 | Shale |
| Kömürlü-2003 | 54 | Marl |
| Kömürlü-2003 | 55 | Marl |
| Kömürlü-2003 | 56 | Marl |
| Kömürlü-2003 | 57 | Sandy Marl |
| Kömürlü-2003 | 58 | Marl |
| Kömürlü-2003 | 59 | Marl |
| Kömürlü-2003 | 60 | Silty Marl |
| Kelereşdere-2003 | 61 | Marl |
| Kelereşdere-2003 | 62 | Marl |
| Kelereşdere-2003 | 63 | Marl |
| Kelereşdere-2003 | 64 | Marl |
| Kelereşdere-2003 | 65 | Marl |
| Kelereşdere-2003 | 66 | Marl |
| Kelereşdere-2003 | 67 | Marl |
| Kelereşdere-2003 | 68 | Marl |
| Kelereşdere-2003 | 69 | Marl |
| Kelereşdere-2003 | 70 | Marl |
| Kelereşdere-2003 | 71 | Marl |
| Kelereşdere-2003 | 72 | Marl |
| Kelereşdere-2003 | 73 | Siltstone |
| Kelereşdere-2003 | 74 | Marl |
| Kelereşdere-2003 | 75 | Marl |
| Kelereşdere-2003 | 76 | Marl |
| Kelereşdere-2003 | 77 | Marl |
| Kelereşdere-2003 | 78 | Marl |
| Kelereşdere-2003 | 79 | Silty Marl |
| Kelereşdere-2003 | 80 | Marl |
| Kelereşdere-2003 | 81 | Marl |
| Kelereşdere-2003 | 82 | Marl |
| Kelereşdere-2003 | 83 | Marl |
| Kelereşdere-2003 | 84 | Marl |
| Kelereşdere-2003 | 85 | Marl |
| Kelereşdere-2003 | 86 | Marl |
| Kelereşdere-2003 | 87 | Marl |
| Kelereşdere-2003 | 88 | Marl |

| SECTION | SAMPLE NO | LITHOLOGY |
|---|---|---|
| Kelereşdere-2003 | 89 | Marl |
| Kelereşdere-2003 | 90 | Marl |
| Kelereşdere-2003 | 91 | Marl |
| Kelereşdere-2003 | 92 | Marl |
| Kelereşdere-2003 | 93 | Limestone |
| Kelereşdere-2003 | 94 | Limestone |
| Kelereşdere-2003 | 95 | Limestone |
| Kelereşdere-2003 | 96 | Marl |
| Kelereşdere-2003 | 97 | Marl |
| Kelereşdere-2003 | 98 | Marl |
| Kelereşdere-2003 | 99 | Marl |
| Kelereşdere-2003 | 100 | Marl |
| Kelereşdere-2003 | 101 | Marl |
| Kelereşdere-2003 | 102 | Marl |
| Kelereşdere-2003 | 103 | Marl |
| Kelereşdere-2003 | 104 | Limestone |
| Kelereşdere-2003 | 105 | Limestone |
| Kelereşdere-2003 | 106 | Marl |
| Kelereşdere-2003 | 107 | Limestone |
| Kelereşdere-2003 | 108 | Limestone |
| Kelereşdere-2003 | 109 | Silty marl |
| Kelereşdere-2003 | 110 | Carb. sandstone |
| Kelereşdere-2003 | 111 | Silty marl |
| Kelereşdere-2003 | 112 | Silty marl |
| Kelereşdere-2003 | 113 | Silty marl |
| Kelereşdere-2003 | 114 | Sandstone |
| Kelereşdere-2003 | 115 | Silty marl |
| Kelereşdere-2003 | 116 | Silty marl |
| Kelereşdere-2003 | 117 | Sandstone |
| Kelereşdere-2003 | 118 | Siltstone |
| Kelereşdere-2003 | 119 | Siltstone |
| Kelereşdere-2003 | 120 | Limestone |
| Kelereşdere-2003 | 121 | Limestone |
| Kelereşdere-2003 | 122 | Sandy limestone |
| Kelereşdere-2003 | 123 | Limestone |
| Kelereşdere-2003 | 124 | Limestone |
| Kelereşdere-2003 | 125 | Limestone |
| Kötek-2003 | 126 | Silty marl |
| Kötek-2003 | 127 | Silty marl |
| Kötek-2003 | 128 | Silty marl |
| Kötek-2003 | 129 | Silty marl |
| Kötek-2003 | 130 | Silty marl |
| Kötek-2003 | 131 | Silty marl |
| Kötek-2003 | 132 | Silty marl |
| Kötek-2003 | 133 | Limestone |

| SECTION | SAMPLE NO | LITHOLOGY |
|---|---|---|
| Kötek-2003 | 134 | Shale |
| Kötek-2003 | 135 | Marl |
| Kötek-2003 | 136 | Marl |
| Kötek-2003 | 137 | Marl |
| Kötek-2003 | 138 | Silty marl |
| Kötek-2003 | 139 | Sandy marl |
| Kötek-2003 | 140 | Sandy marl |
| Kötek-2003 | 141 | Sandy marl |
| Kötek-2003 | 142 | Sandy marl |
| Kötek-2003 | 143 | Sandy marl |
| Kötek-2003 | 144 | Sandy marl |
| Kötek-2003 | 145 | Sandy marl |
| Kötek-2003 | 146 | Sandy marl |
| Kötek-2003 | 147 | Sandy marl |
| Kötek-2003 | 148 | Marl |
| Kötek-2003 | 149 | Siltstone |
| Kötek-2003 | 150 | Marl |
| Çirişlitepe-2003 | 155 | Limestone |
| Çirişlitepe-2003 | 156 | Limestone |
| Çirişlitepe-2003 | 157 | Limestone |
| Çirişlitepe-2003 | 158 | Silty marl |
| Çirişlitepe-2003 | 159 | Silty marl |
| Çirişlitepe-2003 | 160 | Silty marl |
| Çirişlitepe-2003 | 161 | Silty marl |
| Çirişlitepe-2003 | 162 | Silty marl |
| Çirişlitepe-2003 | 163 | Sandstone |
| Çirişlitepe-2003 | 164 | Limestone |
| Çirişlitepe-2003 | 165 | Limestone |
| Çirişlitepe-2003 | 166 | Limestone |
| Çirişlitepe-2003 | 167 | Limestone |
| Çirişlitepe-2003 | 168 | Sandy marl |
| Çirişlitepe-2003 | 169 | Marl |
| Çirişlitepe-2003 | 170 | Silty marl |
| Çirişlitepe-2003 | 171 | Marl |
| Çirişlitepe-2003 | 172 | Marl |
| Ebulbahar-2004 | 34 | Marl |
| Ebulbahar-2004 | 35 | Marl |
| Ebulbahar-2004 | 36 | Marl |
| Ebulbahar-2004 | 37 | Silty Marl |
| Ebulbahar-2004 | 38 | Marl |
| Ebulbahar-2004 | 39 | Marl |
| Ebulbahar-2004 | 40 | Marl |
| Ebulbahar-2004 | 41 | Marl |
| Ebulbahar-2004 | 42 | Marl |
| Ebulbahar-2004 | 43 | Marl |
| Ebulbahar-2004 | 44 | Marl |

| SECTION | SAMPLE NO | LITHOLOGY |
|---|---|---|
| Ebulbahar-2004 | 45 | Marl |
| Ebulbahar-2004 | 46 | Marl |
| Ebulbahar-2004 | 47 | Marl |
| Ebulbahar-2004 | 48 | Marl |
| Ebulbahar-2004 | 49 | Marl |
| Ebulbahar-2004 | 50 | Marl |
| Ebulbahar-2004 | 51 | Marl |
| Ebulbahar-2004 | 52 | Marl |
| Ebulbahar-2004 | 53 | Marl |
| Ebulbahar-2004 | 54 | Marl |
| Ebulbahar-2004 | 55 | Marl |
| Ebulbahar-2004 | 56 | Marl |
| Ebulbahar-2004 | 57 | Marl |
| Ebulbahar-2004 | 58 | Marl |
| Ebulbahar-2004 | 59 | Marl |
| Ebulbahar-2004 | 60 | Marl |
| Ebulbahar-2004 | 61 | Marl |
| Ebulbahar-2004 | 62 | Marl |
| Ebulbahar-2004 | 63 | Marl |
| Ebulbahar-2004 | 64 | Marl |
| Ebulbahar-2004 | 65 | Sandy limestone |
| Ebulbahar-2004 | 66 | Marl |
| Ebulbahar-2004 | 67 | Marl |
| Ebulbahar-2004 | 68 | Marl |
| Ebulbahar-2004 | 69 | Marl |
| Ebulbahar-2004 | 70 | Marl |
| Ebulbahar-2004 | 71 | Carb. limestone |
| Ebulbahar-2004 | 72 | Marl |
| Ebulbahar-2004 | 73 | Marl |
| Ebulbahar-2004 | 74 | Marl |
| Ebulbahar-2004 | 75 | Limestone |
| Ebulbahar-2004 | 76 | Limestone |
| Ebulbahar-2004 | 77 | Marl |
| Ebulbahar-2004 | 78 | Marl |
| Ebulbahar-2004 | 79 | Marl |
| Ebulbahar-2004 | 80 | Marl |
| Ebulbahar-2004 | 81 | Limestone |
| Ebulbahar-2004 | 82 | Marl |
| Ebulbahar-2004 | 83 | Marl |
| Ebulbahar-2004 | 84 | Marl |
| Ebulbahar-2004 | 85 | Marl |
| Ebulbahar-2004 | 86 | Marl |
| Ebulbahar-2004 | 87 | Marl |
| Ebulbahar-2004 | 88 | Marl |
| Ebulbahar-2004 | 89 | Marl |
| Ebulbahar-2004 | 90 | Marl |

| SECTION | SAMPLE NO | LITHOLOGY |
|---|---|---|
| Ebulbahar-2004 | 91 | Marl |
| Ebulbahar-2004 | 92 | Marl |
| Ebulbahar-2004 | 93 | Marl |
| Ebulbahar-2004 | 94 | Marl |
| Ebulbahar-2004 | 95 | Silty Marl |
| Ebulbahar-2004 | 96 | Sandy limestone |
| Ebulbahar-2004 | 97 | Sandy limestone |
| Ebulbahar-2004 | 98 | Sandy limestone |
| Ebulbahar-2004 | 99 | Sandy limestone |
| Ebulbahar-2004 | 100 | Sandy limestone |
| Ebulbahar-2004 | 101 | Sandy limestone |
| Ebulbahar-2004 | 102 | Limestone |
| Ebulbahar-2004 | 103 | Limestone |
| Ebulbahar-2004 | 104 | Limestone |
| Ebulbahar-2004 | 105 | Sandy limestone |
| Ebulbahar-2004 | 106 | Sandy limestone |
| Ebulbahar-2004 | 107 | Sandy limestone |
| Ebulbahar-2004 | 108 | Sandy limestone |
| Ebulbahar-2004 | 109 | Carb. limestone |
| Ebulbahar-2004 | 110 | Silty Marl |
| Ebulbahar-2004 | 111 | Silty Marl |
| Ebulbahar-2004 | 112 | Silty Marl |
| Ebulbahar-2004 | 113 | Limestone |
| Ebulbahar-2004 | 114 | Limestone |
| Ebulbahar-2004 | 115 | Siltstone |
| Ebulbahar-2004 | 116 | Marl |
| Ebulbahar-2004 | 117 | Limestone |
| Ebulbahar-2004 | 118 | Limestone |
| Ebulbahar-2004 | 119 | Limestone |
| Ebulbahar-2004 | 120 | Marl |
| Ebulbahar-2004 | 121 | Marl |
| Ebulbahar-2004 | 122 | Sandy limestone |
| Ebulbahar-2004 | 123 | Carb. limestone |
| Ebulbahar-2004 | 124 | Limestone |
| Ebulbahar-2004 | 125 | Limestone |
| Ebulbahar-2004 | 126 | Carb. limestone |
| Ebulbahar-2004 | 127 | Carb. limestone |
| Ebulbahar-2004 | 128 | Carb. limestone |
| Ebulbahar-2004 | 129 | Sandy limestone |
| Ebulbahar-2004 | 130 | Sandy limestone |
| Ebulbahar-2004 | 131 | Limestone |
| Ebulbahar-2004 | 132 | Limestone |
| Ebulbahar-2004 | 133 | Marl |
| Ağgelin-2004 | 134 | Marl |
| Ağgelin-2004 | 135 | Mudstone |
| Ağgelin-2004 | 136 | Mudstone |

| SECTION | SAMPLE NO | LITHOLOGY |
|---|---|---|
| Ağgelin-2004 | 137 | Marl |
| Ağgelin-2004 | 138 | Marl |
| Ağgelin-2004 | 139 | Marl |
| Ağgelin-2004 | 140 | Marl |
| Ağgelin-2004 | 141 | Marl |
| Ağgelin-2004 | 142 | Marl |
| Ağgelin-2004 | 143 | Marl |
| Ağgelin-2004 | 144 | Marl |
| Ağgelin-2004 | 145 | Marl |
| Ağgelin-2004 | 146 | Marl |
| Ağgelin-2004 | 147 | Siltstone |
| Ağgelin-2004 | 148 | Silty Marl |
| Ağgelin-2004 | 149 | Carb. Sandstone |
| Ağgelin-2004 | 150 | Marl |
| Ağgelin-2004 | 151 | Silty Marl |
| Ağgelin-2004 | 152 | Mudstone |
| Ağgelin-2004 | 153 | Marl |
| Ağgelin-2004 | 154 | Mudstone |
| Ağgelin-2004 | 155 | Silty Marl |
| Ağgelin-2004 | 156 | Silty Marl |
| Ağgelin-2004 | 157 | Silty Marl |
| Keleresdere-2004 | 158 | Siltstone |
| Keleresdere-2004 | 159 | Claystone |
| Keleresdere-2004 | 160 | Mudstone |
| Keleresdere-2004 | 161 | Siltstone |
| Keleresdere-2004 | 162 | Silty Marl |
| Keleresdere-2004 | 163 | Silty Marl |
| Keleresdere-2004 | 164 | Marl |
| Keleresdere-2004 | 165 | Marl |
| Keleresdere-2004 | 166 | Marl |
| Keleresdere-2004 | 167 | Marl |
| Keleresdere-2004 | 168 | Marl |
| Keleresdere-2004 | 169 | Marl |
| Keleresdere-2004 | 170 | Silty Marl |
| Keleresdere-2004 | 171 | Marl |
| Keleresdere-2004 | 172 | Marl |
| Keleresdere-2004 | 173 | Marl |
| Keleresdere-2004 | 174 | Marl |
| Akcaarmut-2004 | 178 | Marl |
| Akcaarmut-2004 | 179 | Marl |
| Akcaarmut-2004 | 180 | Marl |
| Akcaarmut-2004 | 181 | Limestone |
| Akcaarmut-2004 | 182 | Limestone |
| Akcaarmut-2004 | 183 | Marl |
| Akcaarmut-2004 | 184 | Ash |
| Zirnak-2004 | 185 | Sandy Limestone |

| SECTION | SAMPLE NO | LITHOLOGY |
|---|---|---|
| Zirnak-2004 | 186 | Marl |
| Zirnak-2004 | 187 | Marl |
| Zirnak-2004 | 188 | Marl |
| Zirnak-2004 | 189 | Marl |
| Zirnak-2004 | 190 | Marl |
| Zirnak-2004 | 191 | Marl |
| Zirnak-2004 | 192 | Marl |
| Zirnak-2004 | 193 | Coal |
| Zirnak-2004 | 194 | Coal |
| Zirnak-2004 | 195 | Marl |
| Zirnak-2004 | 196 | Siltstone |
| Zirnak-2004 | 197 | Siltstone |
| Zirnak-2004 | 198 | Marl |
| Zirnak-2004 | 199 | Marl |
| Zirnak-2004 | 200 | Marl |
| Zirnak-2004 | 201 | Marl |
| Ahlat-2004 | 202 | Marl |
| Ahlat-2004 | 203 | Limestone |
| Ahlat-2004 | 204 | Limestone |
| Ahlat-2004 | 205 | Limestone |
| Ahlat-2004 | 206 | Limestone |
| Ahlat-2004 | 207 | Limestone |
| Ahlat-2004 | 208 | Limestone |
| Ahlat-2004 | 209 | Limestone |
| Ahlat-2004 | 210 | Limestone |
| Ahlat-2004 | 211 | Limestone |
| Ahlat-2004 | 212 | Limestone |
| Ahlat-2004 | 213 | Limestone |
| Ahlat-2004 | 214 | Limestone |
| Ahlat-2004 | 215 | Limestone |
| Ahlat-2004 | 216 | Marl |
| Ahlat-2004 | 217 | Marl |
| Ahlat-2004 | 218 | Marl |
| Ahlat-2004 | 219 | Marl |
| Ahlat-2004 | 220 | Marl |
| Ahlat-2004 | 221 | Marl |
| Ahlat-2004 | 222 | Marl |
| Ahlat-2004 | 223 | Siltstone |
| Ağgelin-2004 | 224 | Marl |
| Ağgelin-2004 | 225 | Limestone |
| Ağgelin-2004 | 226 | Limestone |
| Ağgelin-2004 | 227 | Limestone |
| Ağgelin-2004 | 228 | Limestone |
| Ağgelin-2004 | 229 | Limestone |
| Ağgelin-2004 | 230 | Marl |
| Ağgelin-2004 | 231 | Marl |

| SECTION | SAMPLE NO | LITHOLOGY |
|---|---|---|
| Ağgelin-2004 | 232 | Marl |
| Ağgelin-2004 | 233 | Marl |
| Ağgelin-2004 | 234 | Limestone |
| Ağgelin-2004 | 235 | Marl |

VITA

Recep Hayrettin Sancay was born in Ankara on August, 16, 1975. He received his B.S. degree in Department of Geological Engineering from Hacettepe University in 1997. Right after his graduation, he was awarded a full government scholarship from Turkish Ministery of Education and Turkish Petroleum Corporation (TPAO) to pursue a M.Sc. degree in the field of Biostratigraphy/Paleontology. He graduated from Texas A&M University, Department of Geology and Geophysics in 2000. Since then, he has been working as a palynologist/biostratigrapher in the Reseach Center of TPAO. He is currently a Board Member of Turkish Association of Petroleum Geologists, and Chamber Member and Master Chair of Turkish Aggie Club. His main areas of interests are Paleozoic and Cenozoic palynology (spore, pollen, fungal spore, dinoflagellate, acritarch, and organic-walled algae). He is married and will have a daughter at the end of this year.