PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY OF THE PALEOCENE-EOCENE SEQUENCES IN THE WESTERN AND CENTRAL BLACK SEA REGION, TURKEY

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submitted by **ALEV GÜRAY** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Geological Engineering Department, Middle East Technical University** by,

Prof. Dr. Canan ÖZGEN
Dean, Graduate School of **Natural and Applied Sciences** ______________________

Prof. Dr. Erdin BOZKURT
Head of Department, **Geological Engineering** ______________________

Prof. Dr. Sevinç ÖZKAN ALTINER
Supervisor, **Geological Engineering Dept., METU** ______________________

Examining Committee Members:

Prof. Dr. Asuman TÜRKMENOĞLU
Geological Engineering Dept., METU ______________________

Prof. Dr. Sevinç ÖZKAN ALTINER
Geological Engineering Dept., METU ______________________

Prof. Dr. Cemal TUNOĞLU
Geological Engineering Dept., Hacettepe University ______________________

Assoc. Prof. Dr. İ.Ömer YILMAZ
Geological Engineering Dept., METU ______________________

Assist. Prof. Dr. Fatma TOKSOY KÖKSAL
Geological Engineering Dept., METU ______________________

Date: August 11, 2014

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules nd 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 : Alev GÜRAY

Signature :

ABSTRACT

PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY OF THE PALEOCENE-EOCENE SEQUENCES IN THE WESTERN AND CENTRAL BLACK SEA REGION, TURKEY

Güray, Alev
Ph.D., Department of Geological Engineering
Supervisor: Prof. Dr. Sevinç Özkan Altıner

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The Paleocene-Eocene sequences are widely distributed around onshore and offshore Black Sea. When the previous studies in the Turkish coasts of the Black Sea are considered, the deficiency of a detailed biostratigraphical framework attracts the attention.

The taxonomy of the planktonic foraminifera and the benthic foraminifera assemblages are important for the establishment of the new biostratigraphical frame in the Paleocene-Eocene sequences of the Western and Central Black Sea regions. The Paleocene-Eocene interval was studied throughout the sequences including Akveren, Atbaşı and Kusuri formations. Taxonomical studies have been carried out on 327 samples collected from 9 stratigraphical sections for the high resolution biostratigraphy. 4 families, 18 genera, 87 species have been identified for the planktonic foraminifera and 30 families, 38 genera, 14 species were defined for the benthic foraminifera. By using the first and last occurrences of the planktonic foraminifera, 13 biozones and 4 subzones have been established in this study: **(1)** *Parvularugoglobigerina eugubina-Praemurica uncinata* Interval Zone (with *Subbotina triloculinoides-Praemurica inconstans* Interval Subzone and *Praemurica inconstans-Praemurica uncinata* Interval Subzone), **(2)** *Praemurica uncinata-Morozovella angulata* Interval Zone, **(3)** *Morozovella angulata-Acarinina nitida* Interval Zone, **(4)** *Acarinina nitida-Globanomalina pseudomenardii* Concurrent Range Zone, **(5)** *Morozovella velascoensis* Partial-range Zone, **(6)** *Morozovella subbotinae* Partial-range Zone (with *Morozovella edgari* Partial-range Subzone and *Morozovella* formosa/Morozovella *lensiformis-Morozovella aragonensis* Interval Subzone), **(7)** *Morozovella aragonensis-Morozovella formosa* Concurrent-range Zone, **(8)** *Acarinina pentacamerata* Partial-range Zone, **(9)** *Acarinina cuneicamerata-Hantkenina* spp. Interval Zone, **(10)** *Hantkenina* spp.-*Acarinina*

boudreauxi Concurrent-range Zone, **(11)** *Globigerina eoceanica* Partial-range Zone, **(12)** *Globigerina turkmenica-Globigerina azerbaidjanica* Concurrent-range Zone and **(13)** *Globigerina azerbaidjanica-Acarinina medizzai* Interval Zone.

The Paleocene-Eocene boundary has been recognized by the first occurrences of *Acarinina wilcoxensis* and *Acarinina pseudotopilensis* in Erfelek 1 and Kaymakam Kayası sections. Response of planktonic foraminifera to the environmental perturbations during the Paleocene-Eocene Thermal Maximum (PETM) is recorded by the absence of the excursion taxa (*Acarinina sibaiyaensis*, *Acarinina africana* and *Morozovella allisonensis*) besides the scarcity or absence of the other warm water surface dwellers during the latest Paleocene-earliest Eocene. The benthic foraminiferal extinction event, which is another important event on the boundary, is recorded by the extinction of *Pullenia coryelli* below the boundary in the Erfelek 1 Section. The XRD studies on the Erfelek 1 Section have recorded two levels for the carbonate dissolution during the PETM, whereas the clay mineralogy indicates different sources for the clay minerals, which show the effect of the tectonism in the region.

The discrepancies in the stratigraphical ranges of the planktonic foraminifera have been recognized especially during the Middle and Late Eocene for the Black Sea region. These differences with respect to Mediterranean and Crimean-Caucasus realms emphasize the importance of the paleogeographical position of the Black Sea Region, as the connection between those two regions, to revise and recalibrate marker planktonic foraminiferal bioevents for the Black Sea region.

Keywords: Planktonic foraminifera, Paleocene-Eocene, Biostratigraphy, Benthic foraminifera, P-Ê boundary, Western and Central Black Sea Region, Turkey

ÖZ

PALEOSEN-EOSEN BİRİMLERİNİN PLANKTONİK FORAMİNİFERA BİYOSTRATİGRAFİSİ, BATI VE ORTA KARADENİZ BÖLGESİ, TÜRKİYE

Güray, Alev
Doktora, Jeoloji Mühendisliği Bölümü
Tez Yöneticisi: Prof. Dr. Sevinç Özkan Altıner

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Paleosen-Eosen çökelleri Karadeniz'in kara ve deniz alanlarında çok geniş bir yayılıma sahiptir. Gerek saha, gerekse kuyu incelemeleri bazında yapılan çalışmalarda bölgedeki bu birimlerin biyostratigrafisi ile ilgili çeşitli bulgular ortaya konulmuş olmasına rağmen detaylı biyostratigrafik çalışmalardaki eksiklik göze çarpmaktadır.

Planktonik ve bentik foraminifera taksonomisi Batı ve Orta Karadeniz için hazırlanan yeni biyostratigrafik zonasyonun oluşturulmasında önemlidir. Bu bağlamda, Paleosen-Eosen çökelleri Akveren, Atbaşı ve Kusuri formasyonlarından derlenen örneklerle çalışılmıştır. Taksonomik çalışmalar 9 ölçülü stratigrafik kesitten alınan toplam 327 örnek üzerinde gerçekleştirilmiştir. Planktonik foraminiferlere ait 4 familya, 18 cins, 87 tür; bentik foraminiferlere ait 30 familya, 38 cins ve 14 tür tanımlanmıştır. Bu çalışmada planktonik foraminiferlerin ortaya çıkış ve yok oluş seviyeleri kullanılarak toplam 13 biyozon ve 4 altzon tanımlanmıştır: **(1)** *Parvularugoglobigerina eugubina-Praemurica uncinata* Aralık Zonu (*Subbotina triloculinoides-Praemurica inconstans* Aralık Altzonu ve *Praemurica inconstans-Praemurica uncinata* Aralık Altzonu ile), **(2)** *Praemurica uncinata-Morozovella angulata* Aralık Zonu, **(3)** *Morozovella angulata-Acarinina nitida* Aralık Zonu, **(4)** *Acarinina nitida-Globanomalina pseudomenardii* Aşmalı Menzil Zonu, **(5)** *Morozovella velascoensis* Kısmi Menzil Zonu, **(6)** *Morozovella subbotinae* Kısmi Menzil Zonu (*Morozovella edgari* Kısmi Menzil Altzonu ve *Morozovella* formosa/Morozovella *lensiformis-Morozovella aragonensis* Aralık Altzonu ile), **(7)** *Morozovella aragonensis-Morozovella formosa* Aşmalı Menzil Zonu, **(8)** *Acarinina pentacamerata* Kısmi Menzil Zonu, **(9)** *Acarinina cuneicamerata-Hantkenina* spp. Aralık Zonu, **(10)** *Hantkenina* spp.-*Acarinina boudreauxi* Aşmalı Menzil Zonu, **(11)**

Globigerina eoceanica Kısmi Menzil Zonu, **(12)** *Globigerina turkmenica-Globigerina azerbaidjanica* Aşmalı Menzil Zonu and **(13)** *Globigerina azerbaidjanica-Acarinina medizzai* Aralık Zonu.

Paleosen-Eosen sınırı *Acarinina wilcoxensis* ve *Acarinina pseudotopilensis*'in ilk çıkışlarıyla ortaya belirlenmiştir. Planktonik foraminiferlerin Paleosen-Eosen Termal Maksimumu (PETM) sırasındaki çevresel değişimlere olan tepkileri, Erfelek 1 Kesitinde yapılan çalışmalarda *Acarinina sibaiyaensis, Acarinina africana* and *Morozovella allisonensis* gibi "excursion taxa" nın görülmemesi ve sıcak ortam koşullarını belirten diğer yüzey formlarının Geç Paleosen-Erken Eosen dönemindeki azlığı veya yokluğu ile kaydedilmiştir. Global bir olay olan bentik foraminiferlerin yokoluşu, Erfelek 1 Kesitinde *Pullenia coryelli* türünün sınırın hemen altında yok olmasıyla tespit edilmiştir. Erfelek 1 Kesitinde yapılan XRD çalışmalarında PETM döneminde global olarak kaydedilen karbonat çözülmesi 2 seviye halinde görülmektedir. Kil mineralojisi çalışmalarında ise elde edilen veriler killerin değişik kaynaklardan geldiklerini göstermektedir ve bunun da bölgedeki tektonizmayla ilgili olduğu düşünülmektedir.

Orta-Geç Eosen dönemlerinde Karadeniz Bölgesi için planktonic foraminiferlerin stratigrafik yayılımlarında değişiklikler kaydedilmiştir. Akdeniz ve Kırım-Kafkas bölgelerinden farklı olarak gözlenen bu değişimler Karadeniz'in paleocoğrafik konumunundan dolayı planktonik foraminiferlerde gözlenen biyo-olayların revize edilmesinin önemini göstermektedir.

Anahtar kelimeler: Planktonik foraminifera, Paleosen-Eosen, Biyostratigrafi, Bentik foraminifera, P-E sınırı, Batı ve Orta Karadeniz Bölgesi, Türkiye

To my family…

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TABLE OF CONTENTS

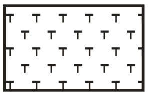
LIST OF FIGURES

FIGURES

LIST OF TABLES

TABLES

EXPLANATION OF SYMBOLS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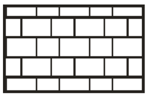
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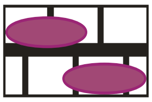
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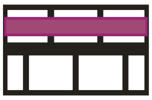
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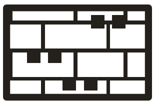
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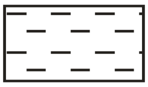
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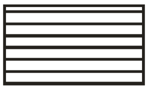
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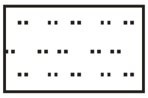
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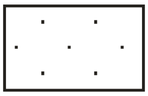
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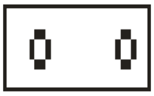
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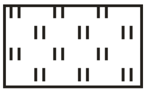
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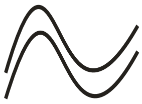
Slump

ABBREVIATIONS

Explanation of the abbreviations which are used in the PhD thesis:

BFEE: Benthic Foraminifera Extinction Event

CIE: Carbon Isotope Excursion

CRZ: Concurrent-range Zone

EECO: Early Eocene Climatic Optimum

FAD: First appearance datum

GSSP: Global Boundary Stratotype Section and Point

ISZ: Interval Subzone

IZ: Interval Zone

LAD: Last appearance datum

MECO: Middle Eocene Climatic Optimum

MSS: Measured Stratigraphic Section

PETM: Paleocene-Eocene Thermal Maximum

PRSZ: Partial-range Subzone

PRZ: Partial-range Zone

CHAPTER 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

The Paleogene is most notable as being the time in which life rapidly recovered in the wake of the Cretaceous-Paleogene extinction event. Besides many micro- and macrofossil groups, one of the most important recoveries was among the planktonic foraminifera. Planktonic foraminifera are widely utilized for the biostratigraphy of Cretaceous and Cenozoic marine sediments. They are mostly regarded as a fundamental component of Cenozoic, in particular Paleogene, chronostratigraphy. The recent enhancements in deep sea drilling recovery, multiple coring and high resolution sampling both offshore and onshore, has improved the planktonic foraminiferal biostratigraphy and/or modified species ranges.

In the Paleogene Period, at the close of the Paleocene Epoch ca. 55Ma, Earth experienced one of the most dramatic global warming events in the geologic record—the Paleocene-Eocene Thermal Maximum (PETM). A global drop in δ13C values of up to 2–3‰, known as the Carbon Isotope Excursion (CIE), marks the onset of the PETM during which global temperatures rose by 5–8 °C within a few thousand years (Kennett and Stott, 1991; Zachos *et al*., 1993; Koch *et al*., 1995; Corfield and Norris, 1998; Jenkyns, 2003). The short lived warming event induced a host of biotic responses, including mass extinction of benthic foraminifera, rapid diversification of planktonic foraminifera.

Being the northernmost tectonic element of Asia Minor, the Pontides is one of the compressive belts that enclose the Black Sea. By the Middle Eocene, a compressional regime has begun in the Western Tethys Ocean. The combination of tectonic uplift and a drop in sea level resulted in a large regression of the sea.

This thesis primarily concerns the analysis of planktonic foraminifera and benthonic foraminifera assemblages from the Paleocene-Eocene sequences from the Western and Central Black Sea region, Turkey. The main purposes of this thesis are (1) to establish a high resolution biostratigraphy, (2) to determine the discrepencies in the stratigraphical ranges of the planktonic foraminifera, (3) to revise and recalibrate marker planktonic foraminiferal bioevents for the Black Sea region, (4) to explore the response of planktonic and benthonic foraminifera to the environmental perturbations occurring during a major portion of the PETM, (5) to infer the changes paleoenvironmental conditions and changes across the Paleocene-Eocene boundary on the basis of changes in diversity and abundance of planktonic foraminifera and the mineralogical changes.

To achieve the objectives, 327 samples were collected from 9 stratigraphical sections which were measured in the Western and Central Black Sea regions, Turkey. The Paleocene-Eocene interval was studied throughout the sequences including Akveren, Atbaşı and Kusuri formations. Detailed planktonic foraminiferal taxonomical analyses have been carried out through the samples. Recording the planktonic foraminiferal taxa in the samples, their first and last occurrences along the measured sections were precisely determined. Due to the changes in the stratigraphical ranges of the forms, scarcity or absence of some index Mediterranean taxa in the Black Sea or presence of some endemic taxa in the region, a regional biostratigraphic scheme was proposed for the Black Sea region. The Paleocene-Eocene boundary was defined in the Erfelek and the Kaymakam Kayası sections. In this manner, firstly the samples of the Erfelek 1 Section were evaluated in terms of planktonic foraminiferal biostratigraphy. Additional studies on the benthic foraminiferal taxonomy were carried out and benthic foraminiferal assemblages with both calcareous and agglutinated walls were recognized. Lastly, in order to investigate bulk rock and clay mineralogy, the XRD studies were carried out from the samples of the boundary interval. Worldwide correlation was also carried out for the Paleocene-Eocene boundary.

1.2. GEOGRAPHIC SETTING

The sample material of this study was collected from 9 stratigraphical sections measured in two regions: Akçakoca, Düzce in the Western Black Sea region and Sinop in the Central Black Sea region (Figure 1).

In the Akçakoca region, the Karaburun Measured Stratigraphic Section (MSS) and the Ayazlı MSS were measured (Figure 1) (Table 1). The Karaburun MSS is located in the topographic map of Düzce-F26-d4 quadrant of 1:25 000 scales. It is situated in the Karaburun coast about 13 km west of Akçakoca, Düzce. The Ayazlı MSS is located in the 1:25 000 scale topographic map of Düzce-F26-d3 quadrant. It is situated in the Kumkent Coast about 3 km east of Akçakoca. It is in the 1:25 000 scale topographic map of Düzce-F26-d3 quadrant.

In the Sinop region, 7 sections, İstafan MSS, Sinay-Karasu MSS, Erfelek, Erfelek 1 and Erfelek 1 MSS, Kaymakam Kayası and Kaymakam Kayası-A MSS, were measured (Figure 1) (Table 1). The Sinay-Karasu MSS is situated at about 20 km west of Ayancık, Sinop. It is placed in the Sinop-E32-b1 quadrant of 1:25 000 scale topographic map. The section was sampled to the north of Çaylıoğlu Village. Erfelek, Erfelek 1 and Erfelek-A MSS are located in the 1:25 000 scale topographic map of in the Sinop-E32-b2 quadrant. The Erfelek 1 Section is a section that is measured by the resampling of the Erfelek Section for the detailed recognition of the Paleocene-Eocene boundary. In this section, the sampling interval is narrower than the Erfelek Section. On the other hand, the upper parts of the Paleogene sequence are measured in the Erfelek-A Section. These sections are situated at about 18 km west of the Erfelek, Sinop. The Kaymakam Kayası and the Kaymakam Kayası-A MSS are located in the Sinop-E34-c1 quadrant in the 1:25 000 scale topographic map.

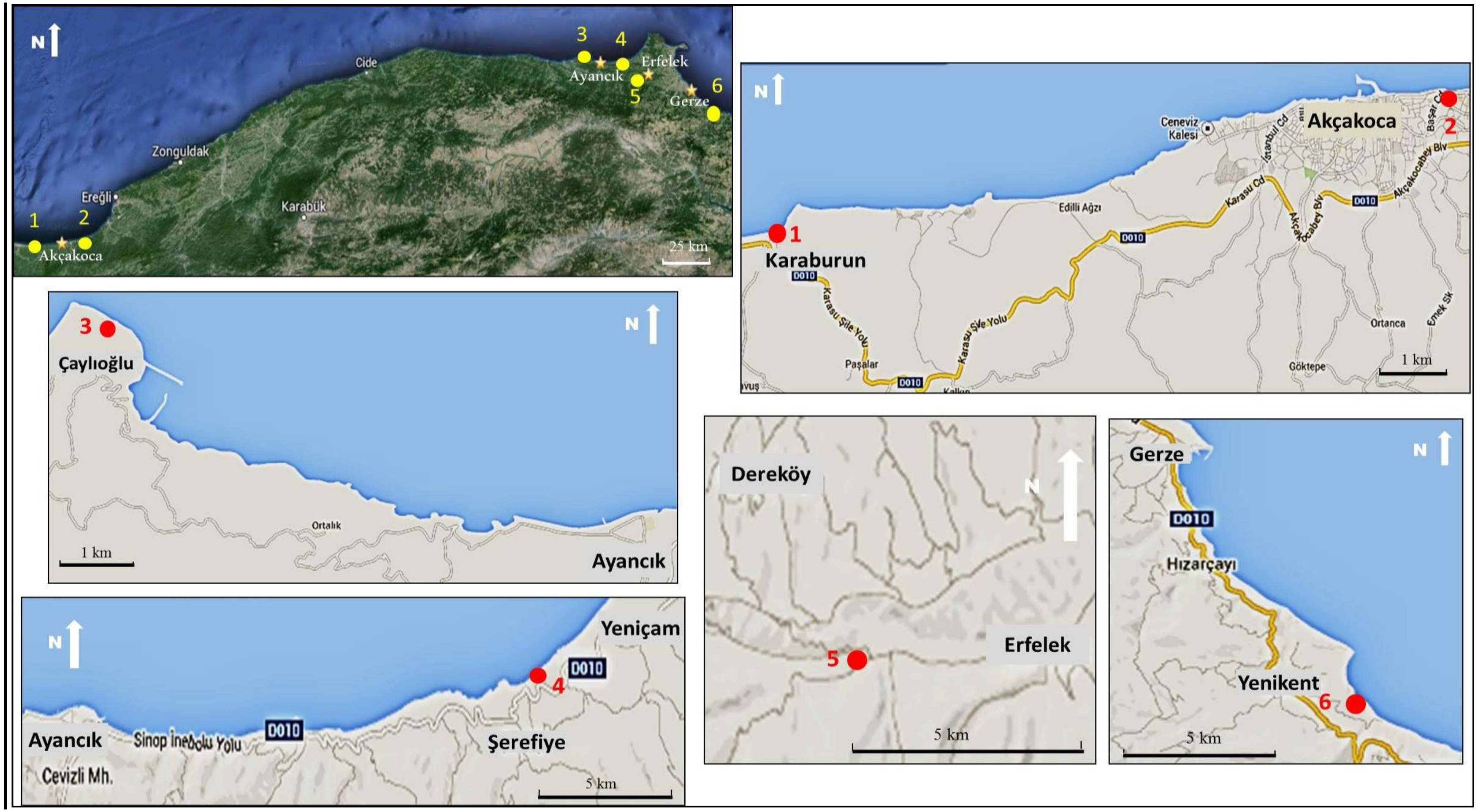

Figure 1. Location map of the study area. 1. Karaburun MSS, 2. Ayazlı MSS, 3. İstafan MSS, 4. Sinay-Karasu MSS, 5. Erfelek, Erfelek 1 Erfelek-A MSS, 6. Kaymakam Kayası and Kaymakam Kayası-A MSS.

The Kaymakam Kayası-A Section is the equivalent for the upper parts of the sequence, which has been measured along the Kaymakam Kayası Section. They are situated at about 4 km southeast of Yenikent, Gerze, Sinop.

All detailed information on the stratigraphic sections including GPS coordinates, thicknesses, numbers of samples are given in the Table 1.

Table 1. Location, GPS coordinates, total thickness and number of samples of all stratigraphic sections.

NAME OF SECTION	LOCATION		STARTING COORDINATE	ENDING COORDINATE	TOTAL THICKNESS	NUMBER OF SAMPLES
KARABURUN	Düzce	Düzce-F26-d4 quadrant	36 334 447 E, 45 492 78 N, 0 m	36 333 937 E, 45 492 63 N, 0 m	127.75 m	34
AYAZLI		Düzce-F26-d3 quadrant	36 345 138 E, 45 508 16 N, 0 m	36 345 350 E, 45 507 95 N, 0 m	70 m	15
İSTAFAN	Sinop	Sinop-E32-b1 quadrant	36 624 201 E, 46 480 14 N, 41 m	36 623 852 E, 46 482 55 N, 39 m	74.5 m	16
SİNAY-KARASU		Sinop-E33-b1 quadrant	36 651 409 E, 46 478 99 N, 0 m	36 651 109 E, 46 477 27 N, 0 m	188.5 m	28
ERFELEK		Sinop-E32-b2 quadrant	36 647 526 E, 46 354 56 N, 442 m	36 647 530 E, 46 358 87 N, 429 m	371 m	104
ERFELEK 1			36 647 526 E, 46 354 56 N, 442 m	36 647 530 E, 46 358 87 N, 429 m	202.5 m	55
ERFELEK - A			36 647 380 E, 46 360 53 N, 437 m	36 647 444 E, 46 361 02 N, 434 m	30 m	15
KAYMAKAM KAYASI		Sinop-E34-c1 quadrant	36 688 554 E, 46 197 62 N, 267 m	36 687 953 E, 46 204 79 N, 258 m	411 m	37
KAYMAKAM KAYASI - A			36 688 057 E, 46 205 39 N, 238 m	36 688 073 E, 46 206 89 N, 206 m	121 m	16

Although these 9 sections cover the time interval from the Maastrichtian, Cretaceous to the Late Eocene, the detailed study was carried out from only Paleogene part of the sequences (Figure 2).

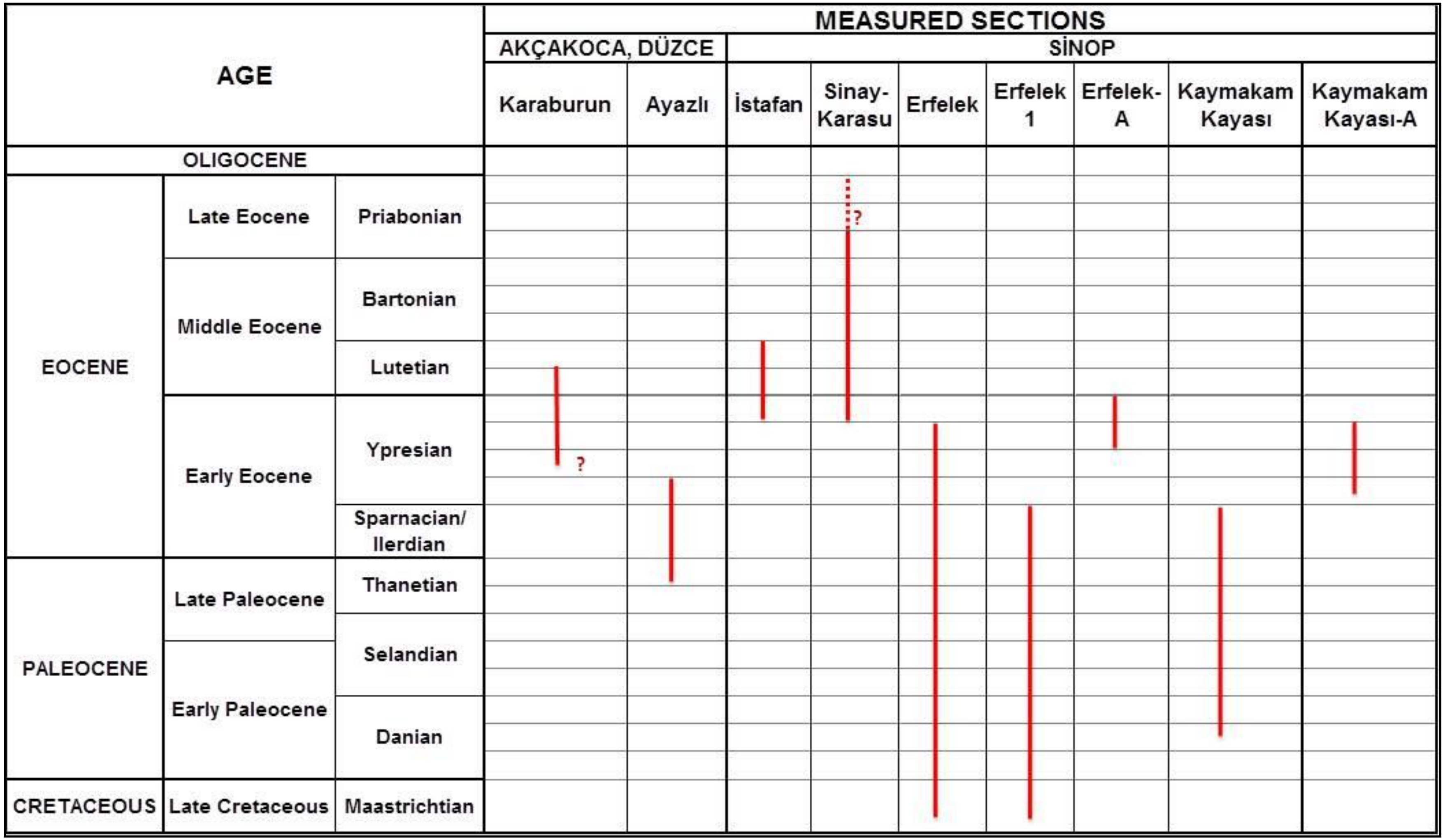

Figure 2. Stratigraphical distribution of the studied sections.

1.3 METHOD OF STUDY

This study is supported by Turkish Petroleum Corporation (TPAO) in terms of their permission and financial support for the field studies and preparation of the samples.

This study includes both field and laboratory work. 4 different field studies were carried out. The first one was for the recognition of the Cretaceous to Cenozoic lithostratigraphic units in the Western Black Sea region from Ayancık, Sinop in the east to Akçakoca, Düzce in the west. Akveren, Atbaşı, Kusuri and Sarıkum formations were identified in this field study and different stratigraphic sections were sampled including the Cretaceous-Paleogene boundary and Paleocene-Eocene boundary, besides the formation boundaries and the youngest outcrops in the study area. A total of 283 samples were gathered, of which 202 were analyzed in terms of planktonic foraminiferal investigation by washed samples.

The results obtained from the investigation of these samples haven't been included directly to this study, but were used to decide the main sections that have been studied in the present thesis. In the second field work, sections were measured for the detailed sampling of Karaburun, Ayazlı, İstafan and Sinay-Karasu sections (Appendix A). A total of 88 samples, suitable for the preparation of washing samples, were collected.

The third field trip was arranged for measuring and sampling Erfelek, Erfelek-A, Kaymakam Kayası and Kaymakam Kayası-A sections (Appendix A). The main purpose of this field study was to identify the Paleocene-Eocene boundary in the sections. Therefore, a wide interval, covering from the Akveren Formation up to the Atbaşı and the Kusuri formations, was sampled. A total of 176 samples were gathered during this field trip.

Lastly, a detailed study was required for the identification of the Paleocene-Eocene boundary, whose existancy has been recognized in the Erfelek Section. The last field trip was for resampling of this section across the boundary. A total of 55 samples were gathered for this reason. This detailed section is called the Erfelek 1 Section in the following chapters.

Concisely, a total of 327 samples have been analyzed from 9 stratigraphical sections in this study.

The gathered samples have been prepared for micropaleontological analyses in TPAO Research Center laboratories. A total of 100-150 gr. of each sample was used for the washing procedures. H_2O_2 treatment was used for the marls. Different concentrations of H_2O_2 from 20 % to 50 % and different treatment durations from 5 minutes up to 3 hours were tried. The best treatment was obtained by 25% H_2O_2 for not more than 10 minutes. This treatment was followed by the boiling of the samples with Na_2CO_3 (soda) for the clayey samples for 2-3 hours. After that, the samples were washed under water and picked from the 80 μm size aperture sieve. However, some of the samples were totally dissolved by this matter and the planktonic foraminifera couldn't be preserved. For these samples, the methodology was changed and only boiling with distilled water was applied for the extraction of the fossils. Na_2CO_3 was also used when needed. On the other hand, H_2O_2 wasn't enough for the preparation of limestones and clayey limestones. Therefore, besides analyzing the thin sections, acetic acid of % 20 concentrations was used for 5-6 hours, followed by the soda treatment for the preparation of washing samples from these lithologies.

After extracting fossils, the gathered planktonic foraminifera assemblage has been used for the taxonomical studies. Detailed taxonomy of the assemblage enables the construction of the biostratigraphic framework. Therefore, the most important aim of this study is the detailed examination of the Western Black Sea biostratigraphy in terms of regional planktonic foraminiferal biozones.

Besides the planktonic foraminifera, the benthic foraminiferal assemblage was also studied by washing samples in the Erfelek 1 MSS across the Paleocene-Eocene boundary. The taxonomies and stratigraphical ranges of the identified fauna were discussed.

Besides the washing samples, the thin sections have also been studied through suitable lithology along the measured sections. The preparation of the thin sections was carried out in the TPAO Research Center. The thin sections have been used for the microfacies analysis.

The planktonic foraminiferal analyses were correlated by nannoplankton and palynology analyses where it was needed. Nannoplankton studies were carried out by Zeynep Alay and palynology analyses by R. Hayrettin Sancay in the TPAO Research Center.

The SEM microphotographs were taken in the TPAO Research Center for the detailed identification of the taxa. The microphotographs were presented as plates in Appendix B.

XRD studies are widely used for the identification of the Paleocene-Eocene boundary. Therefore, samples have been prepared for both bulk rock and clay mineralogy in the XRD laboratories of TPAO Research Center. Crushed and powdered samples are analyzed by Rigaku D/Max-2200 Ultima^{+}/PC (Cu-tube, 40 Kv, 20mA, 1.54059 Angström). For the clay minerals, X-ray diffraction analyses were conducted on air-dried clay slides after saturation with ethylene glycol and after heating at 550°C. The obtained diffractograms have been evaluated by M. Koray Ekinci and Yinal N. Huvaj depending on the Inorganic Crystal Structure Database (ICSD) of International Centre for Diffraction Data (ICCD) with profile-based matching and considering the reference intensity ratios in the Easy Quant software. The diffractograms were presented in Appendix C.

1.4. PREVIOUS WORK

1.4.1. Previous Work on Pontides and Black Sea Region

Being one of the recent targets in the petroleum exploration in Turkey, Pontides is an attractive region for the geologists. For a better understanding of the petroleum system of the region, the opening history and the geological evolution of the Black Sea basin gains importance. The geological work, starting with the studies of Fratschner (1952) and Tokay (1952, 1954/1955), include the establishment of the stratigraphic framework of the region with the maps of wide areas by Ketin and Gümüş (1963), Akyol *et al.* (1974), Saner *et al.* (1979), Siyako *et al.* (1980), Bürkan *et al.* (1981), Kaya and Dizer (1982), Kaya *et al.* (1982/1983, 1986a), Şahintürk and Özçelik (1983), Yergök *et al.* (1987), Aydın *et al.* (1987), Akman (1992) and Tüysüz *et al.* (1997). One of the recent important studies in Western

Pontides is the anthology prepared by Tüysüz *et al.* (2004) that describes all of the lithostratigraphic units of the area.

The petroleum potential of the region was studied by Taşman (1933), Bagdley (1959), Pelin (1977), Siyako *et al.* (1980), Gedik *et al.* (1981), Saner (1981), Şahintürk and Özçelik (1983), Gedik and Korkmaz (1984), Robinson *et al.* (1996), Görür and Tüysüz (1997) and Robinson (1997). Yazman and Çokuğraş (1983) studied the geology and hydrocarbon potential of Adapazarı, Kandıra, Düzce and Akçakoca regions. They associated different formations from Precambrian (Yedigöller Formation) to Pliocene (Örencik Formation), also including the Kusuri Formation with the Akçakoca and the Sürmeli members. They noted that an island arc volcanism was effective in the region due to the subduction of the Sakarya Plate beneath the Pontide Plate during Paleocene. The volcanism was thought to be shifted towards the south during Early Eocene. The Eocene deposits were covered by the Pliocene units only in a limited area. Menlikli *et al.* (2009) summarized the exploration history of the Turkish Black Sea with the comments on the stratigraphy and petroleum systems in the region.

The opening history and evolution of the Black Sea basin is another important issue for the researchers. Şengör and Yılmaz (1981), Görür (1988), Okay (1989), Derman (1990), Görür *et al.* (1993), Tüysüz (1993), Okay *et al.* (1994), Okay and Şahintürk (1997), Ustaömer and Robertson (1997), Yılmaz *et al.* (1997), Yiğitbaş *et al.* (1999) and Sunal and Tüysüz (2002) mentioned the timing of opening of the basin and its geological/tectonic evolution. Brinkmann (1974) is one of the earliest studies on Black Sea that described Paleozoic to Cenozoic evolution of the basin and its relation with Anatolia. Yiğitbaş et al. (1999) separated the Western Pontides into three different tectonic zones (the Pontide Zone, the Armutlu-Ovacık Zone and the Sakarya Zone), which corresponds to the Rhodope-Pontide fragment, the Intra-Pontide Suture and the Sakarya continent of Şengör and Yılmaz (1981). On the other hand, Tüysüz (1999) and Sunal and Tüysüz (2002) limit the Western Pontide to the İstanbul Zone, which is bounded by Araç-Daday-İnebolu Shear Zone in the east, Intra-Pontide Suture in the south and Western Black Sea Fault in the west (Figure 2). The İstanbul Zone corresponds to the Pontide Zone of Yiğitbaş et al. (1999). Okay *et al*. (2006) studied the geologic evolution of the Central Pontides during Triassic and Cretaceous with the comments on the metamorphism and tectonism. Okay *et al*. (2013) indicated that the zircon studies show the Barremian-Aptian age for initiation of the rifting and Turonian-Santonian age for the splitting of the arc. Şen (2013) discussed the evolution of the Central Black Sea basin. Presenting geochemical and seismic data with the lithological logs of 18 wells drilled in the basin, the author argued the petroleum potential of İnaltı and Çağlayan formations, which haven't been explored yet.

Late Paleocene-Middle Eocene period in Western Black Sea region is studied by Tunoğlu (1994), in which the carbonate sequence was analyzed in terms of microfacies characteristics near Devrekani Basin, north of Kastamonu. Here, the studied Gürleyikdere Formation was correlated with Atbaşı Formation of Gedik and Korkmaz (1984).

Being one of the study areas, Akçakoca Region was studied in detail by means of the stratigraphy of the Upper Cretaceous-Paleogene deposits and the depositional facies and reservoir characteristics of the Kusuri Formation - Akçakoca Member's sandstones (Alaygut *et al.*, 1999). In this study, the authors measured and evaluated 15 different stratigraphic sections near Akçakoca and Eregli including the Ayazlı and the Karaburun measured stratigraphic sections, which are also evaluated in the present PhD thesis in detail. Therefore, this study is one of the reference studies for this thesis and it is important for the decision on the determination of the stratigraphic sections that are being studying around Akçakoca.

Yeşilyurt *et al.* (2005) suggested a new lithological unit; Late Lutetian-Bartonian aged Seydiler Formation, around Kastamonu Region. The biostratigraphy and the paleoenvironmental evaluation of this formation were studied by Yıldız *et al.* (2007) and Yeşilyurt *et al.* (2009) using planktonic foraminifera, calcareous nannoplanktons and ostracoda assemblages.

Nikishin *et al*. (2011) discussed the evolution of the Black Sea and Southeastern Europe Region between Late Paleozoic and Cenozoic. They suggested that the rifting began during the Albian in the region and commented to the debate on the differential opening of Eastern and Western Black Sea basins. The evolution of the adjacent Peritethyan areas was also correlated in this study.

Besides the geological studies, there is also the paleontological work in the Western Pontides. Mesozoic sections are mostly of great importance in these studies. Georgescu (1997) studied the Upper Jurassic-Cretaceous planktonic biofacies successions of the Western Black Sea basin. Kaya (2014) studied the benthic foraminifera and microencrustals of Upper Jurassic-Lower Cretaceous Inaltı Formation around Bürnük with detailed microfacies studies and correlation of Jurasssic-Cretaceous boundary around Northern Tethys. Kaya and Altıner (2014) also studied the İnaltı Formation and discussed the taxonomy and paleoenvironmental importance of an annelid species, *Terebella lapilloides*.

Sirel (1973) worked on the description of the new species *Cuvillierina* from the Maastrichtian of Cide (NE Zonguldak, northern Turkey). Dizer and Meriç (1982) established the planktonic foraminiferal biostratigraphy for the Late Cretaceous and the Paleocene in Northwestern Anatolia. Varol (1983) discussed the Late Cretaceous - Paleocene calcareous nannofossils from the Kokaksu Section. In 1991, a new foraminiferal genus of Maastrichtian age was distinguished again in Cide and named as *Cideina* by Sirel (1991). Another study by Sirel (1996) discussed the description, and geographic and stratigraphic distribution of Maastrichtian to Paleocene form; *Laffitteina marie,* all around Turkey including the Northern Turkey.

The study of Özkan-Altıner and Özcan (1999) also included the paleontological work that constructs the Upper Cretaceous biostratigraphy for the Northwestern Anatolia by using planktonic foraminifera. Kirci and Özkar (1999) examined the planktonic foraminiferal bio stratigraphy of the Akveren Formation in Cide (Kastamonu). Güray (2006) studied the Campanian-Maastrichtian planktonic foraminiferal investigation, biostratigraphy and paleoceanographical changes of the Akveren Formation in the Kokaksu Section, Bartın. Besides the standart globotruncanid biozonation, a new biozonation using the heterohelicids was established in Turkey for the first time in this study. Moreover, planktonic foraminiferal responses are discussed in terms of ecological changes and morphologic clusters are established for statistical analysis. Kaya-Özer and Toker (2009) is the most recent work on the planktonic foraminiferal biostratigraphy of the Campanian-Maastrichtian successions (Akveren Formation) in Bartın area.

The microfacies analyses of the Paleocene-Eocene carbonates around the Devrekani Basin was studied by Tunoğlu (1994) and Özgen-Erdem *et al.* (2005). The Eocene section of Sinop Basin was examined in terms of the ostracoda content (Tunoğlu, 2001a). Tunoğlu and Bardet (2006) presented the discovery of *Mosasaurus hoffmanni*; the first marine reptile for the late Maastrichtian section of Davutlar Formation around Devrekani, Kastamonu; towards the southwest of the Ayancık, Sinop that is included to the present study. In this study the Campanian-Maastrichtian section of Davutlar Formation was evaluated in terms of different fossil groups such as planktonic and benthic foraminifera, ostracods, dinoflagellates, nannoplanktons, ammonites, echinoderms, corals, pelecypods and inoceraminids..

Among the Neogene of Black Sea; there is a limited data due to the scarcity of the onshore outcrops. Batı *et al.* (1996) and Kuru *et al.* (1997) studied the biostratigraphy of the offshore wells in Western Black Sea. In terms of the field data, mostly the Pontian units were studied around the Central and Eastern Black Sea regions (Tunoğlu; 2002a, 2002b, 2003). Tunoğlu and Gökçen (1991) examined the Meotian and Pontian (Upper Miocene) successions of Incipinari-Kurtkuyusu (west of Sinop Peninsula) and established the ostracoda biozonation; whereas they studied 32 ostracoda species from the same area and correlated the successions with the Pontian of the Paratethys Province (Tunoğlu and Gökçen, 1997). Tunoğlu (2001b) described twelve different *Tyrrhenocythere* species, which are endemic for the Middle-Late Pontian of the Paratethys Bioprovenance, near Araklı, Trabzon. The author also defined 86 Middle-Late Pontian ostracoda species around Trabzon and Samsun with an additional emphasize on the *Loxoconcha* species (Tunoğlu, 2001c).

1.4.2. Previous Work on the Planktonic Foraminifera

In terms of the evolution of the Paleogene planktonic foraminifera, Pearson (1993) clustered 20 subgroups and established a phylogeny regarding to their lineages with respect to the evolutionary histories. The author evaluated the wall structures of the forms besides the morphological features for the taxonomy.

Morozovella is the first keeled genus for the Paleogene period. Being one of the earliest species, *M.angulata* is thought to be evolved from *Praemurica uncinata* in the Early Paleocene (Danian) - Late Paleocene (Selandian) boundary (Kelly *et al.*, 1996; 1999). On the other hand, *Morozovella velascoensis* is one of the most important species for the Paleocene- Eocene boundary. Kelly *et al.* (2001) proposed a *Morozovella velascoensis* lineage including *M. acuta, M.occlusa* and *M.edgari* and separated it from *Morozovella subbotinae* lineage, which consists of *M.apanthesma, M.aequa, M.gracilis* and *M.formosa.* For the *M.velascoensis* lineage, declining in the shell size, which states the better resistance of small species to extinction with respect to larger forms, Kelly *et al.* (2001) examined a gradual extinction caused by the stressful ecological conditions and onset of cooling in early Eocene. Further extinction of *Morozovella* was in the late middle Eocene, around which the acarininids, another muricate and shallow-dwelling group, also got extinct in a stepwise form (Wade, 2004). The author suggested that the extinction of these genera was due to the destruction of their habitats and elimination of their niche, not primarily because of the surface water cooling.

Sexton *et al.* (2006) present that the planktonic foraminifera diversity has thought to be declined with the extinction of most of the muricate forms during the late middle Eocene; on the other hand there was an increase in the diversity of the globular planktonic foraminifera. They studied the assemblage composition, the depth habitats of the genera during late middle Eocene and suggested that there is not any relationship between wall textures and depth habitats.

Coccioni and Bancalà (2012) studied the evolution of hantkeninids form genus *Clavigerinella.* The authors designated 9 stages in the evolution of this genus. Being a deep water indicator, the evolution of genus *Hantkenina* with the chamber elongation specific for the genus, Middle Eocene was attributed to the presence of the stressful environments.

Rögl and Egger (2012) presented a revision for some of the species identified by Gohrbandt (1963, 1967). Authors studied 5 different outcrops in Salzburg, Austria and discussed the taxonomy and biostratigraphic positions of 9 planktonic foraminifera species.

Arenillas and Arz (2013) studied the evolution of non-spinose lineage of the Danian planktonic foraminifera. They discussed that the evolution of the genera is related with the evolution of the wall texture with the sample of evolution of *Globanomalina* from *Parvularugoglobigerina* with a change from smooth wall texture to cancellate wall texture. They presented the phylogenic linkage between *Eoglobigerina, Parvulorugoglobigerina, Globanomalina* and *Praemurica*, which are the important Early Paleocene genera.

Some of the early biostratigraphy studies on the Cenozoic planktonic foraminifera were Bolli (1957a), Berggren (1960), Blow (1979) and Bolli *et al.* (1985). These are the important studies mostly around the Atlantic, referred by numerous more recent papers.

Berggren *et al.* (2000) compared these important previous Paleocene planktonic foraminifera zonations and did some comments on the stratigraphic ranges of some taxa and the sedimentation rates during the Paleocene. The authors also correlated their zonation with calcareous plankton zonation, magnetostratigraphy and stable isotopes.

Warraich and Nishi (2003) studied the biostratigraphy of Eocene sediments of the Sulaiman Range, Pakistan and distinguished 8 biozones for upper Early Eocene-lower Eocene interval. They correlated their data with the international zonal schemes in tropical and subtropical regions.

One of the latest studied has been prepared by Berggren and Pearson (2005). They explained the major faunal events during the Paleogene. Zonation of Berggren *et al.* (1995) has been revised in this study and a total of 29 biozones were presented for the Paleogene, including 7 zones for Paleocene, 16 zones for Eocene and 6 zones for Oligocene.

Wade *et al.* (2011) mentioned the need in the recalibration of some biostratigraphical events in terms of the Cenozoic planktonic foraminiferal zonation and suggested a new magnetobiochronology.

The biostratigraphy studies including the planktonic foraminiferal zonations of the Paleogene sections around Crimean-Caucasus realm are Khalilov (1962; 1967), Krasheninnikov (1969; 1974; 1975; 1985), Shikhlinsky (1985; 1987; 1988; 1989a; 1991; 1994; 1996a; 2001; 2002) and Shikhlinsky *et al.* (2006). These studies are important in terms of including the endemic fauna and regional schemes for this provenance.

One of the recent regional biostratigraphic studies is by Zakrevskaya *et al*. (2011). Authors investigated the Eocene Gubs Section in northern Caucasus to define the local biozones, of which the stratigraphic ranges of the zonal species are mostly different from the standard zonations. They used different fossil groups, such as larger benthic foraminifera and calcareous nannoplanktons, besides the planktonic foraminifera. They also correlated their zonation with other Crimean-Caucasian regional schemes.

1.4.3. Previous Work on the Climatic Events during Paleocene-Eocene

There were different climatic events during the Paleogene. Paleocene-Eocene Thermal Maximum (PETM), Early Eocene Climatic Optimum (EECO) and Middle Eocene Climatic Optimum (MECO) are the important events. Early Eocene evolution of Egyptian shelf was discussed by Höntzsch *et al.* (2011) with the examination of these Paleogene events. Planktonic foraminifera, alveolinids and calcareous nannoplanktons were studied besides the carbon isotope, TOC and calcium carbonate analyses. Paleogene evolution of Circum-Tethyan Prebetic carbonate platform was studied by Höntzsch *et al.* (2013). The authors linked the climate change and the faunal turnover, i.e. replacement of larger benthic foraminifera with corals, on the carbonate platform. They separated 6 different regional and global tectonic events compared with eustatic sea level change, isotope studies, changes in sea surface temperature and climatic event, such as PETM, EECO, MECO and Oligocene glaciation. In this study, 11 different carbonate platforms in the Tethys, one of which is Northern and Central Turkey are compared in terms of the evolution of the fauna.

One of the main boundaries is Paleocene-Eocene boundary for the present study. Global standart stratotype-section (GSSP) has been defined in Egypt, Dababiya section for the base of the Eocene (Dupuis *et al.*, 2003; Aubry *et al.*, 2007). The authors studied the Dababiya Stratotype sections in terms of lithology, clay mineralogy, geochemistry, magnetostratigraphy and chemostratigraphy. Moreover, the boundary is emphasized with the turnovers in the fauna, i.e. planktonic foraminifera, benthic foraminifera and calcareous nannoplanktons. Foraminiferal turnovers and clay minerology were studied by Ernst *et al*. (2006) and benthic foraminiferal extinction event was highlighted by Alegret *et al.* (2005) and Alegret and Ortiz (2007) for this section.

The Paleocene-Eocene Thermal Maximum (PETM) is of great importance for many researchers studying the boundary. Some of the planktonic foraminiferal taxa, such as *Morozovella allisonensis, Morozovella africana* and *Acarinina sibayiaensis*, are said to be evolved related to this event and their stratigraphic ranges are limited (Kelly *et al*., 1998). Authors examined the relative abundance of planktonic foraminifera assemblage that was dominated by acarininids and morozovellids, and presented the increase in acarininids and decrease in morozovellids during the PETM.

For the Tethyan Realm, including Kazakhstan, Spain, Israel and DSDP sections, Paleocene- Eocene boundary has been examined by Lu *et al.* (1998) and Pardo *et al.* (1999). The authors studied the taxonomy of the planktonic foraminifera and established a biozonation covering Zone P4 to Zone P6 around the boundary. They indicated the regional differences for different locations in terms of faunal changes, changes in relative abundances and isotopic excursions. Mainly, the changes among the subbotinids, morozovellids, acarininids and chiloguembelinids gained importance for this study for emphasizing the paleoecologic and paleoceanographic variations during the Paleocene-Eocene transition.

Molina *et al.* (1999) studied many sections also around the Tethys for the identification of the boundary and establishment of the biostratigraphy around latest Paleocene to earliest Eocene period by comparing their work with the previous biozonations. This study positioned the Paleocene-Eocene boundary within the *Morozovella velascoensis* Zone and *Acarinina berggreni* Subzone, which is indicated by the rapid diversification of acarininids. Although they examined the high resolution planktonic foraminiferal biostratigraphy through the sections, they also placed the BFEE within the *Acarinina berggreni* Subzone.

Kelly *et al*. (2012) studied the boundary event in the Weddell Sea ODP Sites. They examined the carbonate sedimentation and carbon isotope data with the comparisons of calcium carbonate, coarse fraction, planktonic foraminifera and benthic foraminifera percentage. The authors also investigated the turnovers in the planktonic foraminifera by comparing the percentages of some selected taxa, such as morozollids, robust acarininids, subbotinids, *Globanomalina australiformis* and *Acarinina subsphaerica*.

"Benthic Foraminiferal Extinction Event (BFEE)" was assigned as a global event on the Paleocene-Eocene boundary (Speijer *et al*., 1996; Speijer and Schimitz, 1998; Ernst *et* al., 2006; Takeda and Kaiho, 2007; Alegret *et al*., 2009; Giusberti *et al*., 2009; Sprong *et al*., 2012; Stassen *et al*., 2012).

Kaminski and Huang (1991) studied the biostratigraphy of the Eocene deep-water agglutinated foramifers (DWAF) from Celebes Sea and suggested these forms to be cosmopolitan.

Orue-Etxebarria *et al*. (2001) studied the relation of Paleocene thermal maximum with the benthic extinction event along the Campo Section (Spain). They also investigated the Paleocene-Eocene boundary based on the changes of the planktonic foraminifera besides the larger benthic foraminifera and calcareous nannoplanktons. Campo Section was also studied by Molina *et al*. (2003) as they investigated the planktonic foraminifera, calcareous nannofossils and dinoflagellate cysts content of the section to correlate the boundary with the Ilerdian Stage.

Webb (2007) worked on the taxonomy of the Paleocene deep-sea agglutinated foraminifera in South Tasman Basin. The author described 36 species and presented microphotographs of these forms.

D'haenens *et al*. (2012) marked the smaller hyperthermal events around PETM and examined the changes in benthic foraminifera, $\delta^{13}C$ and $\delta^{18}O$ isotopes and $CaCO_3$ percent.

They carried out cluster analyses on benthic foraminifera and investigated the variations in some distinct groups.

Besides the turnovers of planktonic and benthic foraminifera, there are many other fossil groups studied on PETM interval. Hofmann *et al.* (2011) examined the terrestrial palynomophs in Australia and compared their data with other PETM sections in Europe. Therefore, they suggested the environmental changes during PETM in the northwest Tethyan realm. Kalb and Bralower (2012) and Self-Trail *et al.* (2012) studied the changes in the environmental conditions and originations of the nannoplanktons during the PETM. Zamagni *et al.* (2012) examined the coral communities and their evolution during mid-Paleocene to early Eocene interval and suggested the environmental changes during the PETM.

In addition to the faunal changes, Paleocene-Eocene Thermal Maximum event was also studied by the clay mineralogy and stable isotopes. Cramer and Kent (2005) investigated the causes of this boundary event. John *et al.* (2012) studied the east coast of North America. Wadi Nukhul section is another section in Egypt, on which the event is investigated in terms of paleoenvironmental and climatic changes (Khozyem *et al*., 2013).

Ypresian-Lutetian boundary was investigated by an integrated study on the quantitative analyses of planktonic and benthic foraminifera besides the examination of trace fossils and mineralogical changes in the 115 meter-thick Agost section, southeastern Spain (Ortiz *et al*., 2008). The section covers the interval spanning P9-P12 planktonic foraminifera biozonations, which is the uppermost part of Ypresian through Lutetian. The authors suggested the section to be the Global Stratotype Section and Point for the Ypresian-Lutetian boundary.

Payros *et al*. (2006) studied the Early Eocene Climatic Optimum (EECO) and interpreted the warm and cool intervals with respect to the dominancy of the planktonic foraminifera representing low or high latitudes.

Creech *et al*. (2010) analysed the Mg/Ca ratios of foraminifera to record the effects of EECO. Besides some benthic foraminifera, they used 5 planktonic foraminifera species (*Morozovella crater, M. lensiformis, Acarinina primitiva, A. collactea* and *Pseudohastigerina wilcoxensis*) as the indicator of different water conditions, ie. morozovellids for warm waters, acarininids as mixed layer dwellers and genus *Pseudohastigerina* as shallow water indicators. Therefore, they identified the EECO interval and the beginning of the transition from greenhouse to icehouse conditions at New Zeland.

Luciani *et al*. (2010) discussed the effects of middle Eocene climatic optimum (MECO) on the planktonic foraminiferal evolution. They did a quantitative study on the planktonic foraminifera, recorded the numerical changes in the several genera through Middle and Late Eocene (P12 to P15) and correlated with the changes in oxygen and carbon isotopes. Edgar *et al*. (2010) said that MECO was identified mostly across mid- and high-latitudes whereas low latitudes have not been well-studied for this event. They quantitatively studied the changes in the presence and abundance of *Orbulinoides beckmanni*, one of the important biozone marker forms for Middle Eocene. They recognized the environmental changes and suggested that MECO was a global event.

1.5. REGIONAL GEOLOGY

Being the northernmost tectonic element of Asia Minor (Ketin, 1966), the Pontides is one of the compressive belts that enclose the Black Sea (Tüysüz, 1999). Previously, Tüysüz (1993) examined Eastern, Central and Western Pontides with their different geological characteristics, whereas Strandja Zone, İstanbul Zone and Sakarya Zone are separated by Okay (1989) and Okay *et al.* (1994).

In this study, classifications of Tüysüz (1999) and Sunal and Tüysüz (2002) are taken into consideration.The authors limit the Western Pontide to the İstanbul Zone, which is bounded by Araç-Daday-İnebolu Shear Zone in the east, Intra-Pontide Suture in the south and Western Black Sea Fault in the west (Figure 3).

In the Western Pontides, basement units start with a Paleozoic sedimentary sequence of Ordovician to Carboniferous aged Atlantic-type continental margin facies (Tüysüz, 1999). This sequence ends with the Zonguldak Formation that consists of river, swamp and delta clastic sediments with coal deposits in Namurian to Westphalian age (Sunal and Tüysüz, 2002). The Permo-Triassic aged terrestrial units of Çakraz Formation are overlain by Çakraboz Formation (Figure 4). This formation is Late Triassic in age and contains lacustrine limestones, marls and mudstones with varve structures. These formations are the equivalent of the Triassic-Jurassic aged Bekirli Formation, Ophiolite unit and Akgöl Formation that are separated by tectonic contacts towards the eastern part of the Western Pontides (Figure 5). On the other hand, Tüysüz (1999) suggests no evidence for a pre-Cretaceous compressional deformation of regional metamorphism in the east of Akçakoca-Bolu Line in contrast to the basement units of Central Pontides.

Middle Jurassic-aged Himmetpaşa formation is composed of the coal bearing terrestrial sediments, shallow to deep marine turbiditic clastics and shallow marine clastics (Figure 4). Platform-type neritic carbonates in the Late Jurassic-Early Cretaceous, which were the product of the Mesozoic transgression that covered the whole Pontides, were named as the İnaltı Formation (Ketin and Gümüş, 1963; Sunal and Tüysüz, 2002) (Figure 4). In the Sinop Region, İnaltı Formation overlies Bürnük Formation that is composed of the alternations of conglomerates, sandstones and mudstones, which are the products of an alluvial fan (Uğuz and Sevin, 2008) (Figure 5).

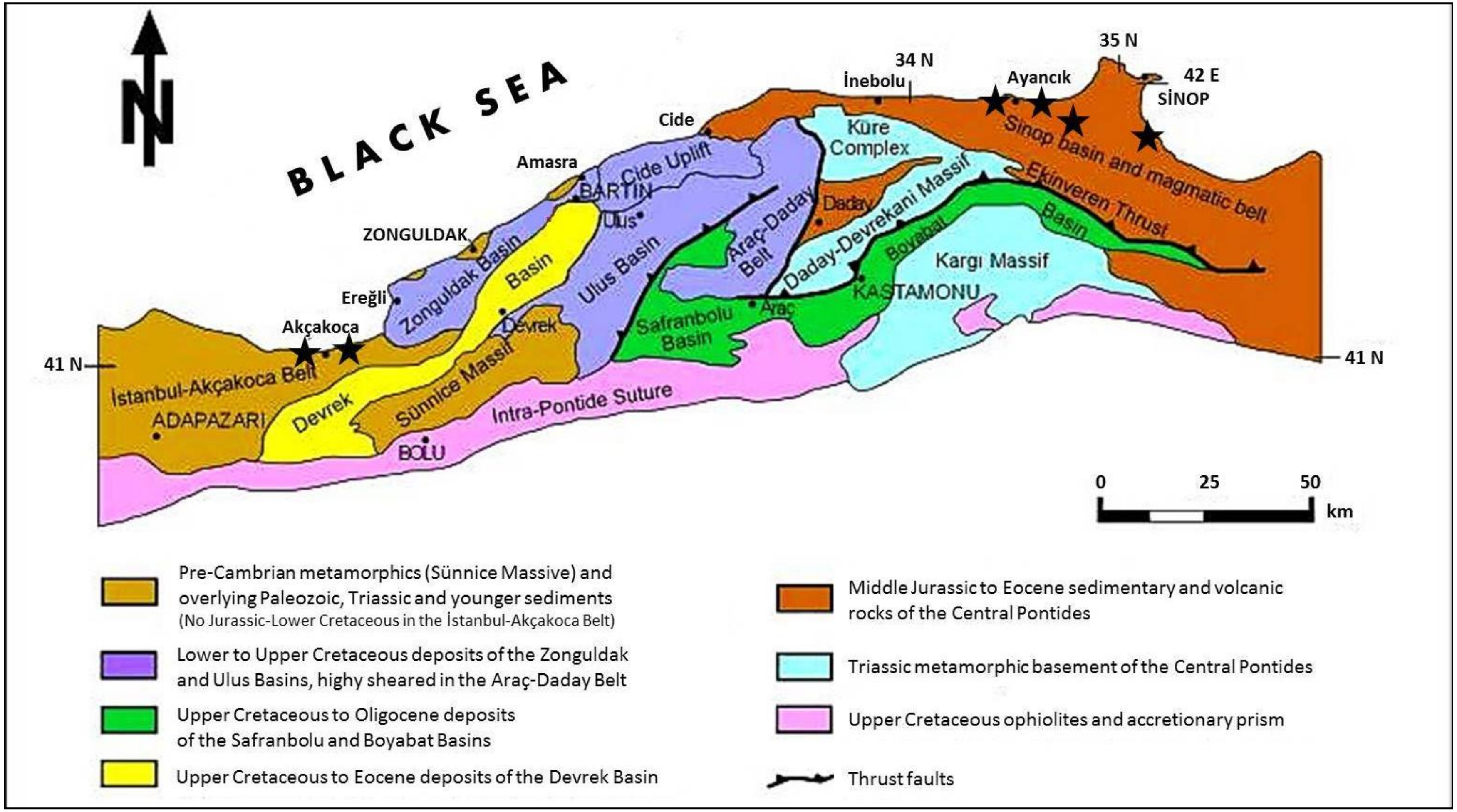

Figure 3. Tectonostratigraphic map of the Western Pontides (Modified from Sunal and Tüysüz, 2002). Black stars indicate the locations of the measured sections.

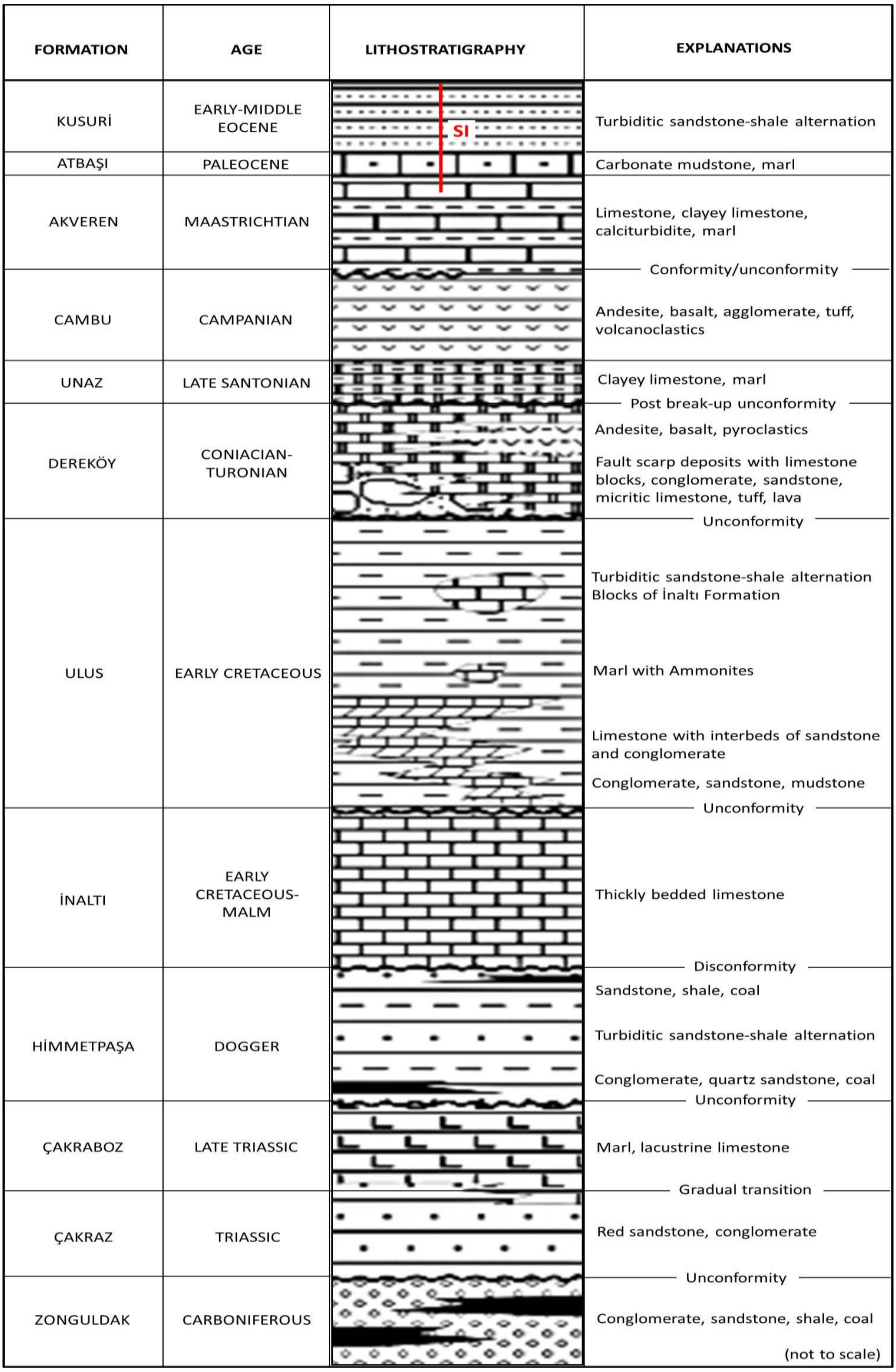

Figure 4. Generalized columnar section of the Akçakoca, Düzce Region (Modified from Sunal & Tüysüz, 2002; Tüysüz *et al*., 2004; Tüysüz *et al*., 2012). The studied interval (SI) is shown by the red line.

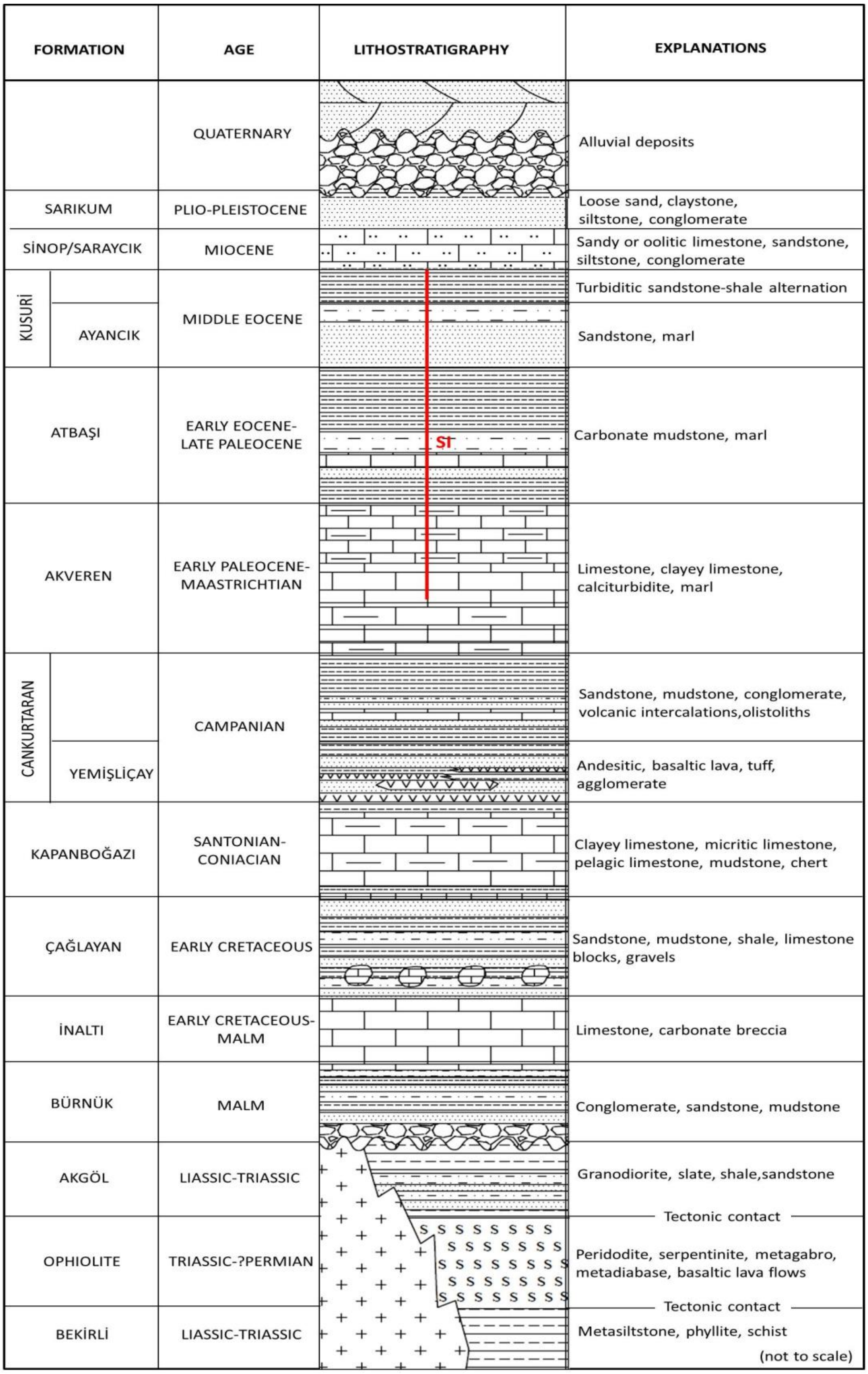

Figure 5. Generalized columnar section of the Sinop Region (Modified from Gedik and Korkmaz, 1984; Tunoğlu and Gökçen, 1991; Uğuz and Sevin, 2008). The studied interval (SI) is shown by the red line.

Lower Cretaceous Ulus Formation unconformably overlies the İnaltı Formation (Figure 4). It consists of clastics at the base, limestones, Ammonite-bearing marls and turbiditic sandstone-shale alternations. On the other hand, the Lower Cretaceous deposits around Sinop Region are represented by the sandstone, mudstone, shale, limestone blocks and gravels of the Çağlayan Formation (Figure 5).

The Dereköy Formation consists of the first magmatic rocks of the Western Pontides that are basaltic and andesitic lava and their pyroclasts alternating with shallow to deep marine carbonates and clastics of Middle Turonian age. The Dereköy Formation represents the "syn-rift units" of Sunal and Tüysüz (2002), whereas the "post-rift units" starts with the Unaz Formation. This formation contains Upper Santonian - Campanian pelagic limestones. Because of the horst – graben topography that developed during the deposition of the Dereköy Formation, the contacts of the Unaz Formation show different characteristics in different regions. The equivalent of Dereköy and Unaz Formations is Kapanboğazı Formation in the Sinop Region that is composed of clayey, micritic or pelagic limestones, mudstones and cherts (Figure 5).

Sunal and Tüysüz (2002) and Yiğitbaş et al. (1999) suggest the domination of the Andean-type island arc magmatism along the southern Black Sea coast in response to the northward subduction of Neotethys under the Pontide Zone. This magmatism is indicated by the thick volcano-sedimentary successions of the Campanian-aged Cambu Formation around the Akçakoca Region and by the Cankurtaran Formation that comprises the Yemişliçay volcanics and volcano-sedimentary units overlying them in the Sinop Region (Figures 4, 5).

Uplift of the southern parts during Late Campanian and Early Maastrichtian and the ongoing volcanic activity show the termination of the Neotethys Ocean. This compressional regime has a peak during the Maastrihtian-Paleocene in Pontides (Nikishin *et al*., 2011). With the continuous sedimentation in the northern Black Sea during the post-arc period, the Akveren and the Atbaşı Formations were deposited as pelagic limestones, marls and calciturbidites (Figures 4, 5). The youngest unit in the Akçakoca Region is recognized as the siliciclastic, upward-coarsening turbidite sequence of Eocene, which was named as the Kusuri Formation (Figure 4). The Quaternary alluvial deposits overlie the Kusuri Formation in Sinop Region (Figure 5).

By the Late Eocene, the compressional regime in the Western Tethys Ocean affected the Pontides-Black Sea-Caucasus-South Caspian realms and caused the disconnection of the Mediterranean and the opening of the intracontinental Paratethys basins (Rögl, 1999, Nikishin *et al*., 2011). Unlike the Mediterranean Realm, the Paratethys Ocean showed various changes from open marine to brackish water conditions depending on the connections of the seaways (Figure 6). Those alternating conditions continued until the collision of Africa and Arabia with Eurasia at the end of Early Miocene. In this manner, Latest Eocene to Early Miocene was the time for the imbrication of all Western Pontides and southern passive margin sediments of the Western Black Sea basin by mainly north-vergent thrusts (Tüysüz, 1999; Sunal and Tüysüz, 2002).

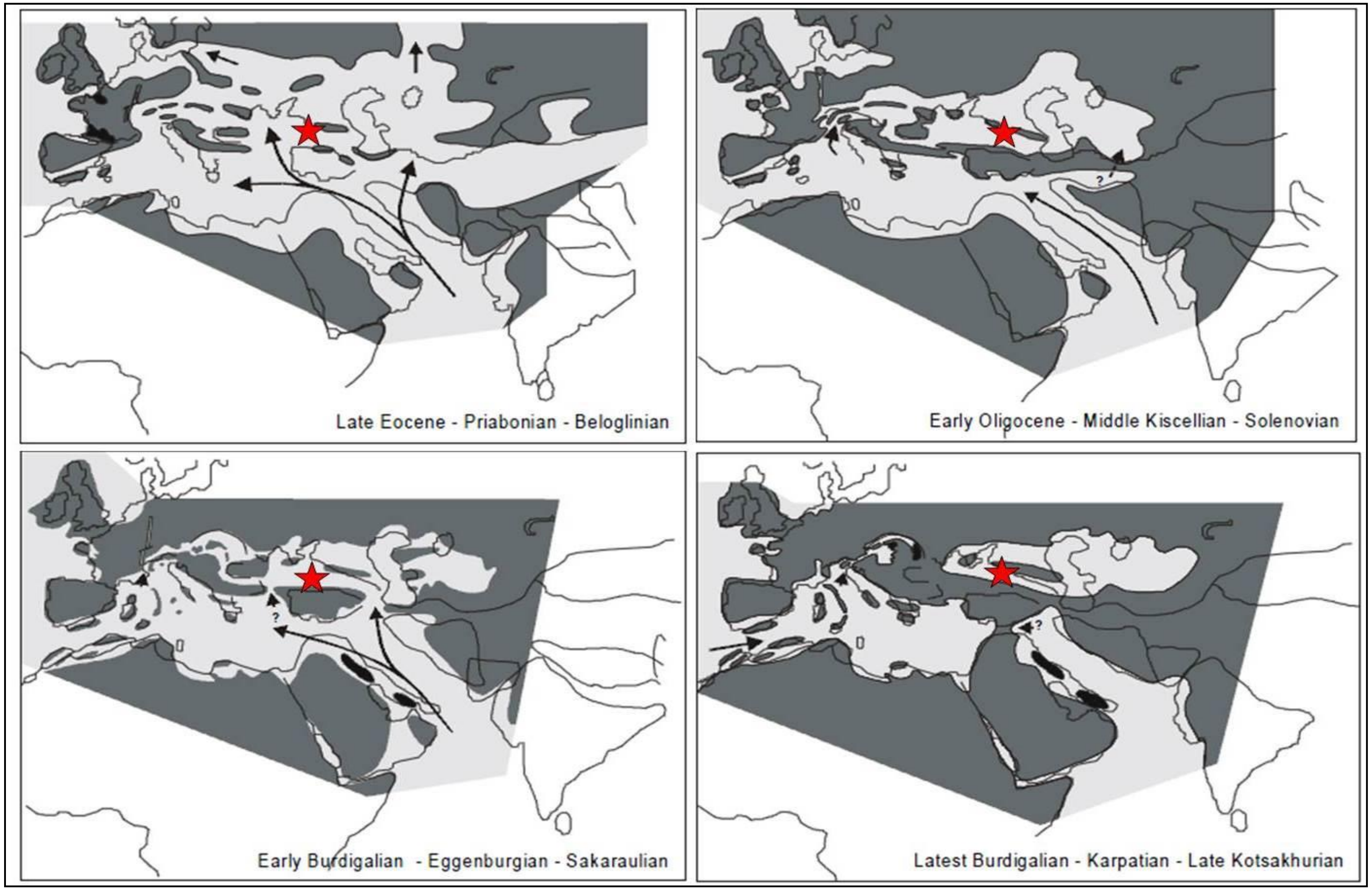

Figure 6. Late Eocene-Early Miocene paleogeography of the Neotethys and Paratethys Oceans (Rögl, 1999). Red rectangles mention the possible position of the study area.

CHAPTER 2

LITHOSTRATIGRAPHY

The Black Sea basin is a back arc basin behind the Pontide magmatic arc that formed as a result of the closure of the Neotethys Ocean (İztan, 2001). Neotethys closed along E-W striking suture zone. In spite of being an extentional basin, the Black Sea is surrounded by many compressional belts such as Pontides, Caucasus, Crimean, Ukraine and Balkanides. Eastern and Western Black Sea sub-basins are separated through the Mid-Black Sea High.

Sunal and Tüysüz (2002) and Yigitbaş *et al.* (1999) suggest the domination of the Andean-type island arc magmatism along the southern Black Sea coast in response to the northward subduction of Neotethys under the Pontide Zone. This magmatism is indicated by the thick deep marine volcano-sedimentary successions of the Late Cretaceous Yemişliçay Formation. Uplift of the southern parts during Late Campanian and Early Maastrichtian and the ongoing volcanic activity show the termination of the Neotethys by the collision of the Pontides with the Sakarya Continent. Conformably overlies the Yemişliçay Formation, Gürsökü Formation is composed of marl, sandstone, sandy limestone and calciturbidite alternations with some tuff levels in the upper parts. This Campanian-Maastrichtian succession is located along the Black Sea shore especially around the Central Pontides (Tüysüz *et al.* 2004).

The Upper Cretaceous-Eocene successions are widely exposed around the Western Black Sea region. The sequence starts with the Akveren Formation (Figure 7); a transgressive unit overlies the Yemişliçay volcanics and volcanoclastics or unconformably the Paleozoic sequences depending on the paleotopography. It is overlain by the Atbaşı and the Kusuri formations.

The Cenozoic units of the study area will be explained below more detailed in the next part, as they are the main interest of the proposed thesis (Figure 7).

2.1. CENOZOIC UNITS IN THE BLACK SEA REGION

2.1.1. Akveren Formation

The first usage of this formation was by Gayle (1959) as the “Akveren beds” for the clayey limestones exposed to the south of Ayancık. Later, Ketin and Gümüş (1963) was defined the alternation of calciturbiditic limestones, sandy micritic limestones and marls that overlies the Late Santonian – Early Maastrichtian aged Gürsökü Formation as the “Akveren Formation”. The Akveren Formation is named under the Amasra Group in the Northern Belt of the Western Pontides (Tüysüz *et al.*, 2004).

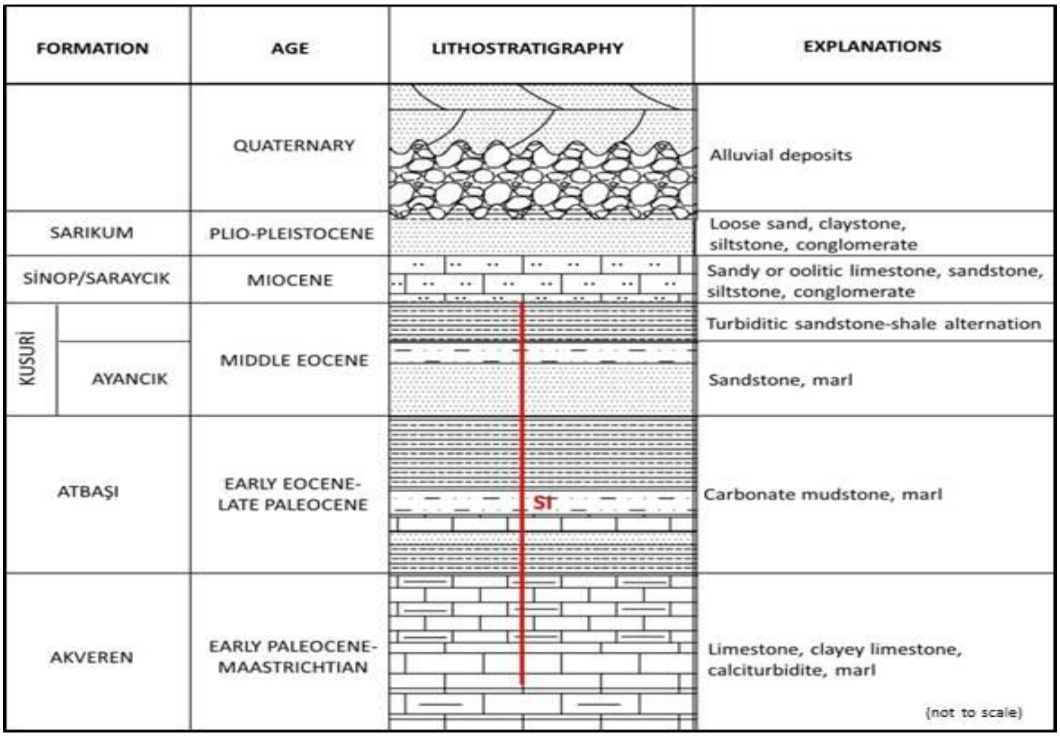

Figure 7. Generalized columnar section of the study area (Cenozoic section) (Modified from Gedik and Korkmaz, 1984; Tunoğlu and Gökçen, 1991; Uğuz and Sevin, 2008). The studied interval (SI) is shown by the red line.

Ketin and Gümüş (1963) didn’t identify the type locality and type section for the formation. Gedik and Korkmaz (1984) measured a reference section in Aksöke between the coordinates 62.735-66.155 and 62.884-66.287 in the 1:25 000 scale topographic map of E33-b3 quadrant. Akman (1992) suggested the type locality between Doğaşı and Kayadibiçavuş villages (between Kurucaşile and Bartın).

The formation overlies the Cambu Formation between Cide and Kurucaşile, whereas the Gürsökü Formation and the Kale Formation were recorded beneath this formation in other areas. The Akveren Formation gradually passes to Atbaşı Formation, Paleocene in age, which is also represented by pelagic mudstones and marls or the Kusuri Formation, Eocene in age, which consists of siliciclastic turbidites (Tüysüz, 1999; Sunal & Tüysüz, 2002; Tüysüz *et al.*, 2004) (Figure 2).

The Akveren Formation is the first products of the transgression in the Black Sea basin (Figure 7). It was deposited as a result of the extentional regime that is formed by the southward migration of the volcanic arc. The deposition is represented by clayey limestones, marls, carbonate muds and calciturbidites. Tüysüz (1993) defends that the turbiditic property, sedimentary structures and fossil content of the Akveren Formation indicates its deposition in a deep marine environment. On the other hand, the basal clastics of the Akveren Formation are investigated by three different members. Those are bioclastic limestones of Alaplı Member, arcosic-to-subarcosic sandstones of Erikli Member and lithic arenitic sandstones of Sarıkorkmaz Member.

The thickness of the formation was measured as 390 m. near Cide-Kurucaşile (Akyol *et al.*, 1974). After that, Aydın *et al.* (1987) measured a succession of approximately 1000m. in the Kastamonu region. Akman (1992) indicated the thickness as 593 m. in the Doğaşı-Kayadibiçavuş section. In the north of Saltukova Town (Bartın), this formation was measured with a thickness of 312 m (Özkan-Altıner & Özcan, 1997).

The age of the Akveren Formation is discussed by many authors. It is defined as Maastrichtian by Ketin and Gümüş (1963), as Maastrichtian-Paleocene by Gedik and Korkmaz (1984), as Maastrichtian-Early Paleocene by Aydın *et al.* (1987), as Campanian-Paleocene by Akman (1992) and as Maastrichtian by Tüysüz *et al.* (1997).

The Akveren Formation was widely distributed in the Black Sea region, especially near the shore lines.

The Akveren Formation was named as a member of the Hisarköy Formation by Akyol *et al.* (1974).This formation is also the deep marine equivalent of the Alaplı Formation of the Southern Belt in the Western Pontides.

2.1.2. Atbaşı Formation

The Atbaşı Formation was defined by Ketin and Gümüş (1963).

Ketin and Gümüş (1963) measured a section between Akveren and Atbaşı villages, however neither the base nor the top of the section could be recorded. The section measured by Gedik and Korkmaz (1984) at E34-a4 quadrant, between 62.894-66.756 and 63.226-66.989 coordinates near Gerze-Tangal was suggested as the type section for the formation.

The Atbaşı Formation shows a gradually transition with the Akveren Formation and it is conformably overlain by the siliciclastic turbidites of the Kusuri Formation (Tüysüz *et al.*, 2004) (Figure 7).

The reddish to sporadic greenish gray colored, fine-medium bedded, tuff containing mudstone, marl and clayey limestone alternations that were deposited during Paleocene-Early Eocene as a result of the maximum transgression of the Akveren transgressive phase were named as the Atbaşı Formation.

The thickness of the Atbaşı Formation was measured 537 m. in its type locality (Gedik and Korkmaz, 1984). Named as Akgüney Formation, Akyol *et al*. (1974) mentioned 260 m. thickness for the measured section.

Ketin and Gümüş (1963) mentioned Paleocene-Early Eocene age, Akyol *et al.* (1974) and Tüysüz *et al*. (1997) defined Paleocene age and Gedik and Korkmaz (1984) defined Early Eocene age for the Atbaşı Formation.

The Atbaşı Formation is an index level that cropped out near Cide. The formation was also defined as Akgüney Formation (Akyol *et al.*, 1974).

2.1.3. Kusuri Formation

The Kusuri Formation was defined by Ketin and Gümüş (1963) in the south of Ayancık, along the Ayancık River.

Ketin and Gümüş (1963) were not defined a type section and type locality for the formation. The lower and upper boundaries of the formation could not be recognized along a single section, because of the thickness and deformations. Gedik and Korkmaz (1984) suggested a type section near Karapınar, between 63.328-66.328 and 63.613-66.220 in the E33-b3 quadrant.

The lower boundary of the Kusuri Formation has a gradual transition with the Atbaşı Formation. The upper boundary mostly isn't recorded. It is overlain disconformably by Neogene units in Sinop; whereas Late Eocene-Oligocene aged Cemalettin Formation covers the Kusuri Formation near Boyabat.

During the evolution of Black Sea basin, an N-S compressional phase was initiated in the majority of Northern Turkey during Early to Middle Eocene (Yılmaz *et al.*, 1997). This period follows the maximum transgressive time and resulted with the deposition of thin-bedded claystones, silty marls and mudstones of calcarenite canals at the base which were the first products of the highstand systems tract that passes into the sandstones towards the upper parts of the Kusuri Formation (Figure 7). Lower parts close to Atbaşı Formation contains gray-green to redish, thin bedded, loose claystone-marl levels. The sandstones at the upper parts are gray-khaki colored, tough and rich in quartz and lithic grains. Flute casts and load casts are recorded at the base of these Turbiditic sandstones.

The thickness of the Kusuri Formation is 1460 m. in its type section (Gedik and Korkmaz, 1984). However, it is most probably thicker in other localities.

The age of the Kusuri Formation was defined as Early-Middle Eocene by Ketin and Gümüş (1963) and Tüysüz *et al.* (1989), Early Eocene by Akyol *et al.* (1974) and Middle Eocene by Gedik and Korkmaz (1984).

The geographical distribution of the Kusuri Formation was very wide towards the east of Cide.

Akyol *et al.* (1974) named the formation as Cide Formation and defined Gecen shale-claystone, red marl, tuffite and Hocaköy shale members. Gedik and Korkmaz (1984) identified a unit as the Kusuri Member of Yenikonak Formation in Sinop. The equivalent of the Kusuri Formation is Çaycuma Formation in the southern belt.

2.1.3.1. Akçakoca Member

Turbiditic sandstones of Early-Middle Eocene aged Akçakoca Member deposited by slope fan to submarine fan depositional model. The canals include the Tc, Td and Te of the Bouma sequence, whereas Ta and Tb parts are mostly missing. Towards its upper parts, the clastic input weakens and the system becomes carbonate dominated represented with the presence of marls. This change in the lithology is also suitable with the regional tectonic evolution as the sea level raised once more in the Lutetian after the compressive phase (Yılmaz *et al.,* 1997).

2.1.3.2. Sürmeli Member

The intense turbidite deposition was decelerated by the initiation of the extensional phase and fine grained siltstones, mudstones and transgressive marls started to be deposited instead of sandstones. The volcanics of this extensional phase are represented with the dark brown tuffs and tuff intercalated sandstone-siltstone-marl alternations. The sediments above this key level are called as the Sürmeli Member around Akçakoca Region.

2.1.3.3. Ayancık Member

This Early-Middle Eocene aged member of the Kusuri Formation studied around Ayancık Region was also the product of a turbidite mechanism (Figure 7). However, in contrast to the Akçakoca Member, it contains mostly the amalgamated Ta and Tb levels of Bouma sequence. The paleocurrent directions show that the sediment influx was from west to east.

2.1.4. Late Eocene, Oligocene and Neogene Deposits

During the Late Eocene-Oligocene boundary, a transpressional regime started to control the evolution of the Black Sea basin. Pontides began to be uplifted, sea level was fallen and the marine deposition was overlain by the continental “red-beds” (Yılmaz *et al.,* 1997).

At the end of Oligocene, Pontides were intensely eroded and peneplene formation was initiated. Lowstand System Tract phase continued until early Early Miocene. However, sea effect was examined once more during Early-Middle Miocene as a result of N-S extensional regime. However, Lower Miocene deposits haven’t been recorded in the Black Sea onshore. Sea level was fallen again before Late Miocene and continental clastics began to deposit. The North Anatolian Fault started to develop at Late Miocene-Pliocene boundary (Yılmaz *et al.,* 1997).

After the Late Eocene, there aren’t common outcrops in the Black Sea onshore. Cemalettin, Saraycık, Sinop and Sarıkum formations are the most common successions being used in literature (Gedik *et al.* 1983; Tunoğlu and Gökçen 1985, 1991, 1997). The

Cemalettin Formation, recorded around Daday-Devrekani (Kastamonu) and Boyabat (Sinop) basins, represents a shallow-marine succession that includes delta, shoreface and mouth bar systems (Sonel *et al.*, 1989; Boztuğ, 1992). Bearing conglomerate-sandstone-siltstone-claystone alternations, the age of the formation is mentioned to be Late Eocene-Early Oligocene. The Saraycık Formation, unconformably overlying the Kusuri Formation, contains Upper Miocene (Messinian/Meotian-Pontian) sandy marls, sandy shales, clayey sandstones and sandy shelly limestones (Tunoğlu and Gökçen, 1991; 1997). The Sinop Formation, also unconformably overlying the Kusuri Formation, contains fossiliferous sandy limestone, sandstone, siltstone, oolithic limestone and conglomerates (Gedik *et al.* 1983). The age of this formation hass been recorded as Miocene. The Sarıkum Formation unconformably overlies the Kusuri, Saraycık or Sinop formations and contains loose sands, claystones, siltstones and conglomerates (Gedik *et al.* 1983). By its fresh water fossil content, its age is Plio-Pleistocene.

2.2. LITHOSTRATIGRAPHY OF THE MEASURED SECTIONS

Through the evolution of the Western Black Sea region, the formations recorded in the field studies have been mentioned in the previous section. The Akveren Formation was recorded in 4 sections, Atbaşı Formation was recorded in 5 sections, the Atbaşı-Kusuri transition is recorded in 3 sections and the Kusuri Formation is recognized in 5 sections. The Akçakoca and the Sürmeli members of the Kusuri Formation is recognized separately only in one of the sections. The lithostratigraphic correlation of the sections is given in figure 8:

2.2.1. Lithostratigraphy in the Akçakoca Region

Two of the studied measured sections are around Akçakoca, Düzce; the Karaburun Measured Stratigraphic Section (MSS) and the Ayazlı MSS (Figure 9). The exact coordinates for the sections have been specified in Table 1.

2.2.1.1. Karaburun Measured Stratigraphic Section

The Karaburun MSS is measured the only section that we recognized both the Akçakoca and the Sürmeli members of the Kusuri Formation (Figures 10, 11; Appendix A). The total thickness of the section is 127.75 m and 34 samples are gathered throughout the section. Here, Akçakoca Member starts with sandstones containing marl intercalations. The sandstones are defined as the sand ball bearing, massive sandstones. In the middle parts of the Akçakoca Member, the thickness of the sandstone beds declines and more regular sandstone-marl alternations have been identified. Towards the upper parts of the member, the grain size decreases and lithology turns into siltstone-marl alternation (Figure 12). At the top of the member, massive sandstones and a thicker marl section have been recorded. Between Akçakoca and Sürmeli members, there is a 16 m thick cover. Sürmeli Member starts with marls with siltstone intercalations. In the middle parts of the member, mostly mudstone, marl and siltstone alternations with some tuff intercalations have been recognized. Top of the member covers the marl-sandstone alternations with limestone and siltstone intercalations (Figure 12).

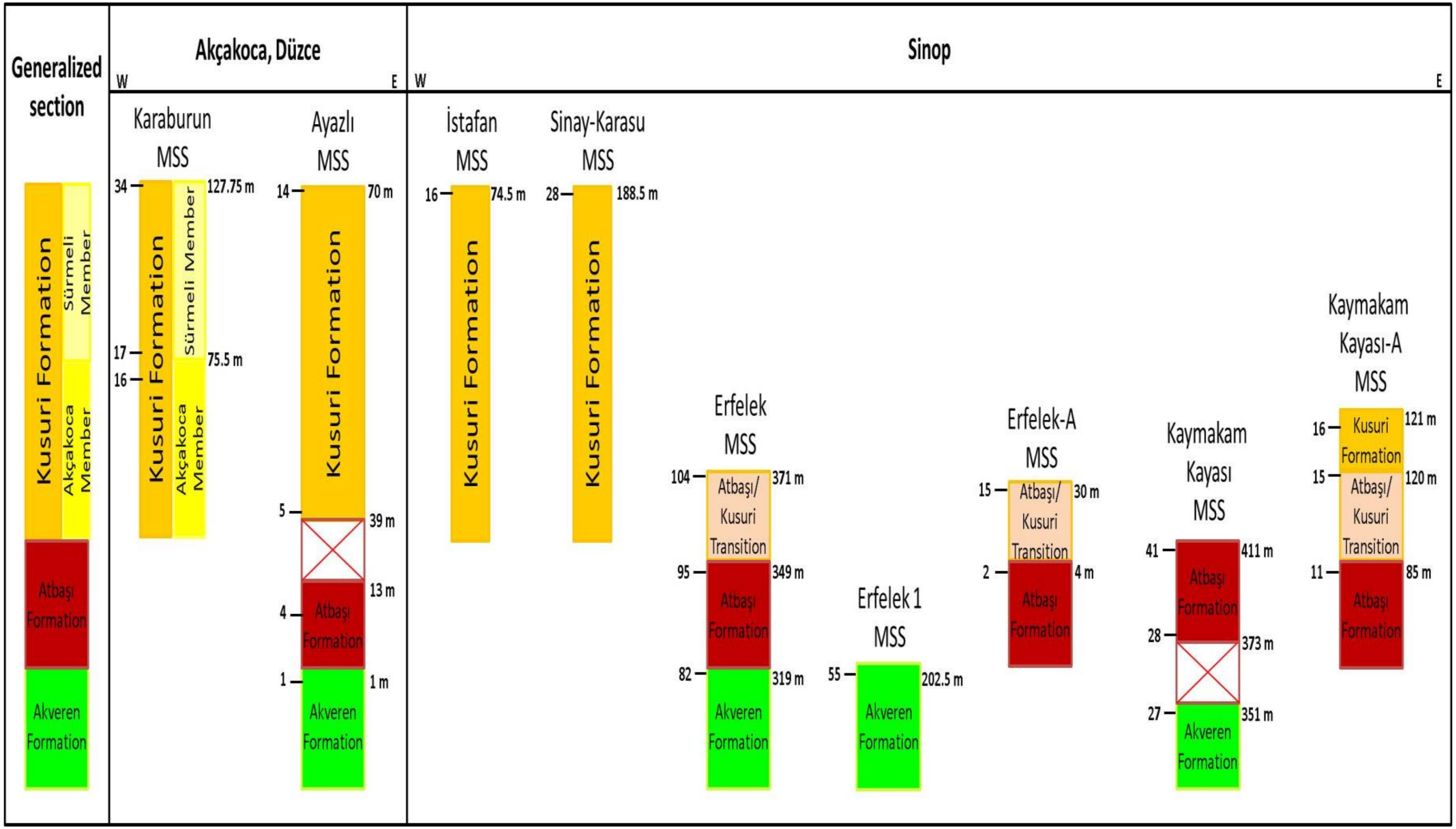

Figure 8. Lithostratigraphical correlation of the measured sections.

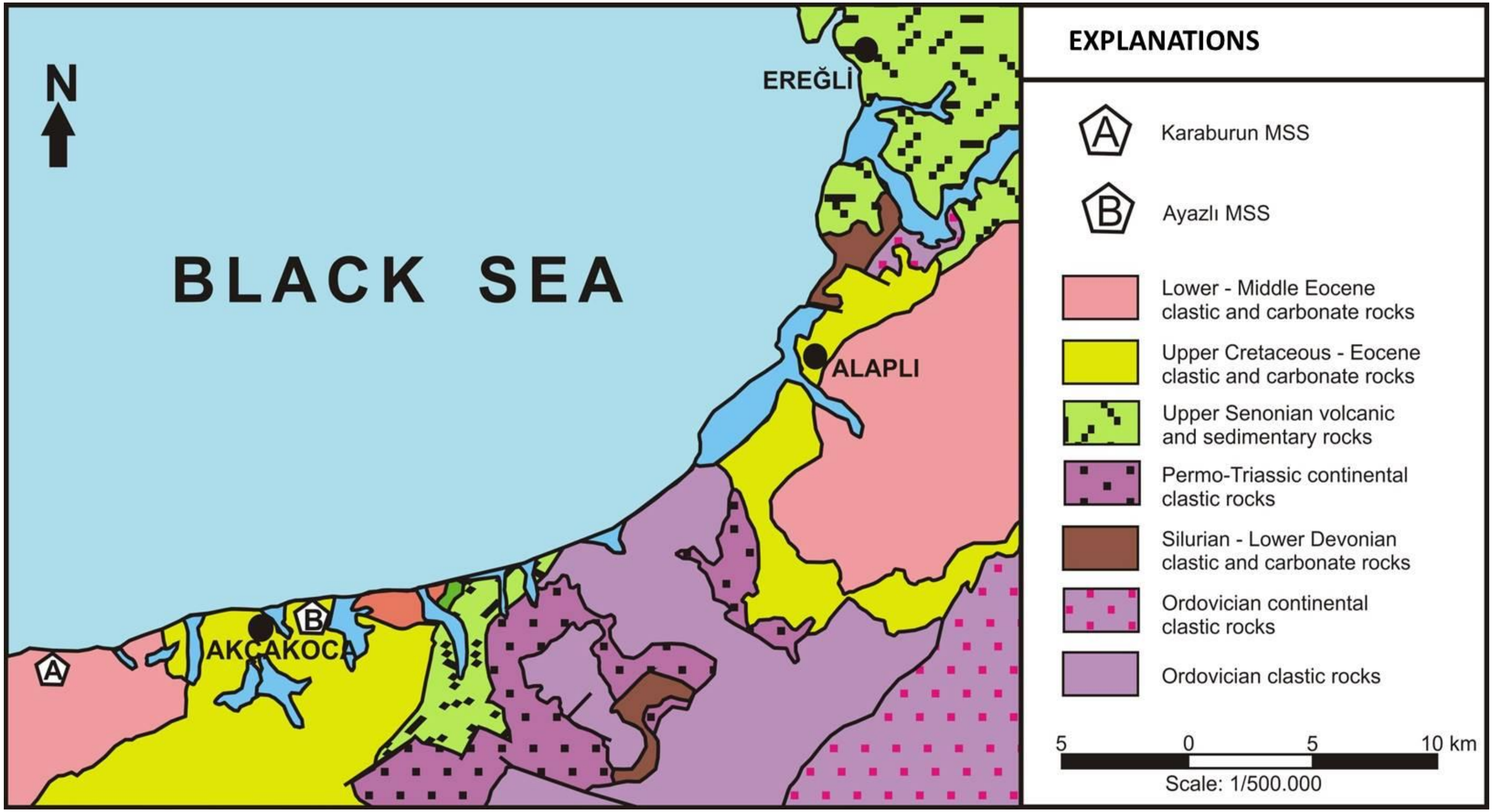

Figure 9 . Geological map of the Akçakoca Region (Compiled from the 1:500.000 scaled Geological Map of Turkey, Zonguldak Section; MTA 2002).

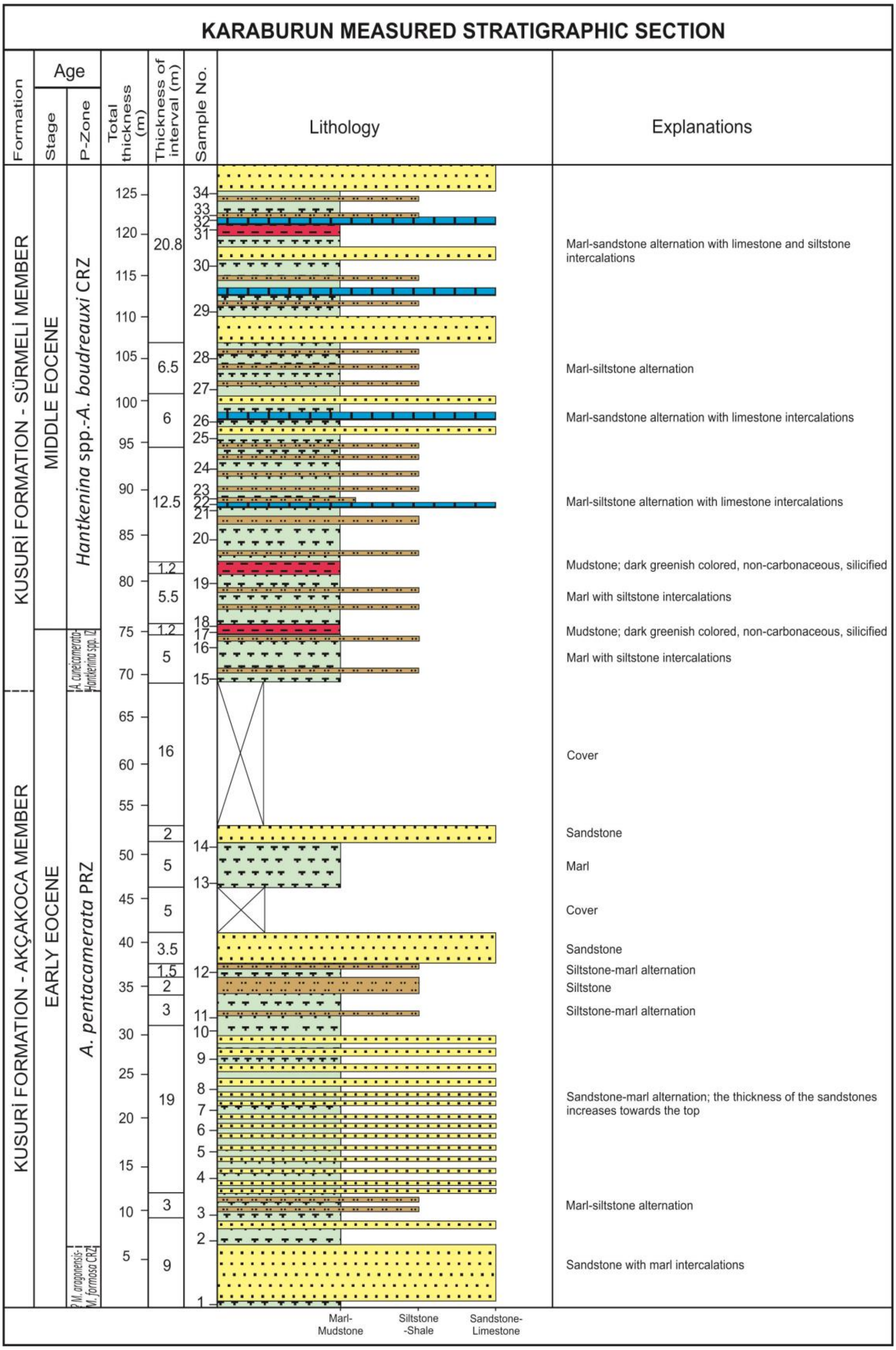

Figure 10. Columnar section of the Karaburun Measured Stratigraphic Section.

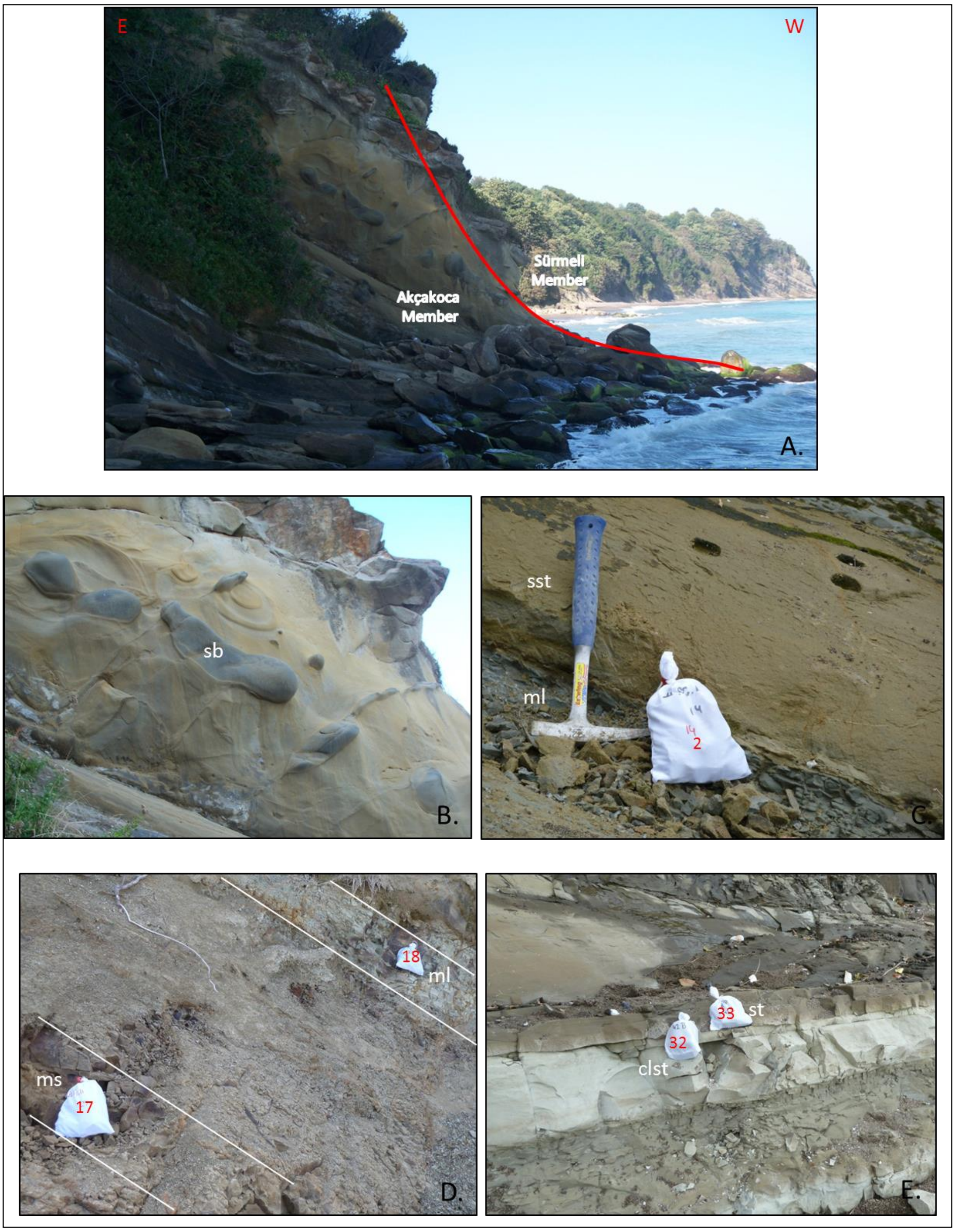

Figure 11. Field photographs of the Karaburun Measured Stratigraphic Section. **A.** Generalized view of the section, **B.** Sanballs (sb) of Akçakoca Member, **C.** Akçakoca Member; marl (ml) – sandstone (sst) alternations, **D.** Sürmeli Member; samples taken from mudstone (ms) and marl (ml), **E.** Uppermost part of the Sürmeli Member; samples taken from clayey limestone (clst) and siltstone (st).

2.2.1.2. Ayazlı Measured Stratigraphic Section

The Ayazlı MSS (Figure 9) starts with the Akveren Formation (Figures 13, 14; Appendix A). The total thickness of the section is 98.1 m and 14 samples are gathered throughout the section. Here, the Akveren Formation is on the core of and anticline and our section is located towards the eastern flank (Figure 14a). The Akveren formation has not been measured and the first sample has been picked from the uppermost part of this formation. This sample represents a planktonic foraminifera wackestone-packstone facies at the uppermost part of the formation (Figures 13, 15 a-b). The transition of the Akveren and the Atbaşı formations is represented with silty mudstones alternating with the limestones of the Akveren Formation (Figure 14b). Overlying this, characteristic pinkish or greenish marls of the Atbaşı Formation take place. Top of the Atbaşı Formation is covered; therefore the section has been shifted towards east for about 30 m. The base of the Akçakoca Member of the Kusuri Formation is represented with the sand ball bearing sandstones (Figure 14c) that are alternating with siltstones or marls (Figure 14d). Sandstones are medium-coarse grained; sometimes bearing macrofossil fragments (Figures 13, 15c-e). The grain size decreases towards the top of the section (Figures 13, 15f). Some sedimentary structures that are the characteristics of Ta-Tb-Tc of the Bouma sequence have been recorded on the large blocks that are the parts of the Kusuri Formation (Figure 14e).

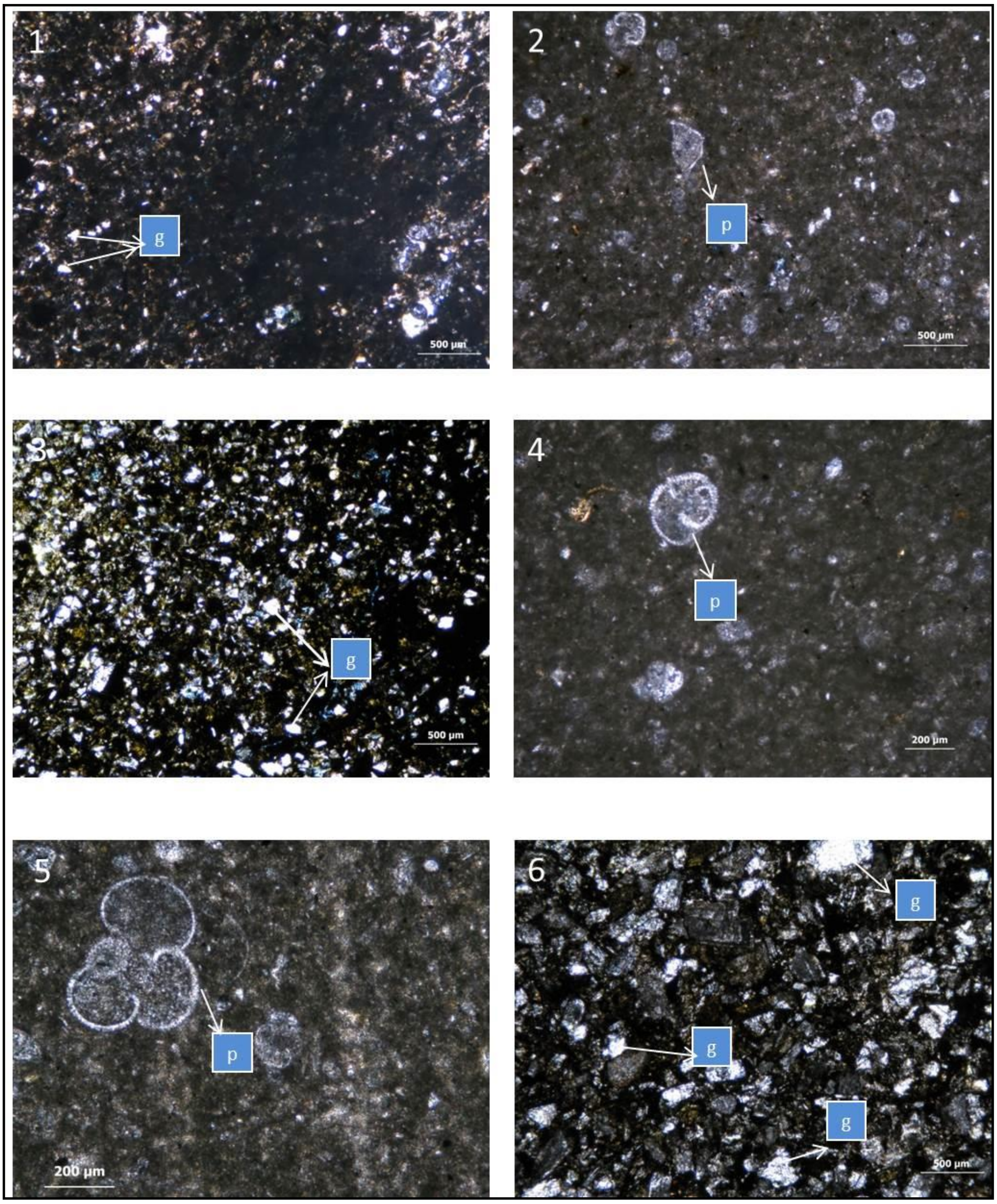

Figure 12. Thin section microphotographs of the Karaburun MSS. 1. Siltstone, Sample No. 17 (g: grains); 2. Planktonic foraminifera wackestone, Sample No. 22 (p: *Morozovella* sp.); 3. Siltstone, Sample No. 23 (g: grains); 4. Planktonic foraminifera wackestone, Sample No. 32 (p: *Globigerinatheka* sp.); 5. Planktonic foraminifera wackestone, Sample No. 32 (p: *Subbotina* sp.); 6. Sandstone, Sample No. 33 (g: grains).

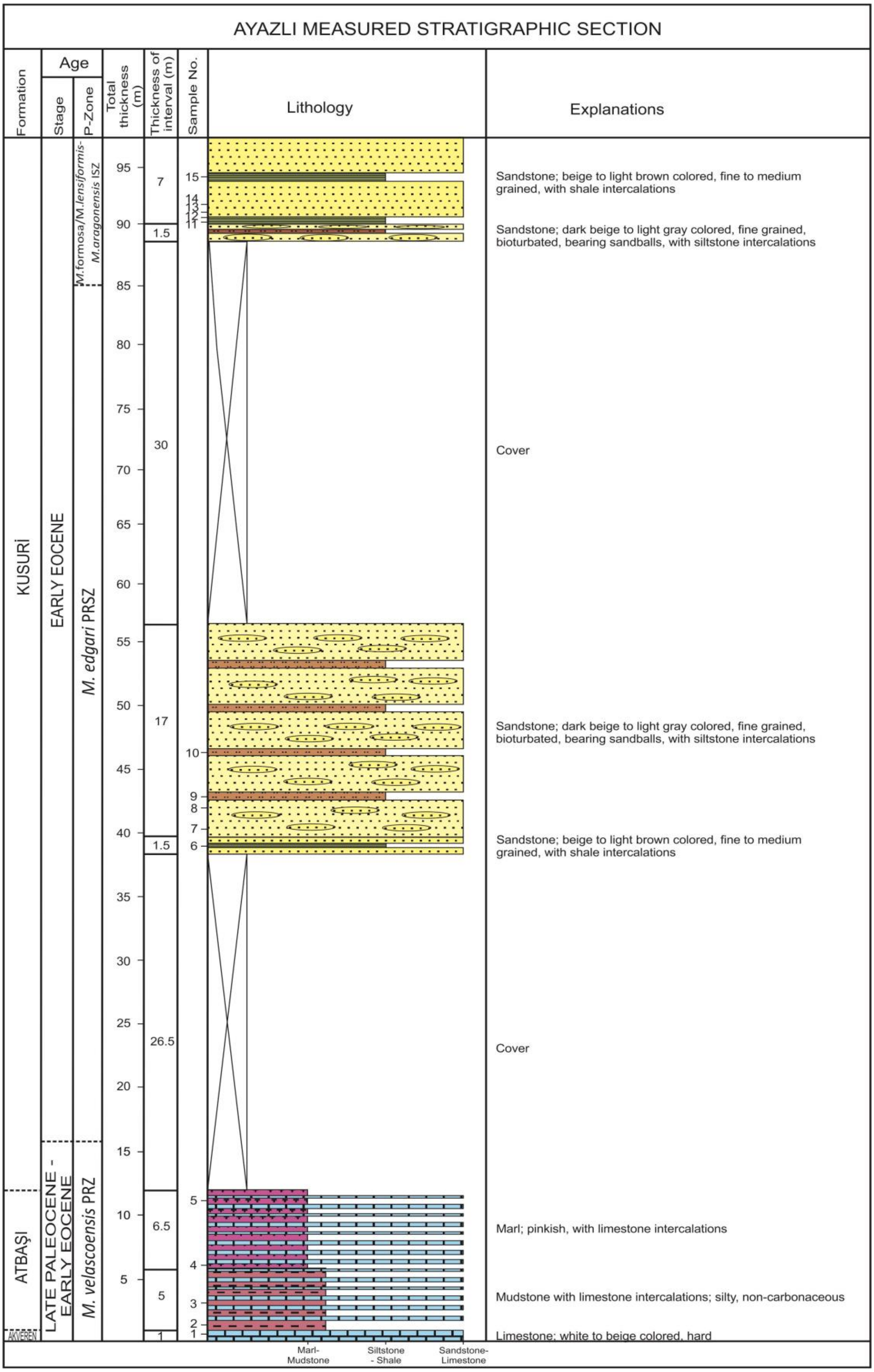

Figure 13. Columnar section of the Ayazlı Measured Stratigraphic Section.

Figure 14. Field photographs of the Ayazlı Measured Stratigraphic Section. A. Akveren Formation; core of the anticline (starting point of the section), **B.** Transition from Akveren to Atbaşı formations, C. Kusuri Formation - Akçakoca Member (sb=sandballs), **D.** Kusuri Formation; sandstone (sst) – marl (ml) alternation, **E.** Kusuri Formation – part of Bouma sequence (Ta=shale clasts equivalent of basal conglomerates, Tb=parallel lamination, Tc=convolute bedding).

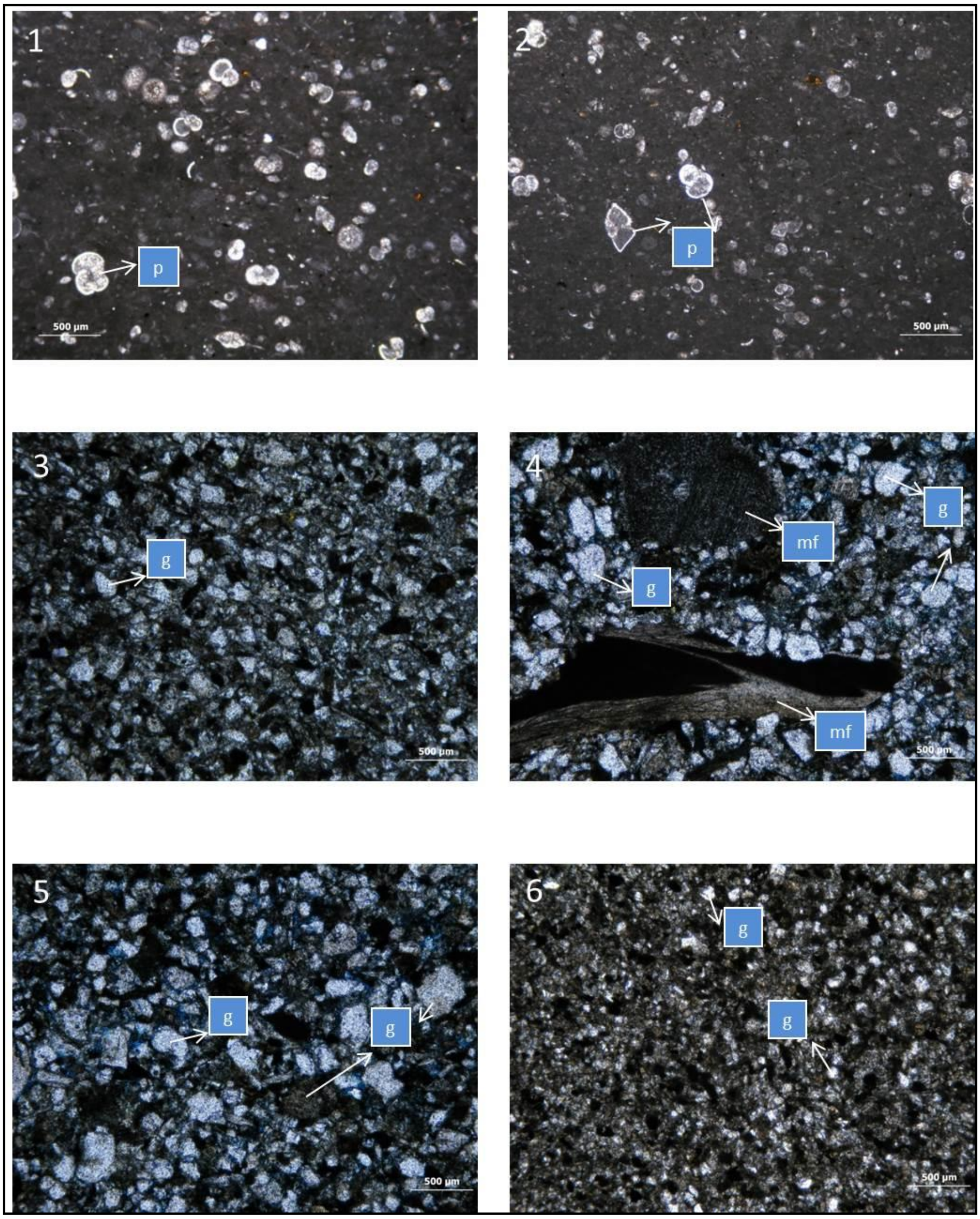

Figure 15. Thin section microphotographs of the Ayazlı MSS. **1.** Planktonic foraminifera wackestone, Sample No. 2 (p: *Acarinina* sp.); **2.** Planktonic foraminifera wackestone, Sample No. 3 (g: grains); **3.** Sandstone, Sample No. 7 (g: grains); **4.** Sandstone, Sample No. 8 (mf: macrofossil fragment, g: grains); **5.** Sandstone, Sample No. 14 (g: grains); **6.** Siltstone, Sample No. 10 (g: grains).

2.2.2. Lithostratigraphy in the Sinop Region

A total of 7 sections are measured around Sinop; İstafan MSS, Sinay-Karasu MSS, Erfelek MSS, Erfelek 1 MSS, Erfelek A MSS, Kaymakam Kayası MSS and Kaymakam Kayası A MSS (Figure 16). The exact coordinates for the sections have been specified in Table 1.

2.2.2.1. İstafan Measured Stratigraphic Section

The İstafan MSS has been measured along the Kusuri Formation (Figures 17, 18; Appendix A). The total thickness of the section is 74.5 m and 16 samples are gathered throughout the section. The section starts with the mudstones and marls, which are intercalated by sandstone beds. The sandstones are relatively more dominant at the bottom parts. Following this bottom part, a covered part of about 1 m has been passed and the section has been horizontally shifted towards west. The section becomes dominated in green to greenish gray colored mudstones with sandstone intercalations. Following a second cover of 1 meter and shifted horizontaly, the color of the mudstones becomes khaki and the carbonate proportion increases. After passing a mudstone-limestone alternation, there is a 12 m. thick massive limestone. These *Nummulites*-bearing limestones are the products of the regression in the basin. Because of the sea level fall, the turbidite deposition was followed by the shallow marine limestones. The section is unmeasured from this point. The last sample has been gathered from the thin marl unit on the massive limestone (Figure 17). At this point, a nummulitic bank, which is thought to be the coarse sands and conglomerates of the beach facies, has been recorded. This part of the section hasn't been sampled.

2.2.2.2. Sinay-Karasu Measured Stratigraphic Section

The Sinay - Karasu MSS is measured throughout the Kusuri Formation (Figures 19, 20; Appendix A). The total thickness of the section is 188.5 m and 28 samples are gathered throughout the section. The section starts with marls, mudstone and siltstones are alternating on the marls before a 20 m thick slumpy section (Figure 21).

The middle part of the section mostly covers marls with siltstone intercalations. Jarosite deposition has been recognized as yellow mottles or very thin layers. The upper part of this marly section is slumpy and followed by siltstone dominated lithology (Figure 19, 20). Uppermost part of the Sinay-Karasu Section covers mudstones and marls with limestone intercalations and jarosite deposition. Jarosite deposition is an indicator for the anoxic environments (Figure 20b).

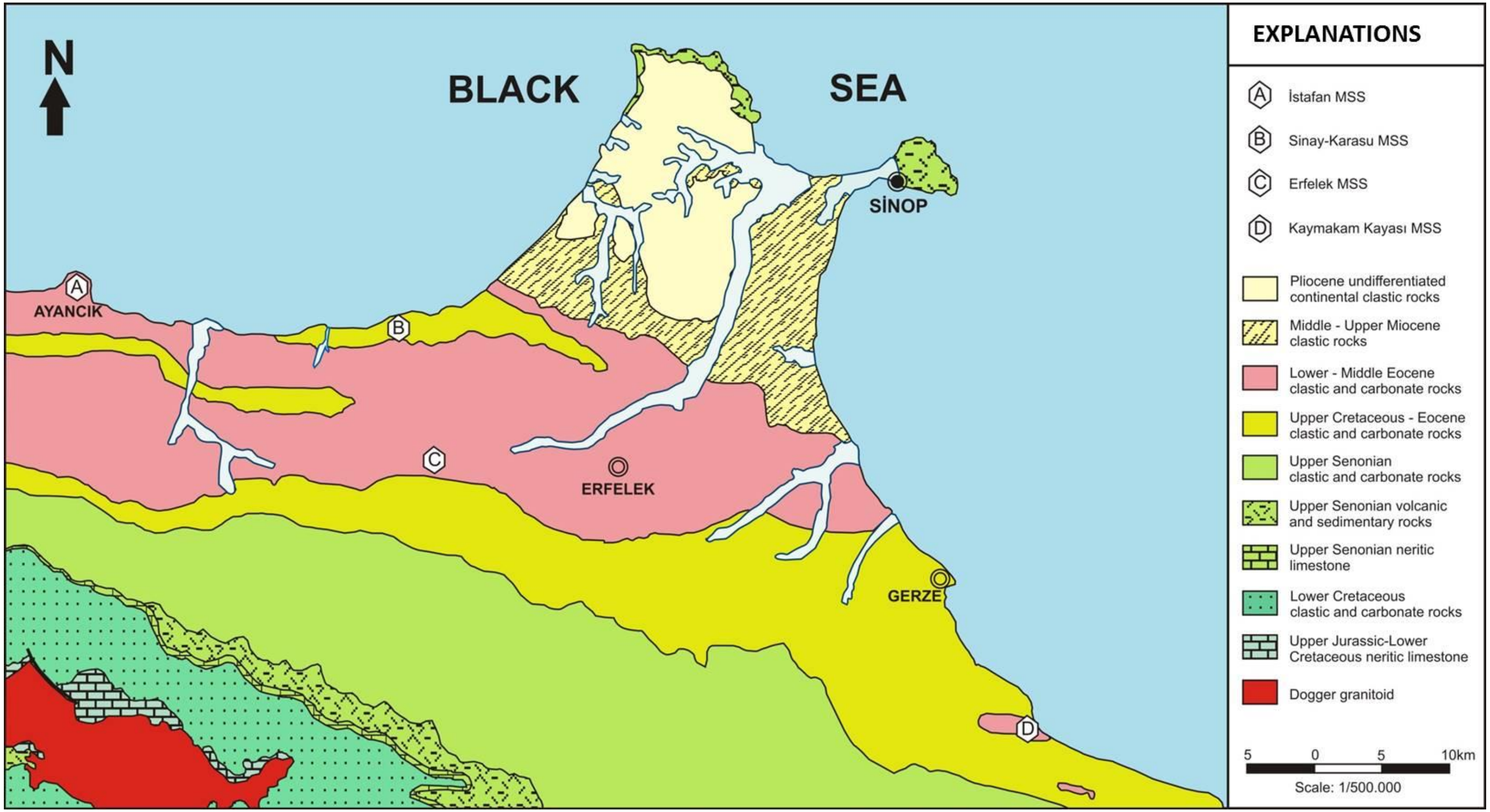

Figure 16. Geological map of the Sinop Region (Compiled from 1:500.000 scaled geological map of Turkey, Sinop; MTA, 2002).

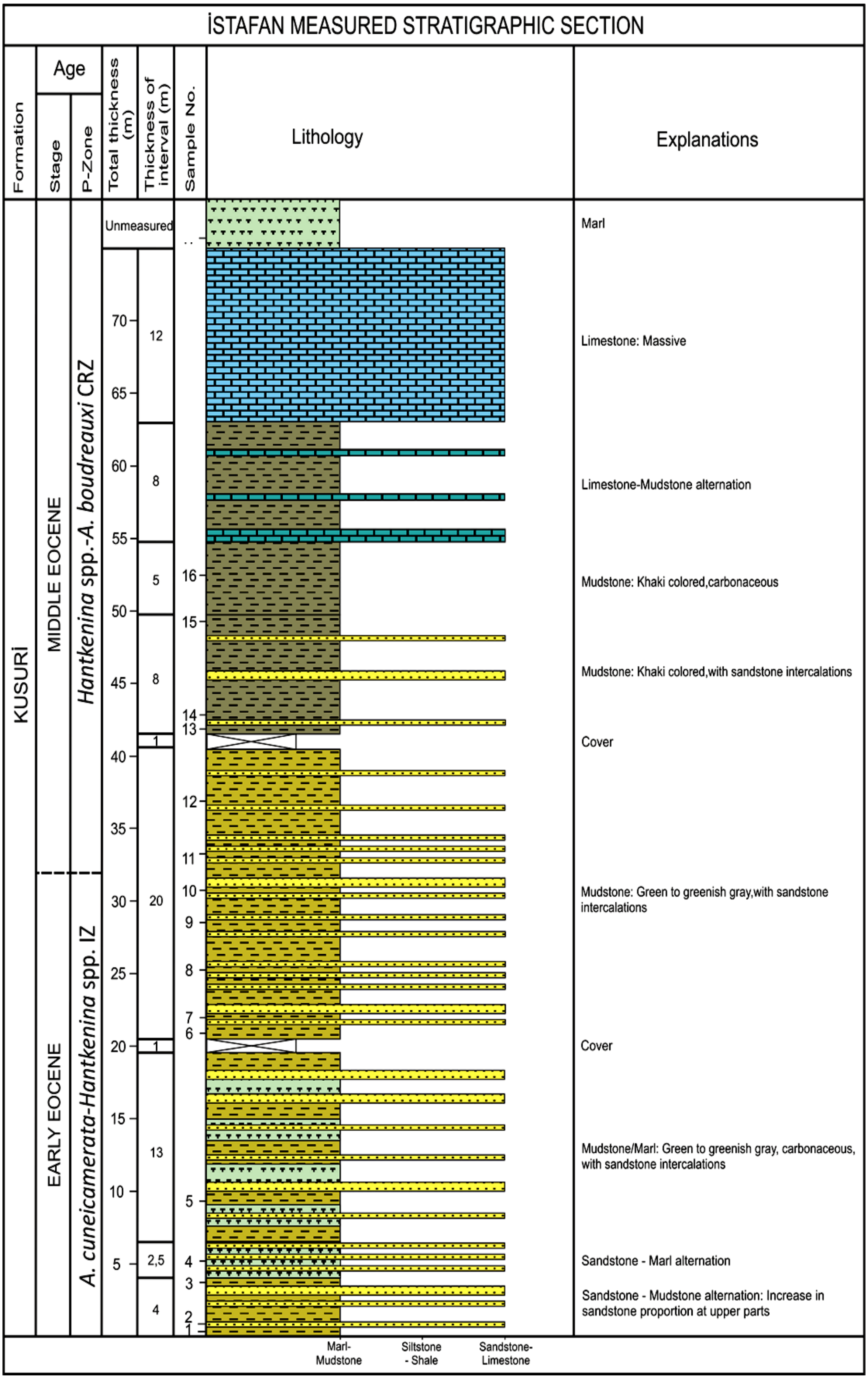

Figure 17. Columnar section of the İstafan Measured Stratigraphic Section.

Figure 18. Field photographs of the İstafan Measured Stratigraphic Section. **A.** Generalized view of the section, **B.** Upper parts of the section, **C.** Close-up view of figure 11.B for the sandstone (s) - marl (m) alternations.

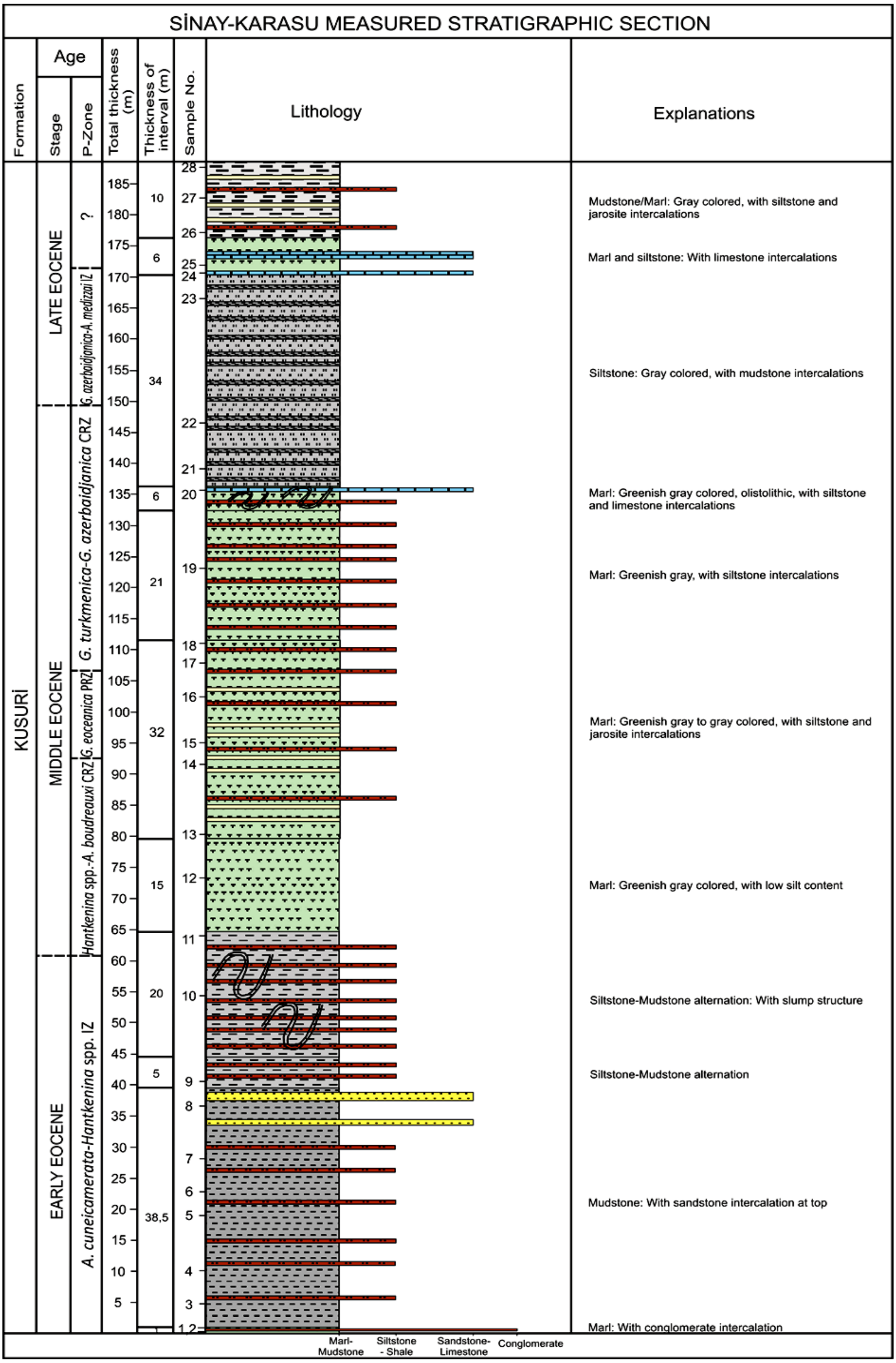

Figure 19. Columnar section of the Sinay-Karasu Measured Stratigraphic Section.

Figure 20. Field photographs of the Sinay-Karasu Measured Stratigraphic Section. A. Starting point (eastern part) of the section; mudstone (md) beds, B. Yellow jarosite mottles (J) inside marn-siltstone alternation at the upper (western part) of the section, **C.** Top part of the section; siltstone (ss)-marl (ml) alternation.

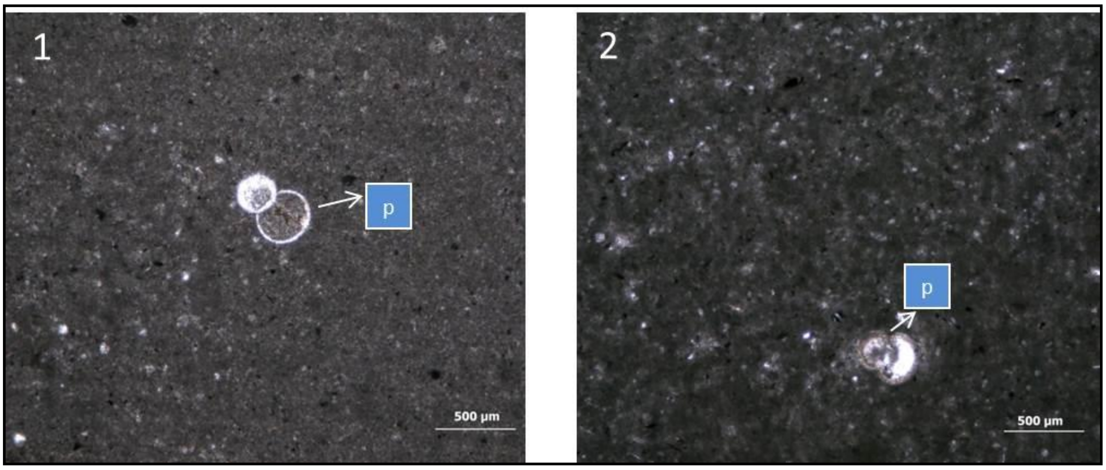

Figure 21. Thin section microphotographs of the Sinay-Karasu MSS. 1. Planktonic foraminifera mudstone, Sample No. 20 (p: Globigerinidae); 2. Planktonic foraminifera mudstone, Sample No. 24 (p: ?*Globigerinatheka* sp.).

2.2.2.3. Erfelek, Erfelek 1 and Erfelek-A Measured Stratigraphic Sections

The Erfelek MSS includes the Akveren and the Atbaşı formations and the transition of Atbaşı-Kusuri formations (figures 22, 25; Table 1; Appendix A). The total thickness of the section is 371 m and 104 samples are gathered throughout the section. The section starts with marl – limestone alternations followed by a red colored slumpy zone (Figure 26). This part is followed by marl – carbonaceous sandtone alternations. Upto this part, it was assumed that the beginning of the section is within the Akveren formation. Above the marl – sandstone alternations, characteristic marl – limestone alternations of the Akveren Formation take place. Marls are mostly greenish gray to gray colored. Being the dominant lithology, limestones are cream, beige to off-white colored, maybe clayey or bioclastic and sometimes bearing chert nodules or interbeds. The studied thin sections from these limestones have wackestone, packstone or grainstone characteristics (figures 26, 27). Overlying the Akveren Formation, Atbaşı Formation basicly covers pinkish marls alternating with limestones. Limestones are clayey, having mudstone-wackestone properties at the lower parts of the formation, and then become pinkish colored and silisified towards the top (Figure 27). Passing a 3 m. thick cover, top of the Erfelek MSS is the Atbaşı – Kusuri transition. This uppermost part covers marl-sandstone alternations. Marls are pinkish or greenish, whereas sandstones are yellow colored. The Erfelek Section is completed with the 22 m. thick Atbaşı-Kusuri transition followed by a large covered area.

The Erfelek MSS has been sampled a second time for the recognition of the Paleocene-Eocene boundary. New samples are gathered as the Erfelek 1 Section. A total of 55 samples were gathered in this section. Samples 1-19 are sporadic samples taken from the lower parts of the section, mainly Cretaceous and Lower Eocene sequence, to increase the sampling frequency. Starting from sample 20, a narrower sampling has been carried out for the uppermost Lower Paleocene-lowermost Eocene sequence for the detail investigation of the boundary. The lithology is recorded in detail through this part of the section (Figure 23).

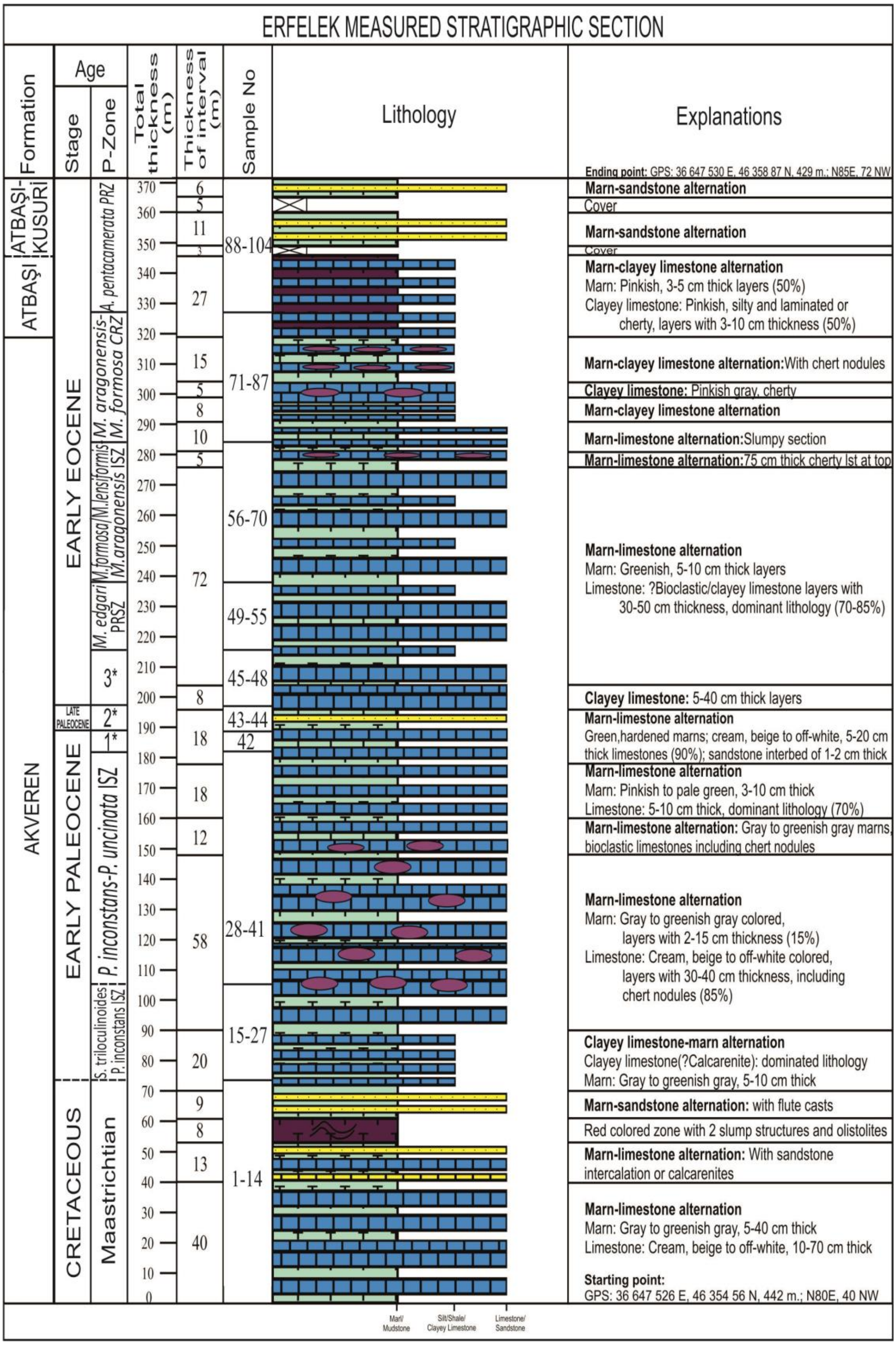

Figure 22. Columnar section of the Erfelek Measured Stratigraphic Section (**1*** *Praemurica uncinata-Morozovella angulata* Interval Zone, **2*** Combined *M. angulata-A. nitida* Interval Zone / *M. velascoensis* Partial-range Zone, **3*** *Morozovella velascoensis* Partial-range Zone).

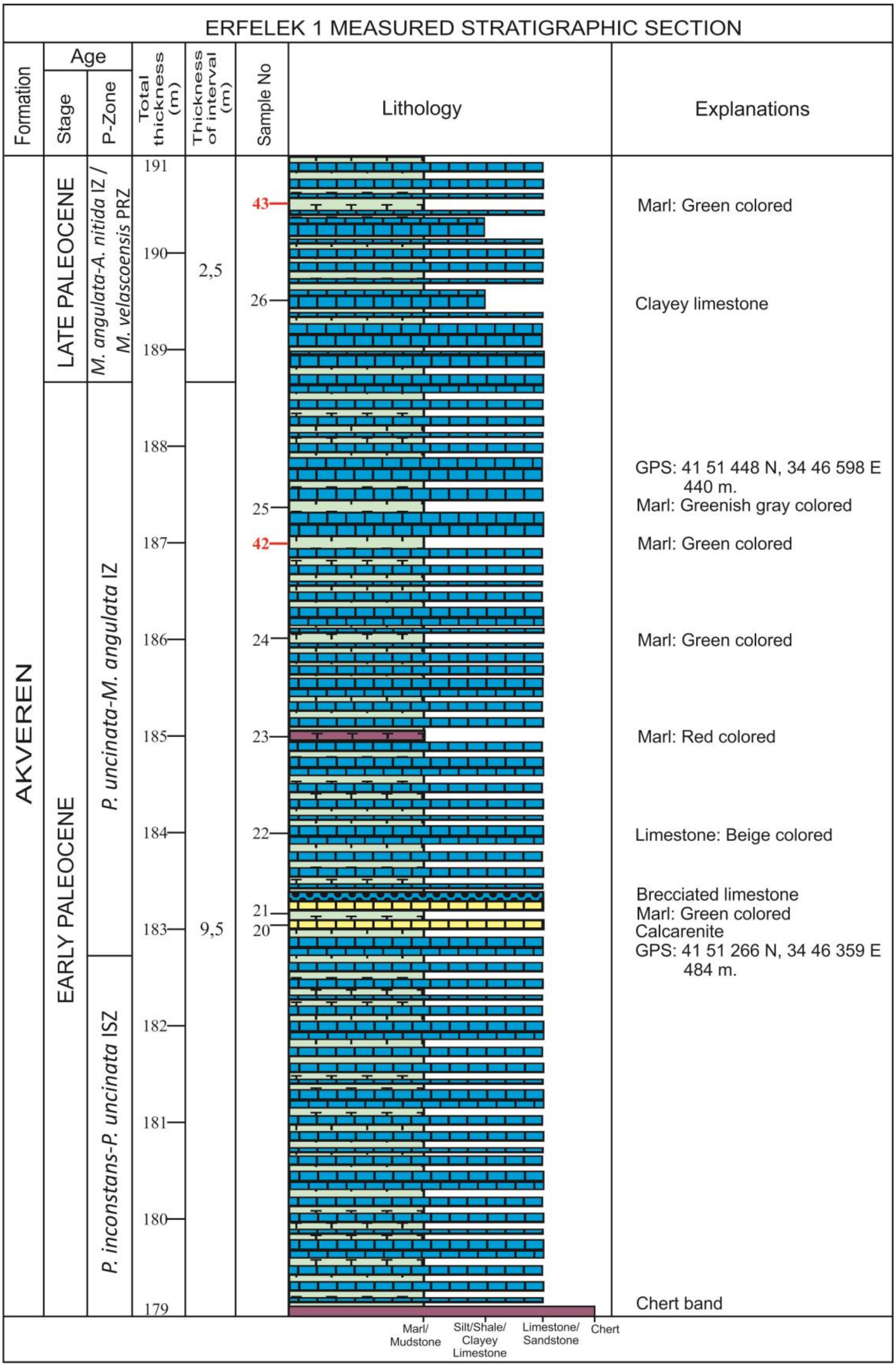

Figure 23. Columnar section of the Erfelek 1 Measured Stratigraphic Section (Red numbers are belong to the samples of the Erfelek Measured Stratigraphic Section).

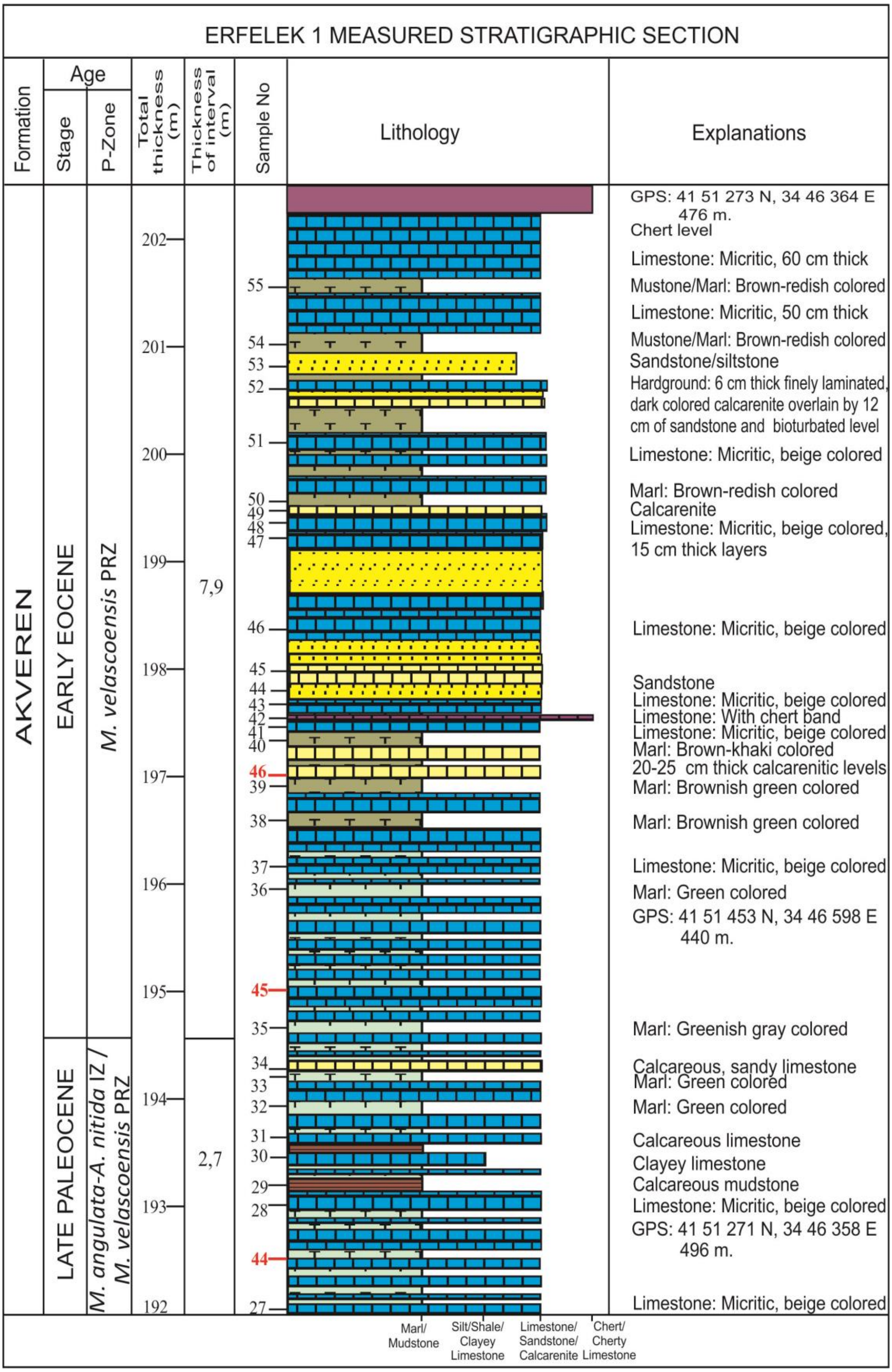

Figure 23. (Continued).

Starting with two distinct calcarenite levels, the Lower Paleocene sequence of the Erfelek 1 Section mostly covers beige colored limestones alternating with the greenish marls (Figure 23). By the Late Paleocene, limestones are clayey or micritic in character, alternating with calcareous mudstones or green colored marls. A calcareous, sandy limestone layer has been recognized in the uppermost part of the Paleocene section. The first 2 meters of the Eocene sequence is the alternation of beige colored micritic limestones and greenish marls. Above it marls are getting a brownish green color through the rest of the section. For the last 5 meters of the section, calcarenites and sandstones are getting dominated. Uppermost part of the section is completed with two 50-60 cm thick micritic limestone layers followed by a chert level (Figure 23). The last sample of the Erfelek 1 Section has been gathered from the last brownish-redish colored marl below the second thick limestone layer followed by the chert level.

Following the Erfelek Section, the road cuts allow us to continue the section, where the pinkish marls of Atbaşı Formation reappear. Here, the section is called as the Erfelek-A section (Figures 24, 25; Table 1; Appendix A). As the base of the Atbaşı Formation hasn’t been detected and the top is covered, 3 spot samples were gathered from this part and the Atbaşı Formation hasn’t been measured. Above the covered part, 4 m. thick green colored marls of the Atbaşı Formation, followed by the 26 m thick Atbaşı-Kusuri transition reappear. This part is thought as the upper parts of what was measured at the top of the Erfelek MSS. The Erfelek-A section was completed when the thicker yellow colored sandstones of the Kusuri Formation has been identified. The section is 30 m thick in total and 15 samples were gathered along the section.

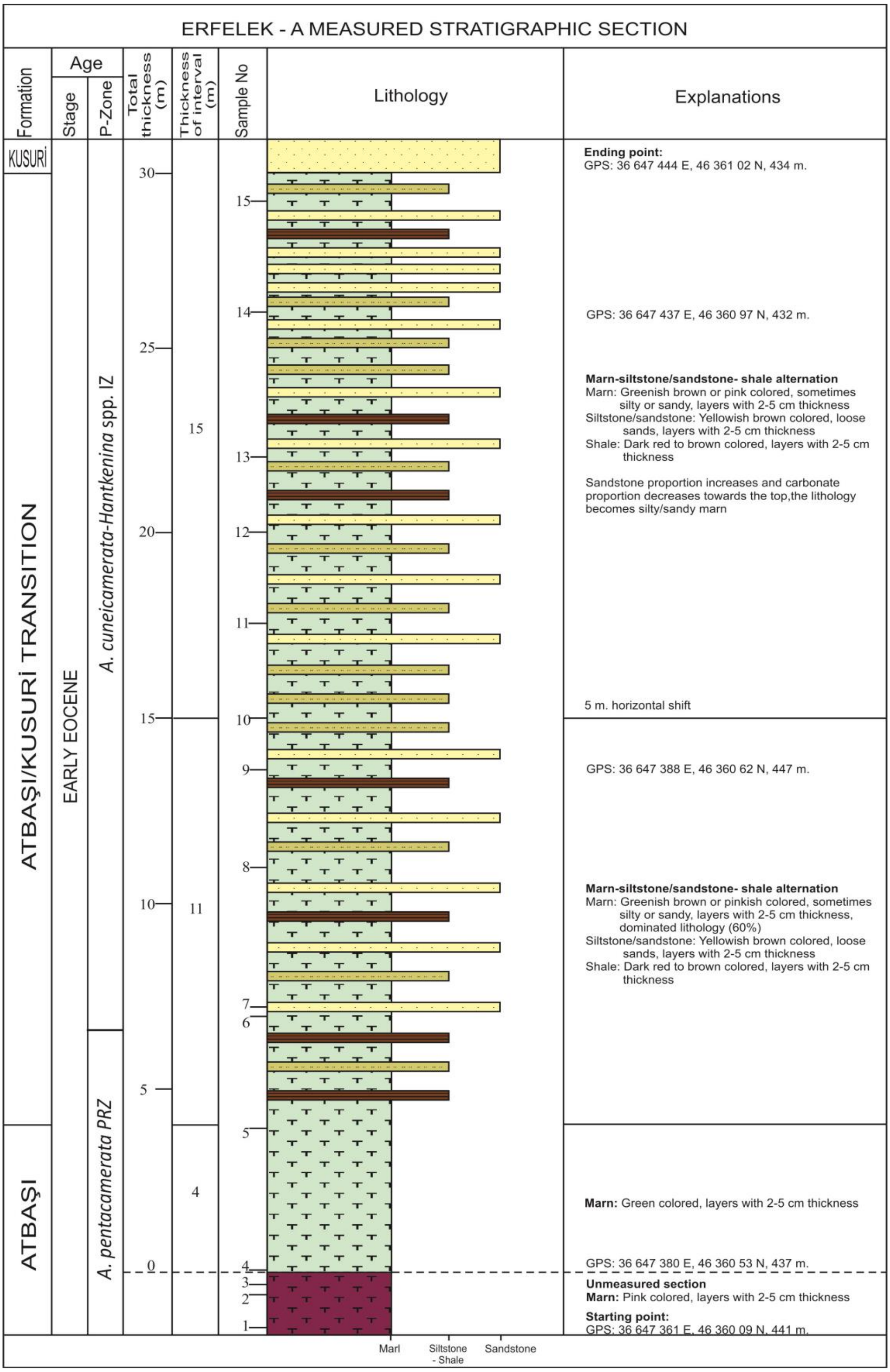

Figure 24. Columnar section of the Erfelek-A Measured Stratigraphic Section.

Figure 25. Field photographs of the Erfelek and the Erfelek-A Measured Stratigraphic Sections. **A.** Akveren Formation; marl (ml) – limestone (lst) alternations from the bottom part of the section, **B.** Akveren Formation; marl (ml) – limestone (lst) – sandstone (sst) alternations **C.** Flute casts showing a W-E flow direction, **D.** Uppermost part of the Akveren Formation; chert nodules (ch) inside limestone (lst) alternating with marls (ml), **E.** General view of Atbaşı formation with pinkish colored marls, **F.** Atbaşı – Kusuri formations' transition; pinkish marls (ml) and yellow colored sandstones (sst) are alternating.

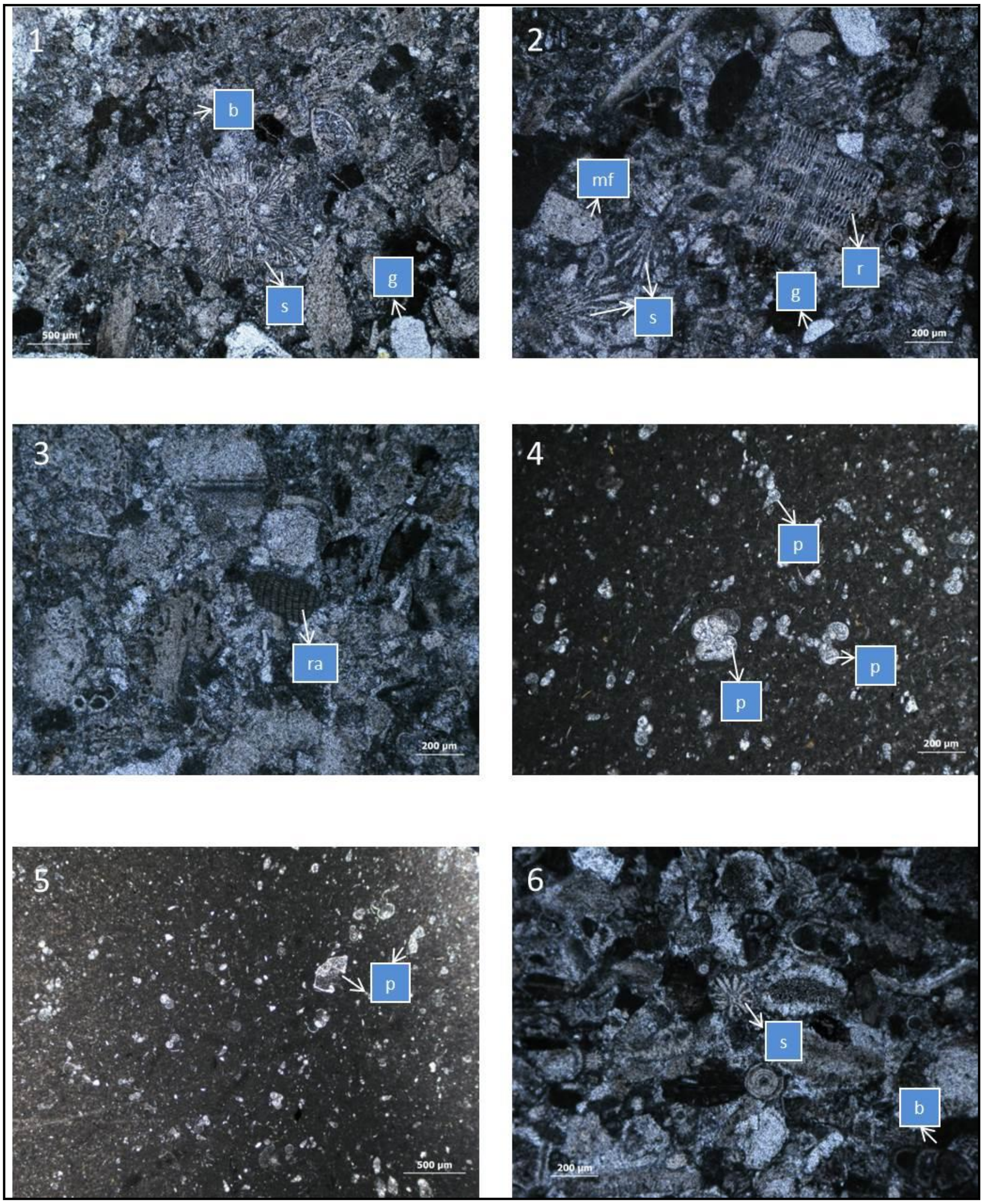

Figure 26. Thin section microphotographs of the Erfelek MSS. **1-3.** Carbonate sandstone with benthic foraminifera (s: *Siderolites* sp., b: undetermined benthic foraminifera), red algae (ra), rudist (r) and macro fossil fragments (mf), Sample No. 7; **4-5.** Planktonic foraminifera wackestone (p: planktonic foraminifera), Sample No. 9; **6.** Packstone, Sample No. 14 (s: *Siderolites* sp., b: undetermined benthic foraminifera).

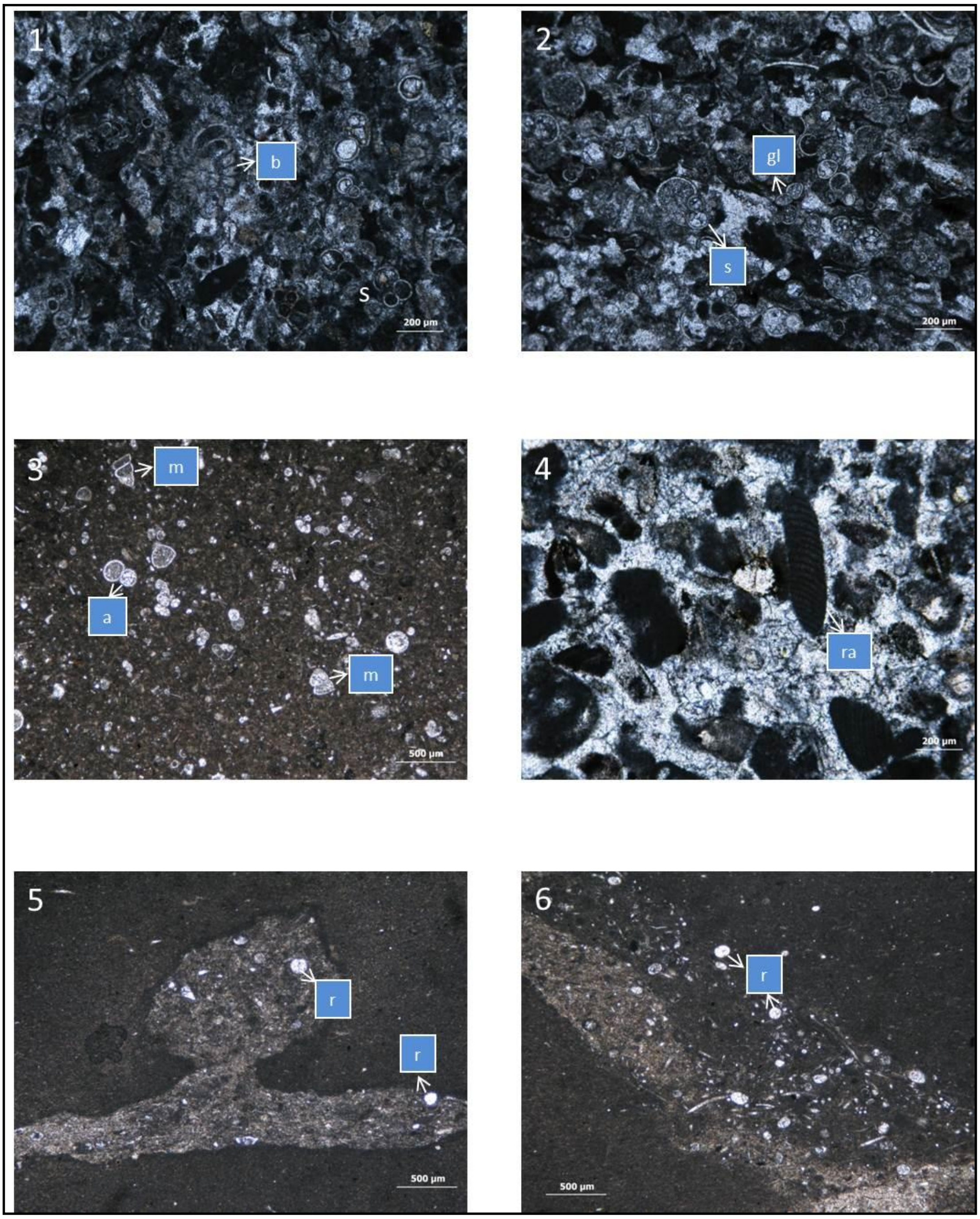

Figure 27. Thin section microphotographs of the Erfelek MSS. **1.** Benthic and planktonic foraminifera packstone (s: *Subbotina* sp., b: undetermined benthic foraminifera), Sample No. 31; **2.** Planktonic foraminifera packstone, Sample No. 39 (s: *Subbotina* sp., gl: *Globanomalina* sp.); **3.** Planktonic foraminifera wackestone, Sample No. 46 (a: *Acarinina* sp., m: *Morozovella* sp.); **4.** Grainstone with red algae (ra), benthic foraminifera and macro fossil fragments, Sample No. 52; **5-6.** Mudstone-wackestone with radiolarian (r), Sample No. 91.

2.2.2.4. Kaymakam Kayası and Kaymakam Kayası-A Measured Stratigraphic Sections

The Kaymakam Kayası MSS is the longest section of this study (Table 1). The total thickness of the section is 461m and 41 samples are gathered throughout the section. The section includes the Akveren and the Atbaşı formations (Figures 28, 30; Appendix A). The section starts with marl – limestone alternation of the Akveren Formation. Marl are pale gray to greenish gray or brownish colored, limestones are beige to off-white colored, sporadically sandy. The dominant lithology is limestones over the Akveren Formation. Also, some calcarenitic levels have been recorded (Figure 31). Followed by a 22 m thick covered section, the uppermost 37 meters of the Kaymakam Kayası Section is Atbaşı Formation. This part is dominated by green colored marls with thin limestone beds in between. Ended with a 2 m thick cherty limestone, the section was shifted at this point and 4 spot samples were gathered from the upper parts of Atbaşı formation, which is the alternation of pinkish and greenish colored marls (Figure 28). However, this part is recognized as a limited outcrop and covered by vegetation.

The upper parts of the Atbaşı Formation in this area have been measured as another section called the Kaymakam Kayası-A section (Figures 29, 30; Table 1; Appendix A). The section is 121 m thick and 16 samples were gathered along the section. The lithology is alternation of pink and green colored marls along the section. After the 84 m thick Atbaşı Formation, silty/sandy lithologies start to appear and alternate with marls. This part is thought to be the Atbaşı-Kusuri transition. The Kaymakam Kayası-A section was completed by the identification of more massive sandstones, which was thought as the base of the Kusuri Formation.

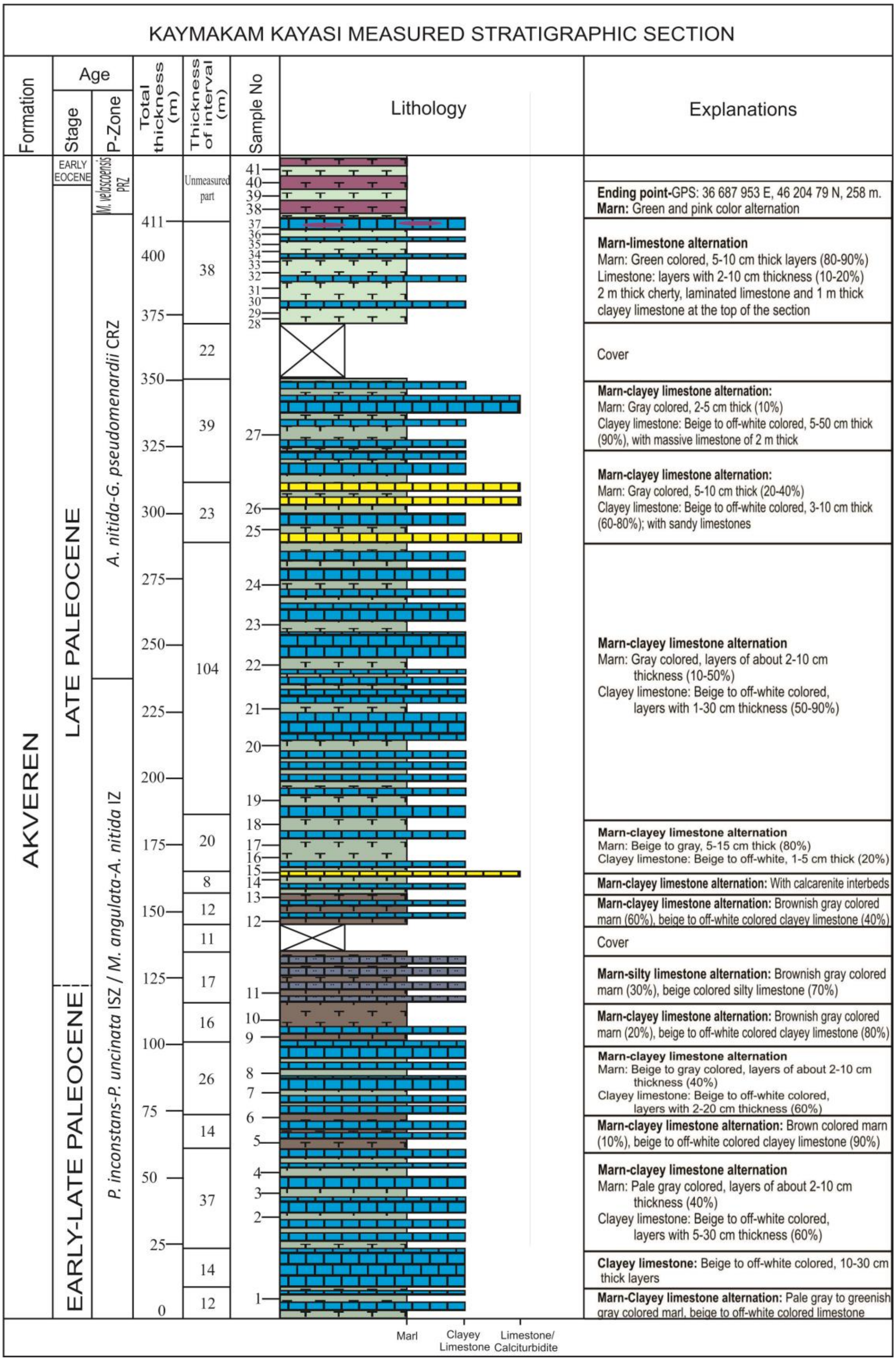

Figure 28. Columnar section of the Kaymakam Kayası Measured Stratigraphic Section.

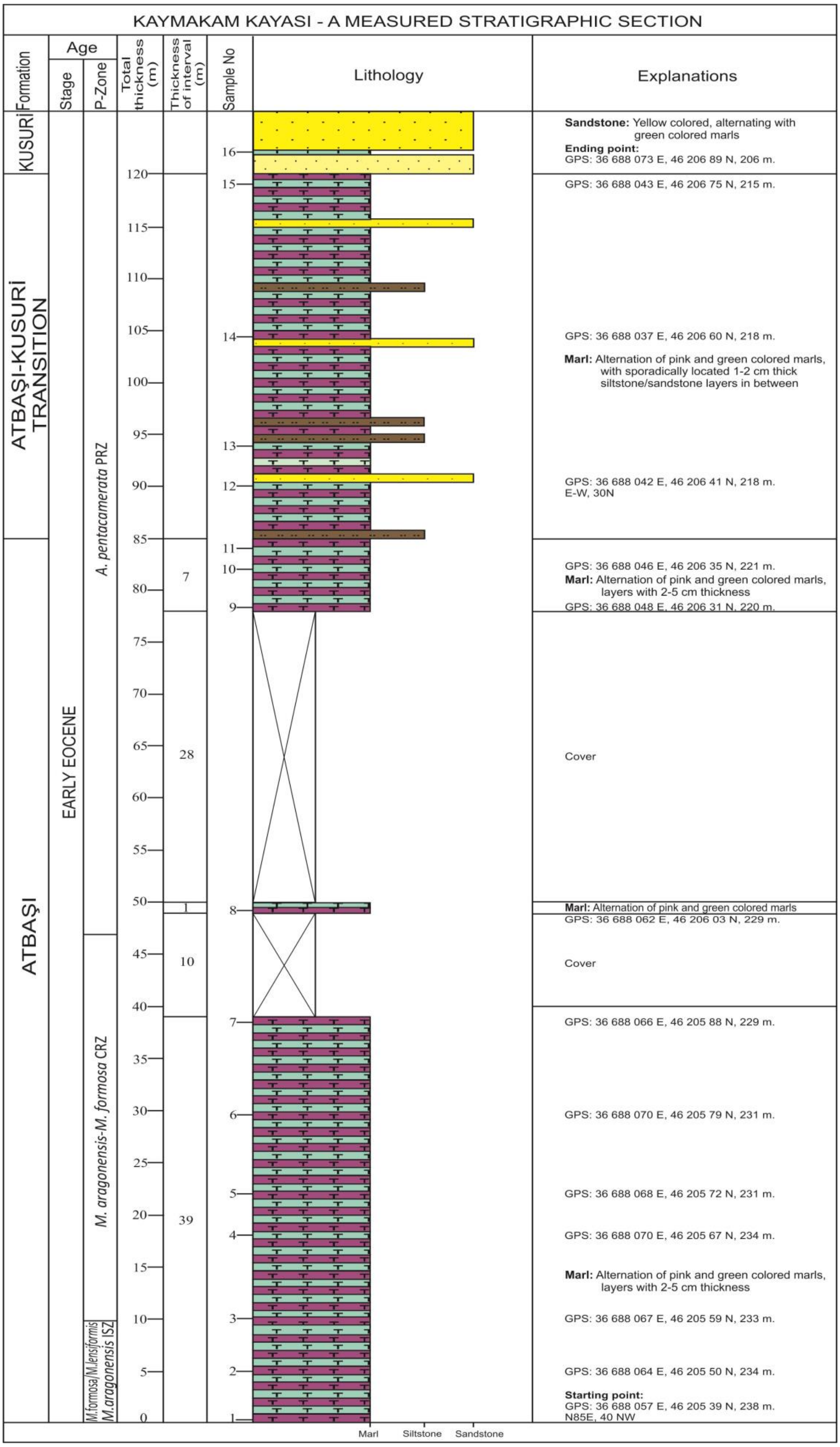

Figure 29. Columnar section of the Kaymakam Kayası-A Measured Stratigraphic Section

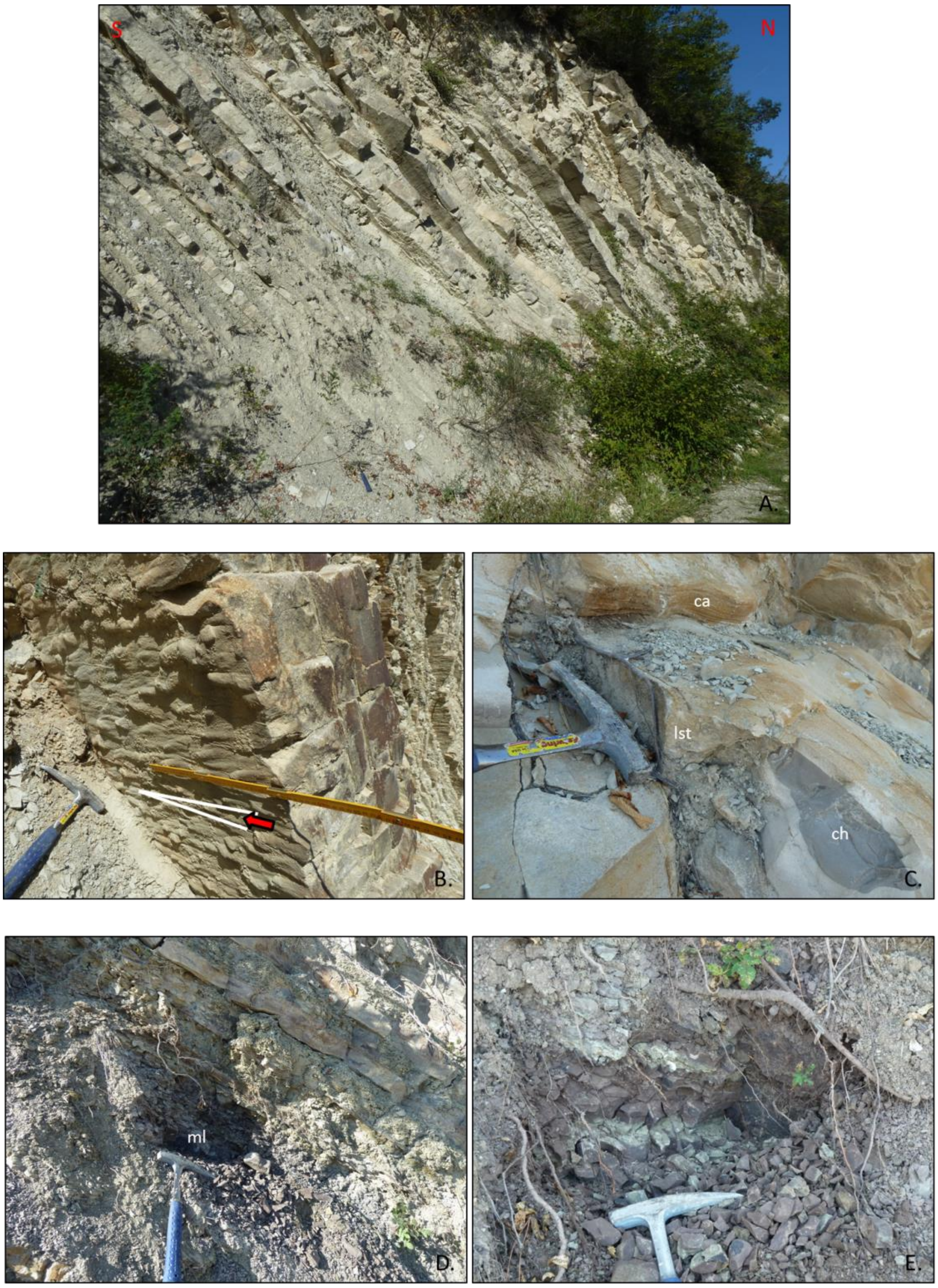

Figure 30. Field photographs of the Kaymakam Kayası Measured Stratigraphic Section. **A.** General view of the Akveren Formation**, B.** Flute casts under the calcarenites of the Akveren Formation, **C.** Uppermost part of the Akveren Formation; chert nodules (ch) inside limestone (lst) overlying by laminated calcarenites (ca), **D.** General view of the Atbaşı formation with pinkish colored marls, **E.** Close-up view of the Atbaşı Formation with alternating pinkish and greenish marls.

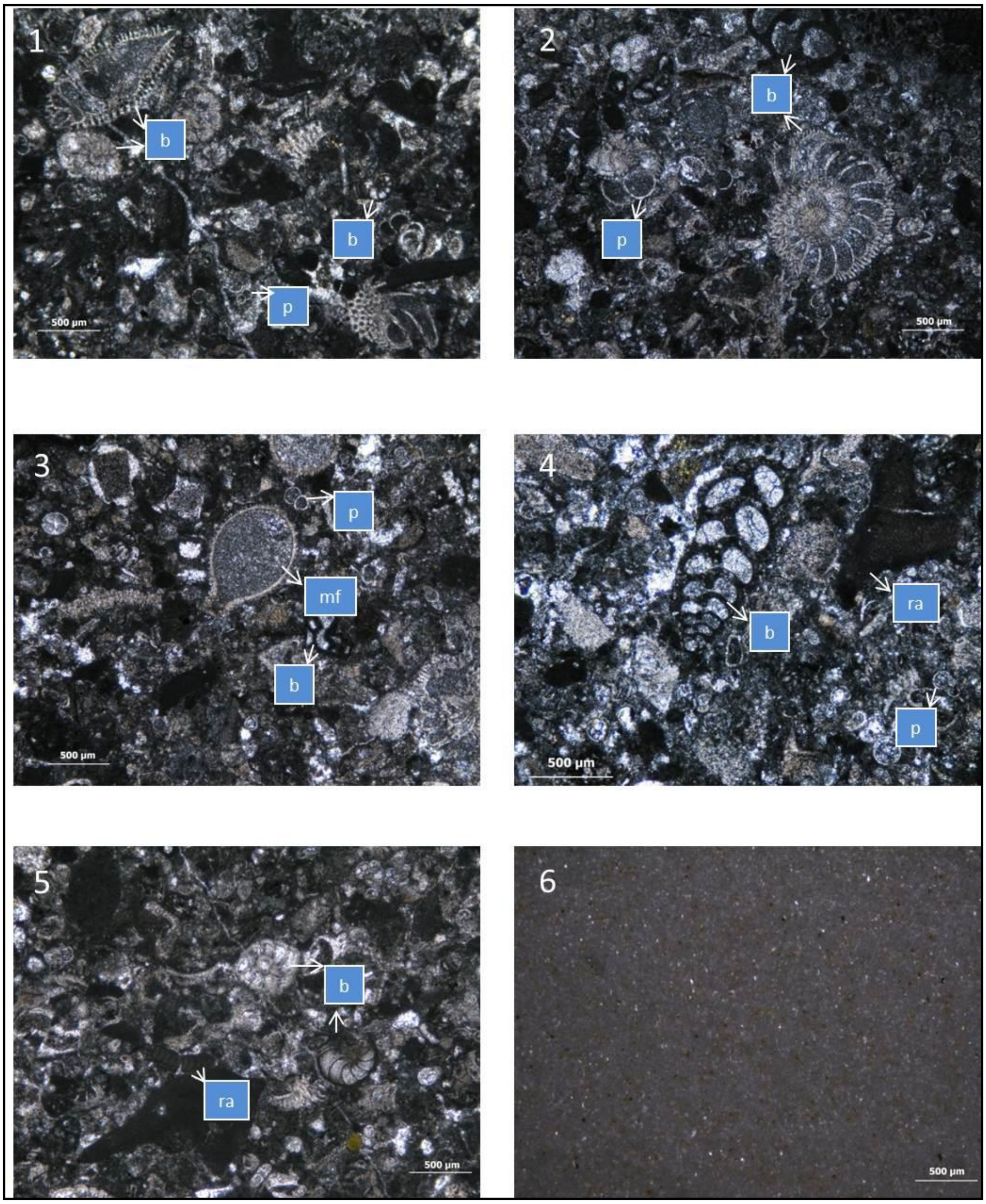

Figure 31. Thin section microphotographs of the Kaymakam Kayası MSS. **1-5.** Calcarenite with benthic foraminifera (b), planktonic foraminifera (p), red algae (ra) and macrofossil fragments (mf), Sample No. 18; **6.** Mudstone, Sample No. 27.

CHAPTER 3

BIOSTRATIGRAPHY

The early Paleogene is increasingly attracting the attention of the scientific community as it represents one of the more climatically and evolutionary dynamic periods in the Earth history. The environmental perturbation induced by the PETM and MECO, as recorded by changes in foraminiferal assemblages and lithology. Planktonic foraminiferal assemblages show prominent changes in composition and relative abundances in this interval.

The potential of planktonic foraminifera as a biostratigraphical tools for the early Paleogene interval has been well documented in many studies since 1930's (Glaessner, 1934; Morozova, 1939; Subbotina, 1947; Subbotina, 1953, Bolli, 1957a, 1957b, 1966; Berggren, 1960, 1971a, 1971b; Shutskaya *et al*., 1965; Shutskaya, 1970; Bolli *et al.,* 1985; Toumarkine and Lutherbacher, 1985; Berggren and Miller, 1988; Pearson, 1993; Berggren *et al.*, 1995; Berggren and Norris, 1997; Molina *et al.*, 1999; Olsson *et al.*, 1999; Berggren and Pearson, 2005; Pearson *et al.,* 2006; Batı *et al.*, 2009; Zakrevskata *et al*., 2011; Beniamovski, 2012). However, there are some differences between the previous work of tropical-subtropical and Peritethys regions through this interval (Figure 32). For example, for the international tropical-subtropical biozonations, P zones have been defined after Berggren and Miller (1988), whereas Berggren and Pearson (2005) defined Paleocene zones as P zones and Eocene zones as E zones (Figure 32). Besides the standard zonations, several authors have defined different biozones and correlated them with these standard zonations (Imam, 2001; Obaidalla, 2001; Warraich and Nishi, 2003; Payros *et al*., 2006; Khalil and Al Sawy, 2014) (Figure 33). For the Peritethys zonation, PF zones, indicating the planktonic foraminifera zones, have been defined by some endemic species (Beniamovski, 2001; Akhmetiev and Beniamovski, 2003; Akhmetiev and Beniamovski, 2006; Zakrevskata *et al*., 2011; Beniamovski, 2012) (Figure 32). On the other hand, as the previous studies in the Black Sea region are considered; the deficiency of a detailed biostratigraphical framework attracts the attention. Batı *et al.* (2009) and Shiklinsky *et al.* (2009) point out that the Paleogene sequences, mostly the Eocene deposits widely distributed on the onshore and offshore Black Sea; comprise planktic foraminiferal distribution data with abundant and diversified taxa that is suitable for the construction of a detailed biostratigraphical framework. The authors also state that the stratigraphical ranges of the planktonic foraminifera along Black Sea realm are different than both Mediterranean faunas and Caspian-Caucasus-Crimean faunas or some index Mediterranean taxa are missing for the Black Sea realm. Therefore, the high diversity of the assemblage makes the correlation of the Black Sea sequences available with the Caspian, Crimean-Caucasus and Mediterranean realms and the establishment of a detailed Paleogene biostratigraphy is important for the Black Sea region.

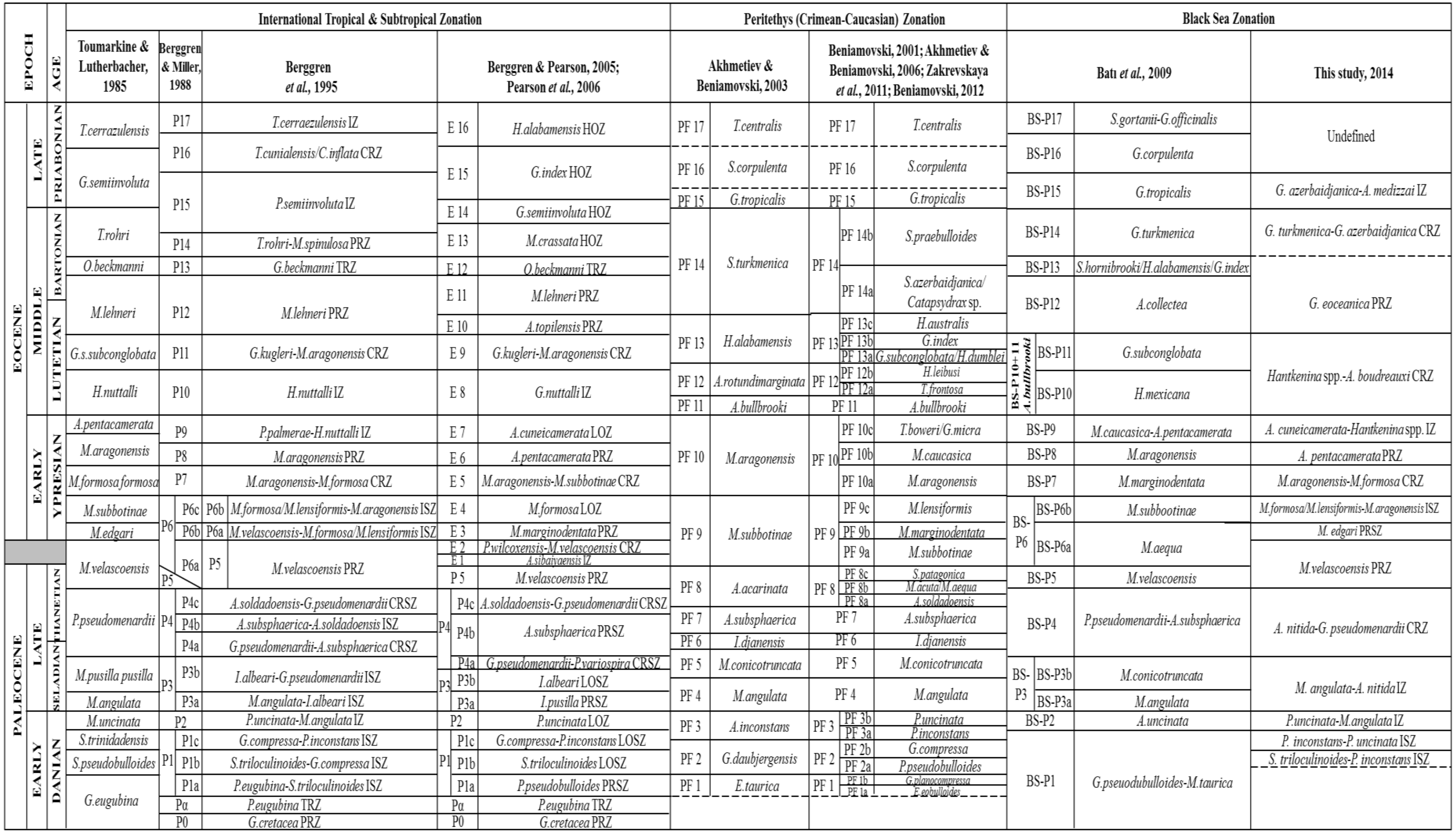

Figure 32. Comparison of planktonic foraminifera zonation schemes.

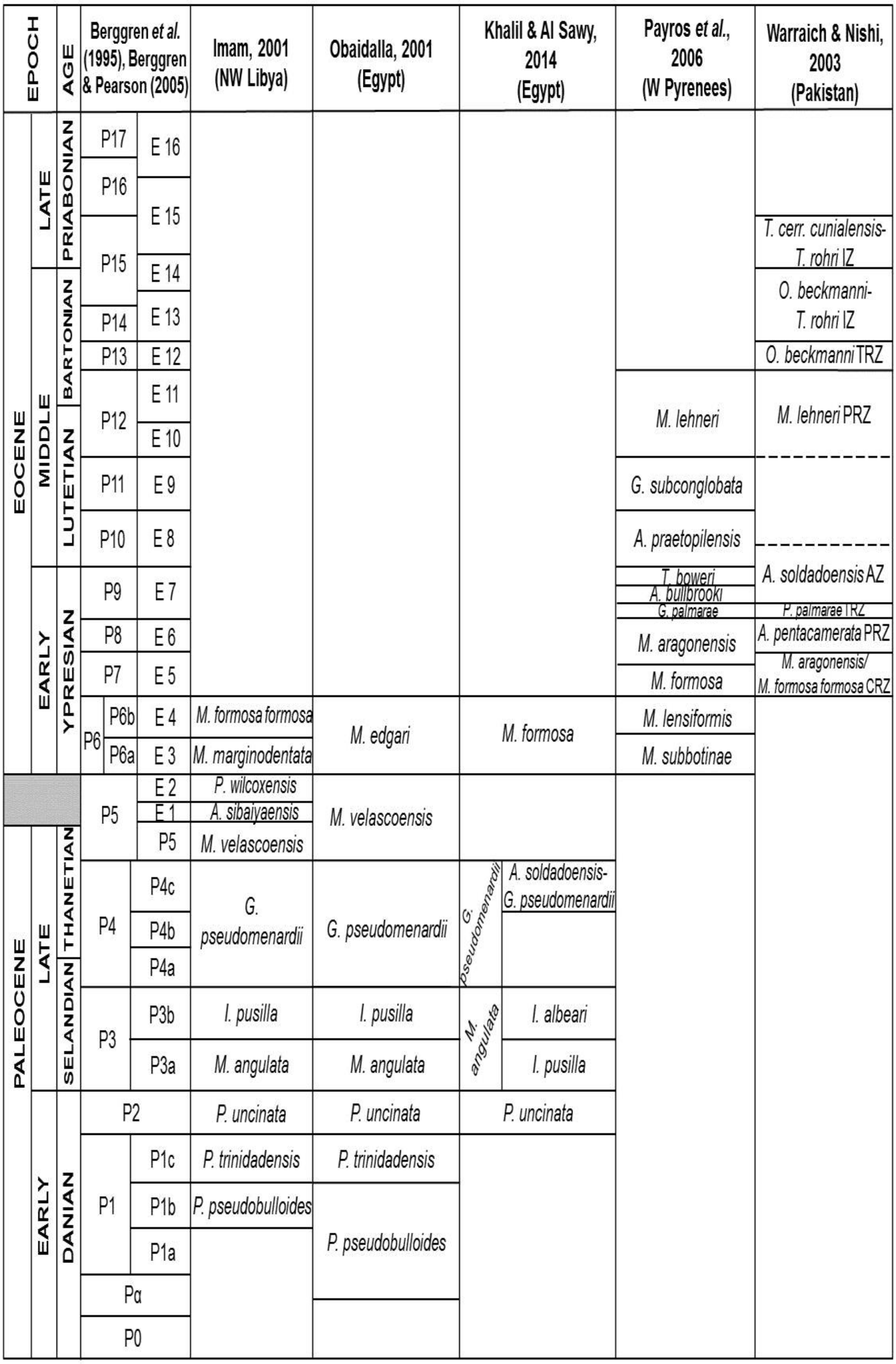

Figure 33. Comparison of planktonic foraminifera zonation schemes in Tethys.

In the present study, the abundance and the diversity of the planktonic foraminifera assemblage aren't as rich as the ones that have recorded in these previous studies in the Black Sea region (Batı *et al.,* 2009; Shiklinsky *et al.,* 2009). Moreover, some discrepancies were noticed with respect to standard zonations as the index species in the standard biozonations aren't always present in our samples. Another problem in establishing the biozonation is to determine the first and last occurrence datum of the fauna. Mainly the datums suggested by Olsson *et al.* (1999) and Pearson *et al*. (2006) are firstly considered to mark the common first and last appearances of zone marker species in the standard Mediterranean biozonation and our index taxa. However, it is noticed that different first and last appearances are recorded for the same species in the different publications **(**Tables 2, 3**)**. These differences make it harder to define a new biozones. Therefore, the range data that is common in many different references are thought to be more confident in our decisions.

In spite of all these difficulties, a new biozonation is established in this study for the Black Sea region. This zonation is different from the ones in Mediterranean, Crimean-Caucasus and also from the previous zonation established by Batı *et al.* (2009) and Shiklinsky *et al.* (2009). In this study biostratigraphical framework for the Early Paleogene in the Black Sea region has been constructed by using planktonic foraminifera.

3.1 PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY

The samples in this study have yielded moderate preservation and low to high abundances. The assemblage consists of a few individuals to tens of specimens per sample with diversity generally more than 4 species which are dominated by subbotinids and morozovellids. The Early Paleocene is dominated by 4 or 5-chambered, low trochospiral groups, such as *Praemurica* and *Parasubbotina.* During the Late Paleocene, the fauna is dominant by robust acarininids, morozovellids, tripartite subbotinids and forms with imperforate band or keel (genus *Globanomalina*) (Figure 34). Morozovellids and acarininids are common also in Early Eocene (Figure 34). By the Middle Eocene, new genera such as *Hantkenina, Globigerinatheka* and *Morozovelloides* appears, whereas *Morozovella* extinct at the end of Lutetian (Figure 34). Accordingly, there is a distinct change between Early and Middle Eocene assemblages. However, the index Middle Eocene genera unfortunately aren't abundant and diversified in our measured sections. Although the Upper Eocene successions aren't widespread over the Western Black Sea, the previous studies show that the assemblage is dominated by *Globigerinatheka* and *Turborotalia* during the Late Eocene (Figure 34), which are also rare in our sections; whereas the planktonic foraminiferal assemblage replaced by the benthic fauna and non-foraminifera towards the end of Late Eocene.

The resulting distribution data is used to divide the Paleocene-Eocene interval into biozones, each zone characterized by a unique assemblage with discrete boundaries defined by the first and last occurrences of certain marker species. In addition to planktonic foraminifera, benthic foraminifera are also recognized from the studied samples. They were only distinguished into two groups: agglutinated and calcareous wall bearing forms.

Table 2. First and last appearances of the Paleocene planktonic foraminifera (FAD: First appearance datum, LAD: Last appearance datum).

Species	**Stott & Kennett, 1990**	**Obaidalla, 2001 (Red Sea Coast, Egypt)**	**Khalil & Sawy, 2014 (Western Desert, Egypt)**	**Obaidalla *et al.*, 2009 (Eastern Desert, Egypt)**	**Pardo *et al.*, 1999 (Kazakhstan)**	**Molina *et al.*, 1999 (Tethys)**	**Lu *et al.*, 1998 (Spain & Israel)**	**Quillevere *et al.*, 2002 (ODP Site 761B, Indian Ocean)**	**Berggren *et al.*, 2000 (DSDP Site 384, NW Atlantic Ocean)**	**Budagher-Fadel, 2012**
S. inconstans (FAD)	Base of AP1b (Middle part of P1b of Berggren & Miller, 1988)			P1c				Base of P1c	Base of P1c	
E. spirialis (FAD)			Upper part of P2	P1c				Upper part of P1c		Upper part of P1c
S. inconstans (LAD)	Top of AP2 (Top of P2 of Berggren & Miller, 1988)		Top of P4	Base of P3b				Top of P2	Upper part of P4a	
E. spirialis (LAD)			Middle part of P3a	Top of P4				Top of P3a		
S. pseudobulloides (LAD)	Lower part of AP4 (Middle part of P4 of Berggren & Miller, 1988)	Middle part of P3a	Top of P3a	Middle part of P3b				Top of P4a		Top of P3b
P. varianta (LAD)		Middle part of P3a						Middle part of P4b	Lower part of P4a	
A. nitida (FAD)		Upper part of P3a		Middle part of P4				Base of P4	Base of P4	Base of P4
S. triangularis (FAD)				Upper part of P3a				Base of P3a		Base of P2
M. praeangulata (FAD)			Base of P3b	Middle part of P1c				Base of P2		
G. compressa (LAD)		Upper part of P3b	Top of P4	Middle part of P2				Top of P3a		
G. chapmani (FAD)			Top of P4	Middle part of P2				Middle part of P4a	Middle part of P4a	
G. planoconica (FAD)			Top of P4	Middle part of P3b						
M. angulata (LAD)			Top of P3b	Top of P4		Lower part of P5		Lower part of P4a	Top of P3b	
M. conicotruncata (LAD)			Top of P3b	Top of P4	P6a	Lower part of P5		Middle part of P4a		
M. velascoensis (FAD)		Middle part of P4		Upper part of P3b	Base of P5a			Base of P3b	Base of P3b	
M. acuta (FAD)			Base of P4	Base of P3b				Base of P4b	Base of P4b	
M. occlusa (FAD)		Middle part of P4	Base of P4					Base of P3b		
A. soldadoensis (FAD)		Middle part of P4	Base of P4c		Middle part of P4	Middle part of P4		Base of P4c	Base of P4c	
A. coalingensis (FAD)							Base of P4c	Base of P4c	Base of P4c	
S. linaperta (FAD)		Middle part of P4		Middle part of P4						
S. triloculinoides (LAD)		Middle part of P4	Top of P3b					Top of P4b	Top of P4b	
P. uncinata (LAD)			Top of P4	Lower part of P3b						
P. variospira (LAD)			Top of P4					Top of P4a	Lower part of P4a	
M. praeangulata (LAD)			Top of P4	Middle part of P3b				Top of P3a		
M. acuta (LAD)			Top of P4	Top of P4						
M. occlusa (LAD)			Top of P4					Middle part of P4b		

Table 3. First and last appearances of the Eocene planktonic foraminifera (FAD: First appearance datum, LAD: Last appearance datum).

Species	Luciani *et al.*, 2007 (NE Italy)	Stott & Kennett, 1990	Lu & Keller, 1995 (DSDP Site 577)	Obaidalla, 2001 (Red Sea Coast, Egypt)	Khalil & Sawy, 2014 (Western Desert, Egypt)	Pardo *et al.*, 1999 (Kazakhstan)	Molina *et al.*, 1999 (Tethys)	Lu *et al.*, 1998 (Spain & Israel)	Quillevere *et al.*, 2002 (ODP Site 761B, Indian Ocean)
I. lodoensis (FAD)	Lower part of P5 (Lower part of *M.aequa* zone of Molina *et al.*, 1999)						P4c	Middle part of P4	
M. gracilis (FAD)	Lower part of P5 (Zone marker for *M.gracilis* zone of Molina *et al*, 1999)		Upper part of P6a (Below P/E boundary)	Base of P5	Base of E1	P5b (E1)	Lower part of P5	Upper part of P5a	
M. aequa (FAD)			Middle part of P3b		Base of P4c			P4	Base of P4c
M. marginodentata (FAD)	Middle part of P5 (Above *M. gracilis)*				Base of P4c		Lower part of P5	Middle part of P4	
A. berggreni (FAD)	Just below P/E boundary (Upper part of P5)	Base of AP6 (Middle part of P6b/E3)					Just before P/E boundary		
A. wilcoxensis (FAD)	Just below P/E boundary (Upper part of P5)		Base of P6b (Just below P-E boundary)			P4		Just below P5b (Below P/E boundary)	
P. varianta (FAD)	Just below P/E boundary (Upper part of P5)			Base of P1					Base of P1b
I. broadermanni (FAD)	At P/E boundary (Upper part of P5)						Base of P6a		
P. wilcoxensis (FAD)	Base of E2					Middle part of P6a	Upper part of P5- Above P/E boundary	Base of P5b (Below P/E boundary)	
M. subbotinae (FAD)			Base of P6a (Below P/E boundary)	Base of P5 (Below P/E boundary)	Base of P4	P4	Upper part of P4c	Middle part of P4	Base of P5
M. edgari (FAD)	Middle part of E2		Base of P6a (Below P/E boundary)	Base of P5 (Below P/E boundary)			Lower part of P5- Below P/E boundary	P4	
M. velascoensis (LAD)	Top of E2			At P/E boundary (Top of P5)	Top of E2	Top of P5b (E1)	Top of P5	Top of P5b (At P/E boundary)	
A. esnaensis (FAD)				At P/E boundary (Top of P5)				Just below P5b (Below P/E boundary)	
M. acuta (LAD)	Top of E2						Lower part of P6a		Upper part of P4b
M. occlusa (LAD)	Top of E2						Lower part of P6a	Lower part of P6b	
M. passionensis (LAD)	Top of E2								Middle part of P5
S. linaperta (FAD)					Base of E3			P4	
M. lensiformis (FAD)					Lower part of E3		Upper part of P5 (E2)	Middle part of P6a	
M. edgari (LAD)			Middle part of P7			Upper part of P6a	Middle part of P6a	P6b	

Table 3. (Continued).

Species	Ortiz *et al.*, 2008	Stott & Kennett, 1990	Abdel-Kireem & Samir, 1995 (Western Desert, Egypt)	Lu & Keller, 1995 (DSDP Site 577)	Zakrevskaya *et al.*, 2011 (Crimean-Caucasian)	Obaidalla, 2001 (Red Sea Coast, Egypt)	Khalil & Sawy, 2014 (Western Desert, Egypt)	Payros *et al.*, 2006 (W Pyrenees)	Pardo *et al.*, 1999 (Kazakhstan)	Molina *et al.*, 1999 (Tethys)	Lu *et al.*, 1998 (Spain & Israel)	Warraich & Nishi 2003 (Pakistan)	Budagher-Fadel, 2012	Pearson *et al.*, 2006
M. formosa (FAD)				Base of P6b (Just below P-E boundary)				Base of P7		Base of P6b	Lower part of P6a			
A. wilcoxensis (LAD)				Top of P8				Upper part of P7	Base of P6b			Top of P7		
M. subbotinae (LAD)				Middle part of P7			Top of E4	Upper part of P7				Top of P7		
M. gracilis (LAD)				Uppermost part of P7			Top of E4	Lower part of P9						
M. aequa (LAD)							Top of E4	Top of P8						
M. formosa (LAD)				Top of P7				Top of P8				Top of P7		
M. crater (FAD)								Base of P9		Middle part of P6b	Upper part of P6b			
A. soldadoensis (LAD)	Base of E10					Middle part of P4	Top of E4	Lower part of P10				Top of P10		
A. pentacamerata (FAD)		Base of AP6b (Base of P8/E6)	Base of *M. aragonensis* Zone					Base of P6b					Upper part of P7	Base of P7
A. cuneicamerata (LAD)				Base of P9									Base of P8	Base of P8
M. lensiformis (LAD)								Top of P8				Top of P7		
T. frontosa (FAD)	Lower part of E7											Middle part of P9		
A. primitiva (FAD)		Base of AP7 (Middle part of P9/E7)	Middle part of *M. uncinata* Zone			Upper part of P3a	Base of P4							
A. primitiva (LAD)						Top of E3	Middle part of P4							
S. linaperta (LAD)					Base of AP7 (Middle part of P9/E7)		Top of E4				Lower part of P5a			
S. triangularis (LAD)								Middle part of P9		Upper part of P6a	Lower part of P5a			
P. wilcoxensis (LAD)								Middle part of P9	P6a			Middle part of P9		
A. pseudotopilensis (LAD)								Middle part of P9				Top of P7		
A. pentacamerata (LAD)								Middle part of P9				Middle part of P9		
G. planoconica (LAD)								Middle part of P10						
A. esnaensis (LAD)								Upper part of P10				Top of P7		
H. mexicana (FAD)	Middle part of E8 (Base of P10)							Upper part of P10				Midlle part of P12	Base of P11b	Base of P10
G. subconglobata (FAD)	Upper part of E8 (Middle part of P10)							Middle part of P10					Base of P10b	Middle part of P10
H. dumblei (FAD)	Upper part of E8 (Middle part of P10)							Upper part of P10				Midlle part of P12		Middle part of P11
A. pentacamerata (LAD)	Top of E9				Middle part of PF13a (Middle part of E9)									
M. aragonensis (LAD)	Top of E9				Top of PF13b (Top of E9)			Upper part of P10				Top of P8		

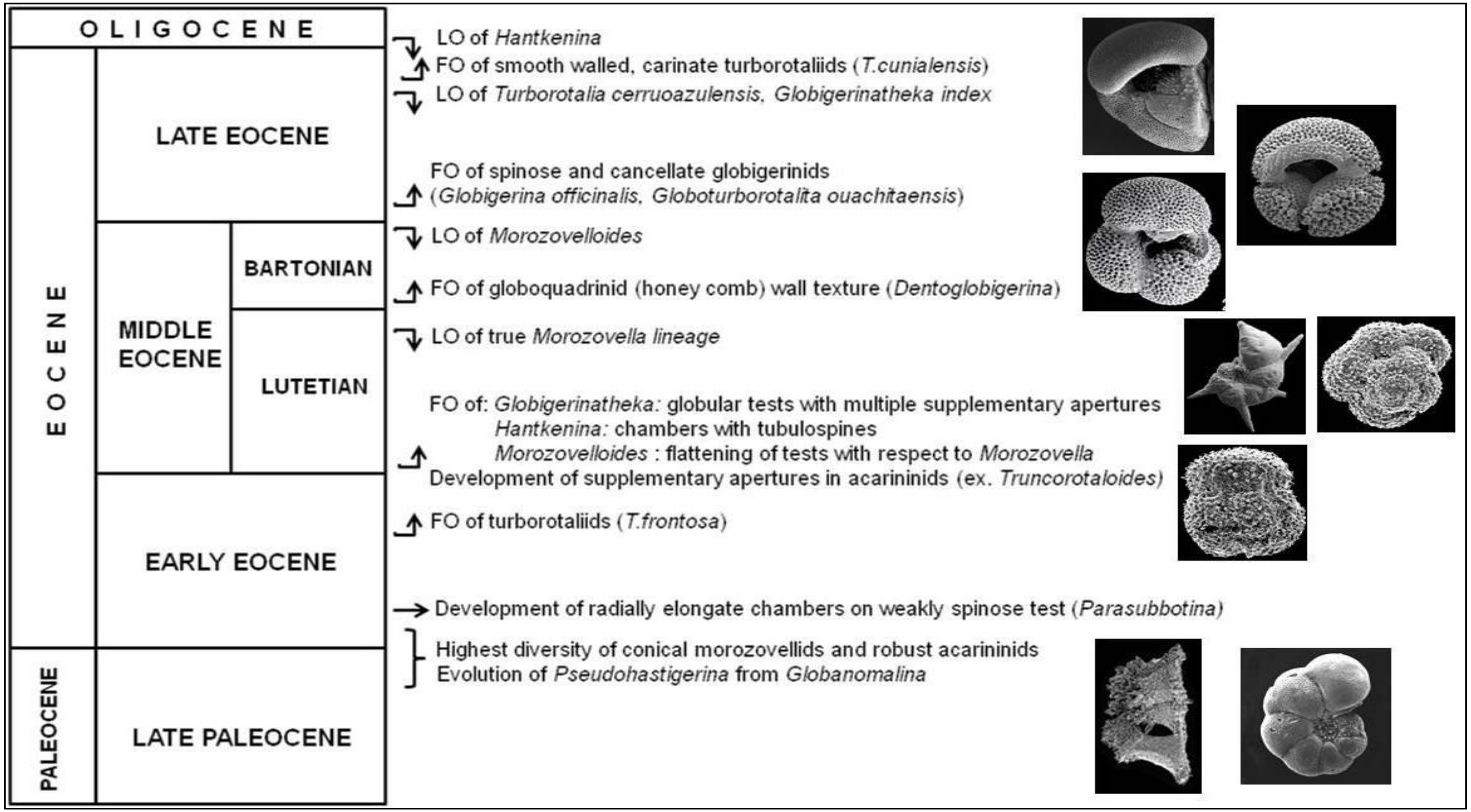

Figure 34 Key events for planktonic foraminifera during Late Paleocene-Eocene interval (based on Berggren and Pearson, 2005).

Relative abundances of them were given. Fish teeth, ostracoda and radiolaria fragments are also recorded.

The Paleocene-Eocene interval of the studied sequences is assignable to the following 13 biostratigraphic zones and 4 subzones. In ascending order: *Parvularugoglobigerina eugubina-Praemurica uncinata* Interval Zone (*Subbotina triloculinoides-Praemurica inconstans* Interval Subzone and *Praemurica inconstans-Praemurica uncinata* Interval Subzone), *Praemurica uncinata-Morozovella angulata* Interval Zone, *Morozovella angulata-Acarinina nitida* Interval Zone, *Acarinina nitida-Globanomalina pseudomenardii* Concurrent Range Zone, *Morozovella velascoensis* Partial-range Zone, *Morozovella subbotinae* Partial-range Zone (*Morozovella edgari* Partial-range Subzone and *Morozovella* formosa/Morozovella *lensiformis-Morozovella aragonensis* Interval Subzone), *Morozovella aragonensis-Morozovella formosa* Concurrent-range Zone, *Acarinina pentacamerata* Partial-range Zone, *Acarinina cuneicamerata-Hantkenina* spp. Interval Zone, *Hantkenina* spp.*-Acarinina boudreauxi* Concurrent-range Zone, *Globigerina eoceanica* Partial-range Zone, *Globigerina turkmenica-Globigerina azerbaidjanica* Concurrent-range Zone and *Globigerina azerbaidjanica-Acarinina medizzai* Interval Zone.

3.1.1. Early Paleocene

Early Paleocene is recognized in the lower parts of Erfelek, Erfelek 1 and Kaymakam Kayası sections. Although the Erfelek and the Erfelek 1 sections starts with Maastrichtian, the lowermost Paleocene (P0, Pα, P1a zones) wasn't defined in this sections probably because of the wide sampling interval in the lower parts of the sections. These zones weren't defined also in the Kaymakam Kayası Section, as the section starts with the *Praemurica inconstans-Praemurica uncinata* Interval Subzone.

Parvularugoglobigerina eugubina-Praemurica uncinata Interval Zone

Definition: Interval between the last appearance of *Parvularugoglobigerina eugubina* and the first appearance of *Praemurica uncinata.*

Author: Berggren and Miller, 1988 (emended by Berggren *et al*., 1995)

Correlation: This zone is the lowermost Paleocene biozone defined in the present study. It is the equivalent of P1 Zone of Berggren and Miller (1988). However, the lowermost part of this zone, which is the equivalent of P1a subzone of the authors, hasn't been recorded in this study. This zone is defined as *Eoglobigerina edita* Partial Range Zone by Berggren and Pearson (2005) and it is the equivalent of the total interval of PF1 to PF3a zones of Akhmetiev and Beniamovski (2006) and upper part of *Globigerina pseuodubulloides-Morozovella taurica* (BS-P1) Zone of Batı *et al.* (2009).

Remarks: The zone is defined as an interval zone by Berggren and Miller (1988), Berggren *et al*. (1995) and Olsson *et al*. (1999). However, the authors defined an interval between the last occurrence and a following first appearance and stratigraphical range of these species aren't coinciding with the zone. Therefore, this zone should be defined as a partial range zone.

Stratigraphic distribution: Erfelek MSS, sample no. 15-41 and Erfelek 1 MSS, sample no. 9-19.

Age: Early Paleocene

***Subbotina triloculinoides-Praemurica inconstans* Interval Subzone**

Definition: Interval between the first appearance of *Subbotina triloculinoides* and the first appearance of *Praemurica inconstans*.

Author: Berggren and Miller, 1988 (emended in this study, 2014)

Correlation: This subzone is the equivalent of P1b Subzone of Berggren and Miller (1988) (Figure 31). Berggren *et al*. (1995) emended the zone as *Subbotina triloculinoides-Globanomalina compressa*/*Praemurica inconstans* Interval Subzone. This zone was also used by Olsson *et al*. (1999). *Parasubbotina pseudobulloides* Subzone is defined by Imam (2001) as P1b and it is the equivalent of the upper part of the same subzone defined by Obaidalla (2001) (Figure 33). Akhmetiev and Beniamovski (2003) defined a PF2 zone that is equivalent of the *Subbotina triloculinoides-Praemurica inconstans* Interval Subzone in this study, except its uppermost part. Berggren and Pearson (2005) defined *Subbotina triloculinoides* Lowest-occurrence Subzone equivalent to this subzone.

Remarks: This subzone is described in the Erfelek Section by the first occurrence of *Subbotina triloculinoides* recorded above the Cretaceous samples (Figure 35). Therefore, the base of the zone is absent in the section. Its upper boundary is defined by the first occurrence of *Praemurica inconstans* in the same section. In this interval, *Subbotina triloculinoides* and *Parasubbotina pseudobulloides* are the dominating species, whereas *Parasubbotina varianta, Subbotina triangularis, Eoglobigerina spirialis* are present. Agglutinated walled benthic foraminifera are generally dominant with respect to calcareous walled benthics. Sporadic fish teeth, ostracoda and radiolaria fragments are also recorded.

Stratigraphic distribution: Erfelek MSS, sample no. 15-27; Erfelek 1 MSS, sample no. 9.

Age: Early Paleocene

***Praemurica inconstans-Praemurica uncinata* Interval Subzone**

Definition: Interval between the first appearance of *Praemurica inconstans* and the first appearance of *Praemurica uncinata.*

Author: Berggren and Miller, 1988 (emended in this study, 2014)

Correlation: This subzone is the equivalent of P1c Subzone of Berggren and Miller (1988). The authors defined the P1c Subzone as *Morozovella inconstans-Planorotalites compressus* Partial Range Subzone. Then, it is emended by Berggren *et al*. (1995) as *Globanomalina*

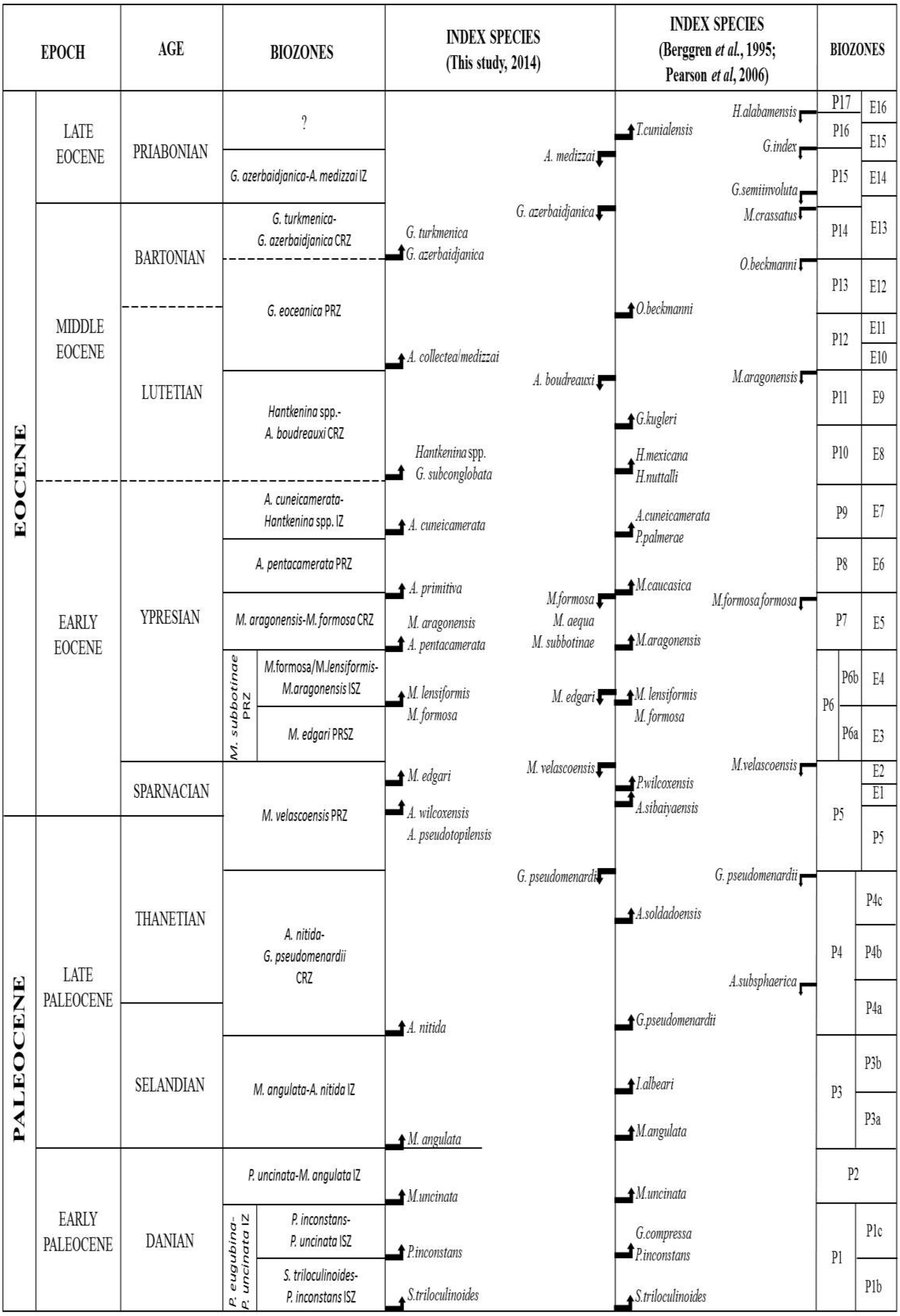

Figure 35. Planktonic foraminifera zonation scheme and bioevents used in this study and their correlations with the standard tropical-subtropical zonations. Key events for planktonic foraminifera observed in the studied sections.

compressa/Praemurica inconstans-Praemurica uncinata Interval Subzone. This subzone was also used by Olsson *et al*. (1999) and Berggren *et al*. (2000) (Figure 32). Imam (2001) and Obaidalla (2001) defined this subzone as *Praemurica trinidadensis* Subzone (Figure 33). Berggren and Pearson (2005) used *Globanomalina compressalPraemurica inconstans* Lowest-occurrence Subzone as the equivalent of this subzone.

In the Peritethys Zonation, this zone is correlated with the *Globanomalina compressa* (PF2b) and *Praemurica inconstans* (PF3a) subzones (Beniamovski, 2001; Akhmetiev and Beniamovski, 2006; Zakrevskaya *et al.*, 2011; Beniamovski, 2012) (Figure 32).

Remarks: This subzone is described in the Erfelek and the Erfelek 1 sections. Its lower boundary is defined in the Erfelek Section by the first occurrence of *Praemurica inconstans*, whereas the first occurrence of *Globanomalina compressa* is after this level in this section (Figure 35). Therefore, *Globanomalina compressa* isn't used to define this subzone in this study. The upper boundary of this subzone is defined in the Erfelek 1 Section by the first occurrence of *Morozovella uncinata* and this level is correlated with the sample 42 of the Erfelek Section.

In this interval, *Subbotina triloculinoides* and *Parasubbotina varianta* are the dominating species in the Erfelek Section. *Globanomalina compressa*, *Subbotina triangularis*, *Parasubbotina pseudobulloides*, *Praemurica inconstans* and *Praemurica pseudoinconstans* are also present in the samples. Both agglutinated and calcareous benthic foraminifera species are common through this interval, while the fish teeth, ostracods and radiolaria are sporadic.

Stratigraphic distribution: Erfelek MSS, sample no. 28-41; Erfelek 1 MSS, sample no. 10-19.

Age: Early Paleocene

***Praemurica uncinata-Morozovella angulata* Interval Zone**

Definition: Interval between the first appearance of *Praemurica uncinata* and the first appearance of *Morozovella angulata.*

Author: Berggren and Miller, 1988 (emended Berggren *et al*., 1995)

Correlation: This zone is the equivalent of P2 Zone of Berggren and Miller (1988). Shutskaya (1965, 1970) defined the P2 zone as *Acarinina inconstans* Zone. His P2 Zone coincides with *Globorotalia uncinata* Zone of Bolli (1966), *Globorotalia uncinata-Globigerina spirialis* Concurrent Range Zone of Berggren (1969), *Globorotalia* (*Acarinina*) *praecursoria* Partial Range Zone of Blow (1979), *Morozovella uncinata-Igorina spirialis* Partial Range Zone of Berggren and Miller (1988) and *Praemurica uncinata-Morozovella angulata* Partial Range Zone of Berggren *et al*. (1995, 2000) (Figure 32). Imam (2001), Obaidalla (2001) and Khalil and Al Sawy (2014) used *Praemurica uncinata* Zone as the equivalent of this zone (Figure 33).

With respect to the Peritethys zonations this zone is correlated by the upper part of *Acarinina inconstans* Zone (PF3) of Akhmetiev and Beniamovski (2003), whereas *Praemurica uncinata* Subzone (PF3b) is described by Beniamovski (2001), Akhmetiev and Beniamovski (2006), Zakrevskaya *et al*. (2011) and Beniamovski (2012). Batı *et al*. (2009) defined the BS-P2 Zone as *Acarinina uncinata* Zone (Figure 32).

The Danian-Selandian boundary was drawn as the upper boundary of P2 Zone until Berggren *et al.* (1995). However, Berggren *et al.* (2000) put the boundary from the upper part of P3a Zone and included P2 to the upper part of Danian. Olsson *et al*. (1999) divided Paleocene into two parts as Early and Late Paleocene, in which the upper boundary of P2 zone coincides with the boundary.

Remarks: In the present study, this zone is defined for the interval between the first appearance of *Praemurica uncinata* and the first appearance of *Morozovella angulata* in the Erfelek 1 Section (Figure 35). The fossil assemblage of this zone isn’t different than that of the previous subzones. This zone is also dominated by the species of *Subbotina*, *Parasubbotina* and *Praemurica* in the sections with abundant agglutinated and calcareous benthic foraminifera and sporadic fish teeth. However, the planktonic foraminifera are absent or very rare in the middle parts of the zone in the Erfelek Section. In these samples, benthic foraminifera are rare and radiolaria are common in one of the samples.

Stratigraphic distribution: Erfelek MSS, sample no. 42; Erfelek 1 MSS, sample no. 20-25.

Age: Early Paleocene

3.1.2. Late Paleocene

Late Paleocene is recognized in Erfelek, Erfelek 1 and Kaymakam Kayası sections. The biozones have not been identified separately as the index species weren’t recorded in the Erfelek and the Erfelek 1 sections, however the base and the top of the Late Paleocene is distinct in these sections. On the other hand, the Early-Late Paleocene boundary has not been defined in the Kaymakam Kayası Section, whereas the two biozones were defined for the Late Paleocene in this section.

Morozovella angulata-Acarinina nitida **Interval Zone**

Definition: Interval between the first occurrence of *Morozovella angulata* and the first occurrence of *Acarinina nitida*

Author: This study, 2014

Correlation: This zone is the equivalent of P3 Zone of Berggren and Miller (1988). P3 zone is used as *Globorotalia* (*Morozovella*) *angulata angulata* Partial Range Zone by Blow (1979), *Morozovella angulata-Igorina pusilla pusilla* Concurrent Range Zone by Berggren and Miller (1988) and *Morozovella angulata-Globanomalina pseudomenardii* Interval Zone by Berggren *et al.* (1995) (Figure 32). Khalil and Al Sawy (2014) defined the zone as Khalil and Al Sawy (2014) defined the zone as *Morozovella angulata* Zone (Figure 33).

This zone is correlated with the total range *Morozovella angulata* (PF4) and *Morozovella conicotruncata* (PF5) zones of Akhmetiev and Beniamovski (2003) except the uppermost part of their PF5 Zone (Figure 32). Batı *et al.* (2009) defined the zone as *Morozovella angulata* Zone (BS-P3) for the Black Sea Region.

The base of P3 Zone coincides with the upper boundary of the Danian, whereas the lower boundary of Selandian is located in the lower parts of the P3 Zone (Berggren *et al*., 1995). According to the authors, there is a gap between Danian and Selandian in the lowermost part of this zone. On the other hand, Berggren *et al*. (2000) didn't record this gap for the DSDP Site 384 and placed the Danian-Selandian boundary from the lower part of P3 Zone. Olsson *et al*. (1999) mentioned the base of P3 Zone as the Early and Late Paleocene boundary.

Two subzones; *Morozovella angulata-Igorina albeari* Interval Subzone and *Igorina albeari-Globanomalina pseudomenardii* Interval Subzone, are defined for this zone that are marked by the first occurrence of *Igorina albeari* (Berggren *et al*., 1995).

Remarks: In this study, the base of this zone is defined by the first appearance of *Morozovella angulata* in the Erfelek and the Erfelek 1 sections (Figure 35). The top of this zone isn't distinct in the Erfelek and the Erfelek 1 sections because of the absence of *Acarinina nitida* or *Globanomalina pseudomenardii*. On the other hand, the lower boundary of the zone isn't defined in the Kaymakam Kayası Section. It is thought to be earlier than the last occurrence of *Parasubbotina pseudobulloides* and *Praemurica inconstans* in sample 11. The upper boundary of the zone is defined by the first appearance of *Acarinina nitida* in the Kaymakam Kayası Section.

Subzones aren't defined for the zone in this study as *Igorina albeari* subzones because of absence of nominal species in the samples.

Parasubbotina and *Praemurica* species of the Early Paleocene mostly disappear in the lower part of this zone. The first appearance of the robust acarininids and the diversification of the morozovellids are also within the *Morozovella angulata-Acarinina nitida* Interval Zone.

Stratigraphic distribution: Erfelek MSS, sample no. 43-44; Erfelek 1 MSS, sample no. 26-?31; Kaymakam Kayası MSS, sample no. ?12-21.

Age: Late Paleocene

Acarinina nitida-Globanomalina pseudomenardii Concurrent Range Zone

Definition: Interval between the first occurrence of *Acarinina nitida* and the last occurrence of *Globanomalina pseudomenardii*

Author: Bolli, 1957a (emended in this study)

Correlation: This zone is the equivalent of *Globanomalina pseudomenardii* total range zone defined by Bolli (1957a). After the first definition of the zone, Bolli (1966) and Berggren (1969) defined a *Globorotalia pseudomenardii* Zone that covers the total of P3b and P4 zones that has been defined by Berggren *et al.* (1995). Berggren *et al.* (1995) defined the zone as an equivalent of *Planorotalites pseudomenardii* Zone of Berggren and Miller (1988), whose base defines the upper boundary of Selandian stage (Figure 32). On the other hand, the base of Thanetian is defined within the P4a Subzone of Berggren *et al.* (1995). On the other hand, Berggren *et al.* (2000) placed the Selandian-Thanetian boundary within the P4b Subzone. Imam (2001), Obaidalla (2001) and Khalil and Al Sawy (2014) defined *Globanomalina pseudomenardii* Zone in their studies (Figure 33).

This standart Mediterranean biozone is correlated with the interval covering the upper part of *Morozovella conicotruncata* (PF5), *Igorina djanensis* (PF 6), *Acarinina subsphaerica* (PF 7) and lower part of *Acarinina acarinata* (PF 8) zones of Akhmetiev and Beniamovski (2003) in the Peritethys Region. On the other hand, Batı *et al*. (2009) defined *Planorotalites pseudomenardii-Acarinina subsphaerica* Zone for BS-P4 Zone in Black Sea Region. This concurrent range zone is defined for P4a Subzone by Olsson *et al.* (1999) (Figure 26).

Globanomalina pseudomenardii-Acarinina subsphaerica concurrent range subzone, *Acarinina subsphaerica-Acarinina soldadoensis* interval subzone and *Acarinina soldadoensis-Globanomalina pseudomenardii* concurrent range subzone are defined for the *Globanomalina pseudomenardii* total range zone (Berggren *et al*., 1995; Olsson *et al*., 1999). The first appearances of *Acarinina subsphaerica* and *Acarinina soldadoensis* are the key events for these separations.

Remarks: In this study, *Globanomalina pseudomenardii* is described in a limited number of samples in the Kaymakam Kayası Section. Therefore, original zonation of Bolli (1957a) is emended and the base of the zone is defined by the first appearance of *Acarinina nitida*. The first occurrence of this species is same with the first occurrence of *Globanomalina pseudomenardii* with respect to Olsson *et al.* (1999), Berggren *et al*. (2000), Quillevere *et al.* (2002) and Boudagher-Fadel (2012). The upper boundary of this zone is defined by the last appearance of *Globanomalina pseudomenardii* (Figure 35).

Subzones aren’t defined for this zone because of the absence of *Acarinina subsphaerica* and *Acarinina soldadoensis* in the Kaymakam Kayası Section. However, the first occurrence of *Acarinina coalingensis* is recorded in sample no. 33. Its first occurrence is at same level with the first occurrence of *Acarinina soldadoensis* with respect to Berggren *et al*. (2000), Quillevere *et al.* (2002), Pearson *et al*. (2006) and Boudagher-Fadel (2012). Therefore, this sample is thought to belong to a level that is equivalent of *Acarinina soldadoensis-Globanomalina pseudomenardii* Concurrent Range Subzone (P4c) of Berggren *et al*. (1995).

The planktonic foraminiferal diversity and abundance is very low within this zone. Even the abundance of the subbotinids decreases with respect to the lower parts of the Kaymakam Kayası Section. The benthic foraminifera are also mostly rare except the middle part of the zone. There are also sporadic fish teeth occurrences.

Stratigraphic distribution: Kaymakam Kayası MSS, sample no. 22-33.

Age: Late Paleocene

***Morozovella velascoensis* Partial-range Zone**

Definition: Interval between the last occurrence of *Globanomalina pseudomenardii* and the last occurrence of *Morozovella velascoensis*

Author: Bolli, 1957a

Correlation: This zone is the equivalent of the P5 Zone of Bolli (1957a) and P5+P6a zones of Berggren and Miller (1988) (Figure 32). Toumarkine and Luterbacher (1985) mentioned the zone as the uppermost zone of the Paleocene. On the other hand, regarding to Berggren *et al.* (1995) and Olsson *et al.* (1999), this zone extends from latest Paleocene to earliest Eocene (55.9-54.7 Ma) (Figure 26). Therefore, the authors identify the Paleocene-Eocene boundary within P5 zone. Later, Imam (2001), Berggren and Pearson (2005) and Pearson *et al.* (2006) limited the P5 zone with the latest Paleocene (55.9-55.5 Ma) by defining E Zones for the Eocene and the Paleocene-Eocene boundary is marked with the boundary of P5-E1 biozones. Obaidalla (2001) used the last occurrence of the nominate taxon for defining the upper boundary of the *Morozovella velascoensis* Zone (Figure 33).

For the Peri-Tethyan correlation, Paleocene section of P5 zone of Berggren *et al*. (1995) is the equivalent of the middle parts of *Acarinina acarinata* Zone of Akhmetiev and Beniamovski (2003), whereas the Eocene section of the zone is correlated with the upper part of the *Acarinina acarinata* Zone (PF 8) and lowermost part of *Morozovella subbotinae* Zone (PF 9) of Akhmetiev and Beniamovski (2003) (Figure 32). On the other hand, Batı *et al*. (2009) named the BS-P5 zone for the uppermost part of the Paleocene for the Black Sea region and their BS-P5 – BS-P6 zone boundary is also marked as the Paleocene-Eocene boundary.

Remarks: In this study, the lower boundary of this zone isn’t defined for the Erfelek and the Erfelek 1 sections because of the absence of *Globanomalina pseudomenardii*. The upper boundary of the zone is marked with the last occurrence of *Morozovella velascoensis* in the Erfelek Section, whereas the Erfelek 1 Section is ended within the *Morozovella velascoensis* partial-range zone.

The lower boundary of the zone isn’t defined also in the Ayazlı Section, whose base starts with this zone. The last occurrence of *Morozovella velascoensis* is used for defining

the upper boundary of the zone.

The last occurrence of *Globanomalina pseudomenardii* defines the lower boundary of this zone in the Kaymakam Kayası Section (Figure 35). This section is ended within the *Morozovella velascoensis* partial-range zone.

In the present study, the Paleocene-Eocene boundary takes place in this zone. The zone markers for the base of Eocene (E1 Zone of Berggren and Pearson, 2005), such as *Morozovella allisonensis, Acarinina africana* and *Acarinina sibaiyaensis,* aren’t present in our sections. The absence of these species is related with either the paleoenvironmental conditions or the sampling interval. However, the Paleocene-Eocene boundary is defined by the first appearance of *Acarinina pseudotopilensis* and *Acarinina wilcoxensis* in the Erfelek and the Kaymakam Kayası sections (Figure 35).

In the Paleocene part of the Kaymakam Kayası Section planktonic foraminifera is low in diversity and abundance. The assemblage mostly contains subbotinids. Benthic foraminifera are abundant with respect to the planktons. In the Eocene section of the zone, both diversity and abundance of the planktonic foraminifera increase in this section. Acarininids diversified although having a low abundance, morozovellids are common especially in the uppermost part of the section and subbotinids are abundant relatively. Benthic foraminifera are also common during the Eocene part of the section.

For the Erfelek Section, the Eocene of P5 zone includes diversified acarininids and morozovellids. Especially the abundance of the morozovellids is higher with respect to the abundance in the Kaymakam Kayası Section. The subbotinids are also abundant, whereas the abundance of globanomalinids is rare to common and igorinids are sporadic. Both calcareous and agglutinated benthic foraminifera are very abundant in this interval. Although the base of the zone is indistinct, the Erfelek 1 Section allows us a more detailed investigation on the P5 Zone. In the lowermost part of the Eocene, the assemblage is dominated by benthic foraminifera and both diversity and abundance of the planktonic foraminifera are very low in a 2 m thick section at the base of Eocene, mainly containing sporadic acarininids, subbotinids and globanomalinids. Morozovellids appear after this interval towards the middle-upper parts of the zone where abundance and diversity of the other planktonic foraminiferal taxa increase. The benthic foraminiferal assemblage is also rich in these levels and the fish teeth are abundant with respect to the rest of section. On the other hand, diversity and abundance of both planktonic and benthic foraminifera decreases at the top of P5 zone. Planktonic foraminifera are dominated by the subbotinids and the benthics are dominated by the agglutinated forms at the top of the zone in the Erfelek 1 Section.

The P5 zone in the Ayazlı Section is dominated by the morozovellids and subbotinids. Benthic foraminiferal assemblage is low to common in abundance, whereas numerous radiolaria and sponge spicules are recorded at the lower part of the section.

Stratigraphic distribution: Ayazlı MSS, sample no. 1-5; Erfelek MSS, sample no. 45-48; Erfelek 1 MSS, sample no. 35-55 and Kaymakam Kayası MSS, sample no. 34-41.

Age: latest Paleocene – earliest Eocene

3.1.3. Early Eocene

Early Eocene is recognized in all of sections in this study. Although different biozones have been defined for each section; the base of the Early Eocene is recorded in Erfelek, Erfelek 1 and Kaymakam Kayası sections, whereas its upper boundary is recognized in the Karaburun, İstafan and Sinay-Karasu sections. 4 zones and 2 subzones have been defined in this interval.

***Morozovella subbotinae* Partial-range Zone**

Definition: Partial range of the nominate taxon between last occurrence of *Morozovella velascoensis* and first occurrence of *Morozovella aragonensis.*

Author: Lutherbacher and Premoli Silva, 1975

Correlation: This zone is the equivalent of P6 Zone of Berggren *et al.* (1995) (Figure 32). In terms of the identification of the Paleocene-Eocene boundary, Bolli (1957a, b, 1966) and Premoli Silva and Bolli (1973) evaluated P5 and P6 zones together as *Morozovella velascoensis* zone and include also P6 zone into latest Paleocene. Blow (1969) included *Globorotalia velascoensis*/*G. subbotinae* zone (P6a) and Blow (1979) included *Globorotalia* (*M.*) *s. subbotinae*/*G.* (*M.*) *velascoensis acuta* zone (P6a) to the latest Paleocene. The base of the Eocene was marked with the base of *Morozovella edgari* Zone by Bolli (1957a, b, 1966) and Premoli Silva and Bolli (1973), which coincides with the lower parts of P6b of Blow, 1969 and P7 of Blow, 1979. On the other hand Berggren and Pearson (2005) and Pearson *et al.* (2006) used E zones for the Eocene and defined *Acarinina sibaiyaensis* Lowest-occurrence Zone (LOZ) as E1 and *Pseudohastigerina wilcoxensis*/*Morozovella velascoensis* Concurrent-range Zone (CRZ) as E2 (Figure 32). These two zones are included to the Sparnacian stage of the Eocene and coincide with the upper part of P5 zone of Berggren *et al*. (1995). The base of the Ypresian coincides with *Morozovella velascoensis*-*Morozovella formosa*/*Morozovella lensiformis* Interval Subzone (ISZ) (P6a) of Berggren *et al*. (1995) and *Morozovella marginodentata* Partial-range Zone (PRZ) (E3) of Berggren and Pearson (2005) and Pearson *et al.* (2006). Obaidalla (2001) defined *Morozovella edgari* Zone in Egypt, whereas Khalil and Al Sawy (2014) used *Morozovella formosa* Zone (Figure 33).

P6 Zone of Berggren *et al*. (1995) is correlated with the *Morozovella subbotinae* Zone (PF 9) of Akhmetiev and Beniamovski (2003) for the Peritethys Region (Figure 32). On the other hand, BS-P6 zone (*Morozovella subbotinae* Zone) is placed at the base of the Eocene for the Black Sea zonation of Batı *et al.* (2009).

Remarks: The lower boundary of the zone is given by the last occurrence of *Morozovella velascoensis* in the Ayazlı and the Erfelek sections. The last occurrence of *Acarinina pentacamerata* in the Erfelek Section marks the upper boundary of the zone, whereas the Ayazlı Section ends within this zone (Figure 35). The Kaymakam Kayası-A Section starts within the *Morozovella subbotinae* partial-range zone. The upper boundary of the zone is defined by the first occurrence of *Morozovella aragonensis* in this section (Figure 35).

Stratigraphic distribution: Ayazlı MSS, sample no. 6-15; Erfelek MSS, sample no. 49-70 and Kaymakam Kayası-A MSS, sample no. 1-2.

Age: Early Eocene

***Morozovella edgari* Partial-range Subzone**

Definition: Partial range of the nominate taxon between last occurrence of *Morozovella velascoensis* and first occurrence of *Morozovella formosa* or *Morozovella lensiformis.*

Author: Toumarkine and Lutherbacher, 1985

Correlation: This subzone is the equivalent of *Morozovella edgari* Zone of Toumarkine and Lutherbacher (1985) and P6a Subzone of Berggren *et al*. (1995). The lower boundary of this subzone has been extended into Paleocene in the early Mediterranean schemes (Bolli 1957a, b, 1966; Blow, 1969, 1979; Premoli Silva and Bolli, 1973). After Berggren *et al*. (1995), the base of P6a Subzone coincides with the base of the Ypresian stage and the new subzone is the equivalent of P6b Subzone of Berggren and Miller (1988) (Figure 32). Berggren *et al*. (1995) defined P6a Subzone as *Morozovella velascoensis-Morozovella formosa*/*Morozovella lensiformis* Interval Subzone. However, the definition of the subzone makes it a partial-range subzone rather than an interval subzone. Imam (2001) used E3 Zone as *Morozovella marginodentata* Zone that is equivalent to *Morozovella edgari* Subzone (Figure 33). E3 Zone (*Morozovella marginodentata* Partial Range Zone) of Berggren and Pearson (2005) also matches with this zone. *Morozovella subbotinae* Subzone of Payros *et al*. (2006) is the equivalent of this subzone (Figure 33).

The zone is also equivalent of *Morozovella marginodentata* Subzone (PF 9b) for the Crimean-Caucasian scheme, which is the middle part of PF9 Zone of Akhmetiev and Beniamovski (2003) (Figure 32). On the other hand, this subzone is named as *Morozovella aequa* Partial Range Subzone by Batı *et al.* (2009).

Remarks: The base of P6a subzone is defined by the disappearance of *Morozovella velascoensis* in the Ayazlı and the Erfelek sections. The upper boundary of the zone is defined by the first appearance of *Morozovella lensiformis* in the Ayazlı Section and by the first appearance of *Morozovella formosa* in the Erfelek Section (Figure 35).

Planktonic foraminiferal assemblage is very poor in the Ayazlı Section, containing a few subbotinids or sporadic morozovellids and acarininids, in contrast to the rich benthic foraminiferal assemblage in this section. On the other hand, the planktonic foraminiferal diversity is relatively higher in the lower part of this subzone in the Erfelek section in spite of low abundance. Contrary to planktonic foraminifera, benthic foraminifera are highly abundant and dominated by agglutinated forms in this section.

Stratigraphic distribution: Ayazlı MSS, sample no. 6-10; Erfelek MSS, sample no. 49-55.

Age: Early Eocene

Morozovella formosa/Morozovella *lensiformis-Morozovella aragonensis* Interval Subzone

Definition: Interval between first occurrence of *Morozovella formosa* or *Morozovella lensiformis* and first occurrence of *Morozovella aragonensis.*

Author: Berggren *et al.*, 1995

Correlation: This subzone is the equivalent of P6b Subzone of Berggren *et al.* (1995). *Morozovella edgari* and *Morozovella subbotinae* zones of Bolli (1957a, b, 1966) and Premoli Silva and Bolli (1973) coincide with *Globorotalia subbotinae*/*Pseudohastigerina* *wilcoxensis* (P6b) Zone of Blow (1969) and *Globorotalia* (*Acarinina*) *wilcoxensis berggreni* (P7) Zone of Blow (1979). Berggren *et al*. (1995) defined the P6b subzone as *Morozovella formosa*/*Morozovella lensiformis–Morozovella aragonensis* ISZ, which is equivalent with *Morozovella formosa* LOZ (E4 Zone) of Berggren and Pearson (2005) and Pearson *et al.* (2006) (Figure 32). *Morozovella lensiformis* Subzone of Payros *et al*. (2006) is the equivalent of this subzone (Figure 33).

For the Peritethys scheme, the upper part of Akhmetiev and Beniamovski (2003)'s PF9 Zone (*Morozovella subbotinae* Zone) is the equivalent of P6b Zone (Figure 32). This coincides with PF9b Subzone (*Morozovella lensiformis* Subzone) of Akhmetiev and Beniamovski (2006). Batı *et al*. (2009) evaluated this subzone as *Morozovella subbotinae* Partial Range Subzone for the Black Sea region.

Remarks: *Morozovella lensiformis* and *Morozovella formosa* appears at the base of this zone in the Ayazlı and the Erfelek sections, whereas the Kaymakam Kayası-A Section starts within this subzone (Figure 35).

The Ayazlı Section ends within this subzone. The upper boundary of the zone is defined by the first occurrences of *Acarinina pentacamerata* in the Erfelek Section; whereas the first appearance of *Morozovella aragonensis* is recognized in the Kaymakam Kayası-A section (Figure 35).

The planktonic foraminiferal diversity is relatively higher at the base of this subzone in Ayazlı, Erfelek and Kaymakam Kayası-A sections. Especially the morozovellids and acarininids are diversified. Benthic foraminiferal abundance is higher than the planktonic foraminifera in the Erfelek Section, generally dominant by the agglutinated forms.

Stratigraphic distribution: Ayazlı MSS, sample no. 11-15; Erfelek MSS, sample no. 56-70 and Kaymakam Kayası-A MSS, sample no. 1-2.

Age: Early Eocene

***Morozovella aragonensis-Morozovella formosa* Concurrent-range Zone**

Definition: Interval between first occurrence of *Morozovella aragonensis* and last occurrence of *Morozovella formosa*

Author: Berggren *et al.*, 1995

Correlation: This zone is the equivalent of P7 Zone of Berggren *et al.* (1995) (Figure 32). *Morozovella formosa formosa* Zone of Bolli (1957a, b, 1966) and Premoli Silva and Bolli (1973) coincides with *Globorotalia formosa* Zone (P7) of Blow (1969). Blow (1979) defined *Globorotalia* (*Acarinina*) *wilcoxensis berggreni* Zone as P7 and this zone is older than the P7 Zone of Blow (1969). On the other hand, *Globorotalia* (*Morozovella*) *formosa*/*Globorotalia (Morozovella) lensiformis* (P8a) Zone of Blow (1979) coincides with the P7 zone of the former authors. Berggren *et al*. (1995) defined P7 as *Morozovella aragonensis*/*Morozovella formosa* CRZ (Figure 32). *Morozovella aragonensis*/*Morozovella* *subbotinae* CRZ (E5) of Berggren and Pearson (2005) and Pearson *et al.* (2006) is the equivalent of P7 Zone of Berggren *et al*., 1995. *Morozovella aragonensis*/*Morozovella formosa formosa* CRZ of Warraich and Nishi (2003) covers *Morozovella formosa* Zone and lower part of *Morozovella aragonensis* Zone of Payros *et al*. (2006) (Figure 33).

For the Peritethys Region, PF10a (*Morozovella aragonensis*) Subzone of Akhmetiev and Beniamovski (2006), which is the lower part of PF10 Zone (*Morozovella aragonensis* Zone) of Akhmetiev and Beniamovski (2003), is the equivalent of the P7 Zone (Figure 32). Batı *et al*. (2009) defined this zone as *Morozovella marginodentata* (BS-P7) Zone.

Remarks: The lower boundary of the zone is defined by the first appearance of *Morozovella aragonensis* in the Kaymakam Kayası-A section. This boundary is recognized with the first occurrences of *Acarinina pentacamerata* in the Erfelek Section as the nominate taxa is not recorded. *Acarinina pentacamerata* is used to define the lower boundary of *Morozovella aragonensis* Zone by Abdel-Kireem and Samir (1995). The first appearance of *Acarinina pentacamerata* is same with the first appearance of *Morozovella aragonensis* according to Pearson *et al.* (2006).

Top of the zone is marked by the last occurrence of *Morozovella formosa* in the Kaymakam Kayası-A Section and by the first appearance of *Acarinina primitiva* in the Erfelek and the Karaburun sections (Figure 35). The first appearance of *Acarinina primitiva* is defined at the base of *Acarinina pentacamerata* PRZ by Pearson *et al.* (2006).

Subbotina and *Acarinina* species are mostly same with the ones in the *Morozovella subbotinae* Partial-range Zone, but they are getting larger in size in this zone. The highest occurrence of *Acarinina wilcoxensis, Morozovella subbotinae, Morozovella aequa* and *Morozovella gracilis* is within that zone.

Stratigraphic distribution: Karaburun MSS, sample no. 1; Erfelek MSS, sample no. 71-87 and Kaymakam Kayası-A MSS, sample no. 3-7.

Age: Early Eocene

***Acarinina pentacamerata* Partial-range Zone**

Definition: Partial range of the nominate taxon between the last occurrence of *Morozovella formosa* and the first occurrence of *Acarinina cuneicamerata.*

Author: Berggren and Pearson, 2005

Correlation: This zone is the equivalent of E6 Zone of Berggren and Pearson (2005) and Pearson *et al.* (2006). Bolli (1957a, b, 1966) and Premoli Silva and Bolli (1973) defined *Morozovella aragonensis* Zone that can be correlated with the *Globorotalia aragonensis* (P8) Zone of Blow (1969). On the other hand, this interval coincides with *Globorotalia* (*Morozovella*) *aragonensis*/*Globorotalia* (*Morozovella*) *formosa* Zone of Blow (1979), which is only the upper part of P8 Zone (P8b). P8 Zone of Berggren *et al.* (1995) is *Morozovella aragonensis* PRZ that is the equivalent of *Acarinina pentacamerata* PRZ (E6) of Berggren and Pearson (2005) and Pearson *et al.* (2006) (Figure 32). Warraich and Nishi

(2003) defines *Acarinina pentacamerata* PRZ that covers the upper part of *Morozovella aragonensis* Zone of Payros *et al*. (2006) (Figure 33).

The middle part of PF10 Zone (*Morozovella aragonensis* Zone) of Akhmetiev and Beniamovski (2003), which is the PF10b Subzone (*Morozovella caucasica* Subzone) of Akhmetiev and Beniamovski (2006), is the equivalent of the P8 Zone for the Peritethys Region (Figure 32). P8 zone is named as *Morozovella aragonensis* (BS-P8) Zone by Batı *et al*. (2009).

Remarks: The base of the zone is defined by the last appearance of *Morozovella formosa* in the Kaymakam Kayası-A Section (Figure 35). On the other hand, it is described by the first occurrence of *Acarinina primitiva* as the nominate species is absent in the Erfelek and the Karaburun sections. The Erfelek and the Kaymakam Kayası-A sections end within this zone. The upper boundary of *Acarinina pentacamerata* Partial-range Zone is defined by the first appearance of *Acarinina cuneicamerata* in the Karaburun and the Erfelek-A sections.

The highest occurrences of *Morozovella lensiformis, Morozovella formosa, Acarinina interposita* and *Acarinina esnehensis* are in this zone. Acarininids and morozovellids are highly diversified within this zone especially in the Karaburun Section. The abundance of the acarininids is mostly higher than the morozovellids. *Subbotina* is another genus with high abundance and diversity in this zone.

Stratigraphic distribution: Karaburun MSS, sample no. 2-14; Erfelek MSS, sample no. 88-104; Erfelek-A MSS, sample no. 1-5 and Kaymakam Kayası-A MSS, sample no. 8-16.

Age: Early Eocene

***Acarinina cuneicamerata-Hantkenina* spp. Interval Zone**

Definition: Interval between the first appearance of *Acarinina cuneicamerata* and the first occurrence of *Hantkenina* spp.

Author: This study, 2014

Correlation: This zone is the equivalent of E7 Zone of Berggren and Pearson (2005) (Figure 32). The zone was defined by Krasheninnikov (1965 a,b) as *Acarinina pentacamerata* Interval Zone for the interval from first occurrence of *Turborotalia cerroazulensis frontosa* to first occurrence of representatives of the genus *Hantkenina*. Later, Tourmarkine and Luterbacher (1985) mentioned the high abundance of *Morozovella aragonensis* and *Turborotalia cerroazulensis frontosa* besides the nominate species within this zone.

Being the uppermost zone in Early Eocene, Bolli (1957a, b, 1966) and Premoli Silva and Bolli (1973) defined *Acarinina pentacamerata* Zone. This zone can be correlated with the *Acarinina densa* Zone (P9) of Blow (1969). On the contrary, P9 Zone is *Globorotalia* (*Acarinina*) *aspensis*/*Globigerina lozanoi prolata* Zone with respect to Blow (1979), which has a shorter range and therefore whose upper boundary does not coincides with the Early-Middle Eocene boundary. Berggren *et al.* (1995) defined P9 zone as *Planorotalites palmerae-Hantkenina nuttalli* Interval Zone (IZ) (Figure 32). Berggren and Pearson (2005) and Pearson *et al.* (2006) correlate its E7 Zone (*Acarinina cuneicamerata* LOZ) with P9

Zone. The total interval of *Planorotalites palmerae* Zone and lower part of *Acarinina soldadoensis* Zone of Warraich and Nishi (2003) and *Globanomalina palmerae*, *Acarinina bullbrooki*, *Turborotalia boweri* and lower part of *Acarinina praetopilensis* zones of Payros *et al* (2006) are the equivalent of *Acarinina cuneicamerata-Hantkenina* spp. Interval Zone in this study (Figure 33).

For the Peritethys Region, PF10c (*Turborotalia boweri*/*Globigerinatheka micra*) Subzone of Akhmetiev and Beniamovski (2006), which is the uppermost part of PF10 Zone (*Morozovella aragonensis* Zone) of Akhmetiev and Beniamovski (2003), is the equivalent of the P9 Zone (Figure 32). Batı *et al*. (2009) defined this zone as *Morozovella caucasica-Acarinina pentacamerata* (BS-P9) Zone for the Black Sea region.

Remarks: The first occurrence of *Acarinina cuneicamerata* defined the base of this zone in the Erfelek-A Section (Figure 35). On the other hand, the first appearance of *Acarinina boudreauxi* is used to define the lower boundary in the Karaburun Section. The Erfelek-A Section ends within this zone, whereas the İstafan and the Sinay-Karasu sections start within this zone. The upper boundary of this zone is defined by the first appearance of *Hantkenina* cf. *mexicana* in the Karaburun Section, by the first appearance of *Hantkenina* cf. *leibusi* in the İstafan Section and by the first appearance of *Globigerinatheka subconglobata* in the Sinay-Karasu Section, all of which are the Middle Eocene assemblage.

First occurences of *Acarinina praetopilensis, A. punctocarinata, Subbotina hagni, S. yeguaensis, Pseudohastigerina micra* and *Parasubbotina eoclava* and the last occurrences of *Acarinina soldadoensis, A. coalingensis, A. pseudotopilensis, A. alticonica, A. pentacamerata, Planorotalites pseudoscitula* are within this zone.

The diversity and abundance of the planktonic foraminifera are high in this zone. Acarininids are the most diversified genus in all of the sections that the zone is recorded. In the İstafan Section, the abundance of subbotinids, globigerinids and pseudohastigerinids are also high.

Stratigraphic distribution: Karaburun MSS, sample no. 15-17; İstafan MSS, sample no. 1-10; Sinay-Karasu MSS, sample no. 1-10 and Erfelek-A MSS, sample no. 6-15.

Age: Early Eocene

3.1.4. Middle Eocene

The Middle Eocene planktonic foraminiferal assemblages of Black Sea are different from the Caucasus and Mediterranean assemblages. Mostly indicating the subtropical conditions, the identified species are useful for the establishment of stratigraphical framework specific for the Black Sea region. Another difference is the absence or scarcity of some of the Mediterranean taxa in the Black Sea and Crimean-Caucasus deposits of the same period. These species are *Acarinina rohri, Globigerinatheka kugleri, G. semiinvoluta, G. barri, Orbulinoides beckmanni, Morozovella spinulosa, M. renzi, Turborotalia pomeroli, T. cerroazulensis, T. cocoaensis, T. cunialensis, Globigerina howei, Subbotina angiporoides.*

On the other hand, some Black Sea planktonic foraminifera species, such as *Globigerinatheka index, G. lutherbacheri, Acarinina rohri, A. rotundimarginata, Subbotina corpulenta*, *Globigerina officinalis*, were recorded to have a shorter stratigrahic range with respect to the Mediterranean equivalents (Batı *et al*., 2009). These taxa reflect the onset of the transition between the Crimean-Caucasus realm and tropical-subtropical Mediterranean realm during the Middle Eocene.

Middle Eocene is defined in Karaburun, İstafan and Sinay-Karasu sections. 3 zones are described for this time interval.

***Hantkenina* spp.-*Acarinina boudreauxi* Concurrent-range Zone**

Definition: Interval between the first occurrence of *Hantkenina* spp. and the last occurrence of *Acarinina boudreauxi.*

Author: This study, 2014

Correlation: This zone is the equivalent of the total interval of P10 and P11 zones of Berggren *et al.* (1995). The base of the Middle Eocene is represented by *Hantkenina nuttalli* Zone with respect to Bolli (1957a, b, 1966) and Premoli Silva and Bolli (1973) and by *Hantkenina aragonensis* with respect to Blow (1969). Bolli (1957a, b, 1966) and Premoli Silva and Bolli (1973) defined *Globigerinatheka subconglobata subconglobata* Zone overlying the *Hantkenina nuttalli* Zone. Blow (1969) used *Globigerinatheka kugleri* Zone as P11, while Blow (1979) suggested *Globigerinatheka kugleri*/*Subbotina frontosa boweri* Zone. Berggren *et al*. (1995) defined *Hantkenina nuttalli* IZ as P10 and *Globigerinatheka* kugleri/*Morozovella aragonensis* CRZ as P11, whereas Berggren and Pearson (2005) and Pearson *et al.* (2006) described *G. nuttalli* LOZ as E8 as the lowermost zone of Middle Eocene and *Globigerinatheka* kugleri/*Morozovella aragonensis* CRZ as E9 overlying the *G. nuttalli* LOZ (Figure 32). Payros *et al*. (2006) defined *Acarinina praetopilensis* and *Globigerinatheka subconglobata* zones, whose total range is the equivalent of the *Hantkenina* spp.-*Acarinina boudreauxi* Concurrent-range Zone defined in the present study (Figure 33).

Akhmetiev and Beniamovski’s (2003) zonation for Crimean-Caucasian Region defined two zones that are the equivalent of the P10 Zone of the Mediterranean Realm (Figure 32). The total interval of the author’s PF 11 (*Acarinina bullbrooki*) and PF 12 (*Acarinina rotundimarginata*) zones are correlated with the P10 Zone of Berggren *et al.* (1995). On the other hand, the interval from the uppermost part of PF12 (*Acarinina rotundimarginata*) Zone to the middle part of PF13 (*Hantkenina alabamensis*) Zone covers the P11 Zone for the Mediterranean scheme (Akhmetiev and Beniamovski, 2003). Later, Akhmetiev and Beniamovski (2006) defined two subzones for PF12 Zone: PF 12a is *Turborotalia frontosa* Subzone and PF 12b is *Hantkenina leibusi* Subzone. The authors divided PF13 Zone into 3 subzones: PF13a is *Globigerinatheka subconglobata*/*Hantkenina dumblei* Subzone, PF13b is *Globigerinatheka index* Subzone and PF13c is *Hantkenina australiformis* Subzone. The upper boundary of P11 Zone of Berggren *et al.* (1995) coincides with the top of PF13b Subzone. Batı *et al*. (2009) defined a BS-P10+11 combined zone as *Acarinina bullbrooki* Zone for the Black Sea region, where the abundance of the nominate species is getting higher. The authors defined BS-P10 Zone as *Hantkenina mexicana* Zone and BS-P11 Zone as *Globigerinatheka subconglobata* Zone.

Remarks: The lower boundary of this zone is represented by the first occurrence of genus *Hantkenina* in this study as the first occurrence of different hantkenids have been used for the base of the first Middle Eocene zone defined in numerous studies.

In the İstafan Section, the first occurrence of *Hantkenina* cf. *leibusi* is used to define the lower boundary of this zone (Figure 35). The base of the zone is defined in the Karaburun Section with the first occurrence of *Hantkenina* cf. *mexicana.* On the other hand, as genus *Hantkenina* isn't defined in the Sinay-Karasu Section, the base of this zone is defined by the first appearance of *Globigerinatheka subconglobata* in this section. This species also belongs to the Middle Eocene taxa and its first occurrence is in the middle part of P10 Zone of Berggren *et al*. (1995) in various studies (Payros *et al.*, 2006; Pearson *et al*., 2006; Ortiz *et al*., 2008; Boudagher-Fadel, 2012). Therefore the Early-Middle Eocene boundary is below its first appearance in the Sinay-Karasu Section.

The Karaburun and the İstafan sections end within this zone. In the Sinay-Karasu Section, top of this zone is defined by the last occurrence of *Acarinina boudreauxi*.

The first occurrences of genera *Globigerinatheka* and *Hantkenina* and the last occurrences of *Subbotina patagonica, Planoglobanomalina pseudoalgeriana, Morozovella aragonensis, M. crater, Acarinina boudreauxi, A. cuneicamerata, Igorina broadermanni, Globanomalina australiformis, Parasubbotina inaequispira* and *Parasubbotina eoclava* are within this zone. Hantkenids and subbotinids are highly abundant in this zone, while acarininids and pseudohastigerinids decrease in abundance and diversity in the İstafan Section. On the other hand, both abundance and diversity of the planktonic foraminiferal assemblage in the Karaburun Section decrease in this zone. Especially, the diversity of the acarininids decreases with respect to Early Eocene like in the İstafan Section.

Stratigraphic distribution: Karaburun MSS, sample no. 18-34; İstafan MSS, sample no. 11-17 and Sinay-Karasu MSS, sample no. 11-14.

Age: Middle Eocene

Globigerina eoceanica Partial-range Zone

Definition: Partial range of the nominate taxon between the highest occurrence of *Acarinina boudreauxi* and the lowest occurrence of *Globigerina turkmenica*.

Author: This study, 2014

Correlation: This zone is the equivalent of the total interval of *Morozovella lehneri* and *Orbulinoides beckmanni* zones of Bolli (1957b).

Premoli Silva and Bolli (1973) and Blow (1969, 1979) used *Globorotalia* (*Morozovella*) *lehneri* Zone and Berggren *et al*. (1995) used *Morozovella lehneri* PRZ as P12 (Figure 32). On the other hand, equivalent of this zone was separated into two different partial range zones by Berggren and Pearson (2005) and Pearson *et al*. (2006). The authors defined *Acarinina topilensis* PRZ as E10 and *Morozovella lehneri* PRZ as E11. Warraich and Nishi (2003) and Payros *et al*. (2006) used the *Morozovella lehneri* Zone in their studies.

The interval from PF13c Subzone to the upper parts of PF14a Subzone of Akhmetiev and Beniamovski (2006) for the Crimean-Caucasian Region coincides with the P12 Zone (Figure 32). Batı *et al*. (2009) defined BS-P12 Zone as *Acarinina collactea* Zone for the Black Sea region.

On the other hand, *Orbulinoides beckmanni* zone (Cordey, 1968), first defined by Bolli (1957b) as *Porticulasphaera mexicana* Zone, is a worldwide used total range zone (Figure 32). Blow (1969, 1979) defined this zone as P13. Toumarkine and Luterbacher described this zone in 1985. Berggren *et al.* (1995) used *Globigerapsis beckmanni* Taxon-range Zone (TRZ) as P13, whereas Berggren and Pearson (2005) and Pearson *et al.* (2006) defined *Orbulinoides beckmanni* TRZ (Figure 32). Zakrevskaya *et al.* (2011) mentioned that P13 Zone is used as *Hantkenina australis* Zone in the Russian literature, although the authors have used *Hantkenina alabamensis* Zone for P13. They defined this zone between the first appearance of *Globigerinatheka subconglobata* and the first appearance of *Subbotina turkmenica*. Their P13 Zone corresponds to the upper half of P11 Zone and lower half of P12 Zone of standart Tethys biozonation (Pearson *et al.*, 2006). On the other hand, the P13 Zone of Tethys biozonation is the correspondence of the middle part of P14 Zone of Zakrevskaya *et al.* (2011).

The absence of *Orbulinoides beckmanni*, which is an index species for Mediterranean P13 Zone and absence of *Hantkenina alabamensis* and *Globigerinatheka index*, which are the zone markers for Caucasus region, are causing the difficulties in the zone definitions for the present study. Therefore, *Globigerina eoceanica* Partial-range Zone is defined in this study.

Remarks: In this study, the lower boundary of this zone is defined by the last occurrence of *Acarinina bıudreauxi* in the Sinay-Karasu Section (Figure 35). The upper boundary of the zone is defined by the first occurrence of *Globigerina turkmenica.*

The first appearances of *Globoturborotalita ouachitaensis* and *Acarinina collectae/medizzai*, a transitional form, are at the base of this zone in this section. The last occurrences of *Acarinina bullbrooki*, *A. punctocarinata, Pseudohastigerina wilcoxensis, Subbotina roesnaensis* and *Parasubbotina varianta* are in this zone.

Stratigraphic distribution: Sinay-Karasu MSS, sample no. 15-16.

Age: Middle Eocene

***Globigerina turkmenica-Globigerina azerbaidjanica* Concurrent-range Zone**

Definition: Interval between the first occurrence of *Globigerina turkmenica* and the last occurrence of *Globigerina azerbaidjanica.*

Author: This study, 2014

Correlation: Being the uppermost zone in the Middle Eocene, this zone is the equivalent of the P14 and lower part of P15 zones of Berggren *et al*. (1995) (Figure 32). The uppermost zone of the Middle Eocene is *Truncorotaloides rohri* Zone with respect to Bolli (1957a, b, 1966) and Premoli Silva and Bolli (1973). Blow (1969) used *Truncorotaloides rohri-G. howei* Zone as P14. On the other hand, Blow (1979) described *Globorotalia* (*Morozovella*) *spinulosa spinulosa* Zone as P14 and this zone doesn't limit the upper boundary of Middle Eocene, which ends within P15. P14 Zone, which is the *Truncorotaloides rohri-Morozovella spinulosa* PRZ, doesn't mark the top of Middle Eocene and the Middle-Late Eocene boundary has been placed within P15 Zone regarding to Berggren *et al.* (1995) (Figure 32). Warraich and Nishi (2003) used *Orbulinoides beckmanni-Truncorotaloides rohri* Interval Zone as the equivalent of this zone (Figure 33). *Morozovelloides crassata* Highest-occurrence Zone (HOZ) (E13 Zone) of Berggren and Pearson (2005) and Pearson *et al.* (2006) is a longer zone and its range can be correlated with the range of P14 and lowermost part of P15 zones of Berggren *et al.* (1995).

P14 zone overlaps with the Peritethyan PF14b (*Subbotina praebulloides*) Subzone of Akhmetiev and Beniamovski (2006), except the lowermost part of PF14b and BS-P14 (*Globigerina turcmenica*) Zone of Batı *et al*. (2009) for the Black Sea region (Figure 32).

This zone ends within the Middle Eocene in the Mediterranean scheme, whereas the Peritethyan scheme marks the Bartonian/Priabonian boundary with the upper boundary of this zone. In the present study, P14 Zone is accepted as the uppermost boundary within the Middle Eocene and Middle-Late Eocene boundary corresponds to the boundary of P14 and P15 zones.

Remarks: The base of the zone is defined by the first occurrences of *Globigerina turkmenica* and the upper boundary is defined by the last occurrence of *Globigerina azerbaidjanica,* whose first appearance is in the same level with *Globigerina turkmenica* in the Sinay-Karasu Section (Figure 35). The other important species in this zone are *Globigerina subcorpulenta, Globigerina incretacea, Subbotina jacksonensis, Subbotina corpulenta, Turborotalia cocoaensis* and *Globoturborotalita ouachitaensis.* The identified assemblage has a complete resemblance to Caucasus fauna (Batı *et al.*, 2009). It shows that the connection with the open marine began to destroy during that time until the transgressive period of Late Eocene.

Stratigraphic distribution: Sinay-Karasu MSS, sample no. 17-22.

Age: Middle Eocene

3.1.5. Late Eocene

Only *Globigerina azerbaidjanica-Acarinina medizzai* Interval Zone is defined for the Late Eocene in the Sinay-Karasu Section. Upper parts of the zone may be present in this section; however a zonation can't be done by the present fossil assemblage.

***Globigerina azerbaidjanica-Acarinina medizzai* Interval Zone**

Definition: Interval between the last occurrence of *Globigerina azerbaidjanica* and last occurrence of *Acarinina medizzai*.

Author: This study, 2014

Correlation: This zone is the equivalent of the Upper Eocene part of the P15 Zone of Berggren *et al.* (1995) and BS-P15 Zone of Batı *et al.* (2009) (Figure 32).

The Middle-Late Eocene boundary is debatable. Some of the authors mark the boundary with the upper boundary of P14 Zone, while the others placed it within P15 Zone. Regarding to Bolli (1957a, b, 1966), Blow (1969) and Premoli Silva and Bolli (1973), the base of the Late Eocene is also the base of P15 Zone. Bolli (1957a, b, 1966) and Premoli Silva and Bolli (1973) defined this zone to be *Globigerinatheka semiinvolutina* Zone, whereas Blow (1969) used *Globigerinatheka mexicana* Zone as P15. Blow (1979) and Berggren *et al.* (1995) placed the boundary inside P15 Zone. Blow (1979) defined P15 as *Porticulasphaera semiinvolutus* Zone. Berggren *et al.* (1995) defined *Porticulasphaera semiinvoluta* IZ (Figure 32). With respect to Berggren and Pearson (2005) and Pearson *et al.* (2006), the lowermost part of P15 Zone of Berggren *et al.* (1995) corresponds to the uppermost part of *Morozovelloides crassata* HOZ (E13). The middle part of P15 is where the Middle-Late Eocene boundary in and defined as *Globigerinatheka semiinvoluta* HOZ. The upper part of P15 of Berggren *et al.* (1995) can be correlated with the lower half of the *Globigerinatheka index* HOZ of Berggren and Pearson (2005) and Pearson *et al.* (2006).

The base of the P15 Zone coincides with the base of PF15 (*Globigerinatheka tropicalis*) Zone of Akhmetiev and Beniamovski (2003). The upper boundary is within the PF16 (*Subbotina corpulenta*) Zone of the authors (Figure 32). Batı *et al.* (2009) defined BS-P15 Zone as *Globigerinatheka tropicalis* Zone.

Remarks: In the present study, the P15 Zone is accepted at the base of Late Eocene. As explained before, this time interval coincides with a distinctive transgressive period for the Black Sea and Caucasus realms (Batı *et al.*, 2009).

The lower boundary of this zone is defined by the last occurrence of *Globigerina azerbaidjanica* and the upper boundary is defined by the last occurrence of *Acarinina medizzai* in the Sinay-Karasu Section (Figure 35). In this interval; *Globoturborotalita ouachitaensis, Subbotina eocaena*, *S. jacksonensis* and *S. yeguaensis* are also observed.

Stratigraphic distribution: Sinay-Karasu MSS, sample no. 23-24.

Age: Late Eocene

3.2 BIOSTRATIGRAPHY OF THE MEASURED STRATIGRAPHIC SECTIONS

The distributions of biozones throughout the stratigraphic sections are explained in detail in the following sections (Figure 36).

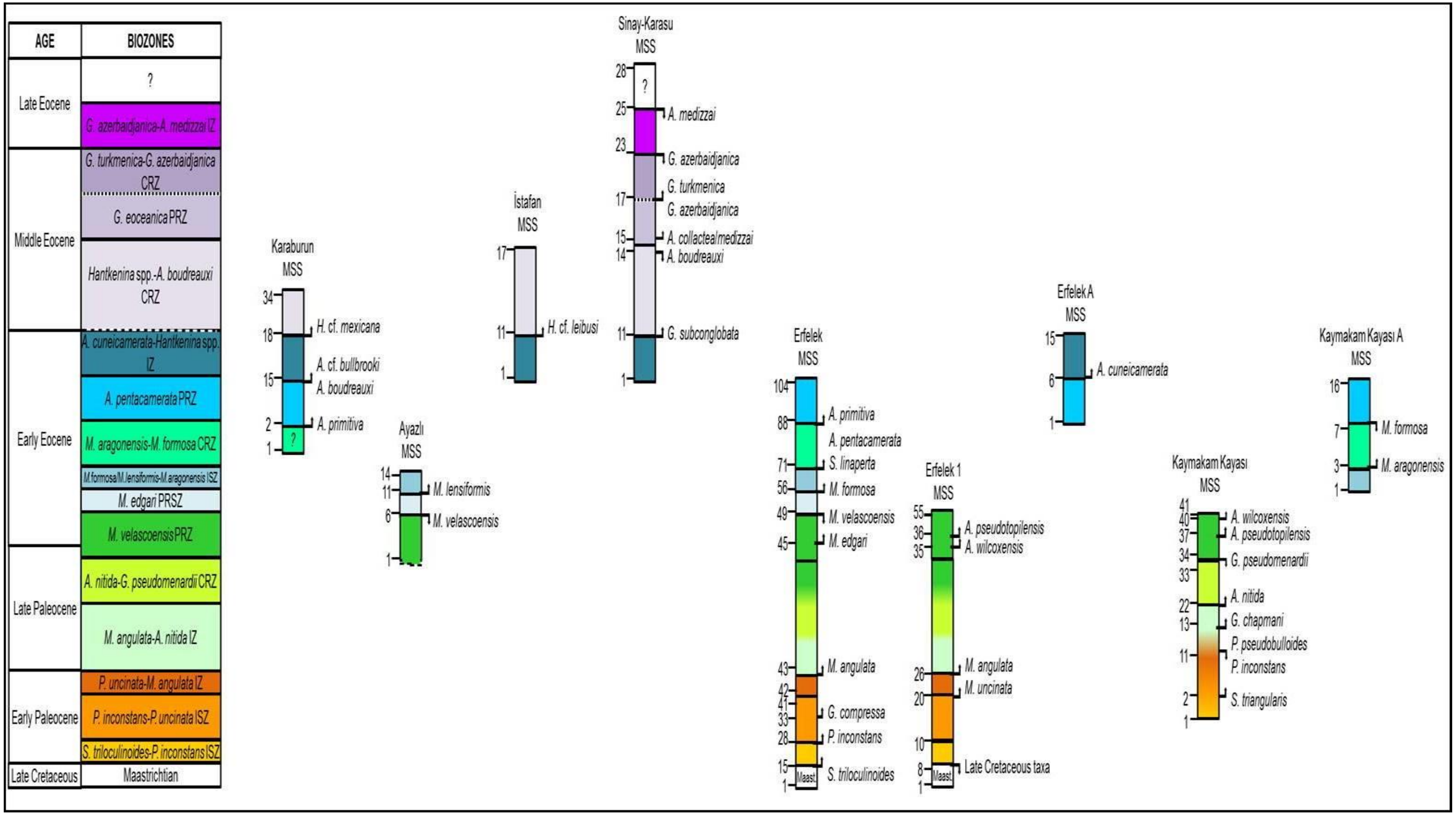

Figure 36. The distributions of biozones throughout the stratigraphic sections.

3.2.1. Karaburun Measured Stratigraphic Section

The Karaburun Measured Stratigraphic Section covers Lower Eocene ?*Morozovella aragonensis*-*Morozovella formosa* Concurrent-range Zone, *Acarinina pentacamerata* Partial-range Zone, *Acarinina cuneicamerata*-*Hantkenina* spp. Interval Zone and Middle Eocene*Hantkenina* spp.-*Acarinina boudreauxi* Concurrent-range Zone (Figure 37).

In the Karaburun Section, the presence of the *Morozovella aragonensis*-*Morozovella formosa* Concurrent-range Zone is questionable because of the lack of the marker forms. Only *Acarinina pseudotopilensis* and some benthic foraminifera are recorded in the first sample. However, as the first appearances of some marker species of the *Acarinina pentacamerata* Partial-range Zone are in the sample 2, a ?*Morozovella aragonensis*-*Morozovella formosa* Concurrent-range Zone is placed at the lowest part of the section due to the scarcity of the species in the sample 1.

Acarinina pentacamerata Partial-range Zone is defined by the first occurrences of *Acarinina primitiva* in sample 2. Some of the important forms identified in this interval are *Acarinina pseudotopilensis, A. pentacamerata, A. primitiva, A. soldadoensis, A. wilcoxensis, A. alticonica, A. coalingensis, Globoturborotalita bassriverensis, Igorina broadermanni, Morozovella aequa, M. aragonensis, M. crater, M. lensiformis, M. subbotinae, Subbotina linaperta, S. roesnaensis, S. patagonica, Parasubbotina inaequispira* and *Pseudohastigerina wilcoxensis.*

Absence of characteristic acarininids of *Acarinina cuneicamerata*-*Hantkenina* spp. Interval Zone, such as *Acarinina bullbrooki*, is suspectable. However, the first appearances of *A. boudreauxi* and *A.* cf. *bullbrooki* with *Globigerina eocaenica* and *Subbotina hagni* in sample 15 is accepted within *Acarinina cuneicamerata*-*Hantkenina* spp. Interval Zone. As there is a covered part in the section between sample 14 and 15, the base of the zone isn't identified. *Acarinina pseudotopilensis, A. pentacamerata, A. primitiva, Igorina broadermanni, Morozovella crater, Pseudohastigerina micra* and *Subbotina eocaena* are some of the other forms identified in this zone.

There is a single occurrence of *Hantkenina* cf. *mexicana* in the sample 18, which is a Middle Eocene form. *Morozovelloides bandyi* has been also recognized in the sample 19. Therefore, starting with the sample 18, the Karaburun Section is evaluated to be within the Middle Eocene *Hantkenina* spp.-*Acarinina boudreauxi* Concurrent-range Zone. *Globigerina eocaenica, Morozovella aragonensis, M. crater, Pseudohastigerina micra, Subbotina eocaena* have been defined within *Hantkenina* spp.-*Acarinina boudreauxi* Concurrent-range Zone.

The details belonging to fossil distribution and biozonation of the Karaburun section is given in Figure 37.

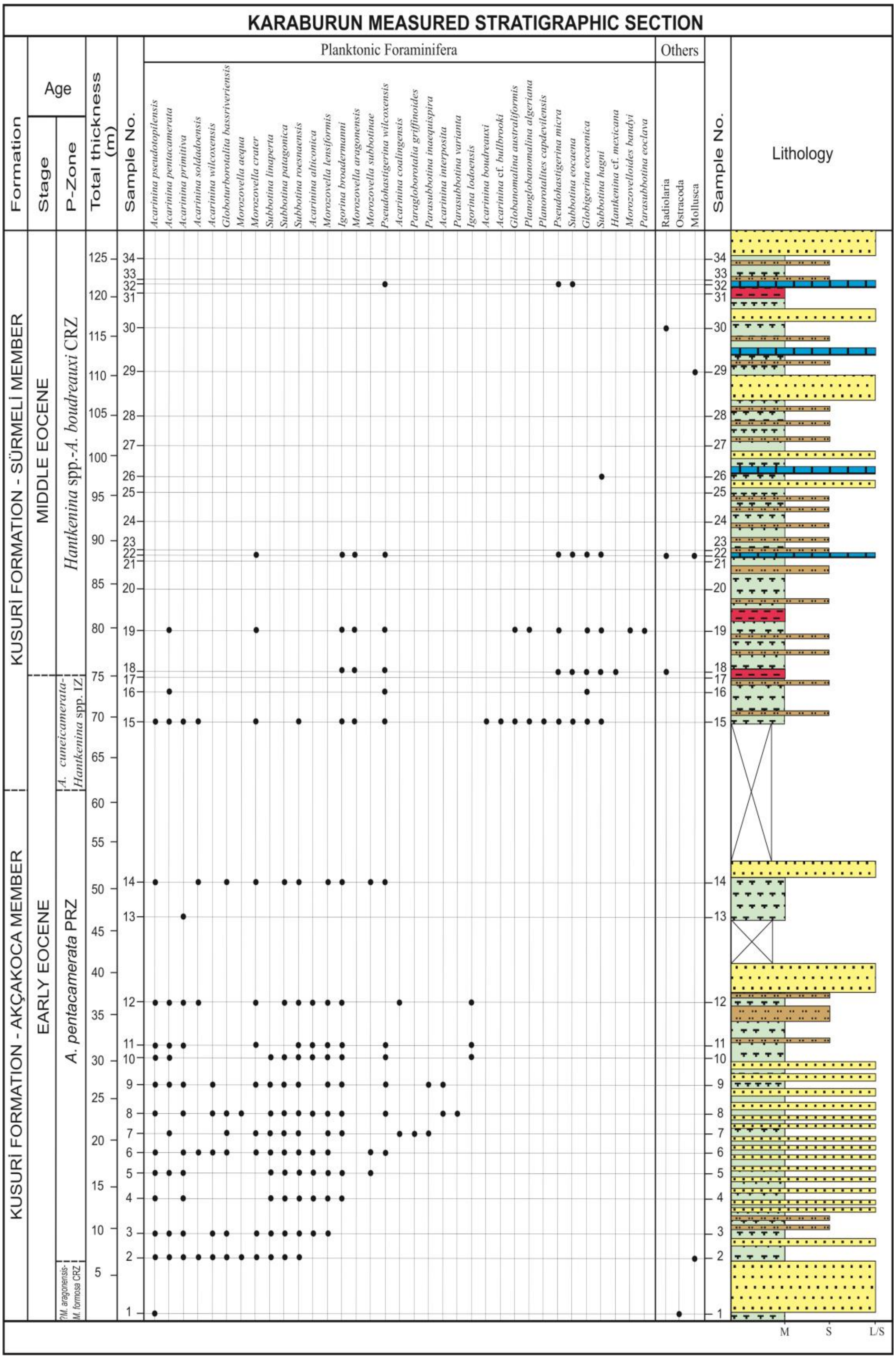

Figure 37. Stratigraphical distribution of planktonic foraminifera and other fossils in the Karaburun Measured Stratigraphic Section.

3.2.2. Ayazlı Measured Stratigraphic Section

The Ayazlı Section contains *Morozovella velascoensis* and *Morozovella subbotinae* partial-range zones (Figure 38).

The existence of the Late Paleocene morozovellids; *Morozovella velascoensis* and *Morozovella occlusa*, together with long ranging *Morozovella aequa, Morozovella gracilis, Morozovella subbotinae, Acarinina soldadoensis, Globanomalina planoconica, Globanomalina australiformis, Subbotina patagonica, Subbotina velascoensis* and *Subbotina triangularis* assign the *Morozovella velascoensis* Partial-range Zone for the samples 1-5. However, because of the absence of the forms, which define the base of Eocene, the Paleocene-Eocene boundary can't be recognized and we can't decide if some part of the P5 Zone belongs to Upper Paleocene, or not.

Passing a 26 m. thick cover, the samples 6 to 10 contain *Morozovella aequa, Acarinina soldadoensis, Subbotina patagonica* and *Subbotina velascoensis,* whose ranges are covering Late Paleocene-Early Eocene interval. However, the disappearance of Late Paleocene morozovellids marks the Early Eocene. The long ranging forms give an interval between *Morozovella velascoensis* Partial-range Zone and *Morozovella aragonensis-Morozovella formosa* Concurrent-range Zone. However, the nannoplankton analysis, carried out by Zeynep Alay in TPAO Research Center from the sample 6, has yielded the NP10 biozone with the presence of *Tribrachiatus contortus*, while the Late Paleocene forms, such as *Fasciculithus tympaniformis, F. alanii, F. thomasii* and *Discoaster multiradiatus* disappear in the previous sample. Therefore, this interval is thought to belong to *Morozovella edgari* Partial-range Subzone.

The first appearance of *Morozovella lensiformis* with the existence of *Morozovella* cf. *marginodentata, Morozovella subbotinae* and *Morozovella gracilis* marks the base of *Morozovella* formosa/Morozovella *lensiformis-Morozovella aragonensis* Interval Subzone starting from the sample 11. The rest of the samples towards the upper parts are barren or contains long ranging forms and/or just benthic foraminifera. Therefore, the upper boundary of the *Morozovella subbotinae* Partial-range Zone isn't be recognized in the section.

Besides the planktonic foraminifera, the benthic foraminifera are abundant through the section, especially close to the Paleocene-Eocene boundary. Some fish teeth, radiolarian and ostracoda fragments have been also recorded in the samples. The details belonging to fossil distribution and biozonation of the Ayazlı section is given in Figure 38.

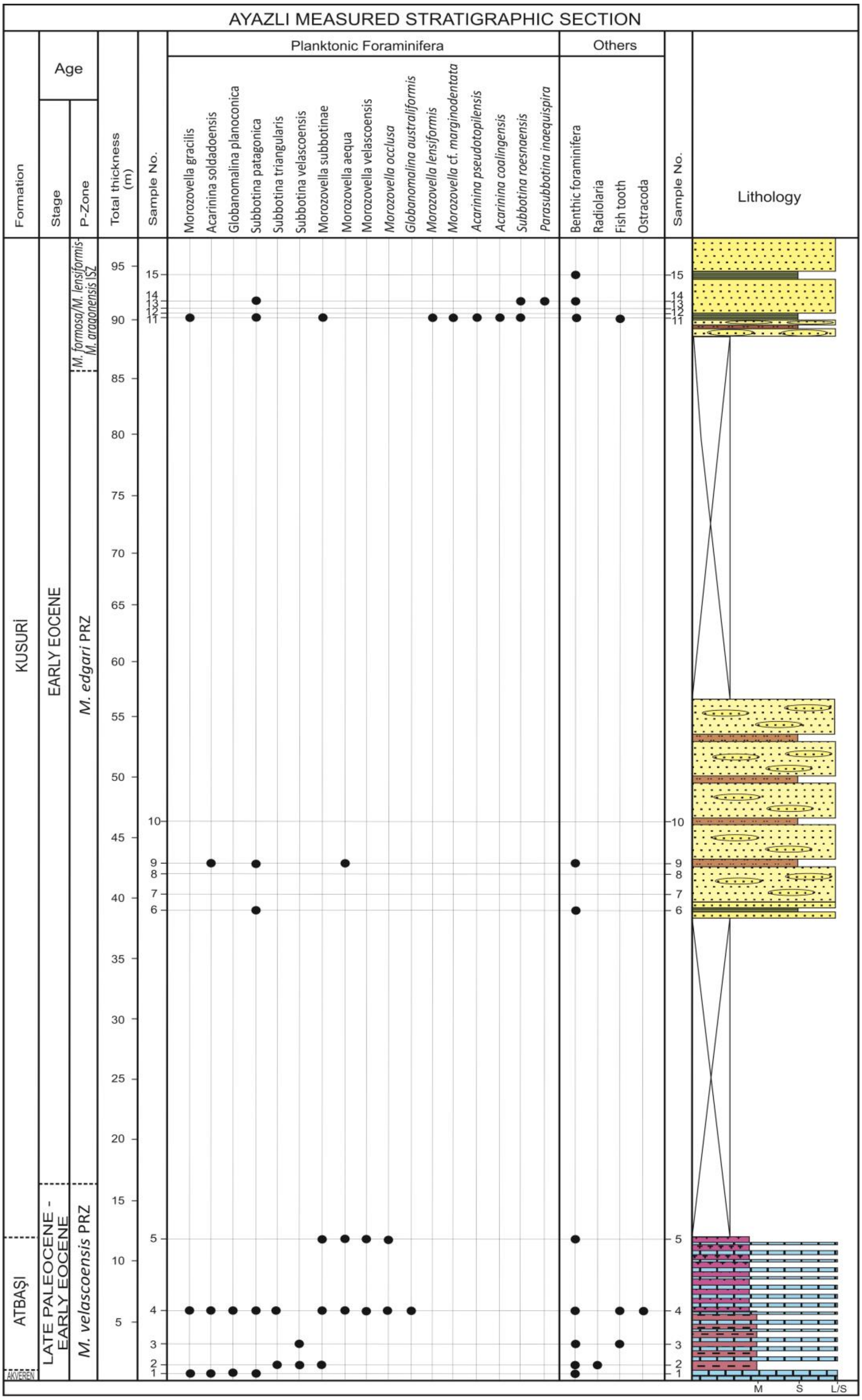

Figure 38. Distribution of planktonic foraminifera and other fossils in the Ayazlı Measured Stratigraphic Section.

3.2.3. İstafan Measured Stratigraphic Section

The İstafan Section covers the uppermost part of Lower Eocene (*Acarinina cuneicamerata-Hantkenina* spp. Interval Zone) and Middle Eocene (*Hantkenina* spp.-*Acarinina boudreauxi* Concurrent-range Zone; Lutetian) (Figure 39).

The Acarinina cuneicamerata-Hantkenina spp. Interval Zone is defined with the presence of Acarinina boudreauxi, A. bullbrooki, A. cuneicamerata, A. pentacamerata, A. punctocamerata, Globigerina eocaenica, Pseudohastigerina micra, P. wilcoxensis, Subbotina eocaena, S. hagni and Turborotalia frontosa.

The first appearance of *Hantkenina* cf. *leibusi* at the sample 11 is used for determining the base of Middle Eocene. The last appearance of *Acarinina pentacamerata*, which is one of the characteristic species for Early Eocene, is also recorded below the Early-Middle Eocene boundary. *Hantkenina* cf. *dumblei, Acarinina boudreauxi, A. bullbrooki, Globigerina eocaenica, Pseudohastigerina micra, Subbotina eocaena, S. hagni* and *Turborotalia frontosa* are the other planktonic foraminifera defined within Middle Eocene *Hantkenina* spp.-*Acarinina boudreauxi* Concurrent-range Zone.

The details belonging to fossil distribution and biozonation of the Ayazlı section are given in Figure 39.

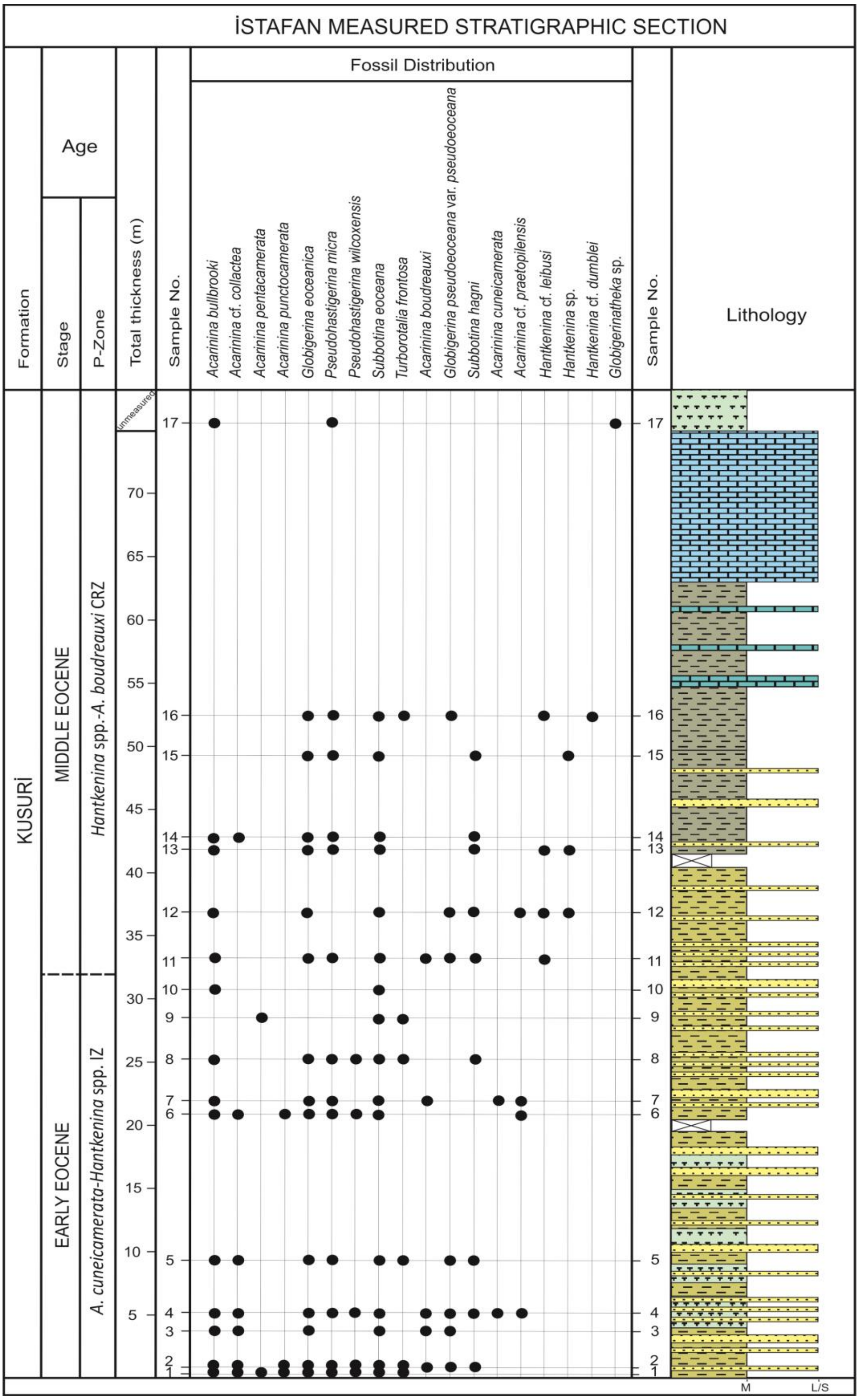

Figure 39. Distribution of planktonic foraminifera and other fossils in the İstafan Measured Stratigraphic Section.

3.2.4. Sinay-Karasu Measured Stratigraphic Section

Sinay-Karasu Section has the longest stratigraphic distribution with respect to the other sections analysed in this study. Section starts with *Acarinina cuneicamerata-Hantkenina* spp. Interval Zone of Early Eocene, followed by *Hantkenina* spp.-*Acarinina boudreauxi* Concurrent-range Zone, *Globigerina eocaenica* Partial-range Zone and *Globigerina turkmenica-Globigerina azerbaidjanica* Concurrent-range Zone of Middle Eocene. The upper part of the section covers Late Eocene with *Globigerina azerbaidjanica-Acarinina medizzai* Interval Zone and an undefined interval (Figure 40).

Acarinina cuneicamerata-Hantkenina spp. Interval Zone is defined with the presence of *Acarinina boudreauxi, A. bullbrooki, A. pseudotopilensis, Igorina broadermanni, Morozovella crater, Parasubbotina eoclava, P. inaequispira, Subbotina eocaena* and *Subbotina yeguaensis* (Figure 40).

The base of Middle Eocene is defined with the first appearance of *Globigerinatheka subconglobata* in sample 11 that defines the lower boundary of *Hantkenina* spp.-*Acarinina boudreauxi* Concurrent-range Zone (Figure 40). Other forms observed in this zone are long ranging forms such as *Acarinina collactea, Pseudohastigerina micra, Subbotina eocaena* and *S. yeguaensis.* The top of the zone is defined by the last occurrence of *Acarinina boudreauxi* in sample 14.

The lower boundary of the *Globigerina eocaenica* Partial-range Zone is defined by the last occurrence of *Acarinina boudreauxi* (Figure 40). The first appearance of *Acarinina collectae/medizzae* is also in sample 15, which is the first sample of this zone. *Orbulinoides beckmanni, Hantkenina alabamensis, Globigerinatheka index* and *Subbotina hornibrooki*, which are the index Middle Eocene forms, haven't been recorded in this interval.

The lower boundary of the *Globigerina turkmenica-Globigerina azerbaidjanica* Concurrent-range Zone is identified in sample 17, which includes endemic Crimean-Caucasus species defining the P14 zone in this region such as *Globigerina azerbaidjanica* and *Globigerina turkmenica. Acarinina collactea, Globigerinatheka subconglobata, Globoturborotalita ouachitaensis, Turborotalia cocoaensis, Pseudohastigerina micra, Subbotina corpulenta, Subbotina eocaena, Subbotina jacksonensis* and *Subbotina yeguaensis* have also been defined within this zone. The upper boundary of this zone is defined by the last occurrence of *Globigerina azerbaidjanica* (Figure 40).

Starting form sample 23 upto the end of the section, the interval is Late Eocene in age (Figure 40). *Globigerina azerbaidjanica-Acarinina medizzai* Interval Zone has been defined between samples 23-24. Long ranging forms such as *Globoturborotalita ouachitaensis*, *Pseudohastigerina micra*, *Subbotina eocaena*, *Subbotina jacksonensis* and *Subbotina yeguaensis* have been identified in this zone. Through the rest of the section, the samples 25-28 mostly contain small benthic foraminifera, fish teeth and other fish fragments like scars and spine. Therefore, age data cannot be supplied by the micropaleontological analyses. However, the palinological analyses, carried out by R. Hayrettin Sancay, from sample 17 and sample 28 identified an Eocene age, so that the age of this interval is recorded as Late Eocene (Figure 40).

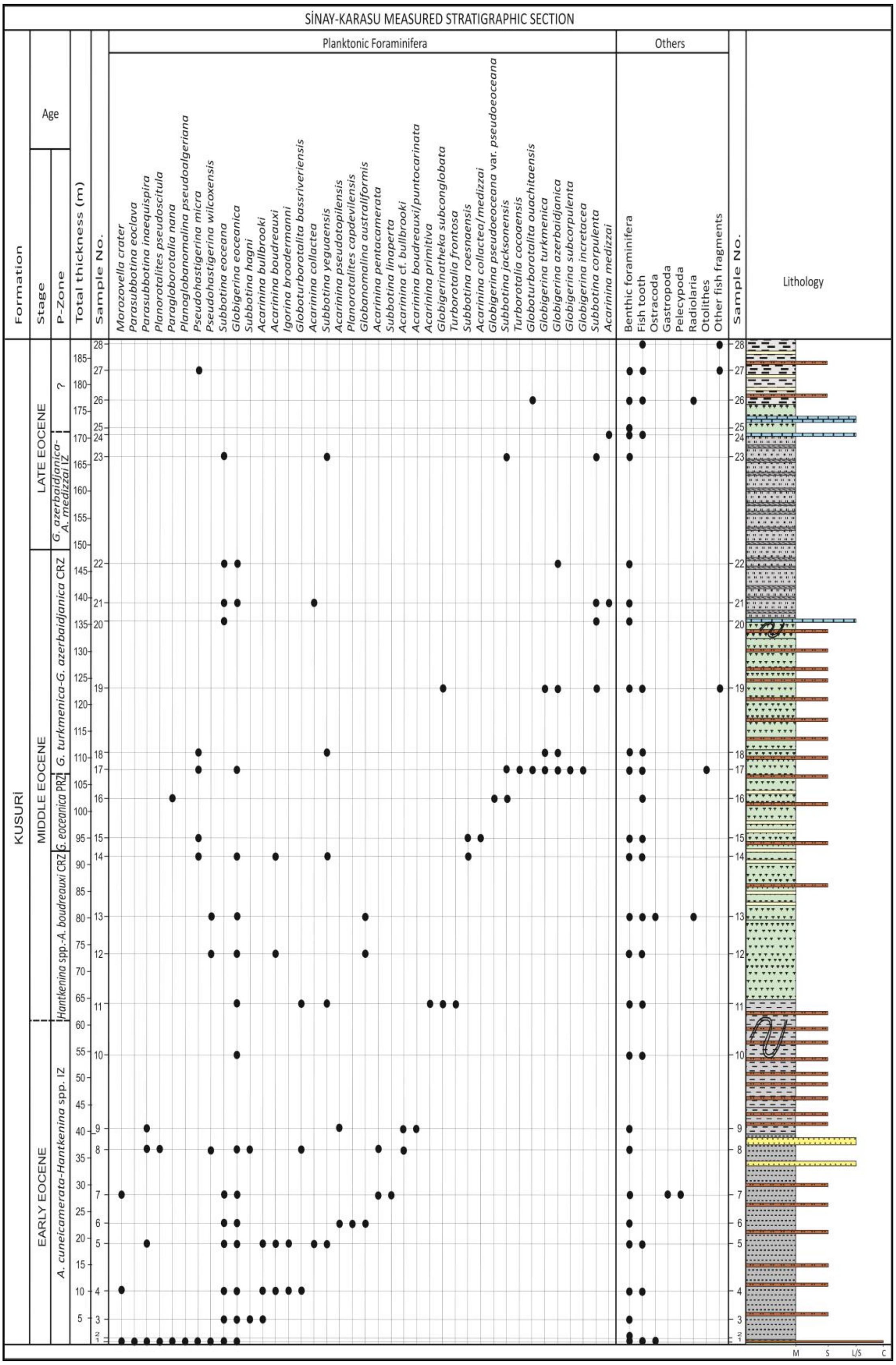

Figure 40. Distribution of planktonic foraminifera and other fossils in the Sinay-Karasu Measured Stratigraphic Section.

3.2.5. Erfelek and Erfelek 1 Measured Stratigraphic Section

The Erfelek Section covers a time interval from latest Cretaceous to Early Eocene. After the establishment of the biostratigraphy in this section, as the Paleocene-Eocene boundary is recognized, a detailed resampling has been needed for this section. Therefore, the boundary interval was measured and resampled in detail as the Erfelek 1 Section. Although the resampling were made throughout the interval from Cretaceous to the P-E boundary, the sampling interval was not frequent in the lower part of this section The sampling frequency was increased around the boundary throughout the Erfelek 1 Section (Figures 41, 42, 43). Both of the sections are described in this part in detail. The stratgraphical positions of the samples of both sections are correlated with each other.

For the samples 1-14 of the Erfelek Section and 1-8 of the Erfelek 1 section, Cretaceous age is assigned by the planktonic foraminifera, mainly globotruncanids and racemiguembelinids, besides the benthic foraminifera (eg. *Siderolites* sp.) and macro fossil fragments (eg. rudists, red algae, etc.) described on the thin sections (Figures 26, 41, 42, 43).

The Cretaceous-Paleocene boundary and the lower part of the Paleocene (P0, Pα zones and P1a subzone) aren’t distinguished in the sections probably because of the sampling frequency. Moreover, the samples in this interval include long ranging small benthic foraminiferal assemblage (samples 15-18 for the Erfelek Section and sample 9 for the Erfelek 1 Section) and the zonation isn’t possible because of the absence of planktonic foraminifera (Figures 41, 42).

The Lower Paleocene covers the interval between samples 15 to 42 of the Erfelek Section and samples 9 to 25 of the Erfelek 1 Section. The first appearance of *Subbotina triloculinoides* in the sample 15 of the Erfelek Section above the Cretaceous taxa marks the base of Lower Paleocene *Subbotina triloculinoides-Praemurica inconstans* Interval Subzone (Figures 41, 42). This subzone is lowermost subzone recorded in the section and the lowest subzone of *Parvularugoglobigerina eugubina-Praemurica uncinata* Interval Zone isn’t identified in the Erfelek Section. *Praemurica pseudoinconstans, Parasubbotina pseudobulloides, Parasubbotina varianta, Subbotina triangularis* and *Subbotina subtriloculinoides* are the identified taxa within this subzone. By the first appearance of *Praemurica inconstans* in sample 28 of the Erfelek Section, *Praemurica inconstans-Praemurica uncinata* Interval Subzone is identified as the upper subzone of the *Parvularugoglobigerina eugubina-Praemurica uncinata* Interval Zone (Figures 41, 42). This level is correlated with sample 10 of the Erfelek 1 Section. The assemblage is the same with the taxa recorded in the previous subzone.

Although the assemblage doesn’t change for the rest of the Lower Paleocene, the first appearance of *Morozovella uncinata* in sample 20 of the Erfelek 1 Section defines the base of the *Morozovella uncinata-Morozovella angulata* Interval Zone. This zone is correlated with the sample 42 of the Erfelek Section. *Globanomalina compressa* and *Eoglobigerina spirialis* are the important forms recorded in this zone. Besides the planktonic foraminifera, rare to common calcareous and agglutinated benthic foraminifera and scarce fish tooth, ostracoda and radiolaria are also present through this interval (Figures 41, 42,43).

Following the Lower Paleocene, the first appearance of *Morozovella angulata* in sample 26 of the Erfelek 1Section and sample 43 of the Erfelek Section marks the base of

Upper Paleocene *Morozovella angulata-Acarinina nitida* Interval Zone. However, neither the subzones defined in the standard Paleocene biozonations, nor the upper boundary of this zone is defined in the sections because of the absence of the index taxa such as *Igorina albeari, Globanomalina pseudomenardii, Acarinina nitida, Acarinina subsphaerica* and *Acarinina soldadoensis.* Therefore, the Upper Paleocene is defined between samples 43-44 of the Erfelek Section and between samples 26-34 of the Erfelek 1 Section. In spite of the absence of a detailed biozonation, some of the first and last occurrences in the sections can be marker levels regarding to the standart biozonation (Figure 42). For example, the last occurrence of *Parasubbotina pseudobulloides* is recorded in sample 28 of the Erfelek 1 Section. The last appearance of this species is towards the middle parts of P3a subzone of Berggren *et al*. (1995) and Olsson *et al*. (1999). The first occurrence of *G. chapmani* is in the middle part of P3b subzone and the last occurrence of *M. angulata* is in the lower part of P4a subzone with respect to the fossil ranges defined by Olsson *et al*. (1999). Therefore, the coexistence of *Morozovella angulata* and *Globanomalina chapmani* for sample 32 of the Erfelek 1 Section represents an interval of P3b-P4a subzones of the standart biozonation. The first appearance of *Subbotina patagonica* is in sample 33 of the Erfelek 1 Section. Its first appearance is at the base of P4b subzone with respect to Olsson *et al*. (1999).

Morozovella conicotruncata, Morozovella velascoensis, Parasubbotina cf. *variospira, Parasubbotina varianta, Subbotina triangularis* and *Subbotina subtriloculinoides* are the important taxa observed for the Upper Paleocene interval in the sections. Besides the planktonic foraminiferal assemblage, both calcareous and agglutinated foraminifera are common in this interval and also rare fish teeth exist (Figures 41, 42, 43).

Although the lower boundary of the zone isn't defined in the sections, the Paleocene-Eocene boundary takes place within *Morozovella velascoensis* Partial-range Zone (Olsson *et al.*, 1999; Pearson *et al.*, 2006). The species such as *Acarinina africana*, *Acarinina sibaiyaensis* and *Morozovella allisonensis*, defining the E1 zone; the lowermost biozone of Eocene defined by Berggren and Pearson (2005), haven't been recorded in the section, either the sampling interval or the absence of these taxa due to the facies control. However, the Paleocene-Eocene boundary is defined between samples 34 and 35 of the Erfelek 1 Section by the presence of *Acarinina wilcoxensis* at sample 35 (Figures 41, 42). This level is correlated between the samples 44 and 45 of the Erfelek Section. The Eocene section of the *Morozovella velascoensis* Partial-range Zone is recognized by the occurrence of *Globanomalina australiformis, Globanomalina chapmani, Globanomalina planoconica, Acarinina pseudotopilensis, Acarinina soldadoensis, Acarinina wilcoxensis, Acarinina esnaensis, Planorotalites pseudoscitula, Igorina broadermanni, Globoturborotalita bassriveriensis, Morozovella aequa, Morozovella subbotinae, Morozovella gracilis, Morozovella edgari, Parasubbotina inaequispira, Subbotina patagonica* and *Subbotina roesnaensis.* Numerous benthic foraminifera, besides rare fish teeth, radiolaria, ostracoda and macrofossil fragments are recognized in this zone. In the Paleocene-Eocene boundary studies, an increase in the number of the fish teeth is mentioned in an interval where the foraminifera got extinct through carbonate dissolution (Berggren and Ouda, 2003; Ernst *et al*., 2006; Soliman *et al*., 2011; Khozyem *et al*., 2013). However, such an increase hasn't been recorded in the present study just above the boundary different than the global data (Figure 41). The Erfelek 1 Section ends within the *Morozovella velascoensis* Partial-range Zone. The upper boundary of the zone is defined by the last occurrence of *Morozovella velascoensis* in sample 48 of the Erfelek Section (Figure 41).

The interval between the last occurrence of *Morozovella velascoensis* and first occurrence of *Morozovella formosa* is defined as the *Morozovella edgari* Partial-range Subzone, which is the lower subzone of the *Morozovella subbotinae* Partial-range Zone in the Erfelek Section (Samples 49-55) (Figure 41). *Acarinina esnaensis, Acarinina wilcoxensis, Acarinina pseudotopilensis, Morozovella gracilis, Morozovella aequa, Igorina broadermanni, Igorina lodoensis, Subbotina patagonica* and *Subbotina roesnaensis* are noticed within this subzone. Agglutinated benthic foraminifera are more frequent in this interval with respect to calcareous benthic foraminifera. Number of fish fragments (teeth, scar and spine) is relatively increasing in sample 51, whereas they are absent or very rare in other samples in the interval.

By the first appearance of *Morozovella formosa;* the lower boundary of *Morozovella* formosa/Morozovella *lensiformis-Morozovella aragonensis* Interval Subzone is defined in sample 56 (Figure 41). This subzone is spanning an interval from sample 56 to sample 70. *Morozovella lensiformis, Morozovella subbotinae, Morozovella gracilis, Acarinina interposita, Acarinina pseudotopilensis, Acarinina esnehensis, Acarinina esnaensis, Acarinina wilcoxensis, Acarinina coalingensis, Igorina broadermanni, Igorina lodoensis, Globoturborotalita bassriveriensis, Subbotina patagonica* and *Subbotina roesnaensis* are the assemblage of this subzone. Agglutinated benthic foraminifera are also more frequent in this subzone with respect to calcareous benthic foraminifera. In addition, rare fish teeth, pelecypoda and ostracoda fragments are present.

Morozovella aragonensis-Morozovella formosa Concurrent-range Zone is defined by the first appearances of *Acarinina pentacamerata* in sample 71 (Figure 41). *Morozovella gracilis, Morozovella subbotinae, Acarinina wilcoxensis, Acarinina esnaensis, Acarinina coalingensis, Acarinina pseudotopilensis, Globanomalina planoconica, Globoturborotalita bassriveriensis, Subbotina linaperta, Subbotina patagonica* and *Subbotina roesnaensis* are observed within this zone. Number of benthic foraminifera is decreasing in the lower parts of the zone with respect to the *Morozovella subbotinae* Partial-range Zone. The assemblage is rich in agglutinated benthic foraminifera.. However, towards the upper parts of the interval, both agglutinated and calcareous benthic foraminifera are frequent except the last 3 samples (Samples 85-87) of the zone. Fish teeth are sporadic within this zone.

The first appearance of *Acarinina primitiva* marks the base of *Acarinina pentacamerata* Partial-range Zone in sample 88 (Figure 41). *Morozovella lensiformis, Acarinina interposita, Acarinina pentacamerata, Acarinina pseudotopilensis, Acarinina soldadoensis, Igorina lodoensis, Globoturborotalita bassriveriensis, Subbotina linaperta, Subbotina patagonica* and *Subbotina roesnaensis* are common in the *Acarinina pentacamerata* Partial-range Zone. Agglutinated benthic foraminifera are more common than calcareous benthic foraminifera and fish teeth are sporadic in this interval. This zone is the uppermost zone observed in the Erfelek Section.

The details belonging to fossil distribution and biozonation of the Erfelek section and the Erfelek 1 section are given in Figure 41, 42 and 43 respectively.

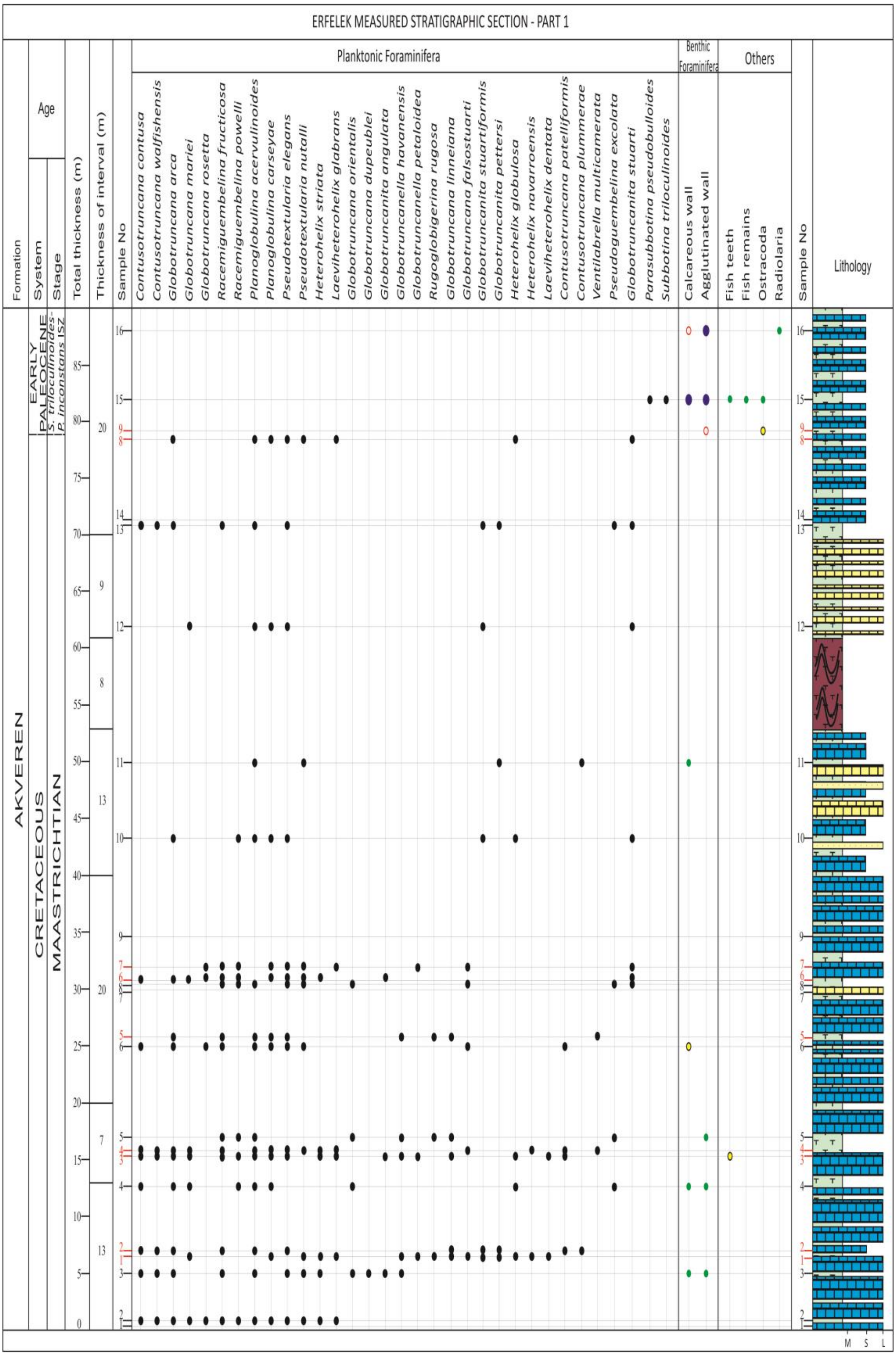

Figure 41. Distribution of planktonic foraminifera and other fossils in the Erfelek Measured Stratigraphic Section. Red colored sample numbers marks the position of the samples of the Erfelek 1 Section. (Number of individuals: black= 1, green=2-5, red=6-20, purple=21-100).

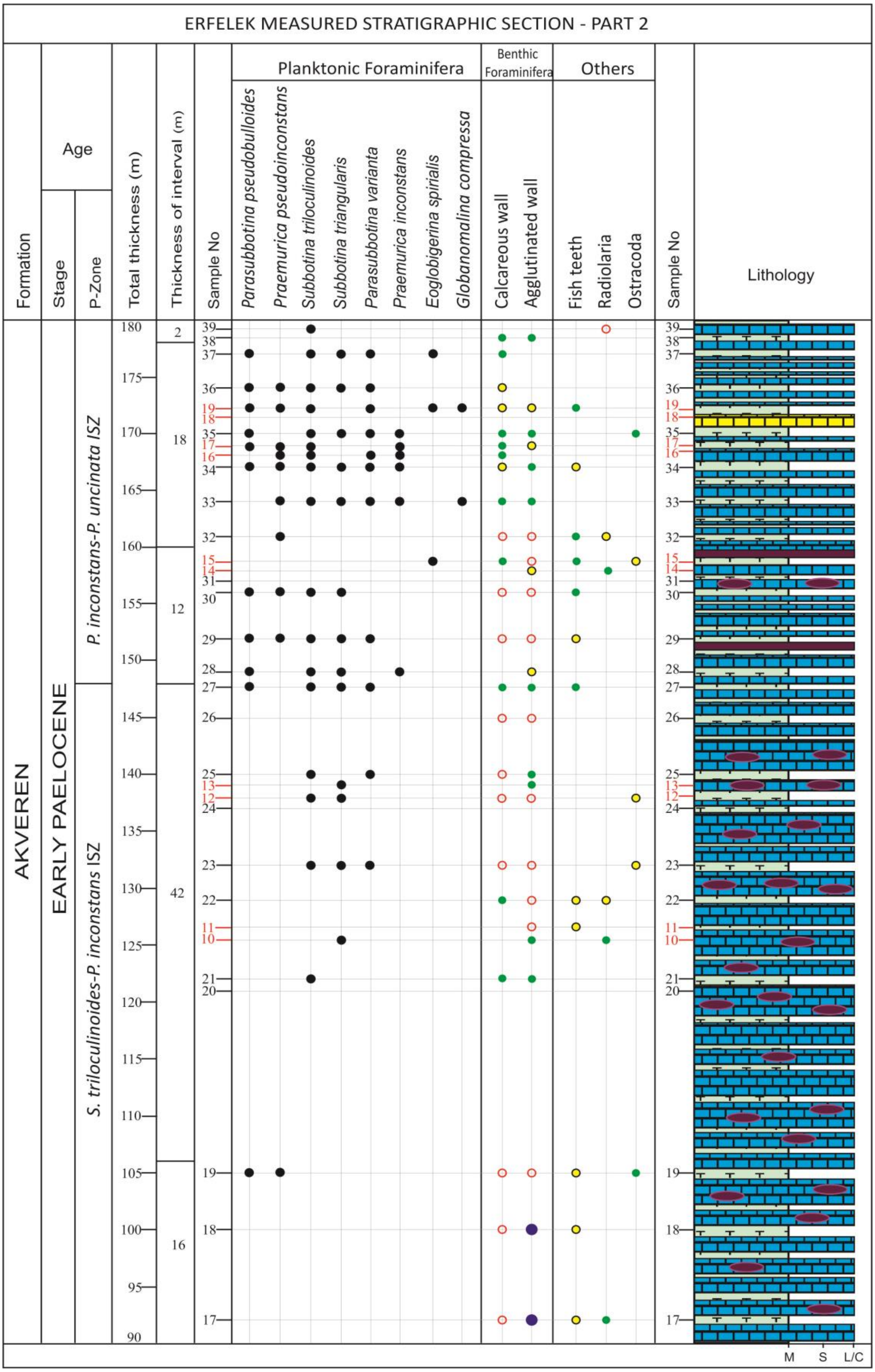

Figure 41. (Continued)

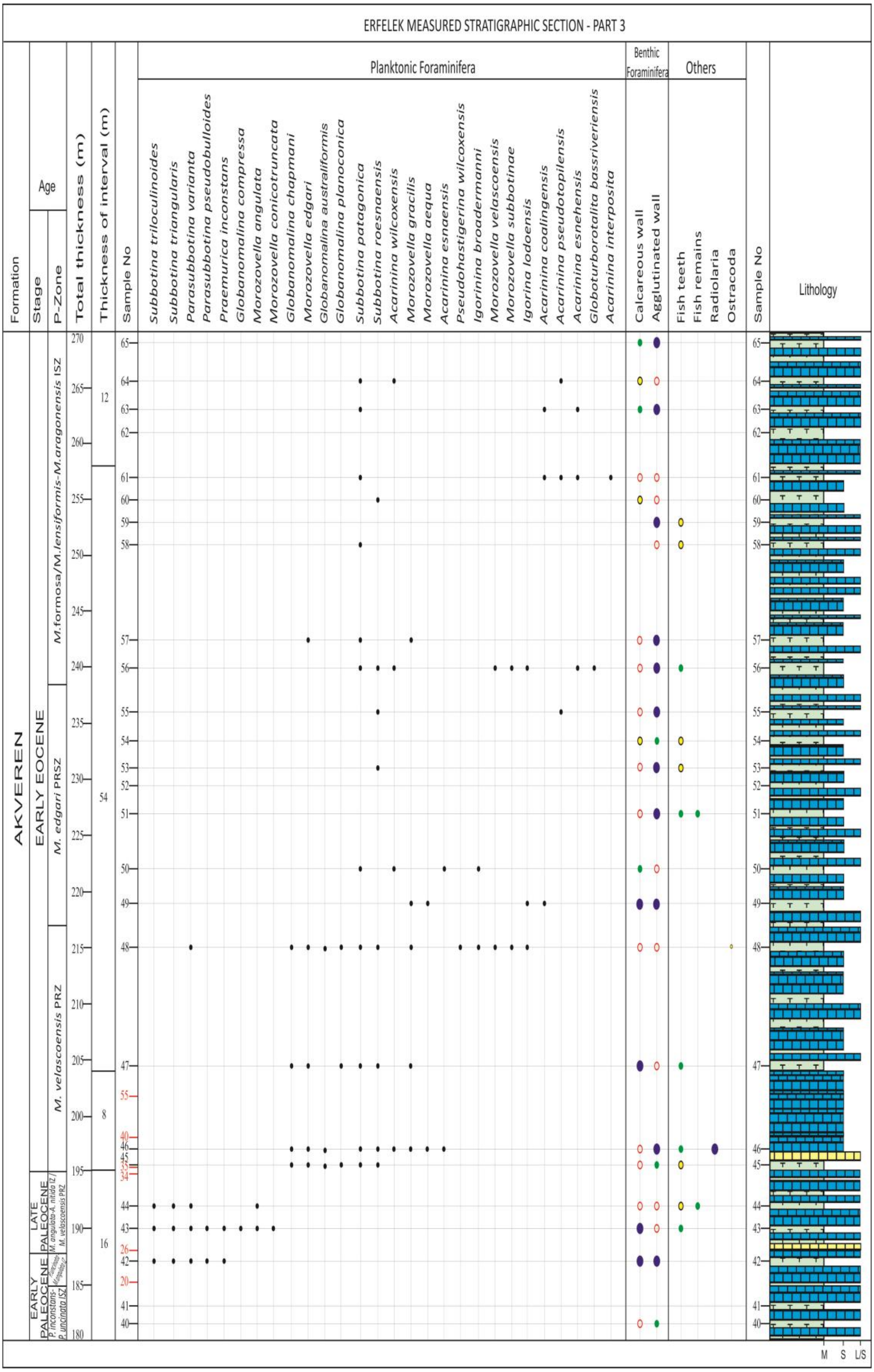

Figure 41. (Continued)

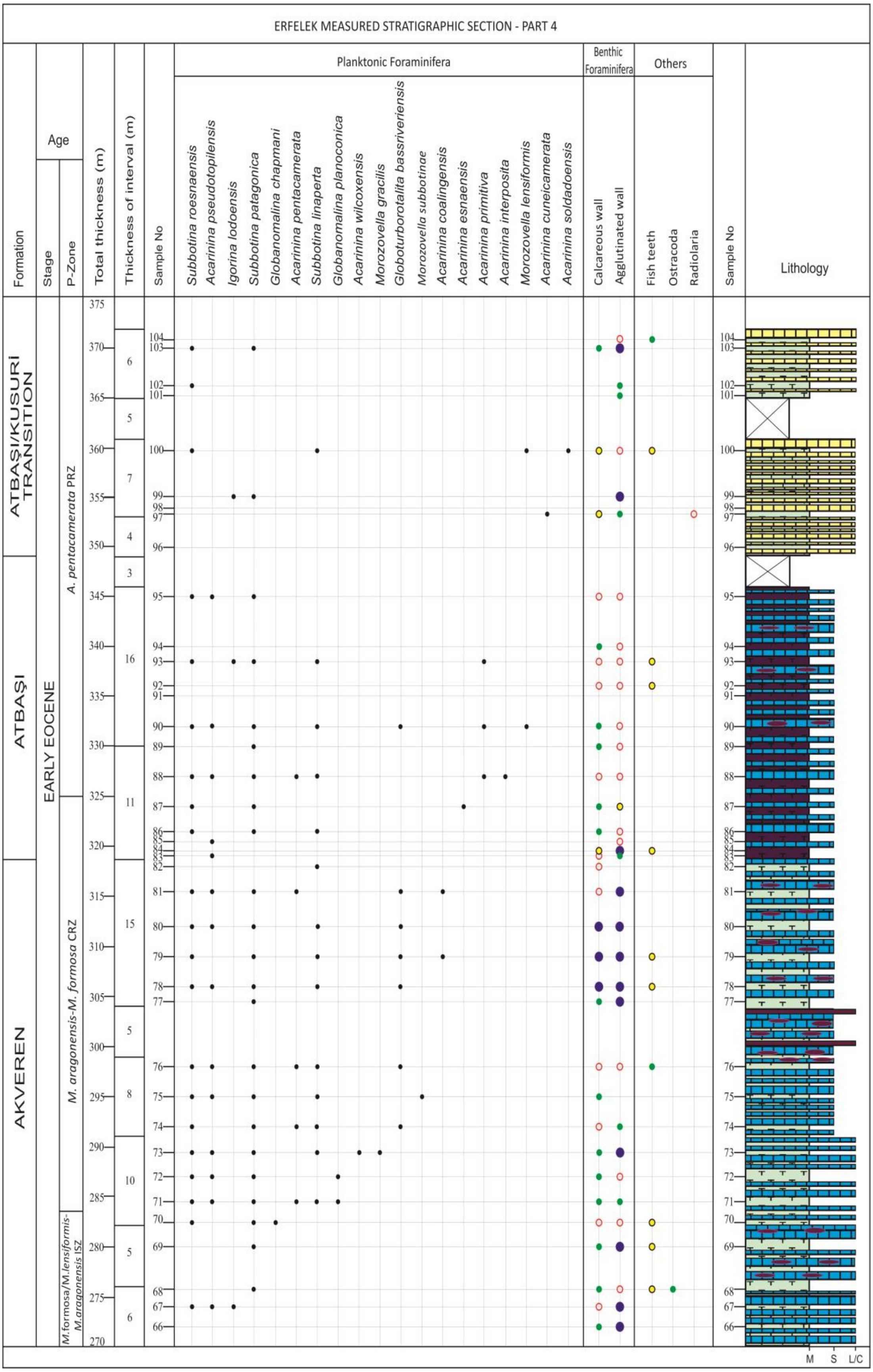

Figure 41. (Continued)

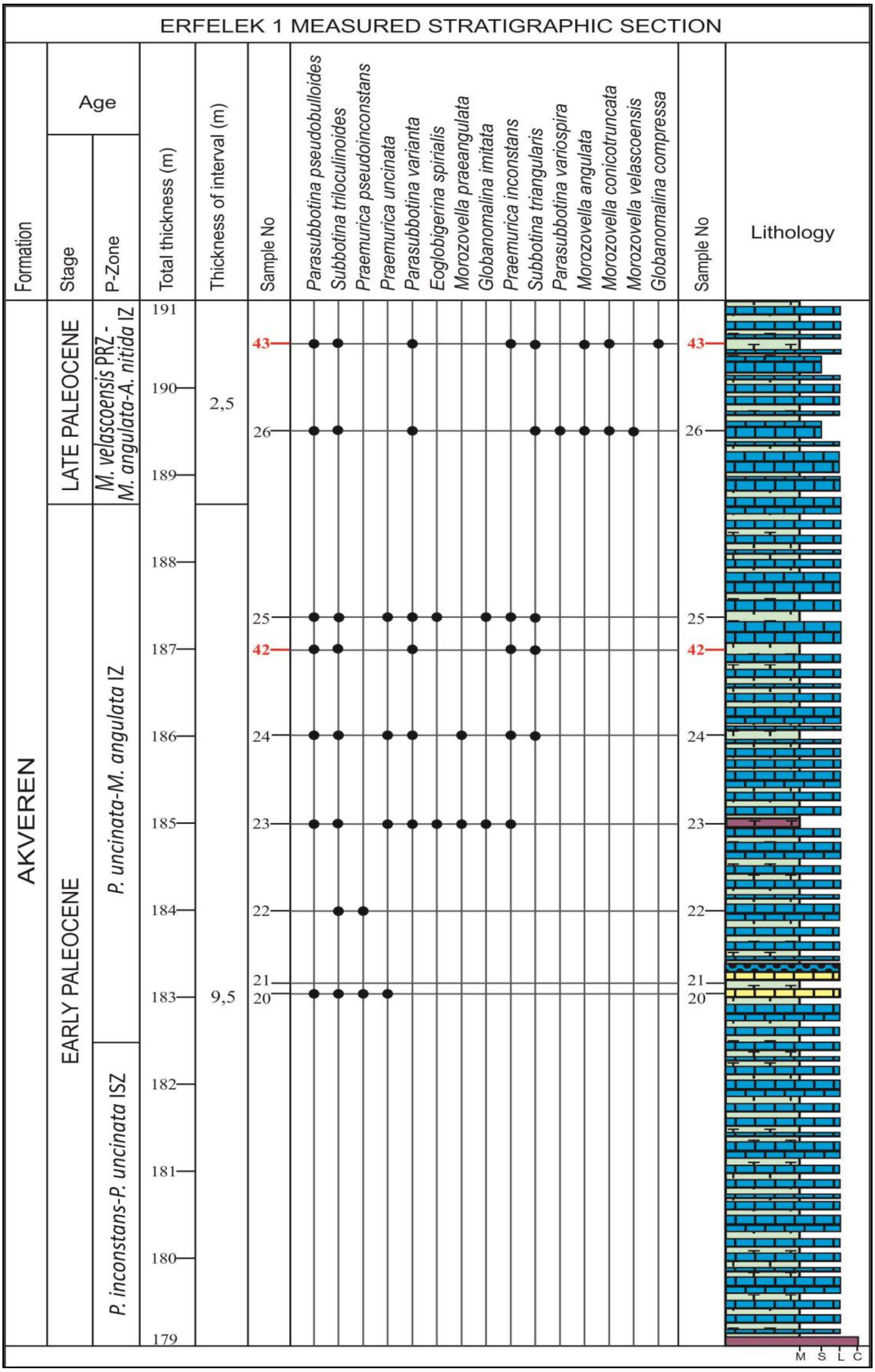

Figure 42. Planktonic foraminifera distribution and biozonation of the Erfelek Measured Stratigraphic Section.

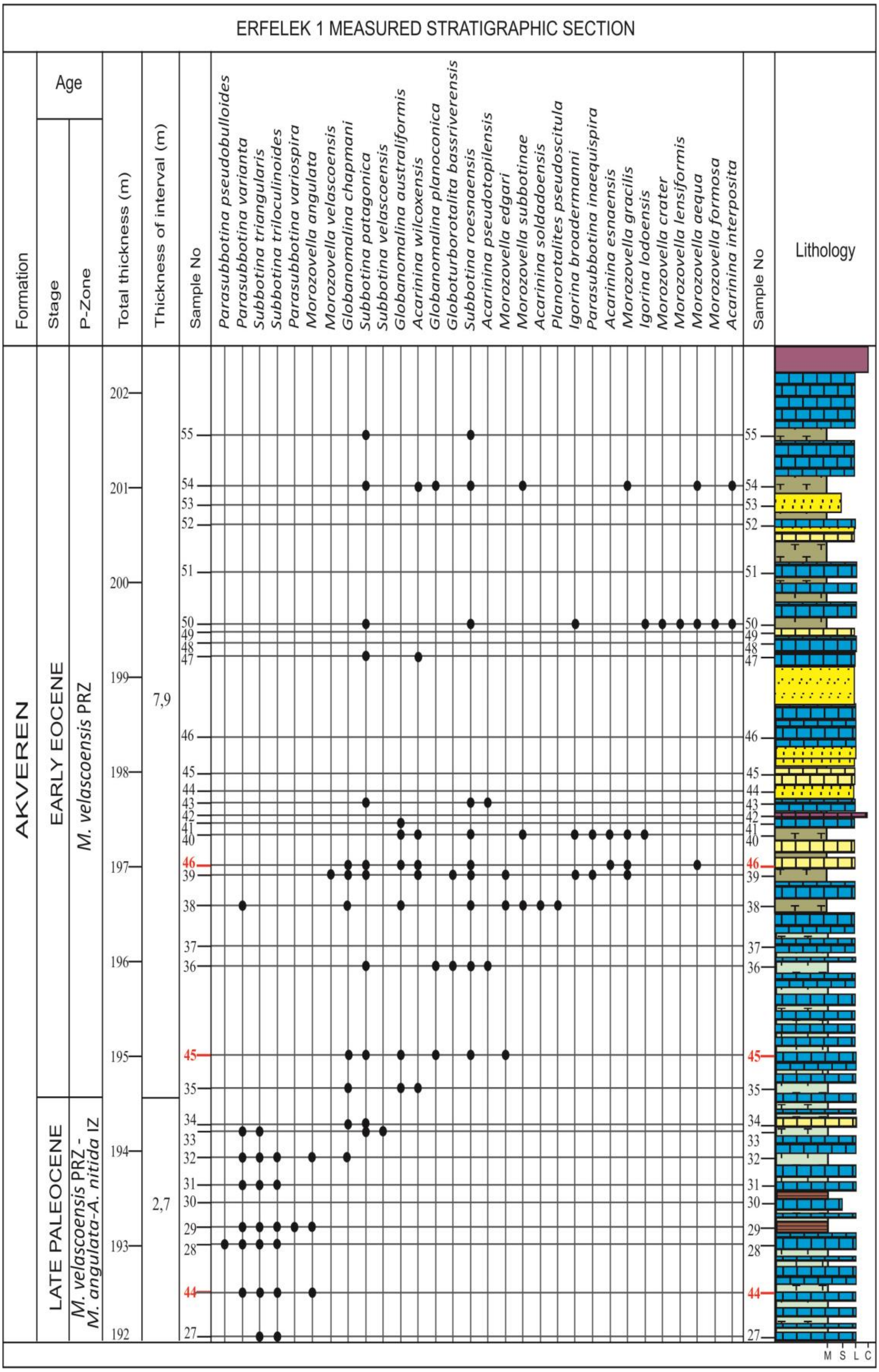

Figure 42. (Continued)

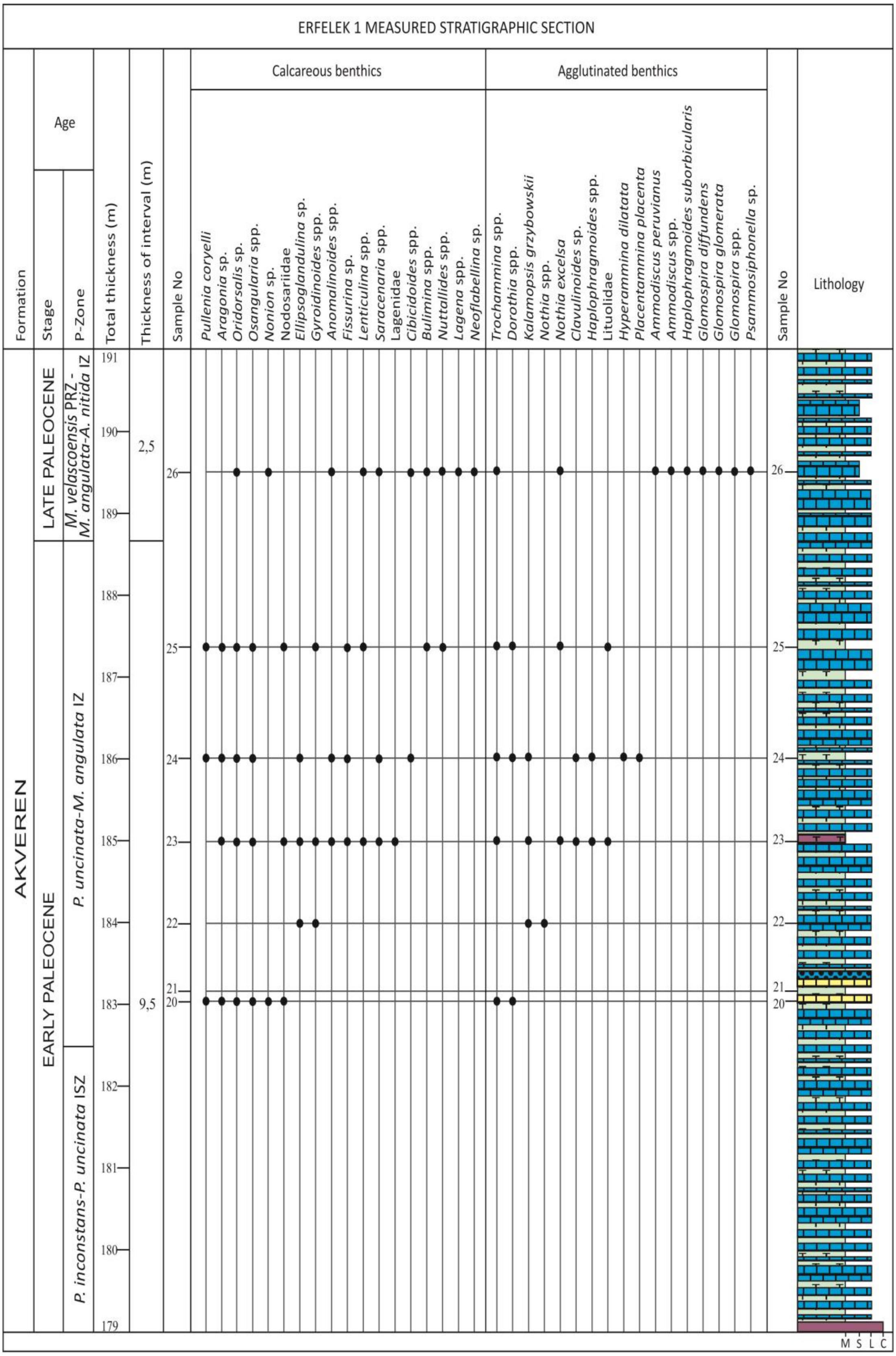

Figure 43. Benthic foraminifera distribution and biozonation of the Erfelek Measured Stratigraphic Section.

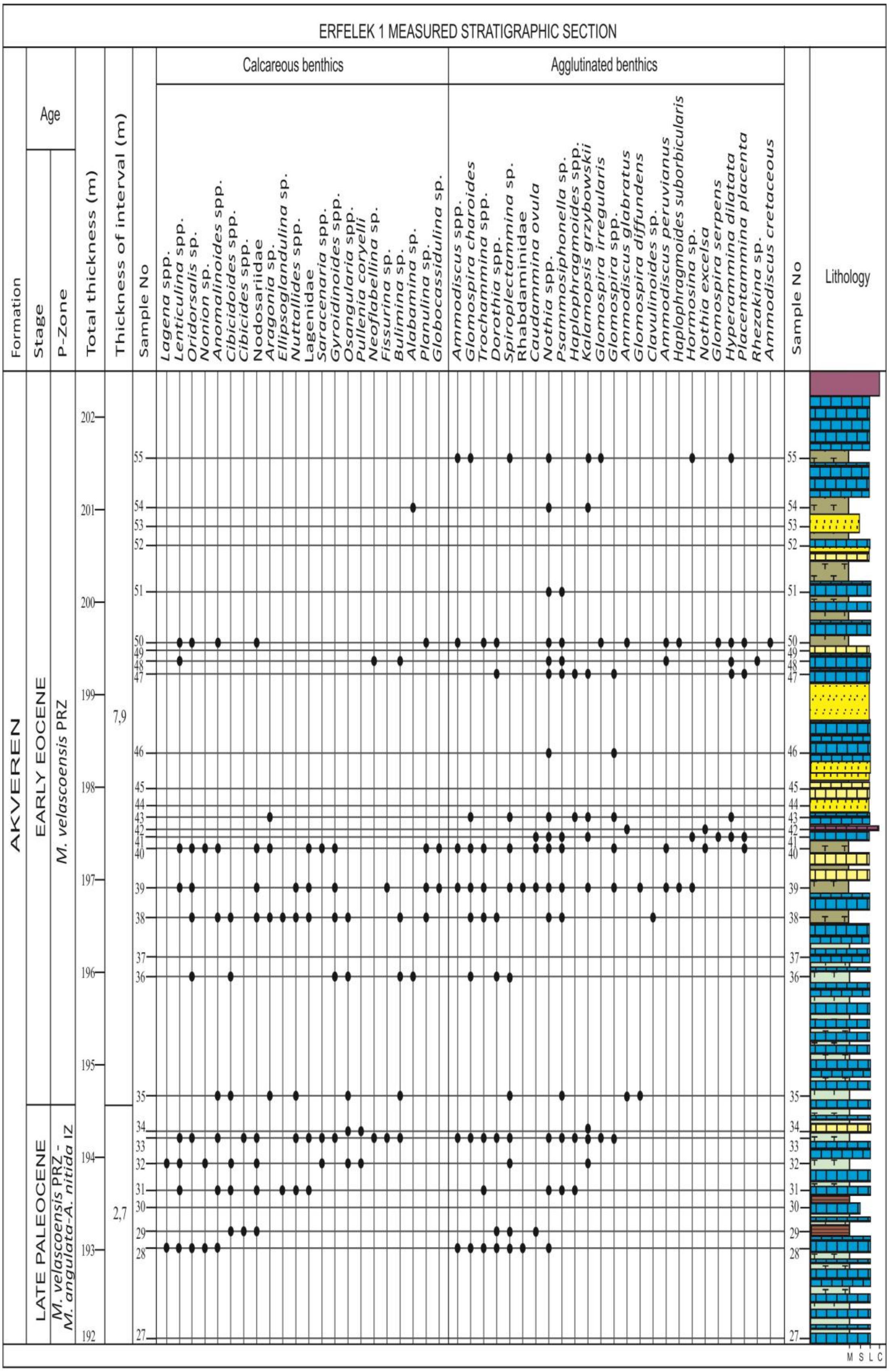

Figure 43. (Continued)

3.2.6. Erfelek-A Measured Stratigraphic Section

The Erfelek-A Section is an Early Eocene section. It covers the upper two zones of Lower Eocene, which are *Acarinina pentacamerata* Partial-range Zone and *Acarinina cuneicamerata-Hantkenina* spp. Interval Zone (Figure 44).

The section starts with the *Acarinina pentacamerata* Partial-range Zone (Figure 44), whose assemblage mainly contains *Planoglobanomalina pseudoalgeriana*, *Acarinina primitiva*, *Acarinina quetra*, *Acarinina pseudotopilensis*, *Acarinina coalingensis*, *Acarinina pentacamerata*, *Morozovella lensiformis*, *Morozovella crater*, *Igorina lodoensis*, *Igorina broadermanni*, *Parasubbotina inaequispira*, *Pseudohastigerina wilcoxensis*, *Subbotina eocaena*, *Subbotina roesnaensis* and *Subbotina patagonica*. Within the samples of this interval, mostly a few calcerous benthic foraminifera and sporadic agglutinated benthic foraminifera are present. Only in sample 4, there is an increase in the number of agglutinated benthic foraminifera within the zone. In the middle part of *Acarinina pentacamerata* Partial-range Zone, radiolaria are commonly present.

The identification of *Acarinina cuneicamerata* in Sample 6 indicates the lower boundary of *Acarinina cuneicamerata-Hantkenina* spp. Interval Zone (Figure 44). This zone continues through the rest of the Erfelek-A Section. *Morozovella crater*, *Morozovella aragonensis*, *Acarinina boudreauxi*, *Acarinina pseudotopilensis*, *Acarinina alticonica*, *Acarinina pentacamerata*, *Acarinina soldadoensis*, *Pseudohastigerina wilcoxensis*, *Igorina lodoensis*, *Subbotina roesnaensis*, *Subbotina eocaena* and *Subbotina patagonica* are described through this interval between samples 12 and 15. Benthic foraminiferal abundance is rare in this last part of the Erfelek-A Section. There is an increase in the number of agglutinated benthic foraminifera in sample 11 within the zone. A few radiolaria and fish tooth specimens are also present in this zone.

The details belonging to fossil distribution and biozonation of the Erfelek-A section are given in Figure 44.

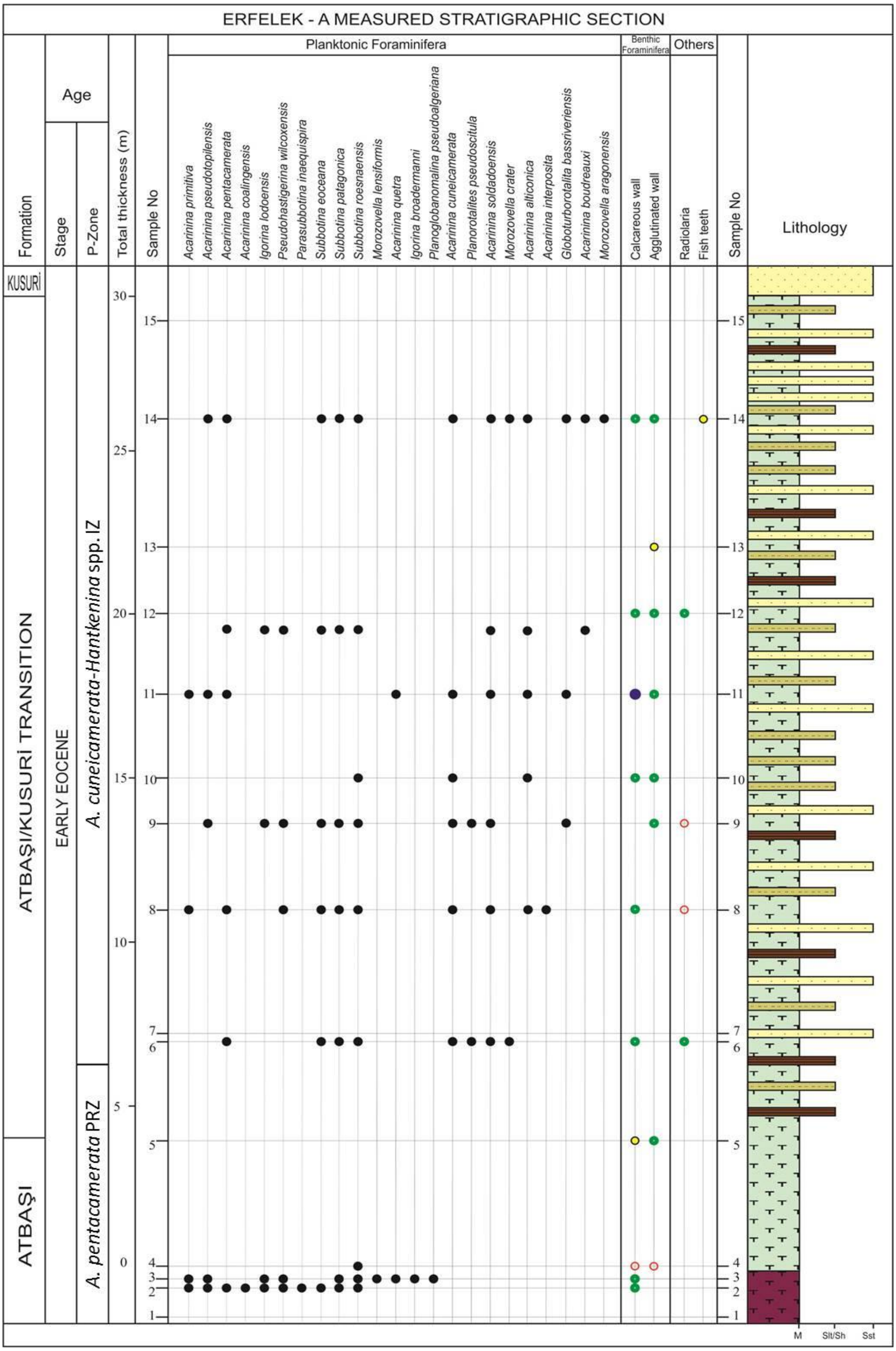

Figure 44. Distribution of planktonic foraminifera and other fossils in the Erfelek-A Measured Stratigraphic Section.

3.2.7. Kaymakam Kayası Measured Stratigraphic Section

The Kaymakam Kayası Section starts with an interval covering the *Praemurica inconstans-Praemurica uncinata* Interval Subzone (uppermost subzone of the *Parvularugoglobigerina eugubina-Praemurica uncinata* Interval Zone) to the *Morozovella angulata-Acarinina nitida* Interval Zone (Figure 45). This interval includes *Eoglobigerina spirialis, Parasubbotina pseudobulloides, Parasubbotina varianta, Praemurica inconstans, Subbotina triangularis, Subbotina triloculinoides, Globanomalina compressa, Globanomalina imitata, Globanomalina ehrenbergi, Globanomalina chapmani* and *Acarinina strabocella.* Rare to common calcareous and agglutinated benthic foraminifera is also present in this interval in addition to sporadic ostracoda, macrofossil fragments, radiolaria and fish teeth.

Lower-Upper Paleocene boundary isn't differentiated in this section because of the absence of *Morozovella angulata* (Figure 45). However, the disappearance of *Parasubbotina pseudobulloides* and *Praemurica inconstans* in the sample 11 notifies that the boundary is below this level as the last occurrences of these species is within the P3a zone of Berggren *et al.* (1995) with respect to Olsson *et al.* (1999), which is the lowermost subzone of the Upper Paleocene.

The first appearance of *Acarinina nitida* in sample 26 marks the base of *Acarinina nitida-Globanomalina pseudomenardii* Concurrent Range Zone (Figure 45). There isn't a rich planktonic foraminifera assemblage through this zone. *Globanomalina pseudomenardii, Parasubbotina varianta, Subbotina triangularis* and *Subbotina triloculinoides* are other described forms. The benthic foraminifera are more common with respect to planktonic foraminifera in this interval and their abundances are increasing towards the top. The subzones cannot be differentiated for this zone in the Kaymakam Kayası Section because of the scarcity of the planktonic foraminifera.

The last occurrence of *Globanomalina pseudomenardii* and *Acarinina nitida* in sample 37 is used to separate *Acarinina nitida-Globanomalina pseudomenardii* Concurrent Range Zone and *Morozovella velascoensis* Partial-range Zone (Figure 45). *Globanomalina chapmani, Parasubbotina varianta, Subbotina velascoensis, Subbotina triangularis* and *Subbotina patagonica* are observed within the *Morozovella velascoensis* Partial-range Zone. Rare to common benthic foraminifera are also present here.

The Paleocene-Eocene boundary in the Kaymakam Kayası Section is marked by the first appearance of *Acarinina pseudotopilensis* in sample (Figure 45). The Eocene section of the *Morozovella velascoensis* Partial-range Zone includes *Morozovella velascoensis, Morozovella aequa, Morozovella acuta, Acarinina wilcoxensis, Acarinina soldadoensis, Globanomalina australiformis, Globanomalina planoconica, Subbotina velascoensis, Subbotina roesnaensis* and *Subbotina patagonica.* Benthic foraminifera are more common in this uppermost part of the section with respect to the lower parts.

The details, belonging to fossil distribution and biozonation of the Kaymakam Kayası section, are given in Figure 45.

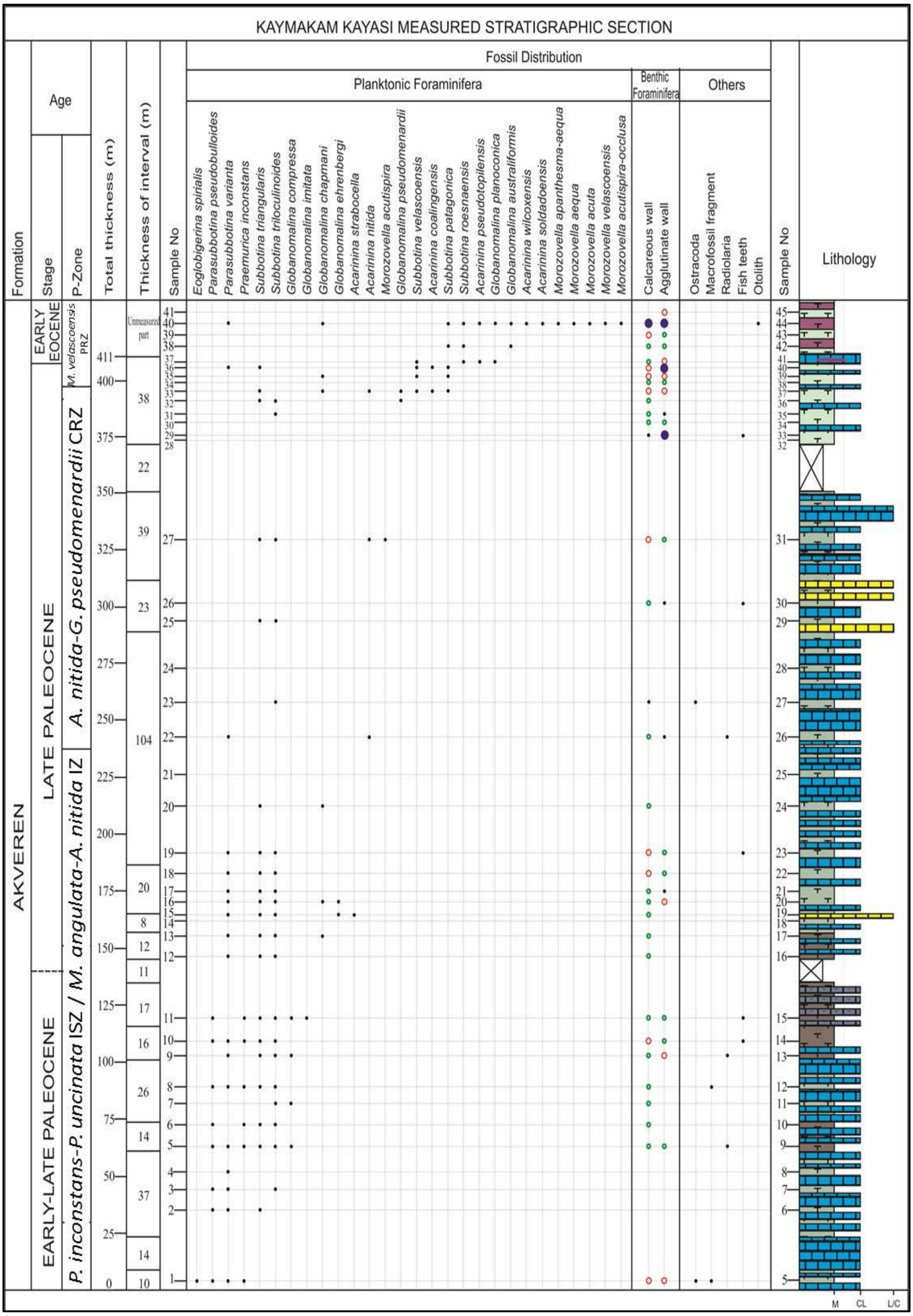

Figure 45. Distribution of planktonic foraminifera and other fossils in the Kaymakam Kayası Measured Stratigraphic Section. The colors of the dots are defining the relative abundance of the benthic foraminifera via quantitative analyses (Number of individuals: black= 1, green=2-5, red=6-20, purple=21-100).

3.2.8. Kaymakam Kayası-A Measured Stratigraphic Section

The Kaymakam Kayası-A Section covers the Lower Eocene *Morozovella* formosa/Morozovella *lensiformis-Morozovella aragonensis* Interval Subzone of the *Morozovella subbotinae* Partial-range Zone, *Morozovella aragonensis-Morozovella formosa* Concurrent-range Zone and *Acarinina pentacamerata* Partial-range Zone.

The presence of *Morozovella aequa, Morozovella lensiformis, Morozovella crater, Acarinina wilcoxensis, Acarinina alticonica, Acarinina coalingensis, Acarinina pseudotopilensis, Acarinina soldadoensis, Igorina broadermanni, Igorina lodoensis, Pseudohastigerina wilcoxensis, Subbotina roesnaensis* and *Subbotina patagonica* defines a *Morozovella* formosa/*Morozovella lensiformis-Morozovella aragonensis* Interval Subzone in samples 1 and 2 (Figure 46). In these two samples, a few calcareous and agglutinated benthic foraminifera are also recorded.

The first appearance of *Morozovella aragonensis* in the sample 3 marks the boundary between the *Morozovella subbotinae* Partial-range Zone and the *Morozovella aragonensis-Morozovella formosa* Concurrent-range Zone. *Morozovella aragonensis-Morozovella formosa* Concurrent-range Zone continues up to the sample 7. The samples in this zone include *Morozovella subbotinae, Morozovella aequa, Morozovella lensiformis, Morozovella crater, Acarinina alticonica, Acarinina coalingensis, Acarinina pseudotopilensis, Acarinina wilcoxensis, Globoturborotalita bassriveriensis, Pseudohastigerina wilcoxensis, Subbotina linaperta, Subbotina roesnaensis* and *Subbotina patagonica.* The benthic foraminifera are also rare in this zone (Figure 46).

The last appearance of *Morozovella formosa* at the sample 7 is used to define the base of the *Acarinina pentacamerata* Partial-range starting with the sample 8 (Figure 46). The first appearance of *Pseudoglobanomalina pseudoalgeriana* is also within this zone. *Morozovella aragonensis, Morozovella crater, Morozovella lensiformis, Acarinina pentacamerata, Acarinina primitiva, Acarinina pseudotopilensis, Acarinina alticonica, Acarinina interposita, Pseudohastigerina wilcoxensis, Parasubbotina inaequispira, Subbotina eoceana, Subbotina patagonica* and *Subbotina roesnaensis* are the other species recoded in this interval. The benthic foraminifera are rare to common in this zone, generally with more abundant calcareous forms except the middle parts of the zone.

The details belonging to fossil distribution and biozonation of the Kaymakam Kayası-A section are given in Figure 46.

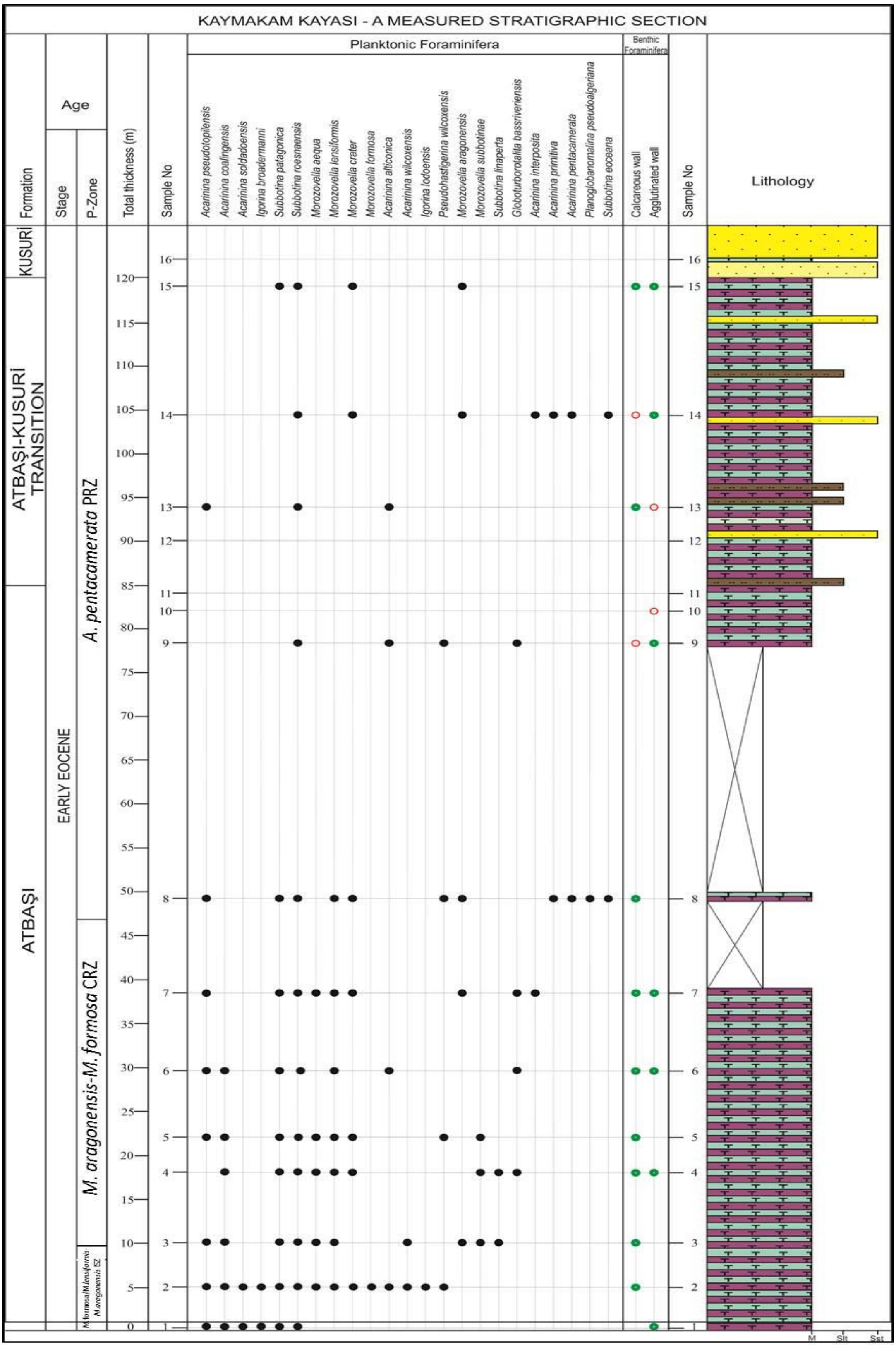

Figure 46. Distribution of planktonic foraminifera and other fossils in the Kaymakam Kayası-A Measured Stratigraphic Section. (Number of individuals: black= 1, green=2-5, red=6-20).

CHAPTER 4

TAXONOMY

In this study, the taxonomical work has been carried out for both planktonic and benthic foraminifera. 4 families, 18 genera and 85 species have been identified for the planktonic foraminifera. For the benthic foraminifera, species rank isn't defined for all specimens and some of the individuals are defined as families or genera. A total of 30 families, 38 genera and 14 species were defined for the benthic foraminifera.

4.1. PALEOCENE – EOCENE PLANKTONIC FORAMINIFERA

The generally accepted classification of the foraminifera is based on that of Loeblich and Tappan (1964). However, one of the oldest classifications for the planktonic foraminifera has been suggested by Subbotina (1953). This classification only consisted of Globigerinidae, Hantkeninidae and Globorotalidae families and explained both Cretaceous and Paleogene forms of USSR. Bolli *et al.* (1957) proposed a classification for families including Hantkeninidae, Orbulinidae, Globorotalidae and Globotruncanidae. Classification of the Globigerinacea was studied by Banner and Blow (1959). Postuma (1971) studied on another classification about the Mesozoic and Cenozoic planktonic foraminifera with the key points for taxa, description and illustrations and biozonations. A Cenozoic biozonation has been suggested by Stainforth (1975) with the characteristics of the index genera. Kennett and Srinivasan (1983) proposed a classification for the Neogene planktonic foraminifera. Within the first volume of "Plankton Stratigraphy" (Bolli *et al,* 1985); Tourmakine and Lutherbacher (1985) have a chapter for the Paleocene and Eocene planktonic foraminifera. Paleogene planktonic foraminiferal phylogeny was discussed by Pearson (1993, 1996). The Paleocene trochospiral planktonic foraminifera were investigated by Berggren and Norris (1997) in terms of their systematics, phylogeny and biostratigraphy. Coxall *et al.* (2003) emphisized the origin and morphology of the genus *Hantkenina.* Coccioni and Bancalà (2012) also studied the evolution of *Hantkenina* form genus *Clavigerinella.* They suggested the pattern, timing, and duration of the evolutionary origin of this genus.

The classification of the Paleogene planktonic foraminifera was based on their morphological characteristics until Pearson (1993). Some of the features used for the taxonomical work were mode of coiling, position of aperture with respect to umbilicus, shape of test, presence/absence of keels, muricae, spines, etc. However, the wall structures gained importance by the developments in the usage of scanning electron microscope (Olsson *et al.*, 1999; Pearson *et al.*, 2006) (Figure 47). Spinose wall texture includes ***sacculifer*-type** (equally distributed pores, symmetrical cancellate (honey-comb) structure as

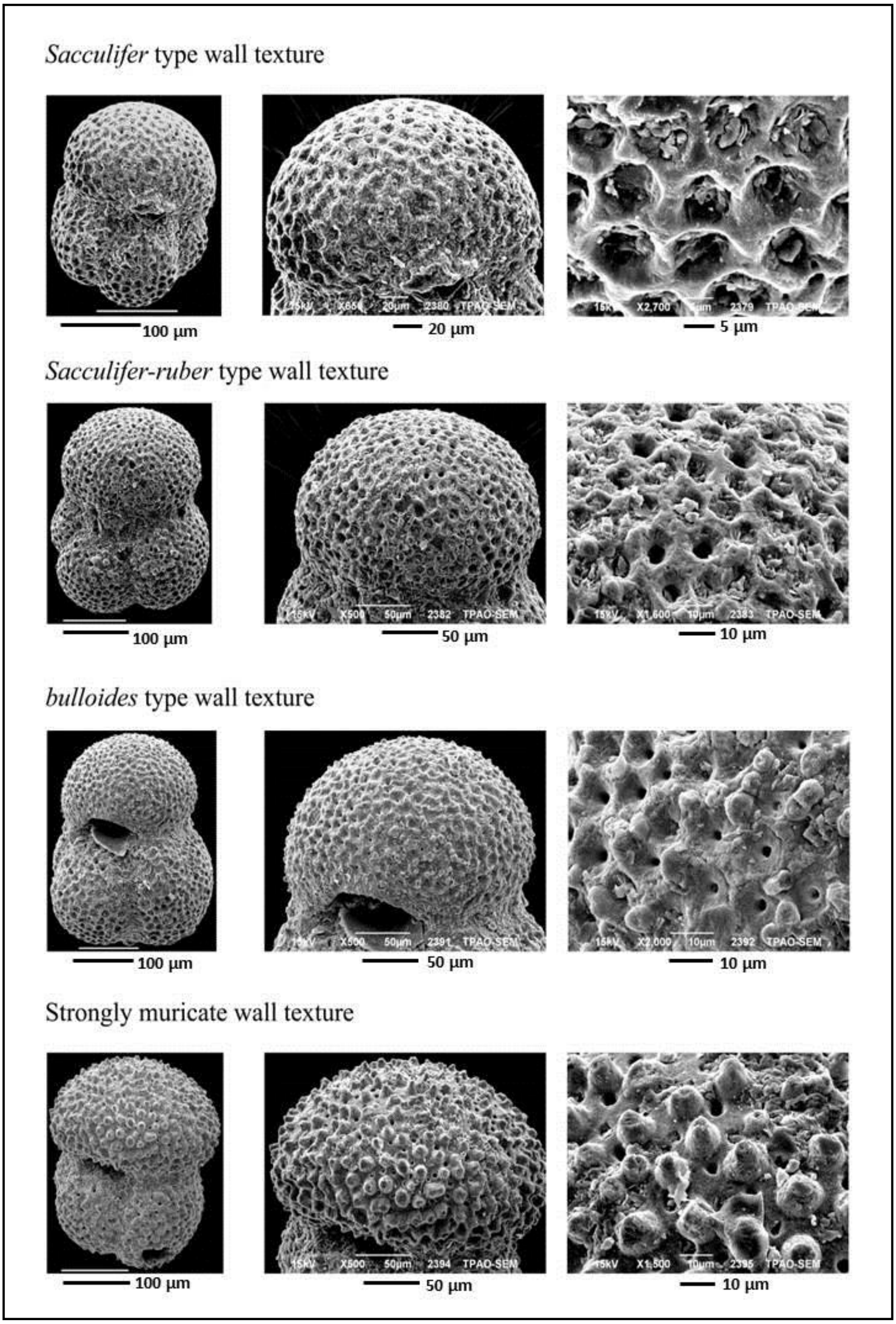

Figure 47. Wall textures for the Paleogene planktonic foraminifera: **sacculifer type:** *Subbotina linaperta*; Karaburun MSS, sample no. 9; **sacculifer-ruber type:** *Subbotina* eocaenica; Karaburun MSS, sample no. 5; **bulloides type:** *Subbotina roesnaensis;* Karaburun MSS, sample no. 9; **strongly muricate:** *Acarinina primitiva*; Karaburun MSS, sample no. 9

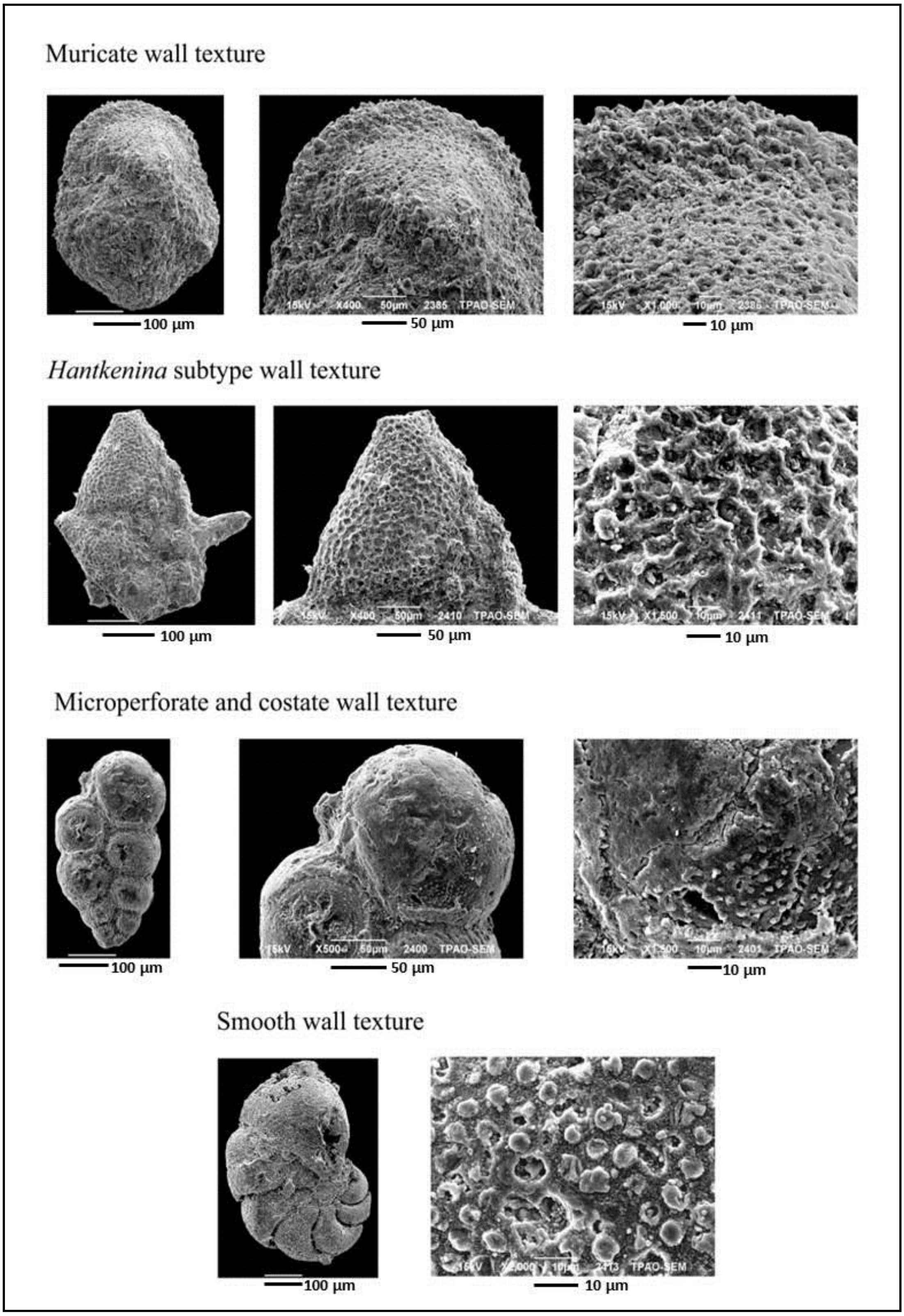

Figure 47. (Cont.) **Muricate wall:** *Morozovella lensiformis*; Karaburun MSS, sample no. 6; ***Hantkenina*-subtype:** *Hantkenina leibusi*; İstafan MSS, sample no. 13; **Microperforate and costate wall:** *Chiloguembelina* sp.; Karaburun MSS, sample no. 9; **Smooth wall:** *Planoglobanomalina pseudoalgeriana*; Ayazlı MSS, sample no. 2.

in some *Subbotina, Catapsydrax, Globoturborotalita* and Parasubbotina) (Figure 47), ***sacculifer-ruber -type*** (cancellate structure is symmetrical in some parts of test and asymmetrical in other part as in some *Subbotina* and *Paragloborotalia)* (Figure 47), ***ruber*-type** (asymmetrical cancellate structure, thin and less regularly distributed spines as in some *Subbotina),* ***Turborotalita-type*** (rather smooth primary wall), ***bulloides*-type** (irregular pore pattern, short and long connecting ridges surrounding pores as in *S.crociapertura* and *G. officinalis)* (Figure 47), ***Clavigerinella-type*** (dense pore pattern with narrow cancellate ridges = reticulate wall with smooth surface as in *Clavigerinella*, *Parasubbotina* and *Pseudoglobigerinella)* and ***Hantkenina*-subtype** (smooth walled in later stages) (Figure 47). Types of non-spinose wall texture are smooth walled (with small, scarce pustules generally confined to umbilical area as in *Globanomalina, Pseudohastigerina, Globanomalina, Pseudohastigerina* and *Planoglobanomalina)* (Figure 47), muricate (with coarse pointed/conical pustules that may form a muricocarina as in *Acarinina*, *Morozovella* and *Morozovelloides*) (Figure 47), *Globoquadrina*-type (honey-comb wall texture with evenly distributed pores, having large pustules around aperture as in *Dentoglobigerina* and *Globoquadrina*), *Turborotalia*-type (cancellate wall texture in initial development step (*T.frontosa*) to smooth wall bearing a keel in the final step (*T.cunialensis*)) and microperforate (pores < 1 (am as in *Chiloguembelina wilcoxensis*) (Figure 47).

In this study, the entire wall structures listed above hasn't been recorded and only sacculifer type, sacculifer-ruber type, *bulloides* type, *Hantkenina* type spinose walls and smooth, muricate/strongly muricate and microperforate non-spinose wall structures are recognized.

The main problem for the identification of the wall structures is the preservation of the specimens. Therefore, when the identification of the genera is impossible because of the poor preservation, some additional morphological features have to be used in the classification.

There are two recent, detailed studies of which the classification for the present study is based on. Olsson *et al.* (1999) prepared the "Atlas of Paleocene planktonic foraminifera", whereas Pearson *et al.* (2006) published the "Atlas of Eocene planktonic foraminifera". These studies classified the present genera under the families presented in Table 4.

Table 4. Taxonomy of Paleogene planktonic foraminifera based on Pearson *et al.* (2006) and Olsson *et al*. (1999).

Family Globigerinidae Carpenter, Parker and Jones, 1862

- *Catapsydrax* Bolli, Loeblich and Tappan, 1957
- *Globorotaloides* Bolli, 1957
- *Guembelitrioides* El Naggar, 1971
- *Paragloborotalia* Cifelli, 1982
- *Parasubbotina* Olsson, Hemleben, Berggren and Liu, 1992
- *Pseudoglobigerinella* Olsson and Pearson, 2006
- *Globigerina* d'Orbigny, 1826
- *Globoturborotalita* Hofker, 1976
- *Subbotina* Brotzen and Pozaryska, 1961
- *Turborotalita* Blow and Banner, 1962
- *Globigerinatheka* Bronnimann, 1952
- *Orbulinoides* Cordey, 1968

Family Truncorotalididae Loeblich and Tappan, 1961

- *Acarinina* Subbotina, 1953
- *Morozovelloides* Pearson and Berggren, 2006
- *Morozovella* McGowran, 1968
- *Astrorotalia* Tumovsky, 1958
- *Igorina* Davidzon, 1976
- *Planorotalites* Morozova, 1957

Family Globoquadrinidae Blow, 1979

- *Dentoglobigerina* Blow, 1979

Family Hantkeninidae Cushman, 1927

- *Clavigerinella* Bolli, Loeblich and Tappan, 1957
- *Cribrohantkenina* Thalmann, 1942
- *Hantkenina* Cushman, 1924

Family Hedbergellidae Loeblich and Tappan, 1961

- *Globanomalina* Haque, 1956
- *Planoglobanomalina* Olsson and Hemleben, 2006
- *Pseudohastigerina* Banner and Blow, 1959
- *Turborotalia* Cushman and Bermudez, 1949

Table 4. (Cont.)

Family Gumbelitriidae Montanaro Gallitelli, 1957 • *Jenskina* Haynes, 1981 • *Cassigerinelloita* Stolk. 1965
Family Chiloguembelinidae Reiss, 1963 • *Chiloguembelina* Loeblich and Tappan, 1956 • *Streptochilus* Bronnimann and Resig, 1971
Family Heterohelicidae Cushman, 1927 • *Zeauvigerina* Finlay, 1939
Family Cassigerinellidae Pokorny, 1955 • *Cassigerinella* Pokorny, 1955 • *Tenuitella* Fleisher, 1974

In this study, some of the genera above have great importance as they are essential for the biostratigraphical studies. On the other hand, some other genera; such as *Orbulinoides, Clavigerinella, Astrorotalia* and *Streptochilus* haven't been recorded in this study. Moreover, as discussed above, it has not been always possible to make a classification based on the wall structures of the taxa because of the preservation problems. Therefore, the basic morphological features for the classification of genera are presented in Table 5, whereas observed fauna have been emphasized in this chapter in terms of species classification based on their basic morphological features.

Table 5. Classification of Paleogene planktonic foraminifera with morphological properties based on Olsson *et al.* (1999) and Pearson *et al.* (2006).

GENUS	TYPE OF WALL	TEST	OUTLINE	# OF CHAMBERS IN LAST WHORL	CHAMBER SHAPE	APERTURE	APERTURAL ELEMENTS	DISTINGUISHING FEATURES
Acarinina	Spinose, muricate; muricae dense and enlarged around aperture	Trochospiral	Ovate, elongate, hemispherical, subangular, inflated or circular	3-8	Rounded, subangular or angular	Umbilical-extraumbilical	Very thin lip (sometimes)	Chambers covered with muricae on the umbilical surface around the aperture
Catapsydrax	Coarsely cancellate, *ruber /sacculifer* - type probably spinose	Low trochospiral compact, radially compressed	Globular, lobate	3-4	Moderately inflated, appressed, globular, near spherical, increasing rapidly in size	Extraumbilical, a circular opening	Umbilical bulla with one or more infralaminal apertures; continuous, narrow lip	More compact and radially compressed morphology
Chiloguembelina	Bilamellar, generally microperforate; striate, smooth or pustulose	Biserial; rarely multiserial in final chambers	Subtriangular	11-15	Slightly to moderately inflate, increasing slowly to moderately in size	Simple arched opening at the base of the final chamber	Narrow bordering rim on one margin, broad collar or flange	Biserial arrangement
Dentoglobigerina	Cancellate, *Globoquadrina*- type, honeycomb wall texture, nonspinose	Trochospiral	Globular, slightly lobate	3,5-6	Subglobular and slightly compressed, ultimate chambers slightly bent towards umbilicus	Umbilical	Asymmetrical triangular tooth	Bending of last chamber, triangular lip
Globanomalina	Normal perforate, smooth, sometimes covered with pustule growth	Very low trochospiral	Imperforate band or keel at periphery	5-6	Globular to ovoid to low conical	Moderately high arched, interiomarginal umbilical to extraumbilical, may extend to spiral side	Narrow lip broaden slightly towards umbilicus	Imperforate band or keel at periphery
Globigerinatheka	Spinose, cancellate, commonly covered by a thick calcite crust	Low trochospiral to streptospiral	Globular to subglobular	3-6	Larger last chambers envelop the previous ones	Interiomarginal, umbilical in globigerinid stage; multiple, arched, sutural in later stage	Bullae with 1 or more small infralaminal accessory apertures (sometimes)	Enveloping last chamber, supplementary apertures
Hantkenina	Normal perforate, smooth, probably nonspinose	Planispiral, biumbilicate or raised spiral side	Stellate with deep incisions between chambers to angular, smooth-continuous to gently lobed	4-7	Early rounded; adults radially elongated, triangular, polygonal or spherical, laterally compressed, tubilospines	Single equatorial arch	Distinctive lip of variable width, symmetrical or slightly asymmetrical	Tubulospine chamber arrangement

Table 5. (cont.)

GENUS	TYPE OF WALL	TEST	OUTLINE	# OF CHAMBERS IN LAST WHORL	CHAMBER SHAPE	APERTURE	APERTURAL ELEMENTS	DISTINGUISHING FEATURES
Igorina	Coarsely cancellate, praemuricate surface texture	Evolute coiling	Peripheral keel	5-9	Chamber compression	Conitinuous,umbilical-extraumbilical low arching slit, extending towards peripheral margin	Thin lip	Evolute coiling with chamber compression
Morozovella	Normal perforate with strongly pustulose adult chambers	Low trochospiral	Lobulate, distinct muricocarina passes at least one intercameral suture	4-9	Strongly anguloconical	Interiomarginal, umbilical-extraumbilical	Lack apertural lips	Peripheral muricocarina
Morozovelloides	Muricate; discontinuous muricae on periphery and umbilical region	Low trochospiral	Lobulate or petaloid	4-8	Imbricate to subangular and weakly inflated to distinct blade-like	Umbilical-extraumbilical or wholly extraumbilical	Umbilical shoulders showing concentrations of muricae	Discontinuous muricocarina
Parasubbotina	Normal perforate, cancellate, spinose	Low trochospiral	Lobulate	4-5	Globular, embracing in ultamate whorl, rapidly increasing in size	High arched, umbilical-extraumbilical	Lip of varying thickness	Rapid increase in chamber size
Pseudohastigerina	Normal perforate, smooth	Planispiral, compressed, tightly coiled	Circular to oval to quadrate, may be lobate	6-8	Globular, increasing slowly in size (except *P.wilcoxensis*)	Singular or bipartite equatorial, asymmetrical to symmetrical in position	Distinct lip of varying thickness	Planispiral coiling
Subbotina	Cancellate, spinose; sacculifer or sacculifer/ruber type	Low trochospiral	Tripartite	3-4	Globular, rapidly increasing in size	Low arched, interiomarginal umbilical to slightly extraumbilical	Narrow to fairly broad lip with a distinct apparatus extending over umbilicus	Tripartite arrangement, large test
Turborotalia	Smooth, pustulose, sometimes weakly cancellate	Trochospiral	Globular and inflated to strongly compressed and biconvex, imperforate band or keel in some species	3-6	Inflated, appressed and embracing, radially compressed	High arched, umbilical-extraumbilical	Bordering lip	Smooth wall with compressed test, imperforate band or keel
Zeauvigerina	Microperforate, with irregular pustules	Biserial to uniserial in later stage	Small, subcircular to elliptical	14-16	Compressed to globular, slightly inflated, increasing gradually in size	Asymmetrical low interiomarginal arched opening, areally or terminally positioned	Narrow lip or short neck that may or may not have encircling lip	Short neck on the aperture

4.1.1. Species observed throughout the sections

Through 9 measured stratigraphic sections, a wide time interval from Cretaceous to Late Eocene has been studied. The Cretaceous taxa are included in the stratigraphical range charts (Figure 41), however their definitions aren’t included to the following part and only Paleocene and Eocene forms are mentioned below.

A total of 87 species related to 18 genera have been identified though the sections among the Paleogene taxa. As the taxonomy of identified genera has been summarized at the previous section as tables; the species taxonomy, arranged from the definitions by Olsson *et al.* (1999) and Pearson *et al.* (2006), have been summarized as tables for each genera (Tables 6-23) and the distinguishing features of each species have been given as remarks below. The information on the geographical distributions was gathered from the specified articles given in the synonym lists of the species.

Phylum Protozoa

Order Foraminiferida Eichwald, 1830

Superfamily Globigerinaceae Carpenter, Parker and Jones, 1862

Family Globigerinidae Carpenter, Parker and Jones, 1862

Genus *Eoglobigerina* Morozova, 1959

Type species: *Globigerina* (*Eoglobigerina*) *eobulloides* Morozova, 1959, emended

The classification of the species of genus *Eoglobigerina* is summarized in Table 6.

***Eoglobigerina spirialis* (Bolli), 1957a**

1957a *Globigerina spirialis* Bolli, p. 70, pl. 16, figs. 16-18.

1960 *Globigerina spirialis* Bolli and Cita, p. 12, pl. 32, figs. 2a-c.

1991c *Igorina spirialis* (Bolli), - Huber, p. 461, pl. 3, figs. 13-15.

1999 *Eoglobigerina spirialis* (Bolli), - Olsson *et al*., p. 22, pl. 16, fig. 10-12; pl. 20, figs. 1-11.

Remarks: This species is distinguished easily by its higher trochospire with respect to other globigerinids of same age. It has a rounded, lobate periphery. The specimens which has been recorded in the studied samples have had 5 chambers in the last whorl separated by radial sutures. Its narrow umbilicus that is mostly overlapped by the last chamber is a distinguishing feature with respect to *Eoglobigerina edita.*

Table 6. Classification of genus *Eoglobigerina* (* indicates the identified species in this study)

Species name	Test outline	Wall Texture	Chambers			Sutures		Umbilicus	Aperture	Size (mm)	Age
			# of chamber	Increase in size	Chambers	Spiral	Umbilical				
E. edita	Moderately high trochospiral, more convex spiral side, strongly lobate	Weakly cancellate, spinose, smooth	4,5-5	Gradually	Globular	Deep, slightly curved	Deep, slightly curved	Small, shallow, open, distinct	Rounded umbilical to slightly extraumbilical aperture bordered by narrow lip	0.25	Early Paleocene
E. eobulloides	Moderately high trochospiral	Weakly cancellate, smooth or micro-cellular	4-4,5	Gradually	Globular	Slightly curved	Slightly curved	Small, open	Umbilical to slightly extraumbilical rounded aperture bordered by narrow, slightly flaring lip	0.23	
E. spirialis *	Medium to high trochospiral, biconvex, spiral side distinctly convex, equatorial periphery lobate, axial periphery rounded	Cancellate, smooth	5-6	Moderately	Inflated, globular or slightly compressed laterally	Radial or slightly curved, depressed	Radial, depressed	Narrow, often overlapped by ultimate chamber	Interiomarginal, umbilical distinct arches with faint discontinuous lip	0.28	

Geographic Distribution: Trinidad, N Italy, Salzburg Basin, Kerguelen Plateau, South Atlantic Ocean.

Occurrence: Erfelek 1 MSS, Sample no. 15, 16, 18, 19, 22; Kaymakam Kayası MSS, Sample no. 1-8, 11-16.

Genus *Globigerina* d'Orbigny, 1826

Type species: *Globigerina bulloides* d'Orbigny, 1826

Remarks: After the use of the wall types in the classification (Olsson *et al*., 1999; Pearson *et al*., 2006), most of the species of genus *Globigerina* have been included to genus *Subbotina.* In the present study, the wall structure mostly can't be identified because of the poor preservation. Therefore, the morphology of the specimens is the main criteria to classify the forms as *Globigerina* or *Subbotina.*

The classification of the species of genus *Globigerina* is summarized in Table 7.

Globigerina azerbaidjanica Khalilov, 1956

Plate 1, Figures 1-3

2011 *Globigerina azerbaidjanica* Khalilov.- Zakrevskaya *et al*., p. 777, fig. 14t.

Remarks: Its most important property is very large, wide and deep umbilical aperture. Having a trilobate outline seperates *G. azerbaidjanica* from *G. turkmenica*.

Occurrence: Sinay-Karasu MSS, Sample no. 17-19, 22.

Globigerina eoceanica Terquem, 1882

Plate 1, Figure 4

1882 *Globigerina eocaenica* Terquem, p. 86, pl. 9, fig. 4.

1953 *Globigerina eocaenica* Subbotina, p. 106, pl. 11, figs. 8- 14.

Remarks: This form has an elongated outline with 3 packed chambers in its last whorl. It has been a synonym of *Subbotina eocaena* (Pearson *et al.*, 2006). However, the outline of this species is different from *Subbotina eocaena*, which is having a relatively quadrate outline. The increasing in the chamber size is rapid, so that size of the last chamber of is almost equal to the rest of the test. *Globigerina eocaenica* differs from *Turborotalia frontosa* by the hemispherical shape of its last chamber rather than being axially compressed.

Geographic Distribution: Low to mid latitudes

Table 7. Classification of genus *Globigerina* (* indicates the identified species in this study)

Species Name	Test	Wall	Chambers			Sutures		Umbilicus	Aperture	Size (mm)	Age
			# of Chambers	Increase in size	Chamber	Spiral	Umbilical				
G. lozanoi	High trochospiral, loose, irregular	Smooth, non-spinose	4-6	Slowly	Globular	Deprressed, straight, radial		Medium sized, deep	Umbilical	0,35-0,40	Early-Middle Eocene
G. eocaenica *	Low trochospiral, spherical, elongated, trithalamous	Spinose, normally perforate		Slowly					Umbilical	0,2-0,4	
G. pseudoeocaena *	Low trochospiral	Spinose, normally perforate	3-4	Rapidly	Spherical chambers	Short, straight	Oriented as a diagonal cross		Umbilical	0,5-0,7	
G. azerbaidjanica *	Low trochospiral, lobate	Spinose, normally perforate	3	Slowly	Spherical			Open, deep	Umbilical, with imperforate rim	0,2	Middle Eocene
G. subcorpulenta *	Low trochospiral, lobate	Spinose, normally perforate	5	Slowly	Spherical			Open, deep	Umbilical	0,2-0,4	
G. turkmenica *	Low trochospiral, quadrate	Spinose, normally perforate	4	Slowly	Spherical			Open, deep	Umbilical, with imperforate rim	0,2	
G. officinalis	Low trochospiral, lobate	Spinose, normally perforate, bulloides-type	4	Rapidly	Globular, slightly embracing chambers	Moderately depressed, straight		Small, open	Umbilical, with imperforate rim	0,2	Middle-Late
G. bulloides	Low trochospiral, freely, not compact	Bulloides-type	4	Gradually	Spherical	Depressed	Oriented as a diagonal cross	Open	Umbilical		Late Eocene
G. inflata	Low trochospiral, freely, tetrathalamous, rounded, lobed	Spinose, normally perforate	4-4,5	Rapidly	Spherical	Short & straight	Oriented as a oblique cross	Small, deep, open	Umbilical, lip slendering over whole length	0,2-0,35	Late Eocene-Oligocene

Occurrence: Karaburun MSS, Sample no. 15, 16, 18, 19, 22; İstafan MSS, Sample no. 1-8, 11-16; Sinay-Karasu MSS, Sample no. 1, 3-8, 10-14, 17, 21, 22.

Globigerina incretacea Khalilov, 1956

Remarks: This species is one of the 5 chambered globigerinids in its last whorl. It is distinguished with its globular chambers, which increase slowly in size. Its sutures are radial and straight. The umbilicus of *Globigerina incretacea* is very wide and its aperture nearly extends towards the periphery.

Occurrence: Sinay-Karasu MSS, Sample no. 17.

Globigerina pseudoeoceana var. *pseudoeoceana* Subbotina, 1953

1953 *Globigerina pseudoeocaena* var. *pseudoeoceana* Subbotina, p. 83, pl. 5, fig. 1-2.

Remarks: This form has a rounded outline. Having 4 spherical chambers that aren't packed closely, the growth of the chambers is rapid. Umbilicus is well defined and broad. Comparing with *Subbotina eoceana*, this species doesn't have tightly-coiled, closely packed chambers. The periphery is axially elongated and radially narrower.

Geographic Distribution: Low to mid latitudes

Occurrence: İstafan MSS, Sample no. 2-5, 11, 12, 16; Sinay-Karasu MSS, Sample no. 16.

Globigerina subcorpulenta Khalilov, 1956

Plate 1, Figure 5

Remarks: This species has 5 globular chambers in its last whorl, which resembles to *Globigerina incretacea*. However, the growth rate of the chambers is rapid and the umbilicus is narrower in this species. Its sutures are radial and straight.

Occurrence: Sinay-Karasu MSS, Sample no. 17.

Globigerina turkmenica Khalilov, 1956

Plate 1, Figures 6-7

2011 *Globigerina turkmenica* Khalilov.- Zakrevskaya *et al*., p. 777, fig. 14v.

Remarks: Like *G. azerbaidjanica,* this species also have a very large, wide and deep umbilical aperture. However, *G. turkmenica* has a quadrate and lobate test with slowly enlarging chambers.

Occurrence: Sinay-Karasu MSS, Sample no. 17-19.

Genus *Globigerinatheka* Brönnimann, 1952 emanded Proto Decima and Bolli, 1970

Type species: *Globigerinatheka barri* Brönnimann, 1952

The classification of the species of genus *Globigerinatheka* is summarized in Table 8.

Globigerinatheka subconglobata (Shutskaya, 1958)

Plate 1, Figures 8-9

1958 *Globigerinoides subconglobatus* Shutskaya var. *subconglobatus* Shutskaya, 86, pl. 1, figs. 4-11.

1971 *Globigerapsis subconglobatus* (Shutskaya).-Toumarkine, pl. 3, figs. 13-14.

1972 *Globigerinatheka subconglobata subconglobata* (Shutskaya).-Bolli, 134, text-figs. 43-46.

1995 *Globigerinatheka subconglobata* (Shutskaya).-Poag and Commeau, pl. 4, figs. 18-19.

2006 *Globigerinatheka subconglobata* (Shutskaya). - Pearson *et al*., p. 201, pl. 7.10, figs. 1-20.

2010 *Globigerinatheka subconglobata* (Shutskaya).- Edgar *et al*., pl. 1, fig. b.

2011 *Globigerinatheka subconglobata* (Shutskaya). - Zakrevskaya *et al*., p. 777, fig. 14q.

Remarks: This species has an evolute outline with 4 chambers in its last whorl. It has an umbilical primary aperture and various secondary apertures.

Geographic Distribution: Caucasus, Hungary, Italy, Egypt, Atlantic Ocean, Pacific Ocean.

Occurrence: Sinay-Karasu MSS, Sample no. 11, 19.

Table 8. Classification of genus *Globigerinatheka* (* indicates the identified species in this study)

G. curryi	equatorial outline, inner spire low, low trochospiral to streptospiral, loosely coiled	pores about 0.08 mm in diameter	3 (6-7 in total)	penultimate chamber twice as large as antepenultimate chamber; initially slowly, then rapidly growing for second whorl	progressively more depressed in final stage	Low umbilical arch	apertures at the base of last chamber		0,56	Middle Eocene
G. euganea	Almost spherical, low trochospiral to streptospiral, compact	Spinose, cancellate with dense pores about 0.08 mm in diameter	3 (4-6 in total)	Hemispherical last chamber covering the umbilicus of previous whorls, equal size or larger than penultimate chamber; initially slowly, then rapidly increasing size for second whorl	Distinct, weakly depressed in earlier whorl, clearly depressed in intermediate whorls, less depressed between last chambers	Not visible in adult	2-3, rarely 4 small arched to subcircular, along base of last chamber at the junction of previous chambers	Small bullae	0,53	
G. kugleri	Subtriangular outline, lobate, tight initial coil	Spinose, cancellate, with pores about 0,04-0,05 mm in diameter	4	Very small globular chambers increasing gradually but rather rapidly in size as added in last whorl, antepenultimate chamber=twice as lasrge as previous one & 1/2 of last chamber	Not visible in inner coil, then straight and radial, depressed	Umbilical, low arch	2-3, small arched, at the base of last chamber	Small slightly inflated bullae both on primary & secondary apertures	0,36-0,47	
G. subconglobata *	Globular to nearly spherial, initially low trochospire becoming progressively higher & slightly streptospiral in last whorl	Spinose, cancellate, rather thick, frequently recrystallized, pores about 0,04 mm in diameter	4 (12-14 in total)	Globular, small & very slowly increasing in size as added up to half of the second whorl, then increasing gradually but progressively faster, first chamber of last whorl = 1/2 of antepenultimate, the latter & penultimate similar sized, last chamber smaller & flattened; chambers longer than wide, elongate in spiral view	Distinct throughout, weakly depressed in inner coils, then moderately depressed	Umbilical, low arch	1-2 small, low arched, at the intersections between base of last chamber & previous sutures, frequently poorly visible		0,30-0,65	
G. barri	Subglobular to globular, low to medium high trochospire in first 2 whorls, then streptospiral in last whorl	Spinose, cancellate, with cylindrical pores, slightly funneled in final stage, about 0.04 mm in diameter	4	Subglobular, last chamber inflated covering the umbilical area of previous chambers	Depressed	Not visible in adult	3, rather small, semicircular in shape, at the intersection of sutures between 3 chambers of last whorl & at the base of last chamber	Small bullae each of which may possess 3 small subcircular openings on secondary apertures	0,35	Middle-Late Eocene
G. index	Slightly elongate, subrectangular in outline, compact, broadly rounded & subrectangular in side view, low trochospiral	Spinose, cancellate, frequently encrusted, with mainly cylindrical pores about 0,04-0,05 mm in diameter	3	Early chambers poorly visible, inflated chambers in last whorl at least twice as large as previous ones, ante- & penultimate chambers are almost equal in size, last chamber = 1/2 of test	Poorly visible, possibly straight or slightly curved in inner chambers; distinct, deeply incised, straight and radial in last whorl	Umbilical, rather high & large, symmetrical arch at the base of last chamber	2 medium sized, semicircular arched, at the base of the last chamber above sutures of previous chambers	Thick lip, bullae not common	0,35-0,55	
G. korotkovi	Sac-like, high trochospire, compact	Spinose, cancellate, moderately encrusted with pores about 0.04 mm in diameter	3	Subglobular in last whorl	Distinct, depressed, straight to slightly curved	Medium sized subcircular arch at junction of the sutures of last 3 chambers	1 subcircular, almost identical to primary one, other smaller secondary apertures may be present on spiral side of previous chambers		0,35	
G. lutherbacheri	Nearly globular, sometimes elongate, low trochospire, initially tight then looser coiling becoming streptospiral, robust	Spinose, cancellate, rather thick & coarsely perforate, pores > 0,05 mm in diameter		Inflated; increasing very slowly in first whorl, then moderately & gradually in size as added, chambers in last whorl much larger with last two hemispherical, last chamber may be smaller than penultimate	Depressed, almost incised except in first whorl		Numerous, along sutures mainly at intersection of last chambers	More or less inflated bullae that is nearly as large as last chamber	0,40-0,60	
G. mexicana	Very close to spherical, low trochospiral	Spinose, cancellate, densely porous, pores about 0.04 mm in diameter		Globular except for last one that is hemispherical, ultimate chamber = 1/2 of test; initially graduately, then rapidly growing in size	Poorly visible initially; very slightly depressed between last 2 to 3 chambers	Not visible in adult	3 visible apertures at the base of last chamber, small to medium sized arches close to subcircular, located at the junction of previous chambers		0,30-0,60	
G. semiinvoluta	Spherical, early chambers low & short trochospire	Spinose, cancellate, thin, with density of pores < 0,04 mm in diameter		Very large hemispherical last chamber embracing half or more of earlier chambers	Poorly visible initially; slightly more distinct & slightly depressed in adult	Not visible in adult	1 to 4 (commonly 3) prominent, circular	Distinct rims	Up to 0,55	
G. tropicalis	Globulose with a subrectangular to subtriangular, slightly lobate outline, initially low trochospire- then streptospiral	Spinose, cancellate, with slightly funneled pores about 0,04-0,05 mm in diameter	3 (8 in total)	Inflated; increasing slowly first, then very rapidly in last whorl, penultimate chamber twice as large as antepenultimate, last chamber=1/3 to1/2 of test and sometimes smaller than penultimate	Distinct, weakly depressed, straight to gently curved in earlier whorl; depressed, straight, radial in last chambers	Moderately high to subcircular, medium sized arch, at base of last chamber	2-3 subcircular, slightly smaller than primary aperture, at the junction of earlier chamber sutures, one may be present in penultimate chamber	Lip & bullae	0,25-0,50	

Genus *Globoturborotalita* Hofker, 1976

Type species: *Globigerina rubescens* Hofker, 1956

The classification of the species of genus *Globoturborotalita* is summarized in Table 9.

***Globoturborotalita bassriverensis* Olsson and Hemleben, 2006**

Plate 1, Figure 10

2006 *Globoturborotalita bassriverensis* (Olsson and Hemleben).-Pearson *et al*., p. 117, pl. 6.3, figs. 1-19.

Remarks: This species is identified with is quadrate test with 4 globular, embracing chambers in the last whorl. It has a umbilical aperture with the development of lip, which differentiates *G. bassriverensis* from *G. ouachitaensis.* In our samples, the lip is mostly preserved. On the other hand, umbilical aperture is useful to distinguish this form from the subbotinids, in which they resemble because of their globular outline bearing 3-4 chambers in their last whorls.

Geographic Distribution: Mid- to low-latitudes

Occurrence: Karaburun MSS, Sample no. 2, 3, 6-8, 14; Sinay-Karasu MSS, Sample no. 4, 8, 11; Erfelek MSS, Sample no. 56, 74, 76, 78-81, 90; Erfelek MSS, Sample no. 36, 39; Kaymakam Kayası-A MSS, Sample no. 4.

***Globoturborotalita ouachitaensis* Howe and Wallace, 1932**

1932 *Globigerina ouachitaensis* Howe and Wallace, 74, pl. 10, fig. 5a-b.

1962 *Globigerina ouachitaensis ouachitaensis* Howe and Wallace,-Blow and Banner, 90, pl. 9, figs. D, H-K.

2006 *Globoturborotalita ouachitaensis* (Howe and Wallace). - Pearson *et al*., p. 122, pl. 6.5, figs. 1-16.

Remarks: This species looks like *G. bassriverensis;* however *G. ouachitaensis* has a rounded arch umbilical aperture bordered by a rim, not with a prominent lip.

Geographic Distribution: Lousiana, India, Pakistan.

Occurrence: Sinay-Karasu MSS, Sample no. 17, 26.

Table 9. Classification of genus *Globoturborotalita* (* indicates the identified species in this study)

Species name	Test outline	Wall Texture	Chambers			Sutures	Umbilicus	Aperture	Size (mm)	Age
			# of chamber	Increase in size	Chambers					
G. bassriverensis *	Moderately low trochospiral, globular, lobate, initial spire slightly elevated	Cancellate, normal perforate, spinose, sacculifer-type	4	Moderately	Globular, slightly embracing in ultimate whorl	Depressed, straight	Small, open, enclosed by surrounding chambers	Umbilical, a rounded arch, bordered by a narrow lip	0.16	Early-Middle Eocene
G. ouachitaensis *	Moderately low trochospiral, globular, lobate, initial spire slightly elevated	Cancellate, normal perforate, spinose, sacculijer-type	4	Moderately	Globular, slightly embracing in ultimate whorl	Depressed, straight	Large, open, enclosed by surrounding chambers	Umbilical, a rounded arch, bordered by thickened rim	0.19	Middle Eocene-Oligocene
G. anguliofficinalis	Moderately low trochospiral, globular, lobate, initial spire slightly elevated	Cancellate, normal perforate, spinose, sacculifer-type	4,5-5	Moderately	Globular, slightly embracing in ultimate whorl	Depressed, straight	Small, open, enclosed by surrounding chambers	Umbilical, a low rounded arch, bordered by a narrow lip	0.27	Late Eocene-Oligocene
G. gnaucki	Moderately low trochospiral, globular, lobate, initial spire slightly elevated	Cancellate, normal perforate, spinose, ruber-type	4-4,5	Moderately	Globular, slightly embracing in ultimate whorl	Depressed, straight	Large, open, enclosed by surrounding chambers	Umbilical, a rounded arch, bordered by a thin thickened rim	0.25-0.36	
G. martini	Moderately low trochospiral, globular, lobate, slightly embracing in edge view	Cancellate, normal perforate, spinose, ruber-type	4	Rapidly	Globular, slightly embracing in ultimate whorl, final chamber reduced in size and partially covering the umbilicus	Depressed, straight	Small, partially covered by the ultimate chamber	Umbilical, a rounded arch, bordered by thickened rim	0.32	

Genus *Paragloborotalia* Cifelli, 1982

Type species: *Globorotalia opima subsp. opima* Bolli, 1957

The classification of the species of genus *Paragloborotalia* is summarized in Table 10.

Table 10. Classification of genus *Paragloborotalia* (* indicates the identified species in this study)

Species name	Test outline	Wall Texture	Chambers: # of chamber	Chambers: Increase in size	Chambers: Chambers	Sutures	Umbilicus	Aperture	Size (mm)	Age
P. griffinoides *	Very low trochospiral, globular, subquadrate in outline, periphery rounded in edge view	Normal perforate, coarsely cancellate, sacculifer-type	4	Rapidly	Globular, much inflated, embracing, ultimate chamber may be slightly reduced in size	Slightly depressed, straight	Very small, enclosed by surrounding chambers	High arch extending midway onto the peripheral edge, bordered by a thickened lip	0.40	Eocene
P. nana *	Very low trochospiral, globular, quadrate in outline, spiral side flat, periphery rounded in edge view	Normal perforate, coarsely cancellate, sacculifer-type	4-4,5	Slowly	Globular, much inflated, embracing chambers, ultimate chamber may be slightly reduced in size	Slightly depressed, straight, forming a cross	Very small, deep, enclosed by surrounding chambers	Low arch extending midway onto the peripheral edge, bordered by a thickened lip	0.25	Middle Eocene-Oligocene

Paragloborotalia griffinoides Olsson and Pearson, 2006

2006 *Paragloborotalia griffinoides* (Olsson and Pearson). - Pearson *et al.,* p. 91, pl. 5.7, figs. 1-19.

Remarks: *P. griffinoides* is distinguished from other species of the genus by being relatively less compact and by its rapidly enlarging chambers. This form is another quadrate form like *Subbotina hagni, Globoturborotalita bassriverensis* and *Globoturborotalita ouachitaensis*. However, it differs from the species of *Globoturborotalita* by the extraumbilical position of its aperture instead of umbilical aperture and its lower trochospire. The rapid increase in its chamber size distinguishes this species from *S. hagni*, which has chambers more or less equal in size. *S. hagni* also has a wider umbilicus with repsect to *P. griffinoides.*

Geographic Distribution: Mid- to low-latitudes

Occurrence: Karaburun MSS, Sample no. 7

Paragloborotalia nana (Bolli, 1957)

1957a *Globorotalia opima nana* Bolli. p. 118, pl. 28, fig. 3a-c.

1969 *Globorotalia* (*Turborotalia*) *opima nana* Bolli. – Blow, p. 154, pl. 39, fig. 1.

1977 *Globorotalia nana* Bolli. – Krasheninnikov and Plaufmann, p. 606, pl. 6, figs. 10-11c.

1978 *Globorotalia opima nana* Bolli. – Toumarkine, p. 714, pl. 8, figs. 3-4.

1985 *Globorotalia opima nana* Bolli. – Bolli and Saunders, p. 202, pl. 26, fig. 16a-c.

1995 *Jenkinsella opima nana* Bolli. – Poag and Commeau, p. 149, pl. 6, figs. 21-22.

2004 *Paragloborotalia nana* Bolli. – Pearson *et al.*, p. 36, pl. 1, fig. 21.

2006 *Paragloborotalia nana* Bolli. – Pearson *et al.*, p. 95, pl. 5.8, figs. 1-16.

Remarks: This species has a quadrate test with 4 chambers in its last whorl, nearly equal in size. These properties of the form resembles to *Subbotina hagni*, however its aperture is totally different. *Paragloborotalia nana* has an umbilical-extraumbilical aperture with a well developed lip and its umbilicus is very slow. On the other hand, *Subbotina hagni* has a wider umbilicus and it has a loose coiling compared with *Paragloborotalia nana.*

Geographical Distribution: Trinidad, Tanzania, Atlantic Ocean.

Occurrence: Sinay-Karasu MSS, Sample no. 1, 16.

Genus *Parasubbotina* Olsson, Hemleben, Berggren and Liu, 1992

Type species: *Globigerina pseudobulloides* Plummer, 1926

The classification of the species of genus *Parasubbotina* is summarized in Table 11.

Parasubbotina eoclava Coxall, Huber and Pearson, 2003

1979 *Subbotina inaequispira* Subotina.-Blow, 1272, pl. 163, figs. 9-10.

2003 *Parasubbotina eoclava* Coxall, Huber and Pearson, 256, pl.8, figs. 1-11.

2004 *Parasubbotina eoclava* (Coxall, Huber and Pearson). - Pearson and others, 36, pl.1, fig. 14.

2006 *Parasubbotina eoclava (*Coxall, Huber and Pearson). - Pearson *et al.*, p. 99, pl. 5.9, figs. 1-16.

Remarks: *Parasubbotina eoclava* is a loosely coiled form with elongation of last two chambers. Its chamber growth is very rapid. It has a distinct apertural lip.

Geographic Distribution: North Atlantic Ocean, Allison Guyot, Tanzania.

Occurrence: Karaburun MSS, Sample no. 19; Sinay-Karasu MSS, Sample no. 1.

Table 11. Classification of genus *Parasubbotina* (* indicates the identified species in this study)

Species Name	Test outline	Wall	Chambers			Sutures		Umbilicus	Aperture	Size (mm)	Age
			# of Chambers	Increase in size	Chamber	Spiral	Umbilical				
P. pseudobulloides *	Very low trochospiral, rotaliform	Cancellate, spinose	5	Rapidly	Inflated, globular, highly ventricose	Not deeply incised	Short, very slightly curved to straight	Narrow, deep, open	Interiomarginal, umbilical-extraumbilical, with high rounded arch bordered by narrow lip	0,4	Early Paleocene
P. variospira *	Low to moderately high, loosely coiled trochospiral, strongly lobate outline	Distinctly cancellate, spinose	4-4,5	Slowly	Final chamber directed towards umbilicus	Narrow, deeply depressed, radial	Narrow, deeply depressed, radial	Wide, open, shallow	Interiomarginal, umbilical-extraumbilical arch with umbilical teeth	0,4-0,7	Late Paleocene
P. varianta *	Very low trochospiral, globigerinelliform planoconvex, oval outline	Cancellate, spinose	4	Rapidly	Compressed on spiral side, inflated and hemispherical on umbiical side	Short, very slightly curved almost straight, not incised deeply	Short, very slightly curved almost straight, strongly incised	Small, rounded, deep, open	Umbilical-extraumbilical, a rounded high arch bordered by fairly broad continuous lip	0,28-0,5	Paleocene-Early Eocene
P. eoclava *	Very low trochospiral, laterally compressed, lobate-petaloid in outline	Reticulate Clavigerinella-type, spinose	4	Rapidly	Globular and well separated, final chamber slightly radially elongated	Slightly depressed, straight	Slightly depressed, straight	Moderately small, narrow, deep	Interiomarginal umbilical-extraumbilical aperture bordered by a broad, flaring apertural lip	0,48	Eocene
P. griffinae	Very low trochospiral, globular, lobate in outline	Normal perforate, high porosity, reticulated Clavigerinella-type, spinose	4-5	Moderately	Globular, much inflated, embracing chambers in ultimate whorl	Moderately depressed, straight	Moderately depressed, straight	Small, enclosed by surrounding chambers	Umbilical-extraumbilical, low arch bordered by a narrow continuous, lip or thickened rim	0,41	
P. inaequispira *	Very low trochospiral, globular, lobate in outline	Symmetrically to asymmetrically cancellate, normal perforate, spinose	4-4,5	Moderately	Globular, ultimate chamber usually slightly reduced in size	Moderately depressed, straight	Moderately depressed, straight	Moderate sized, enclosed by surrounding chambers	Umbilical to extraumbilical, directed towards anterior side of test, bordered by a narrow, continuous lip	0,42	
P. pseudowilsoni	Very low trochospiral, compact, globular, lobate in outline	Cancellate, normal perforate, spinose, ruber-sacculifer type	5	Moderately	Globular, moderately embracing chambers in ultimate whorl, ultimate chamber usually slightly reduced in size	Moderately depressed	Moderately depressed	Moderate sized, enclosed by surrounding chambers	Umbilical to extraumbilical, bordered by a continuous lip, which varies in its width from narrow to broad	0,25	

Parasubbotina inaequispira (Subbotina, 1953)

Plate 1, Figure 11

1953 *Globigerina inaequispira* Subbotina, 84, pl.6, figs. 1a-c, 4a-c; pl.6, figs.2a-3c.

1979 *Subbotina inaequispira* (Subbotina).-Blow, 1272, pl.151, figs. 5-7; pl. 163, figs. 4-8; pl.180, figs. 1,4-7; pl.191, fig. 7.

2001 *Subbotina inaequispira* (Subbotina).-Warraich and Ogasawara, 48, fig.13: 17-19.

2004 *Parasubbotina inaequispira* (Subbotina).- Pearson and others, 36, pl. 1, fig. 13.

2006 *Parasubbotina eoclava* (Subbotina).- Pearson *et al.*, p. 101, pl. 5.11, figs. 1-15.

Remarks: This species is less more compact with respect to *P. eoclava* and it doesn't show elongation in the shape of chambers. It has a very lobate outline and moderate chamber growth.

Geographic Distribution: Northern Caucasus, North Atlantic Ocean, Gulf of Mexico, Tanzania, Pakistan.

Occurrence: Karaburun MSS, Sample no. 7, 9; Ayazlı MSS, Sample no. 14; Sinay-Karasu MSS, Sample no. 1, 5, 8, 9; Kaymakam Kayası-A MSS, Sample no. 8.

Parasubbotina pseudobulloides (Plummer, 1926)

Plate 1, Figures 12-14

1926 *Globigerina pseudobulloides* Plummer, p. 133, pl. 8, figs. 9a-c.

1950 *Globigerina pseudobulloides* Plummer. – Subbotina, p. 106, pl. 4, figs. 8-10.

1957a *Globorotalia pseudobulloides* Plummer. – Bolli, p. 72, pl. 17, figs. 19-21.

1963 *Globigerina pseudobulloides* Plummer. – Gohrbandt, p. 44, pl. 1, figs. 7-9.

1979 *Globorotalia* (*Turborotalia*) *pseudobulloides* Plummer. – Blow, p. 1096, pl. 69, figs. 2, 3; pl. 71, figs. 4, 5; pl. 75, figs. 2, 3; pl. 248, figs. 6-8; pl. 255, figs. 1-6.

1992 *Subbotina pseudobulloides* Plummer. – Berggren, p. 563, pl. 1, figs. 7, 8.

1992 *Parasubbotina pseudobulloides* Plummer. – Olsson, Hemleben, Berggren and Liu, p. 197, pl. 3, figs. 1-7.

Remarks: This form is similar to *Praemurica inconstans* in having 5 chambers in its last whorl. However, the increase in chamber size is rapid and chambers are globular in contrast to *P. inconstans.*

Geographic Distribution: Texas, Alabama, New Jersey, N Caucasus, Austria, Trinidad,

Denmark, Shatsky Rise (NW Pacific Ocean), Kerguelen Plateau (S Indian Ocean).

Occurrence: Erfelek MSS, Sample no. 40.

Parasubbotina varianta **(Subbotina, 1953)**

Plate 1, Figure 15

1953 *Globigerina varianta* Subbotina, 63, pl.3, figs. 5a-c, 6a-7c, 10a-11c, 12a-c; pl. 4, figs. 1a-3c.

1962 *Globorotalia* (*Globorotalia*) *varianta* (Subbotina).- Hillebrandt, 125, pl. 12, figs. 10a-c, 11a,b.

1992 *Subbotina varianta* (Subbotina). - Berggren, 563, pl. 1, fig. 3.

2006 *Parasubbotina varianta* (Subbotina). - Pearson *et al.*, p. 104, pl. 5.13, figs. 1-16.

2012 *Parasubbotina varianta* (Subbotina). - Birch *et al*., p. 378, fig. 3.28.

Remarks: *Parasubboitna varianta* is the most compact species of genus *Parasubbotina* observed in our samples. It has 4 globular, inflated chambers in the final whorl.

Geographic Distribution: Northern Caucasus, Austro-German border, Kerguelen Plateau, Tanzania.

Occurrence: Erfelek MSS, Sample no 38, 42, 44; Karaburun MSS, Sample no. 8.

Parasubbotina **cf.** ***variospira*** **(Belford, 1984)**

1984 *Globorotalia* (*Turborotalia*) *variospira* Belford. p. 18, pl. 24, figs. 15-17; pl. 25, figs. 1-7.

1984 *Morozovella variospira* (Belford). – emended Van Ejden and Smit, p. 113, pl. 5, figs. 1-8; text-figs. 26A-D.

1999 *Parasubbotina variospira* (Belford). – Olsson *et al*., p. 28, pl. 23, figs. 1-16.

Remarks: *Parasubbotina* cf. *variospira* has been recognized as a 5-chambered species. It has a loosely coiled, lobulated outline and wide umbilicus. Although this species is described as *P*. cf. *variospira* here as the originally described umbilical tooth structure hasn’t been recognized in the specimens probably because of the preservation.

Geographic Distribution: Papua New Guinea, ODP Hole 758A.

Occurrence: Erfelek MSS, Sample no. 26, 29.

Genus ***Pseudohastigerina*** **Banner and Blow, 1959**

Type species: *Nonion micrus* Cole, 1927

The classification of the species of genus *Pseudohastigerina* is summarized in Table 12.

Table 12. Classification of genus *Pseudohastigerina* (* indicates the identified species in this study)

Species Name	Test Outline	Wall Texture	Chambers			Sutures	Umbilicus	Aperture	Apertural features	Size (mm)	Age
			# of chambers	Increase in size	Chambers						
P. sharkriverensis	Planispiral, compressed with a rounded periphery, tightly coiled, involute, oval to quadrate in outline, oval to circular in edge view, slightly lobate	Smooth, normal perforate	6	Rapidly for first 4 chambers, more gradually for last 2	Globular, inflated, last 3 chambers composing about 1/3 of test, last chamber slightly reduced in size	Moderately depressed, straight to slightly curved	Small, circular	Oval, low arch, commonly bipartite	Narrow lip	0,35	Early-Middle Eocene
P. wilcoxensis *	Planispiral, compressed with a rounded, tightly coiled, involute, oval in outline	Smooth, normal perforate	6-7	Rapidly	Globular, inflated	Slightly depressed, straight to slightly curved	Small, circular	Equatorial, symmetric to slightly asymmetric, a circular high arch, sometimes bipartite	Narrow lip	0,17	
P. micra *	Planispiral, compressed with a rounded to slightly acute periphery, tightly coiled, involute, circular to oval in outline	Smooth, normal perforate	6-7	Slowly	Globular	Slightly depressed, straight, may be slightly curved between ultimate chambers	Small, circular	Equatorial, symmetric, a circular high arch, sometimes bipartite	Narrow lip	0,17	Early Eocene-Oligocene
P. naguewichiensis	Planispiral, much compressed with a rounded periphery, tightly coiled, involute, circular to oval in outline, slightly lobate	Smooth, normal perforate; in adult wall becomes thickened & openings to pores enlarged, coarsely perforate wall	6-8	Very slowly	Globular	Slightly depressed, straight to slightly curved	Circular	Moderately high arch	Thickened prominent lip	0,20	Late Eocene-Oligocene

Pseudohastigerina micra (Cole, 1927)

Plate 1, Figure 16

1927 *Nonion micrus* Cole, 22, pl. 5, fig. 12

1953 *Globigerinella micra* Subbotina, p. 119, pl. 13, figs.16-17.

1957 *Hastigerina micra* (Cole). - Bolli, p. 161, pl. 35, fig. 2a-b.

1967 *Pseudohastigerina micra* Berggren and others, p. 275, text-fig. 9.

1971 *Globanomalina micra* (Cole) Jenskins, p. 78, pl. 2, figs. 50-54.

1975 *Pseudohastigerina micra* Toumarkine and Bolli, p. 82, pl. 1, figs. 1-2.

1979 *Pseudohastigerina micra* Blow, p. 1185, pl. 166, fig. 11; pl. 198, figs. 8, 9.

1985 *Pseudohastigerina micra* Toumarkine and Bolli, p. 118, figs. 21:1, 21: 2a-b, 21: 3-6.

1995 *Pseudohastigerina micra* Pearson, p. 55, pl. 1, fig. 2.

2000 *Pseudohastigerina micra* Gallagher and Holdgate, p. 42, pl. 14, fig. 3.

2004 *Pseudohastigerina micra* Pearson *et al.*, p. 36, pl. 1, fig. 11.

2006 *Pseudohastigerina micra* Pearson *et al.*, p. 425, pl. 14.3, figs. 11-24.

Remarks: This species described as the planispiral forms with compressed, tightly coiled outline. The test has a small size. The distinguishing feature used in the present study is the relatively slow increase in the chamber size.

Geographic Distribution: Low to high latitudes; Mexico, northern Caucasus, Trinidad, Italy, Tanzania, Egypt, Pakistan, Atlantic Ocean, Pacific Ocean, New Zeland.

Occurrence: Karaburun MSS, Sample no. 15, 18, 19, 22, 32; İstafan MSS, Sample no. 1, 2, 4-8, 11, 13-17; Sinay-Karasu MSS, Sample no. 1, 14, 15, 17, 18, 27.

Pseudohastigerina wilcoxensis (Cushman and Ponton, 1932)

Plate 1, Figures 17-19

1932 *Nonion wilcoxensis* Cushman and Ponton, 64, pl. 8, fig. 11.

1967 *Pseudohastigerina wilcoxensis* Berggren, Olsson and Reyment, p. 278, text-figs. 2: s-v, 3: 2a-5c, 4: 2a-5c, 6: 1a-6c.

1967 *Globanomalina wilcoxensis globulosa* Gohrbandt, p. 321, pl. 1, figs. 16, 17.

1975 *Pseudohastigerina wilcoxensis* Stainforth and others, p. 243, text-figs. 99: 1-5.

1985 *Pseudohastigerina wilcoxensis* Toumarkine and Bolli, p. 108, figs. 12: 9a-c, 10a-c, 11a-b, 12a-c.

1995 *Pseudohastigerina wilcoxensis* Lu and Keller, p. 102, pl. 6, figs. 7, 8.

1997 *Pseudohastigerina wilcoxensis* Speijer and Samir, p. 54, pl. 2, figs. 5a-c.

2001 *Pseudohastigerina wilcoxensis* Orue-Etxebarra *et al.*, p. 57, pl. 1, figs. 6-7.

2006 *Pseudohastigerina wilcoxensis* Pearson *et al.*, p. 429, pl. 14.4, figs. 1-8.

2007 *Pseudohastigerina wilcoxensis* Luciani *et al.*, p. 206, pl. 1, figs. 12-13.

Remarks: The distinguishing features of *Pseudohastigerina wilcoxensis* are having inflated chambers that are rapidly increasing their size. The chambers are not tightly coiled like in *P. micra.*

Geographic Distribution: Mid to highlatitudes; Austria, Atlantic Ocean, Egypt, Pacific Ocean, Germany, northern Caucasus.

Occurrence: Karaburun MSS, Sample no. 6, 8-11, 14-16, 18, 19, 22, 32; İstafan MSS, Sample no. 1, 2, 4, 6, 8; Sinay-Karasu MSS, Sample no. 1, 8, 12, 13; Erfelek-A MSS, Sample no. 12; Kaymakam Kayası-A MSS, Sample no. 8.

Genus *Subbotina* Brotzen and Pozaryska, 1961

Type species: *Globigerina triloculinoides* Plummer, 1926

The classification of the species of genus *Subbotina* is summarized in Table 13.

Subbotina cancellata (Blow, 1979)

1953 *Globigerina fringa* Subbotina. p. 62, pl. 3, fig. 3.

1979 *Subbotina triangularis cancellata* Blow. p. 1284, pl. 80, figs. 2-9.

1999 *Subbotina cancellata* Blow. – Olsson *et al*., p. 29, pl. 9, figs. 7-9; pl. 24, figs. 1-14, pl. 25, figs. 1-15.

Remarks: This is a compact, triangular Paleocene subbotinid with 3,5-4 chambers in its last whorl. The wall of this species is coarsely cancellate, which differentiates *S. cancellata* from *S. triangularis*.

Geographic Distribution: Caucasus, South Atlantic Ocean.

Occurrence: Erfelek MSS, Sample no. 17, 19.

Table 13. Classification of genus *Subbotina* (* indicates the identified species in this study)

Species Name	Test		Wall	Chambers				Sutures		Umbilicus			Aperture	Apertural features	Size (mm)	Age
	Coiling	Outline		# of Chambers	Increase in size	Last Whorl	Last Chamber	Spiral	Umbilical	Size	Shape	Orifice				
S. cancellata *	Low trochospiral, tight	Compact, rounded, dorso-ventrally compressed	Coarsely cancellate	3,5-4		Inflated and subglobular chambers, moderately appressed and embracing	Drawn out to dorsal side	Short, slightly curved	Longer, strongly curved, deep	Small	Open & deep		Umbilical	Broad, irregular lip	0,29	Paleocene
S. triangularis *	Low trochospiral, loose	Triangular, rounded axially	Cancellate, spinose, asymmetric pores	3,5			Overlap umbilicus, smaller than penultimate	Deep			Narrow & deep		Umbilical-extraumbilical	Thin, irregular lip	0,4	
S. triloculinoides *	Low trochospiral, freely	Lobate, compressed	Strongly cancellate & reticulate, spinose, coarse pores	3,5	Rapid		1/2 of test, hemispherical, height>width	Depressed, straight to slightly curved			Narrow & deep	Small arched slit, notched flap	Asymetrically umbilical	Well-developed lip	0,3-0,56	
S. trivialis	Inflated with tall 1st whorls, tight	Compact	Weakly cancellate	3,5-4,5	Slight		Equal to or smaller than penultimate	Curved & deeply incised		Small		Slit-like	Umbilical	Thin lip	0,25-0,4	
S. velascoensis *	Low trochospiral, tight	Rounded, subquadrate, compressed	Symetrically cancellate	3-4			1/2 of test, overhangs earlier chambers						Elongate, umbilical	Thin, elongate lip	0,45	
S. patagonica *	Very low	Compact, globular, slightly lobate	Coarsely cancellate, spinose, normally perforate, sacculifer type wall	3-3,5	Rapid	Globular, embracing chambers	Large, about 1/2 of test	Slightly depressed, straight		Very small	Nearly closed	Rounded arch	Umbilical	Thickened rim that display as lip	0,32	Late Paleocene-Middle Eocene
S. hornibrooki	Low trochospiral	Compact, globular, slightly lobate	Coarsely cancellate, spinose, normally perforate, sacculifer type wall	3,5-4	Rapid	Globular & embracing chambers	Reduced in size & directed over umbilicus	Slightly depressed, straight		Small	Partly closed	Enclosed by surrounding chambers	Umbilical	Narrow, continuous lip	0,25	Early Eocene
S. roesnaesensis *	Very low	Tripartite, globular, lobate	Spinose, normally perforate, ruber-type wall	3-4	Rapid	Ovoid, loosely embracing, wider than height		Strongly depressed, straight or gently curved		Fairly large		Low arched	Umbilical	Narrow lip	0,3-0,55	Early-Middle Eocene
S. senni	Moderately elevated initial whorl	Compact, ovate to circular	Cancellate, spinose, normally perforate, thick, sacculifer-type wall	3,5-4	Slowly or moderately		Ovoid, slightly embracing, equal to or smaller than penultimate	Moderately depressed, straight		Small	Nearly closed		Umbilical	Thick rim	0,28-0,42	

Table 13. (Cont.)

Species Name	Test		Wall	Chambers				Sutures		Umbilicus			Aperture	Apertural features	Size (mm)	Age
	Coiling	Outline		# of Chambers	Increase in size	Last Whorl	Last Chamber	Spiral	Umbilical	Size	Shape	Orifice				
S. Linaperta *	Low trochospiral, tight	Globular, rounded	Coarsely & symetrically cancellate, spinose, normally perforate, sacculifer wall	3-3,5	Rapid	Globular, embracing chambers	Broader than high, compressed, flattened appearance	Slightly to moderately depressed, straight to slightly curved		Very small	Shallow	Low arched, enclosed by surrounding chambers	Umbilical-extraumbilical	Thin lip	0,38	Early-Late Eocene
S. crociapertura	Low trochospiral	Globular, oval	Cancellate, spinose, normally perforate, bulloides-type wall	4	Rapid	Slightly embracing globular chambers		Moderately depressed, straight		Small	Open	Moderately high, circular arch (hook-shaped)	Umbilical-extraumbilical	Prominent lip	0,43	Middle Eocene
S. eocaena *	Low trochospiral, tight	Quadrate	Coarsely cellular pores	4	Uniform chamber size	Chambers in close contact to each other	Spherical		Sutures 90° to each other (form a cross)	Small		Along marginal suture between umbilicus & periphery			0,5-0,7	Middle-Late Eocene
S. hagni *	Low trochospiral	Quadrate	Cancellate, spinose, normally perforate, sacculifer-ruber wall	4	Moderate	Globular, embracing chambers		Moderately depressed, straight		Small		Low arched, enclosed by surrounding chambers	Umbilical-extraumbilical	Thin, irregular lip	0,58	
S. jacksonensis *	Low trochospiral	Globular, oval	Cancellate, spinose, normally perforate, sacculifer-ruber wall	4	Moderate	Globular, embracing chambers	Smaller than penultimate, directing over & cover umbilicus	Very slightly depressed, straight		Small	Closed		Umbilical		0,39	
S. yeguaensis *	Moderately elevated	Globular, lobate	Symetrically cancellate, spinose, normally perforate, sacculifer wall	3,5	Moderate	Globular, slightly embracing chambers	Equal to or smaller than penultimate	Moderately depressed, straight		Small		Low rounded opening, enclosed by surrounding chambers	Umbilical	Broad lip	0,52	
S. angiporoides	Low trochospiral	Non-umbilical, spherical, rounded, quadrilobate	Moderately cancellate, spinose, normally perforate, sacculifer-ruber wall	4		Chambers elongated along radial axis	Strongly embracing & extended over umbilical sutures	Weakly depressed, radial to slightly curved				Low, indistinct, interiomarginal slit		Thick lip	0,45-0,55	
S. corpulenta *	Moderately high, freely	Lobate, moderately elevated initial whorl, spherical	Cancellate, spinose, normally perforate	4-4,5	Moderate	Globular chambers	Cantilevered over umbilicus, sometimes centered like bulla	Moderately depressed, straight to slightly curved		Moderate	Closed		Umbilical	No lip	0,45-0,55	
S. gortanii	High trochospiral	Globular	Cancellate, spinose, normally perforate,	4	Moderate	Globular, loosely embracing chambers		Deeply depressed, straight		Large		Enclosed by surrounding chambers	Umbilical	Thickened, narrow lip	0,6	
S. utilisindex	Low trochospiral	Trilobate, rounded equatorial margin, compact	Moderately cancellate, spinose, normally perforate, sacculifer-ruber wall	3	Slightly		Comprising less than half of test, not enveloping	Moderately depressed, radial to slightly curved			Narrow & shallow	Low arched	Very low interiomarginal, umbilical-extraumbilical	Narrow lip	0,37	Late Eocene-Early Oligocene

Subbotina corpulenta (Subbotina, 1953)

1953 *Globigerina corpulenta* Subbotina. p. 101, pl. 9, figs. 5a-7c.

1953 *Globigerina inflata* d'Orbigy. – Subbotina. p. 94, pl. 7, figs. 6a-8b; pl. 8, figs. 1a-6c; pl. 15, figs. 4a-6c.

1957 *Globigerina pera* Todd, p. 301, pl. 70, figs. 10, 11.

1962 *Globigerinita pera* Todd. – Blow and Banner, p. 112, pl. 14, figs. E-H.

1975 *Globigerina cryptomphala* Glaessner. – Toumarkine, p. 742, pl. 1, fig. 5.

1980 *Catapsydrax pera* Todd. – Charollais *et al*., pl. 5, fig. 14.

1985 *Globigerina cryptomphala* Glaessner. – Toumarkine and Luterbacher, p. 149, pl. 42, fig. 5a-b; fig. 42:6.

2006 *Subbotina corpulenta* Subbotina. – Pearson *et al*., p. 129, pl. 6.7, figs. 1-14.

Remarks: This species is one of the large subbotinids. There are 4-4,5 chambers in its last whorl and the chambers of the previous whorls are also very distinct on its spiral side. The test is quadrate and lobate. The chambers are globular. The last chamber of the form is projected over the umbilicus like a bullae.This projection look likes the position of the last chamber of *Subbotina jacksonensis*. However, the quadrate test of *Subbotina corpulenta* distinguishes these two species.

Geographical Distribution: France, Caucasus, Crimea, Tanzania, Pacific Ocean.

Occurrence: Sinay-Karasu MSS, Sample no. 19-21, 23.

Subbotina eoceana (Guembel, 1868)

Plate 1, Figures 20-21; Plate 2, Figures 1-2

1968 *Globigerina eocaena* Guembel, p. 662, pl. 2, fig. 109.

Not 1953 *Globigerina eocaena* Subbotina, p. 87, pl. 6, fig. 5; p. 87, pl. 7, fig. 1.

1969 *Globigerina (Subbotina) eoceana* Guembel. - Hagn and Lindenberg, p. 336, pl. 1, figs. 1a-c, 5a-c.

1985 *Globigerina eocaena* Tourmakine and Luterbacher, p. 149, pl. 42, fig. 1a-c.

1995 *Globigerina eocaena* Poag and Commeau, p. 149, pl. 6, fig. 19.

2000 *Subbotina eocaena* Sztrakos, p. 125, pl. 22, fig. 8.

2006 *Subbotina eocaena* Pearson *et al.*, p. 135, pl. 6.9, figs. 1-16.

Remarks: The forms classified under Genus *Globigerina* above are classified as the synonyms of *Subbotina eocaena* in the recent publications (e.g. Pearson *et al.*, 2006). However, in the present study, some differences are observed between those forms and there becomes a need of separating them as different species. For example, having a tripartite, triangular outline and tightly-coiled chambers are the main characteristics that separate this species from *Subbotina (Globigerina) pseudoeoceana.* Its sutures are straight in the spiral side rather than being curved.

Geographic Distribution: Low to mid latitudes; Austria, Italy, Atlantic Ocean, France, northern Caucasus, Mexico, Crimea.

Occurrence: Karaburun MSS, Sample no. 15, 18, 22, 32; İstafan MSS, Sample no. 1-16; Sinay-Karasu MSS, Sample no. 1, 3-7, 20-23.

Subbotina hagni (Gohrbandt, 1967)

Plate 2, Figures 3-4

1967 *Subbotina hagni* Gohrbandt, 324, pl. 1, fig. 1-9.

1953 *Globigerina eocaena* Subbotina, p. 87, pl. 6, fig. 5; p. 87, pl. 7, fig. 1.

1977 *Subbotina hagni* (Gohrbandt). – Poore and Brabb, p. 269, pl. 4, figs. 13, 14.

2000 *Subbotina hagni* Sztrakos, p. 125, pl. 22, fig. 11.

2001 *Subbotina hagni* (Gohrbandt). – Warraich and Ogasawara, p. 48, fig. 14: 5-7.

2006 *Subbotina hagni* Pearson *et al.,* p. 139, pl. 6.11, figs. 1-17.

2007 *Globigerina hagni* Yıldız *et al.*, p. 49, pl. 1, figs. 2-3.

Remarks: *Subbotina hagni* is an easily distinguishing species via its perfectly quadrate outline and slowly increasing chamber size.

Geographic Distribution: Low to mid latitudes; northern Caucasus, Austria, Italy, Pakistan, California (USA), Kastamonu (NW Turkey).

Occurrence: Karaburun MSS, Sample no. 15, 18, 19, 22, 26; İstafan MSS, Sample no. 2, 4, 5, 8, 11-15; Sinay-Karasu MSS, Sample no. 3, 8.

Subbotina jacksonensis (Bandy, 1949)

1949 *Globigerina rotundata jacksonensis* Bandy, p. 121, pl.23, fig. 6a-c.

1949 *Globigerina ouachitaensis senilis* Bandy, p. 121, pl.22, fig. 5a-c.

1985 *Globigerina* (Eoglobigerina) *bizkaiensis* Orue-Etxebarria, p. 469, pl.1, fig. 1-10.

2006 *Subbotina jacksonensis* Bandy. – Pearson *et al*., p. 146, pl. 6.13, figs. 1-20.

Remarks: This species has 4 chambers in its last whorl. The chambers are globular and increasing gradually in size. The most distinguishing property of *Subbotina jacksonensis* is that its last chamber is very embracing to cover its umbilicus.

Geographical Distribution: Alabama, Spain.

Occurrence: Sinay-Karasu MSS, Sample no. 16, 17, 23.

Subbotina linaperta (Finlay, 1939)

Plate 2, Figures 5-10

1939 *Globigerina linaperta* Finlay, 125, pl. 12, figs. 54-57.

1958 *Globigerina linaperta* Finlay. - Hornibrook, p. 33, pl. 1, figs. 19-21.

1962 *Globigerina linaperta* Finlay. - Saito, p. 216, pl. 32, figs. 4a-c.

1971 *Globigerina (Subbotina) linaperta* Finlay.- Jenkins, p. 162, pl. 18, figs. 551-554.

1975 *Globigerina linaperta* Finlay. - Toumarkine, p. 742, pl. 1, figs. 1-2.

1983 *Globigerina linaperta* Finlay. - Krasheninnikovand Basov, p. 838, pl. 2, figs. 8-11.

1991 *Subbotina linaperta* (Finlay). - Huber, p. 440, pl. 5, figs. 1.

1992 *Subbotina linaperta* (Finlay). - Berggren, p. 583, pl. 3, figs. 1-4.

2004 *Subbotina linaperta* (Finlay). - Wade, p. 28, pl. 1, figs. d-f.

2006 *Subbotina linaperta* (Finlay). - Pearson *et al.,* p. 149, pl. 6-14, figs. 1-16.

Remarks: This species is separated with its tight coiling and flattened last chamber in the edge view. It has a coarsely cancellate wall, 3-3,5 chambers in last whorl rapidly increasing in size.

Geographic Distribution: New Zeland, Austria, Pacific Ocean, Atlantic Ocean, California, New Guinea, Indian Ocean, Caucasus.

Occurrence: Karaburun MSS, Sample no. 2-10; Sinay-Karasu MSS, Sample no. 7.

Subbotina patagonica (Todd and Kniker, 1952)

Plate 2, Figures 11-13

1952 *Globigerina patagonica* Todd and Kniker, 26, pl. 4, figs. 32a-c.

1989 *Globigerina patagonica* Todd and Kniker.- Murray, Curry, Haynes and King, p.

530, pl. 10.10, figs. 10-12.

1991 *Subbotina patagonica* (Todd and Kniker).- Huber, p. 441, pl. 4, figs. 16, 17.

2006 *Subbotina patagonica* (Todd and Kniker).- Pearson *et al.*, p. 154 pl. 6-15, figs. 1-16.

2014 *Subbotina patagonica* (Todd and Kniker).- Bornemann *et al*., p. 71, text fig. 2.3.

Remarks: It looks like *S. linaperta* in which it differs in having an arched, semicircular aperture and lacking a flattened ultimate chamber in the edge view. It has also a compact test with a coarsely cancellate texture.

Geographic Distribution: High latitudes of southern hemisphere and low-to-mid latitudes; Chile, UK, Indian Ocean, Trinidad.

Occurrence: Karaburun MSS, Sample no. 2-10, 12, 14; Ayazlı MSS, Sample no. 1, 4, 6, 9, 11, 14; Erfelek MSS, Sample no. 48; Kaymakam Kayası MSS, Sample no. 36, 37.

Subbotina roesnaensis (Olsson and Berggren, 2006)

Plate 2, Figures 14-16

2006 *Subbotina roesnaensis* Olsson and Berggren, p. 157 pl. 6-16, figs. 1-15.

1953 *Globigerina eocaenica* var. *eocaenica* Terquem.- Subbotina, p. 80-81, pl. 11, figs. 8a-c, 9a-c.

1960 *Globigerina yeguaensis* Weinzierl and Applin.- Berggren, p. 73-83, pl. 2, figs. 1a-4c; pl. 3, figs. 1a-3c; pl. 4, figs. 1a-2c; pl. 8, figs. 1a-5c.

1979 *Subbotina* sp. - Blow, p. 1260, pl. 158, fig. 5.

1989 *Globigerina patagonica* Todd and Kniker.- Murray, Curry, Haynes and King, p. 260, pl. 8.10, figs. 6-8.

1991 *Subbotina velascoensis* (Cushman). - Huber, p. 441, pl. 4, figs. 11, 12.

1992 *Subbotina patagonica* (Todd and Kniker). - Berggren, p. 563, pl. 2, fig. 16.

1995 *Subbotina patagonica* (Todd and Kniker). - Lu and Keller, p. 102, pl. 5, figs. 12-14.

2000 *Subbotina patagonica* (Todd and Kniker). - Warrick and others, p. 299, figs. 18: 4, 5, 11.

2001 *Subbotina patagonica* (Todd and Kniker). - Warrick and Ogasawara, p. 48, figs. 13: 4, 8, 12.

Remarks: It has a lobulate test with 3 ½ -4 rapidly growing chambers in its last whorl that distinguishes this species from other subbotinids in the measured section.

Geographic Distribution: Widespread in low to mid latitudes; Pakistan, Indian Ocean, Pacific Ocean, UK, Caucasus, Atlantic Ocean, Denmark, Germany.

Occurrence: Karaburun MSS, Sample no. 2-12, 14, 15; Ayazlı MSS, Sample no. 11, 14; Sinay-Karasu MSS, Sample no. 14, 15.

Subbotina triangularis (White, 1928)

Plate 2, Figure 17

1928 *Globigerina triangularis* White, p.195, pl. 28, figs. 1a-c.

1957a *Globigerina triangularis* White. – Bolli, p.71, pl. 15, figs. 12-14.

1970a *Globigerina triangularis* White. – Shutskaya, p.104, pl. 3, figs. 5a-c.

1970b *Globigerina triangularis* White. – Shutskaya, p.118, pl. 20, figs. 7a-c; p. 220, pl. 23, figs. 1a-c; p. 224, pl. 25, figs. 1a-c.

1979 *Globigerina triangularis triangularis* (White). – Blow, p.1281, pl. 91, figs. 7, 9; pl. 107, figs. 8, 9.

1997 *Subbotina triangularis* (White). – Berggren and Norris, p. 81, pl. 5, figs. 1, 5, 9.

1999 *Subbotina triangularis* (White). – Olsson *et al*., p. 30, pl. 26, figs. 1-13.

2008 *Subbotina triangularis* (White). – Handley *et al*., p. 20, text-fig. 2.4.

2009 *Subbotina triangularis* (White). – Obaidalla *et al*., p. 4, pl. 2, fig. 9.

Remarks: *Subbotina triangularis* has a triangular test in which the last chamber overlaps the umbilicus. Its umbilicus is deep and narrow. There are 3 ½ chambers in its last whorl and the last chamber is smaller than the previous one.

Geographical Distribution: Mexico, Trinidad, N Caucasus, Turkmenia, Tanzania, South Atlantic Ocean, Kerguelen Plateau (S Indian Ocean).

Occurrence: Ayazlı MSS, Sample no. 2, 4; Erfelek MSS, Sample no. 43.

Subbotina triloculinoides (Plummer, 1926)

Plate 2, Figure 18

1926 *Globigerina triloculinoides* Plummer, p.134, pl. 8, figs. 10a-b.

1957a *Globigerina triloculinoides* Plummer. – Bolli, p.70, pl. 15, figs. 18-20.

1957a *Globigerina triloculinoides* Plummer. – Loeblich and Tappan, p. 183, pl. 40, figs. 4a-c; pl. 41, figs. 2a-c; pl. 42, figs. 2a-c; pl. 42, figs. 2a-c; pl. 43, figs. 5a-c, 9a-c; pl. 45, figs. 3a-c; pl. 49, figs. 2a-c.

1961 *Subbotina triloculinoides* (Plummer). – Brotzen and Po aryska, p. 160, pl. 4, fig. 4; p. 160, text-fig. 2

1962 *Globigerina triloculinoides* Plummer. – Berggren, p. 86, pl. 14, figs. 1a-2c.

1962 *Globigerina triloculinoides* Plummer. – Hillebrandt, p. 119, pl.11, figs. 1a-c.

1970b *Globigerina triloculinoides* Plummer. – Shutskaya, p. 118, pl. 18, figs. 1a-c; pl. 19, figs. 3a-c; pl. 21, figs. 12a-c.

1979 *Subbotina triloculinoides triloculinoides* (Plummer). – Blow, p. 1287, pl. 74, fig. 6; pl. 80, fig. 1; pl. 98, fig. 7; pl. 238, fig. 5; pl. 248, figs. 9, 10; pl.255, fig. 9; pl. 257, fig. 9.

1985 *Subbotina triloculinoides* (Plummer). – Synder and Waters, p. 448,449, pl.11, figs. 7-9.

1989 *Globigerina triloculinoides* (Plummer). – De Klasz *et al.*, p.33, pl. 1, figs. 6a-c.

1990 *Subbotina triloculinoides* (Plummer). – Stott and Kennett, p. 559, pl. 2, fig. 12.

1991 *Subbotina triloculinoides* (Plummer). – Huber, p. 461, pl. 3, fig.19.

1997 *Subbotina triloculinoides* (Plummer). – Berggren and Norris, pl. 4, figs. 1-3, 5-7,9,10, 19, 21, 22.

1999 *Subbotina triloculinoides* (Plummer). – Olsson et al., p. 31, fig. 12; pl. 9, figs. 13-15; pl. 14, figs. 15-16; pl. 27, figs. 1-13.

2012 *Subbotina triloculinoides* (Plummer). – Birch *et al.*, p. 378, fig. 3.26.

Remarks: This species is a common species recorded in the Paleocene samples. The most important properties of *Subbotina triloculinoides* are its trilobate test shape and its last chamber forms about the half of the test. Its aperture is slightly extraumbilical.

Geographical Distribution: Alabama, New Jersey, Texas, Trinidad, Denmark, Sweden, Australia, Turkmenia, N Caucasus, Senegal, Tanzania, Maud Rise (Antartic Ocean), Shatsky Rise (NW Pacific Ocean), Kerguelen Plateau (S Indian Ocean).

Occurrence: Erfelek MSS, Sample no. 38.

Subbotina velascoensis (Cushman, 1925)

1925 *Globigerina velascoensis* Cushman, p. 19, pl. 3, figs. 6a-c.

1928 *Globigerina velascoensis* Cushman. – White, p. 196, pl. 28, figs. 2a-b.

1928 *Globigerina velascoensis* Cushman var. *compressa* White, p. 196, pl. 28, figs. 3a-b.

1957a *Globigerina velascoensis* Cushman. – Bolli, p. 71, pl. 15, figs. 9-11.

1960 *Globigerina velascoensis* Cushman. – Bolli and Cita, p. 374, pl. 34, figs. 8a-c.

1962 *Globigerina velascoensis* Cushman. – Hillebrandt, p. 120, pl. 11, figs. 4a-b.

1963 *Globigerina velascoensis* Cushman. – Gohrbandt, p. 47, pl. 2, figs. 1-3.

1970a *Globigerina velascoensis* Cushman. – Shutskaya, p. 94, pl. 4, figs. 3a-4c, 6a-c.

1970 *Globigerina nana* Khalilov. – Shutskaya, p. 90, pl. 2, figs. 2a-c.

1975 *Globigerina velascoensis* Cushman. – Stainforth *et al.*, p. 239, 240, text-fig. 96. 1; 96. 2-4.

1977 *Subbotina velascoensis* Cushman. – Tjalsma, p. 510, pl. 4, fig 1.

1979 *Subbotina velascoensis* Cushman. – Blow, p. 1292-1294, pl. 98, fig. 9.

1983 *Globigerina velascoensis* Cushman. – Pujol, p. 645, pl. 2, fig. 9.

1985 *Subbotina velascoensis* Cushman. – Snyder and Waters, p. 443, pl. 11, figs. 13-15.

1991 *Subbotina velascoensis* Cushman. – Huber, p. 441, pl. 4, figs. 11, 12.

1995 *Subbotina velascoensis* Cushman. – Basov, p. 165, pl. 2, figs. 15-17.

1997 *Subbotina velascoensis* Cushman. – Beggren and Norris, pl. 5, figs. 2, 6,7,11.

1999 *Subbotina velascoensis* Cushman. – Olsson et al., p. 33, fig. 13; pl. 29, figs. 1-12.

2008 *Subbotina velascoensis* Cushman. – Handley *et al.*, p. 20, text-figs. 2.1-3.

2011 *Subbotina velascoensis* Cushman. – Nguyen *et al.*, pl. 2, fig. 5.

Remarks: It is another 3-lobate subbotinid. The difference of this species is the test is distinctly compressed and the last chamber is very large and elongated in the edge view.

Geographical Distribution: Mexico, Trinidad, Italy, Austria, Crimea, Azerbaidzhan.

Occurrence: Ayazlı MSS, Sample no. 2, 3; Kaymakam Kayası MSS, Sample no. 37.

Subbotina yeguaensis (Weinzierl and Applin, 1929)

Plate 2, Figure 19

1929 *Globigerina yeguaensis* Weinzierl and Applin, 409, pl. 43, fig. 1a-b.

1957 *Globigerina yeguaensis* (Weinzierl and Applin).-Bolli, 163, pl. 35, fig. 15a-c.

1962 *Globigerina linaperta pseudoeocaena* (Subbotina).-Blow, 87, pl.11, fig M.

2006 *Subbotina yeguaensis* Pearson *et al.*, p. 162 pl. 6-18, figs. 1-16.

Remarks: This form is more lobate with respect to most of the subbotinids. It has a triangular outline with 3,5-4 chambers in its last whorl.

Geographic Distribution: Trinidad, western India, Kerguelen Plateau, South Indian Ocean, Pacific Ocean, northern Caucasus, Tanzania.

Occurrence: Sinay-Karasu MSS, Sample no. 5, 11, 14, 18, 23.

Genus *Turborotalia* Cushman and Bermudez, 1949

Type species: *Globorotalia centralis* Cushman and Bermudez, 1937

The classification of the species of genus *Turborotalia* is summarized in Table 14.

Turborotalia cocoaensis (Cushman, 1928)

Plate 2, Figure 20

1928 *Globorotalia cocoaensis* Cushman, p. 75, pl. 10, figs. 3a-c.

1932 *Globorotalia cocoaensis* Cushman. – Howe and Wallace, p. 75-76, pl. 14, fig. 4.

1935 *Globorotalia cocoaensis* Cushman, p. 50, pl. 21, figs. 1a-3c.

1949 *Globorotalia cocoaensis* Cushman. - Bandy, p. 79-80, pl. 12, fig. 1a-c.

1957c *Globorotalia cocoaensis* Cushman. - Bolli, p. 169, pl. 39, figs. 5a-7b.

1962 *Globorotalia cocoaensis* Cushman. - Aubert, p. 59-60, pl. 3, fig. 3a-c.

1963 *Globorotalia cocoaensis* Cushman. - Eckert, p. 1063, pl. 6, figs. 4a-5d.

1970 *Globorotalia cerroazulensis cocoaensis* Cushman. – Toumarkine and Bolli, p. 144, pl. 1, figs. 28-33.

1975 *Globorotalia cerroazulensis cocoaensis* Cushman. – Toumarkine, p. 744, pl. 2, fig. 7.

1983 *Globorotalia cocoaensis* Cushman. - Pujol, p. 651, pl. 10, fig. 1.

1985 *Globorotalia cerroazulensis cocoaensis* Cushman. – Snyder and Waters, p. 460, pl. 3, figs. 3-5.

1985 *Turborotalia cerroazulensis cocoaensis* Cushman. – Toumarkine and Luterbacher, p. 138, figs. 34.2, 36.7-12.

Table 14. Classification of genus *Turborotalia* (* indicates the identified species in this study)

Species Name	Test Outline	Wall Texture	Chambers: # of chambers	Chambers: Increase in size	Chambers: Chambers	Sutures: Spiral	Sutures: Umbilical	Umbilicus	Aperture	Apertural features	Size (mm)	Age
T. frontosa *	Trochospiral, globorotaliform in early chambers, globigeriniform in last whorl, strong tendency to dextral coiling	Weakly cancellate with raised cylindrical pustules on early chambers, becoming smoother on final chamber, tendency to defoliate	3-3,5	Rapidly	Inflated, radially compressed, final chamber=1/2 of test	Moderately depressed, straight	Depressed, slightly curved	Very narrow	Broad, high arch, in intra-extraumbilical position, sometimes extending almost to periphery	Pronounced imperforate lip of constant thickness	0,44	Early-Middle Eocene
T. altispiroides	High trochospiral, globular, weak tendency to sinistral coiling	Smooth with pustules or weakly cancellate, especially on early chambers, tendency to defoliate	4,5-6	Slowly	Moderately inflated, radially compressed but elongate in dorso-ventral direction, final 1 or 2 chambers flattened & reduced in size, arching over umbilicus	Depressed, slightly curved	Depressed, slightly curved	Varying from narrow to broad and deep as # of chambers in last whorl increases	Broad arch overhanging umbilicus	Narrow, imperforate lip	0,51	Middle Eocene
T. possagnoensis	Trochospiral, compressed, strong tendency to dextral coiling	Weakly cancellate in earlier chambers, becoming smoother with cylindrical pustules in later chambers, tendency to defoliate	3 (rarely 3,5)	Moderately	Inflated, radially compressed, appressed	Depressed, straight or slightly curved	Depressed, slightly curved	Generally narrow	Broad, low arch, in intra-extraumbilical position	Sometimes thin imperforate lip	0,38	
T. cerroazulensis	Moderately trochospiral, rounded conical shape, strong tendency to sinistral coiling	Smooth, normal perforate with pustulose earlier chambers & around umbilicus, smooth calcification over proloculus tendency to defoliate	4-5	Moderately	Appressed, embracing, strongly radially compressed, dorso-ventrally flattened final chamber showing obtuse or right angle at periphery & arching over umbilicus	Flat or slightly depressed, curved	Depressed, slightly curved	Very narrow	Broad arch, slit-like or circular, generally not extending towards periphery	Imperforate or pustulose lip; sometimes visible	0,35	Middle-Late Eocene
T. cocoaensis *	Large, low to moderate trochospiral, compressed, conical to slightly biconvex, strong tendency to sinistral coiling; imperforate band or weak raised keel in some specimens	Smooth, normal to finely perforate with pustules around umbilicus & smooth calcification over proloculus, tendency to defoliate	4-5	Moderately	Appressed, embracing, semicircular in spiral side, wedge-shaped in umbilical side, final chamber distinctly acute at periphery in edge view	Flat or raised, strongly curved, commonly with imperforate band	Depressed, moderately curved	Very narrow	Broad arch, sometimes almost circular, generally not extending towards periphery	Imperforate or pustulose lip; usually visible	0,48	
T. cunialensis	Low trochospiral, dorso-ventrally strongly compressed, biconvex, strong tendency to sinistral coiling; distinctly raised imperforate keel	Smooth, normal perforate, tendency to defoliate	4-5	Moderately	Appressed, embracing, wedge-shaped in umbilical side, final chamber distinctly acute (<40°) at periphery in edge view	Flat or raised, strongly curved, commonly with imperforate band	Depressed, moderately curved	Very narrow	Broad arch, sometimes almost circular, in extraumbilical position		0,45	
T. pomeroli	Large, moderate to high trochospiral	Smooth, normal perforate with cylindrical pustules around umbilicus, weakly cancellate chambers, tendency to defoliate	4-5	Moderately	Inflated, appressed, strongly radially compressed, final chamber commonly flattened in a radial direction, arching towards umbilicus	Depressed, slightly curved	Depressed, slightly curved	Narrow	Broad, often irregular arch , in umbilical-extraumbilical position, sometimes extending almost to periphery	Occasionaly an imperforate lip visible, but more commonly obscured by inward folding of final chamber	0,51	
T. increbescens	Moderate to high trochospiral, compact, rounded, strong tendency to sinistral coiling	High porosity, weakly cancellate and coarsely pustulose, often smoother on final chamber, tendency to defoliate	3,5-4	Moderately	Appressed, embracing, radially compressed, final chamber radially flattened & arching towards umbilicus	Depressed, curved	Depressed, slightly curved	Narrow to moderately open	Very broad arch, in intra-extraumbilical position, often irregular & elongate	Imperforate or pustulose lip; usually visible	0,51	Middle Eocene-Oligocene
T. ampliapertura	Moderately high trochospiral, compact, globular; lobate or rounded in edge view	Smooth to weakly cancellate, frequently densely pustulose, tendency defoliate	3-4	Moderately	Inflated, appressed, embracing	Depressed, slightly curved	Depressed, moderately curved	Wide & deep	Umbilical-extraumbilical, high arch, circular		0,49	Late Eocene-Oligocene

1994 *Globorotalia cerroazulensis cerroazulensis* (Cole). – Nishi and Chaproniere, p. 260, pl. 3, figs. 2-24.

2006 *Turborotalia cocoaensis* Cushman. – Pearson *et al*., p. 449, pl. 15.4, figs. 1-12.

Remarks: It is a plano-convex form with elevated initial whorls. The acute periphery of this species makes its resemblance to acarininid or morozovellid species; however the smooth wall structure of this species distinguishes this form. Keel development has been recognized in *Turborotalia cocoaensis*.

Geographical Distribution: Alabama, Lousiana, California, Morocco, Switzerland, Italy, India, Tanzania, Atlantic Ocean, Pacific Ocean.

Occurrence: Sinay-Karasu MSS, Sample no. 17.

Turborotalia frontosa (Subbotina, 1953)

Plate 2, Figure 21

1953 *Globigerina frontosa* Subbotina, p. 115, pl. 12, figs. 3-7.

1970 *Globorotalia cerroazulensis frontosa* (Subbotina). - Toumarkine and Bolli, p. 139, pl. 1, figs. 1-3.

1979 *Subbotina frontosa frontosa* (Subbotina).- Blow, p. 1263-1265, pl. 158, figs. 6-7; pl. 160, fig. 3; pl. 162, figs. 10-11; pl. 163, figs. 1-3; pl. 175, figs. 4-6; pl. 238, figs. 1-4.

1985 *Turborotalia cerroazulensis frontosa* (Subbotina). - Toumarkine and Luterbacher, p. 135-136, figs. 34.11; 35.16-18.

1988 *Turborotalia frontosa* (Subbotina). - Poore and Bybell, p. 21, pl. 2, figs. 1-3.

1995 *Turborotalia frontosa* (Subbotina). - Poag and Commeau, pl. 4, fig. 13; pl. 5, fig. 3.

2005 *Turborotalia frontosa* (Subbotina). - Mukhopadhyay, p. 45, pl. 1, figs. 1-7.

2006 *Turborotalia frontosa* (Subbotina). - Pearson *et al.,* p. 447, pl. 15.5, figs. 1-15.

2011 *Turborotalia frontosa* (Subbotina). - Zakrevskaya *et al*., p.777, figs. 14 i-j.

2012 *Turborotalia frontosa* (Subbotina). - Benyamovskiy, p. 123, text- fig. 9.

Remarks: *Turborotalia frontosa* has 3-3,5 globular chambers rapidly increasing in size, a high arched aperture and a final chamber whose size reaches the half of the total size of the test. It resembles *Globigerina eocaenica* in which separates with the radially compressed final chamber rather than a globular one. *Turborotalia frontosa* is differentiated from the other species of the genus by its relatively globular test.

Geographic Distribution: Atlantic Ocean, northern Caucasus, Crimean, India, Pacific Ocean, Italy, Mexico, New Zeland, Cuba.

Occurrence: İstafan MSS, Sample no. 1, 2, 5, 8, 9, 16; Sinay-Karasu MSS, Sample no. 11.

Family Hantkeninidae Cushman, 1927

Genus *Hantkenina* Cushman, 1924

Type species: *Hantkenina alabamensis* Cushman, 1924

The classification of the species of genus *Hantkenina* is summarized in Table 15.

Hantkenina cf. *dumblei* Weinzierl and Applin, 1929

Plate 2, Figures 22; Plate 3, Figures 1-3

1929 *Hantkenina dumblei* Weinzierl and Applin, 402, pl. 43, fig. 5.

1942 *Hantkenina (Applinella) dumblei* Weinzierl and Applin. - Thalmann, 814, pl. 1, figs. 2a-b.

1950 *Hantkenina* (*Applinella*) *dumblei* Weinzierl and Applin. - Brönnimann, 408, pl. 55, figs. 18, 22-23.

1978 *Hantkenina dumblei* Weinzierl and Applin. - Gasinski, p. 54, pl. 1, fig. 8.

1979 *Hantkenina* (*Aragonella*) *dumblei* Weinzierl and Applin. - Blow, 1169, pl. 182, figs. 5-10.

2000 *Hantkenina dumblei* Weinzierl and Applin. - Sztrakos, p. 125, pl. 22, fig. 17.

2006 *Hantkenina dumblei* Weinzierl and Applin. - Pearson et al., p. 239, pl. 8.7, figs. 1-19.

2011 *Hantkenina dumblei* Weinzierl and Applin. - Zakrevskaya et al., p.777, fig. 14 n.

Remarks: This form has a non-lobate outline that rapidly expands along its radial axis. 5-7 triangular chambers are developed in its last whorl and the tubulospines are inclined at a low angle.

In the studied samples, as the preservation of the forms are poor, the tubulospine structure hasn't been recorded in all chambers. However the hantkeninids having a relatively non-lobate outline and inclination at their tubulospines are described as *Hantkenina* cf. *dumblei*.

Geographic Distribution: Low to mid latitudes; Poland, India, Indian Ocean, Trinidad, South Atlantic Ocean, Texas Gulf Coast.

Occurrence: İstafan MSS, Sample no. 16.

Table 15. Classification of genus *Hantkenina* (* indicates the identified species in this study)

Species name	Test outline	Wall Texture	Chambers			Sutures	Aperture	Tubulospines	Size (mm)	Age
			# of chamber	Increase in size	Chambers					
H. nuttalli	Planispiral, stellate shape	Smooth, normal perforate and nonspinose	4-5	Rapidly	Radially elongate, well separated from each other	Depressed	Equatorial arch	Short spines	0.50-1.0	Early Eocene
H. singanoae	Planispiral or pseudoplanispiral, laterally compressed	Layered and perforate, with a smooth or weakly cancellate surface	4-5	Rapidly	Radially elongate, at least one of these ending in either a terminal nub or cylindrical projection 'proto-tubulospine'	Shallow, usually curved in a posterior direction	High equatorial arch with a smooth, broad lip; lips of relict apertures observed along sutures of final whorl	Smooth and distinctly porous prototubulospines	0.63	Early-Middle Eocene
H. alabamensis	Planispiral, compact, biumbilicate, quadrate or polygonal peripheral outline	Smooth, normal perforate and nonspinose	5-6	Slowly	Rounded to polygonal, moderately inflated, closely appressed in the adult whorl, becoming globular in final stages, adult chambers extend into a hollow tubulospine	Depressed, slightly sigmoidal	High equatorial arch, narrow at the top, broadening at the base into lateral lobes, bordered by an imperforate lip	Long and slender to short and stout, straight and inclined forwards in the coiling direction, tangential with respect to shell periphery	0.30-0.60	Middle Eocene
H. australis	Planispiral, laterally compressed, lobed or slightly angular outline	Smooth, normal perforate, probably nonspinose	5-6	Slowly	Subtriangular, closely appressed, most or all of the adult chambers extend into a hollow tubulospine	Depressed, straight to slightly sigmoidal	Equatorial high arch extending about halfway up the apertural face, widening towards the base into weak basal lobes, bordered by an imperforate lip	Recurved, slender, often long, positioned at or just spanning anterior chamber suture, sometimes partially contacting adjacent younger chamber	0.45-0.56	
H. dumblei *	Planispiral, involute, biumbilicate and laterally compressed	Smooth, normal perforate and probably nonspinose	5-7	Rapidly	Subtriangular, closely appressed, in contact with each other along entire radial length, extends into a hollow tubulospine in last whorl	Depressed, straight, becoming sigmoidal with small 'web-like' remnants of relict apertures	Elongated equatorial arch, extending about halfway up the apertural face, widening towards base into weak basal lobes, bordered by an imperforate flaring lip	Short and stout on early chambers, long and slender in later stages, arising sharply from supporting chamber wall, inclined forward slightly in coiling direction	0.40-0.90	
H. lehneri	Planispiral, involute, biumbilicate, deeply incised, stellate outline	Smooth, normal perforate, probably nonspinose	4,5-6	Rapidly	Early chambers are subtriangular, final 2-3 chambers radially elongated and 'finger-like', each chamber of the adult whorl extends into a hollow tubulospine	Depressed, straight, becoming curved, web-like remnants of apertural lips along sutures	Elongated equatorial arch extending halfway up the apertural face, bordered by a well pronounced imperforate lip	Broad based, directed radially and positioned forward of the central chamber axis toward the anterior chamber suture	Up to 1 mm	
H. leibusi *	Planispiral, involute, biumbilicate and laterally compressed, slightly lobate outline	Smooth, normal perforate probably nonspinose	4-6	Rapidly	Subtriangular, somewhat appressed, each chamber of the final whorl extends into a hollow tubulospine	Depressed, straight, becoming curved, remnants of apertural lips along sutures	Narrow, elongated equatorial arch bordered by an imperforate lip that extends about two-thirds up the apertural face	Constricted at the base, stout on early adult chambers, longer and more slender in final chambers, directed radially, positioned close to or at the anterior suture	0.48	
H. mexicana *	Planispiral, evolute, biumbilicate or showing a slightly raised spiral side, laterally compressed	Smooth, normal perforate and probably nonspinose	4-5	Rapidly	Radially elongate or digitate, well-separated, inflated peripherally and more compressed within umbilical region	Straight, curved in final stages, only partially contacting adjacent chamber	Narrow, elongate equatorial arch bordered by an imperforate flaring lip, relict apertural lips are sometimes preserved as 'webs' along sutures	Variable in form, broad-based and stout or long and slender, positioned centrally with respect to radial chamber axis, distal ends usually blunt and closed and commonly possess terminal finger-like projections	0.50-0.75	

Hantkenina cf. liebusi Shokhina, 1937

Plate 3, 4-9

1937 *Hantkenina liebusi* Shokhina, 427, pl. 2, figs. 2-3.

1875 *Siderolina kochi* Hantken, p. 79, pl. 16, fig. 1.

1911 *Pullenia kochi* Leibus, p. 942, pl. 11, fig. 9-10.

1924 *Hantkenina kochi* (Hantken). - Cushman, p. 2, pl. 2, fig. 1a-c.

1953 *Hantkenina liebusi* Shokhina. - Subbotina, p. 141, pl. 1, fig. 2.

1978 *Hantkenina liebusi* Shokhina. - Gasinski, p. 54, pl. 1, fig. 1-7; p. 55, pl. 2, fig. 1-5.

2000 *Hantkenina liebusi* Shokhina. - Sztrakos, p. 125, pl. 22, fig. 18.

2006 *Hantkenina liebusi* Shokhina. - Pearson *et al.*, p. 243, pl. 8.9, figs. 1-20.

2011 *Hantkenina liebusi* Shokhina. - Zakrevskaya *et al*., p.777, fig. 14 m.

Remarks: This form has 4-6 subtriangular chambers in its last whorl that are rapidly in size. The outline of the form is lobulated and slightly incised instead of being non-lobate, which differentiates the form from *H. dumblei.* Due to the poor preservation, the species hasn't been defined accurately. However, because of the outline of the studied specimens, the observed forms are evaluated as *Hantkenina* cf. *liebusi.*

Geographic Distribution: Low to mid latitudes; Hungary, Yugoslavia, northern Caucasus, Trinidad, south Atlantic Ocean, Tanzania, India.

Occurrence: İstafan MSS, Sample no. 11-13, 16.

Hantkenina mexicana Cushman, 1924

Plate 3, Figure 10

1924 *Hantkenina mexicana* Cushman, p. 3, pl. 2, fig. 2.

1950 *Hantkenina* (*Aragonella*) *mexicana* Cushman – Brönnimann, p. 405, pl. 55, figs. 1-6.

1953 *Hantkenina aragonensis* Nuttall – Subbotina, p. 143, pl. 1, figs. 13.

1962 *Hantkenina* (*Aragonella*) *mexicana* Cushman – Ramsey, p. 81, pl. 16, figs. 1-2, 5, 15.

1979 *Hantkenina* (*Aragonella*) *mexicana mexicana* Cushman – Blow, p. 1166, pl. 167, figs. 1-5.

1981 *Hantkenina nuttalli* Toumarkine, p. 112, pl. 1, figs. 4.

1985 *Hantkenina nuttalli* Toumarkine – Toumarkine and Luterbacher, p. 121, pl. 23, figs. 3-5.

2003 *Hantkenina nuttalli* Toumarkine –Coxall and others, p. 245, pl. 3, figs. 1, 5.

2006 *Hantkenina mexicana* Cushman. - Pearson *et al.,* p. 244, pl. 8.10, figs. 1-21.

2011 *Hantkenina mexicana* Cushman. - Zakrevskaya *et al*., p.777, figs. 14 i-j.

Remarks: The peripheral outline is distinctly stellate. It has 4-5 chambers in its last whorl, which are increasing rapidly in size. The tubulospines of this species are positioned more centrally, which distinguish this form from *H. leibusi*.

Form recorded in the sample no. 18 of the Karaburun Section is identified as "*Hantkenina* cf. *mexicana*" since the chambers are not distinctly separate from each other. However, the tubulospines of the form are centered on the chambers, which make the resemblage with *H. mexicana.*

Geographic Distribution: ODP Site 865, Mexico, US Gulf Coast, Tanzania, Trinidad, Jamaica, equatorial Pacific Ocean.

Occurrence: Karaburun MSS, sample no. 18; İstafan MSS, sample no. 12.

Family Hedbergellidae Loeblich and Tappan, 1961

Genus *Globanomalina* Haque, 1956

Type species: *Globanomalina ovalis* Haque, 1956

The classification of the species of genus *Globanomalina* is summarized in Table 16.

Globanomalina australiformis Jenkins, 1966

Plate 3, Figure 11

1966 *Globorotalia australiformis* Jenkins, 112, fig.11.

1969 *Globorotalia australiformis* (Jenkins).-Ludbrook and Lindsay, 367, pl. 1, figs.4-5.

1977 *Planorotalites australiformis* (Jenkins).-Tjalsma, 495, pl.2, figs.10-13.

1989 *Globorotalia* (*Planorotalites*) *australiformis* (Jenkins).-Hornibrook, Braizer and Strong, 128, fig. 24:15a-c.

1999 *Globanomalina australiformis* (Jenkins). – Olsson *et al*., p. 38; fig. 16; pl. 33, figs. 1-13.

2006 *Globanomalina australiformis* (Jenkins). - Pearson *et al.,* p. 415, pl. 14.1, figs. 1-10.

Table 16. Classification of genus *Globanomalina* (* indicates the identified species in this study)

Species Name	Test Outline	Wall Texture	Chambers: # of chambers	Chambers: Increase in size	Chambers: Chambers	Sutures: Spiral	Sutures: Umbilical	Umbilicus	Aperture	Apertural features	Size (mm)	Age
G. archaeocompressa	Low, lax trochospire, moderately lobate, almost circular in outline, flattened & compressed, biconcave with depressed initial spire below level of spiral surface of later chambers	Smooth, very finely perforate	5-6	Gradually	Almost hemispherical & inflated, equidimentional with tangential lenght only very slightly greater than radial breadth in spiral side; subglobular, quite deeply depressed in umbilical side	Depressed, radial	Depressed, radial	Open, shallow, broad, no umbilical shoulders	Interiomarginal, low, only slightly arched opening extending from umbilicus to very nearly to peripheral margin	Well marked, flange-like narrow lip	0,14	Early Paleocene
G. planocompressa	Subpolygonal outline, strongly compressed along growth axis, early whorl slightly above surface of last whorl, axial outer margin weakly asymmetric & broadly rounded	Smooth, finely perforate	5-6	Moderately	Subspherical, inflated, freely arranged; last chamber asymmetrical, flattened at the spertural face & slightly shifted to umbilical surface	Depressed, straight	Deep, straight	Narrow	Semicircular slit located between umbilicus & outer margin	Very narrow lip, uniform over whole length	0,32-0,45	Early Paleocene
G. compressa *	Rotaliform, closely coiled, compressed, equally biconvex, peripheral margin bluntly angular, lobate, moderately to strongly developed imperforate peripheral margin	Smooth, thin, finely punctate	5	Gradually	Moderately inflated, overlapping on spiral side	Distinctly depressed, strongly curved		Small, distinct	Single, moderately arched slit, umbilicaextraumbilical, at base of septal face extending to umbilical depression	Well defined lip	0,40	Early-Late Paleocene
G. ehrenbergi	Low trochospiral, compressed, strongly lobate, axial periphery acute & pinched, thickened imperforate margin with a faint keel on last chamber	Smooth, perforate	5-5,5	Moderately	Compressed, ultimate chamber smaller than penultimate	Distinctly depressed, slightly curved	Depressed, radial	Open, shallow	Low arch, interiomarginal, umbilical-extraumbilical	Lip	0,28	Early-Late Paleocene
G. imitata *	Rotaliform, strongly convoluted with broadly oval outline, flattened dorsal side, convex & subconical ventral side	Smooth, thin, fine scattered to dense pustules in early stage	4-4,5 (occasionally 5)	Rapidly	Oval in spiral side, drawn out in direction of the spiral; triangular in umbilical side; umbilical ends of chambers are disposed above rest of surface of ventral side & forming the apex of a short cone	Recessed, almost straight to slightly curved	Recessed, almost straight to slightly curved	Very small, hardly discernible	Straight slit, high umbilical-extraumbilical arch	Thin continuous lip	0,15-0,25	Early-Late Paleocene
G. pseudomenardii *	Very low trochospiral, biconvex, equatorial periphery elongate, lobate; axial periphery sharply angular with distinct keel	Smooth, perforate	5-6	Rapidly	Strongly compressed	Depressed, strongly curved	Depressed, radial	Narrow, open, shallow	Low arch, interiomarginal, umbilical-extraumbilical	Lip	0,34-0,66	Late Paleocene
G. australiformis *	Low trochospiral, biconvex, quadrilobate outline, acute axial periphery, sinistrally coiled	Smooth, finely perforate	4	Rapidly	Low conical, compressed; in edge view rounded for first 3 chambers of last whorl, last chamber angled with an incipient keel	Slightly depressed, recurved, very short w.r.t umbilical sutures	Slightly depressed, nearly radial	Small, open	Interiomarginal, low arch, umbilical-extraumbilical		0,26	Late Paleocene-Early Eocene
G. chapmani *	Compressed, & pinched periphery, oval outline, biconvex with more convex spiral side, umbilicate, lobate, rounded outline	Smooth, punctate with a silvery lustre	5-6	Rapidly		Depressed, not limbate, gently curved	Depressed, not limbate, gently curved		Elongate slit, opening at the base of final chamber into umbilical depression	Slight lip	0,65	Late Paleocene-Early Eocene
G. luxorensis	Very low trochospiral, compressed with a rounded periphery, tightly coiled, oval in outline, slightly lobate, evolute to partly involute	Smooth, normal perforate	6-7 (occasionally 5-8)	Rapidly	Inflated, globular, inner whorl of chambers depressed	Moderately depressed, straight to slightly curved	Moderately depressed, straight to slightly curved	Small, circular	Oval, umbilical-extraumbilical high arched, extends slightly onto spiral side but not to spiral suture	Narrow lip	0,25	Late Paleocene-Early Eocene
G. ovalis	Oval, longer than broad, biconvex, nearly biterally symmetrical, subacute periphery, broadly rounded, lobate, umbilicate ventral side	Smooth, shiny, finely perforate	5-6	Rapidly	Distinct, inflated, globose, somewhat overlapping, last 2 chambers occupy more than half of test	Depressed, distinct, somewhat curved	Radial		Elongate slit at the base of last chamber extending from umbilicus to periphery, high arch	Narrow lip	0,26	Late Paleocene-Early Eocene
G. planoconica *	Planoconvex, oval, highly compressed, well developed & thickened imperforate peripheral margin, rounded periphery in first chambers of last whorl & more lobate through the end, first whorl very small & poorly distinguished	Smooth, thin, transparent, finely perforated	5-6	Gradually	Semicircular on spiral side, triangular on umbilical side, last chamber considerably larger than penultimate, umbilical ends of chambers closely joined together	Recessed, slightly curved	Recessed, slightly curved	Open, deep	High, umbilical-extraumbilical arch	Thin continuous lip	0,23-0,26	Late Paleocene-Early Eocene

Remarks: This form has a acute periphery like acarininds. However, the smooth wall texture of *G.australiformis* like other globanomalins differentiates this genus from the genus *Acarinina*. *G. australiformis* has 4 chambers in its last whorl; semicircular on spiral side and triangular on umbilical side. Its planoconvex test with acute periphery, and number and shape of its chambers separates this species from the other species of this genus.

Geographic Distribution: New Zeland, South Australia, South Atlantic Ocean, Kerguelen Plateau, Southern Indian Ocean.

Occurrence: Ayazlı MSS, Sample no. 4; Karaburun MSS, Sample no. 15, 19; Sinay-Karasu MSS, Sample no. 6, 12, 13; Erfelek MSS, Sample no. 35, 38, 40, 41; Erfelek MSS, Sample no. 45, 46, 48; Kaymakam Kayası MSS, Sample no. 42, 44.

Globanomalina chapmani (Parr, 1938)

Plate 3, Figure 12

1938 *Globanomalina chapmani* Parr. Holotype: pl.3, figs. 9a, b; topotype: pl. 3, fig 8.

1953 *Globorotalia membranacea* Subbotina, p. 205, pl. 16, figs. 12 a-c.

1967 *Globanomalina chapmani* (Parr). – Berggren, Olsson and Reyment. p. 277, text-figs. 1, 3, nos. 1a-c, 4, pl. 1, figs. 1-6.

1987 *Globanomalina chapmani* (Parr). – Nederbragt and Van Hinte p. 586 pl. 2, figs. 3-10; pl. 3, figs. 4-6.

1991 *Globanomalina chapmani* (Parr). – Huber, p. 440, pl. 6, figs. 19-20.

1999 *Globanomalina chapmani* (Parr). – Olsson *et al*., p. 39; pl. 34, figs. 1-7.

2013 *Globanomalina chapmani* (Parr). – Sarı, p. 2, figs. 2-3.

Remarks: *Globanomalina chapmani* is a biconvex globanomalinid. The species has 5-6 chambers, rapidly increasing in size in its last whorl. In our samples, the identified specimens mostly have 5 chambers. The imperforate peripheral keel and pinched periphery of this species are the distinguishing characteristics. The pinched periphery is observed for all the specimens, although the peripheral keel isn’t thickened for all forms in our samples.

Geographic Distribution: Western and northwestern Australia, Egypt, Pakistan, Crimea, Trinidad, Mexico, South Atlantic Ocean, South Indian Ocean

Occurrence: Erfelek MSS, Sample no. 32, 34, 35, 38, 39; Erfelek MSS, Sample no. 45-48, 70; Kaymakam Kayası MSS, Sample no. 15, 17, 20, 24, 37, 39, 44.

Globanomalina compressa (Plummer, 1926)

Plate 3, Figure 13

1926 *Globigerina compressa* Plummer. p. 135, pl. 8, figs. 11a-c.

1953 *Globigerina compressa* var. *compressa* Plummer. – Subbotina, p. 63, pl. 2, figs. 2a-6c.

1957a *Globorotalia compressa* Plummer. – Bolli, p. 77, pl. 20, figs. 21-23.

1960 *Globorotalia compressa* Plummer. – Bolli and Cita, p. 20, pl. 32, figs. 3a-c.

1979 *Globorotalia* (*Turborotalia*) *compressa compressa* Plummer. – Blow, p. 1062, pl. 75, figs. 10-11; pl. 78, figs. 5-10; pl. 254, figs. 1-3; pl. 257, figs. 5-7.

1991c *Planorotalites compressus* (Plummer). – Huber, p. 461, pl. 3, figs. 1-2.

1992 *Globanomalina compressa* (Plummer). – Berggren, p. 563, pl. 3, figs. 14-16.

1999 *Globanomalina compressa* (Plummer). – Olsson *et al*., p. 40, fig. 17; pl. 14, figs. 1-3; pl. 32, figs. 11-16; pl. 35, figs. 1-13, 17.

2013 *Globanomalina compressa* (Plummer). – Arenillas and Arz, p. 242, text-figs. 5A-B.

Remarks: This species is a 5-chambered, biconvex globanomalinid. The chamber growing rate is lower than that of *G. chapmani.* It is a compressed form with an angular periphery.

Geographic Distribution: Texas, Caucasus, Trinidad, south Atlantic Ocean, Italy, Denmark, Kerguelen Plateau, Tanzania, Tunisia, Spain.

Occurrence: Erfelek MSS, Sample no. 33, 43; Kaymakam Kayası MSS, Sample no. 9, 11, 13, 15.

Globanomalina ehrenbergi (Bolli, 1957a)

1957a *Globorotalia ehrenbergi* Bolli. p. 77, pl. 20, figs. 18-20.

1963 *Globorotalia haunsbergensis* Gohrbrandt. p. 53, pl. 6, figs. 10-12.

1979 *Globorotalia* (*Turborotalia*) *haunsbergensis* Gohrbrandt. – Blow, p. 1075, pl. 88, figs. 6, 8, 9.

1999 *Globanomalina ehrenbergi* (Bolli). – Olsson *et al*., p. 42, pl. 14, figs. 4, 8, 12; pl. 35, figs. 14-16.

2013 *Globanomalina ehrenbergi* (Bolli). – Sarı, pl. 2, fig. 3.

Remarks: *Globanomalina ehrenbergi* is another compressed form. Its faint keel on the ultimate chamber differentiates the species from *G. compressa*. It has 5 rapidly enlarging, lobate chambers in its last whorl.

Geographic Distribution: Cuba, Trinidad, Austria, Shatsky Rise, Tanzania, western Turkey.

Occurrence: Kaymakam Kayası MSS., Sample no. 19, 20.

Globanomalina imitata (Subbotina, 1953)

Plate 3, Figure 14

1953 *Globorotalia imitata* Subbotina. p. 259, pl. 16, figs. 14a-c, 15a-c, 16a-c.

1957a *Globorotalia imitata* Subbotina. – Loeblich and Tappan, pl. 54, figs. 8a-c; pl. 59, figs. 5a-c; p. 63, figs. 3a-c.

1960 *Globorotalia imitata* Subbotina. – Olsson, p. 46, pl. 9, figs. 7-9.

1999 *Globanomalina imitata* (Subbotina). – Olsson *et al*., p. 42, pl. 10, figs. 12-14; pl. 12, figs. 10-12; pl. 36, figs. 7-12, 16.

2013 *Globanomalina imitata* (Subbotina). – Arenillas and Arz, p. 241, text-figs. 4G-J.

Remarks: *Globanomalina imitata* looks like *G. australiformis* in terms of its planoconvex test and number of chambers in its last whorl. Olsson *et al.* (1999) mentioned the presence of a phylogenetic link between these two species. These species are separated by the more oval and compressed dorsal chambers of *G. imitata.*

Geographic Distribution: Caucasus, New Jersey, Maryland, Mexico, Spain, Tunisia.

Occurrence: Erfelek MSS, Sample no. 23, 25; Kaymakam Kayası MSS., Sample no. 15.

Globanomalina planoconica Subbotina, 1953

Plate 3, Figure 15

1953 *Globorotalia planoconica* Subbotina. p. 263 holotype: pl. 17, figs. 4a-c; paratypes, figs. 5a-c, 6a-c.

1999 *Globanomalina planoconica* (Subbotina). – Olsson *et al*., p. 44., pl. 10, figs. 15-17; pl. 34, figs. 8-17.

2006 *Globanomalina planoconica* (Subbotina). - Pearson *et al.* p. 418.

Remarks: This species is a planoconvex, compressed form with a keeled margin. It has 5-6 chamber; the ones in the spiral side are semicircular, whereas the umbilical chambers are triangular. *G. australiformis* is thought to be evolved from *G. planoconica* (Olsson *et al.*, 1999). The aperture of the form is a high umbilical-extraumbilical arch with a thin lip, however in the present study the aperture cannot be observed clearly.

Geographic Distribution: Mid- to low-latitudes.

Occurrence: Ayazlı MSS, Sample no. 1, 4; Erfelek MSS, Sample no. 45, 71.

Globanomalina pseudomenardii (Bolli, 1957)

1957 *Globorotalia pseudomenardii* Bolli. p. 77, pl. 20, figs. 14-17.

1960 *Globorotalia pseudomenardii* Bolli. – Bolli and Cita, p. 26, pl. 33, figs. 2a-c.

1979 *Globorotalia* (*Globorotalia*) *pseudomenardii* Bolli. – Blow, p. 892, pl. 89, figs. 1-5; pl. 94, figs. 1-5; pl. 108, figs. 4-7, pl. 111, figs. 1-4; pl. 112, figs. 2, 3, 9, 10.

1987 *Planorotalites pseudomenardii* Bolli. – Nederbraght and Van Hinte, p. 587, pl. 1, figs. 1-16.

1991 *Planorotalites pseudomenardii* Bolli. – Nocchi *et al.*, p. 269, pl. 1, figs. 7-9.

1999 *Globanomalina pseudomenardii* (Bolli). – Olsson *et al*., p. 45.; fig 18; pl. 14, figs. 5-7; pl. 38, figs. 1-16.

2009 *Globanomalina pseudomenardii* (Bolli). – Obaidalla *et al*., p. 4, pl. 2, fig. 6.

2012 *Globanomalina pseudomenardii* (Bolli). – Robertson *et al*., p. 273, fig. 6 l, m.

Remarks: *Globanomalina pseudomenardii* is a keeled globanomalinid, which is an index species for P4 Zone. Different than all other species of the genus, it has a spiroconvex test. The rapid chamber enlargement and the overlapping spiral chambers are other distinguishing features fot *G. pseudomenardii*.

Geographic Distribution: Crimea, Italy, Alabama, Trinidad, Austria, Papua, Tanzania, Atlantic Ocean.

Occurrence: Kaymakam Kayası MSS, Sample no. 36, 37.

Genus *Planoglobanomalina* Olsson and Hemleben, 2006

Type species: *Planoglobanomalina pseudoalgeriana* Olsson and Hemleben, 2006

The classification of the species of genus *Planoglobanomalina* is summarized in Table 17.

Table 17. Classification of genus *Planoglobanomalina* (* indicates the identified species in this study)

Species name	Test outline	Wall Texture	Chambers			Sutures	Umbilicus	Aperture	Size (mm)	Age
			# of chamber	Increase in size	Chambers					
P. pseudoalgeriana *	Asymmetrical to fully planispiral, compressed, loosely coiled, evolute, oval in outline	Smooth, normal perforate, discontinuous smooth bands on the test periphery	9-10	Gradually	Compressed, distinctly elongate, inner spire of chambers visible due to loose coiling, uncoiling trend in last 3 chambers	Slightly depressed, straight to moderately curved	Moderate in size, circular	Equatorial, asymmetric, oval-shaped opening bordered by a broad lip; relict apertures where apertural lips are not completely fused	0.39	Early Eocene

Planoglobanomalina pseudoalgeriana Olsson and Hemleben, 2006

Plate 3, Figures 16-17

2006 *Planoglobanomalina pseudoalgeriana* Olsson and Hemleben, p. 419, pl. 14.2, figs. 1-20.

1976 *Pseudohastigerina micra* (Cole) – Hillebrandt, 337, pl. 4, figs. 16, 17.

1979 *Pseudohastigerina danvillensis* (Howe and Wallace). – Blow, 1181, pl. 159, figs. 6, 7; pl. 161, figs. 2-7; pl. 166, figs. 2-10.

Remarks: *Planoglobanomalina pseudoalgeriana* differs from *Pseudohastigerina micra* with its compressed, loosely coiled test. It has 9-10 chambers in its last whorl that are gradually increasing in size. It shows a pinched periphery in the edge view.

Geographic Distribution: Wide spread in low to mid latitudes; southeastern Spain, equatorial Atlantic Ocean

Occurrence: Karaburun MSS, Sample no. 15, 19; Sinay-Karasu MSS, Sample no. 1.

Family Truncorotaloididae Loeblich and Tappan, 1961

Genus *Acarinina* Subbotina, 1953

Type species: *Acarinina acarinata* Subbotina, 1953

The classification of the species of genus *Acarinina* is summarized in Table 18.

Acarinina alticonica Fleisher, 1974

Plate 3, Figures 18-21

1974 *Acarinina mattseensis alticonica* Fleisher, pl. 2, figs. 1-5.

1957 *Globigerina collactea* (Finlay). Bolli, 1957a: p.72, pl. 15, fig. 21-23, Bolli, 1957b: 162, pl. 35, figs 18 a,b.

1995 *Acarinina appressocamerata* Blow. Lu and Keller, pl. 3, figs. 9-10.

2006 *Acarinina alticonica* Pearson *et al.* p. 262, pl. 9.2, figs. 1-8.

Remarks: *Acarinina alticonica* is identified with its almost spherical outline, possessing 5 chambers. It has a compressed test.

Geographic Distribution: Caribbean, South Atlantic Ocean, Tethys, Shatsky Rise, Arabian Sea.

Occurrence: Karaburun MSS, Sample no. 3-6, 8, 10-12.

Table 18. Classification of genus *Acarinina* (* indicates the identified species in this study)

Species name	Test outline	Wall Texture	Chambers			Sutures		Umbilicus	Aperture	Apertural features	Size (mm)	Age
			# of chamber	Increase in size	Chambers	Spiral	Umbilical					
A. mckannai	Moderately to low spired, slightly convex spiral side, very convex umbilical side	Strongly muricate on umbilical surface with deep, funnel-shaped entrances to pores over the rest of test	4,5-6	Slowly	Elongate parallel to coiling axis and to direction of coiling; final chamber often curving partly over umbilicus	Gently depressed, slightly curved	Deep, incised, straight	Large, deep	Umbilical-extraumbilical, interiomarginal		0,4	Late Paleocene
A. nitida *	Subglobular to quadrate, more convex ventrally than dorsally, compact	Moderately muricate, particularly on umbilical side with deep, funnel-shaped entrances to pores	4 (rarely 5)	Rapidly	Tightly packed, rounded, radially compressed, axially elongated, early whorls raised above surface of last whorl	Slightly depressed, nearly straight	Deep, incised, straight	Narrow slit	Extending from umbilicus about halfway along base of chamber toward periphery	Slight lip	0,29	
A. strabocella	Nearly circular, lobate, broadly rounded to sunangular axial periphery	Weakly pustulose (muricate) over entire surface	5-6	Gradually	Moderately convex on umbilical side, early whorls raised above later whorls	Depressed, distinct, curved and oblique	Radial, nearly straight	Broad & open	Umbilical-extraumbilical, interiomarginal opening, extending to periphery		0,33	
A. coalingensis *	Subglobular-subtriangular-subquadrate, robust, compact	Strongly & bluntly muricate	3	Rapidly	Arranged at distinct right angles to each other, closely packed	Deep, short, slightly curved	Very deep, incised	Small, slightly open, slit-like	Umbilical-extraumbilical, interiomarginal		0,6	Late Paleocene - Early Eocene
A. esnaensis *	Subquadrate, low trochospiral, lobate, periphery rounded to subacute (elongate & oval)	Densely muricate particularly along periphery, nonspinose, normal perforate	4-4,5	Gradually	Subovate to spherical, moderately inflated, closely appressed, embracing, later chambers on spiral side tangentially longer than radially broad	Depressed, distinct, straight to slightly curved	Radial to slightly curved	Small, narrow, open	Umbilical-extraumbilical, interiomarginal, long, low arch extending nearly to periphery	Very thin lip	0,44	
A. soldadoensis *	Low trochoid, lobate, spiral side centrally more or less elevated, umbilical side convex, loosely coiled	Moderately to strongly muricate, thick	4-5	Gradually	Rounded, distinctly elongated in axis of coiling, often overlapping, final chamber often reduced in size	Deep, curved &/or tangential in direction of coiling	Deep, incised, straight	Large, deep & wide	Umbilical-extraumbilical, interiomarginal	Minute, lip-like border on apertures of last formed chambers		
A. subsphaerica	Small, nearly spherical-globular, strongly elevated spire, tightly coiled	Smoother outer surface	5-6	Gradually	Trapezoidal on spiral side, triangular on umbilical side; closely packed	Depressed, slightly curved	Depressed, slightly curved	Narrow & deep, surrounded by muricae	Semi-rounded, occupying 1/3 of distance between umbilicus & periphery		0,27	

Table 18. (cont.)

Species name	Test outline	Wall Texture	Chambers			Sutures		Umbilicus	Aperture	Apertural features	Size (mm)	Age
			# of chamber	Increase in size	Chambers	Spiral	Umbilical					
A. africana	Weakly planoconvex to biconvex, oval, elongate, axially compressed, acutely pinched, strongly lobate	Muricate, normal perforate, nonspinose; weak muricate keel	4-6	Moderately	Triangular on both sides, early chambers globular to subconical, later chambers more lenticular, strongly compressed	Slightly raised to depressed, gently curved, radial	Slightly raised to depressed, gently curved, radial	Narrow	Umbilical-extraumbilical, low arch, extending to periphery	Faint lip (sometimes)	0,20-0,30	Early Eocene
A. alticonica *	Biconvex to subspherical, medium to high trochospiral, circular outline, weakly lobate	Densely muricate particularly around umbilicus	5	Gradually	Moderately inflated, embracing, appressed, angulate, tightly coiled; tangentially longer than radially broad	Weakly incised, radial	Incised, weakly curved	Narrow, deep, bordered by muricae	Umbilical-extraumbilical, low arch slit	Distinct lip	0,31	
A. angulosa	Flat to slightly convex spiral side, low trochospiral, strongly lobate	Muricate, normal perforate, nonspinose	4,5-5	Gradually	Subangular, strongly angularly dispositioned	Curved, oblique	Depressed, straight, radial	Moderately wide, open, deep	Interiomarginal-umbilical, low arch extending nearly to periphery		0,4	
A. aspensis	Low trochospiral, rounded periphery	No circumumbilical concentration of muricae	6-8 (rarely 10)	Gradually	Subglobular, weakly embracing	Weakly recurved between early chambers, straight & radial later	Moderately depressed, radial	Wide, deep	Umbilical-extraumbilical, interiomarginal opening, extending to periphery		0,5	
A. esnehensis *	Subangulate peripheral margin, low to moderately high spired trochoid, rounded margin in edge view, loosely coiled, strongly cancellate	Muricate, with strong concentration of muricae around umbilicus, well developed on umbilical side, weakly developed on spiral side	5-6 (rarely 7)	Moderately	Inflated, moderate to strong lateral chamber compression	Incised, radial to only slightly curved	Incised, radial to only slightly curved	Wide, open, deep	Low slit extending along margin pf last chamber, but not reaching to periphery	No circumumbilical rim		
A. interposita *	Planoconvex, low trochospiral, large, robust, circular outline, rounded periphery in edge view, weakly lobate, loosely coiled	Densely muricate on both sides & around umbilicus & along peripheral margin, nonspinose, normal perforate	4-4,5	Slowly	Generally globular, embracing, appressed, essentially equidimentional, flatenning in ante- &/or penultimate chamber	Slightly depressed, straight, radial	Depressed, radial, weakly curved	Narrow, deep	Umbilical-extraumbilical arch extending almost to peripheral margin	Thin lip	0,35-0,55	
A. pentacamerata *	Weakly biconvex, low trochospiral, compact, rounded periphery in edge view, weakly lobate	Densely muricate on both sides and around circumumbilical region, nonspinose, normal perforate	5 (rarely 4,5-7)	Gradually	Rounded, inflated, early chambers elevated slightly above plane of final whorl	Radial, weakly retorse	Radial, weakly retorse	Small, deep	Umbilical-extraumbilical, low slit		0,40-0,50	
A. pseudotopilensis *	Planoconvex, subquadrate to suboval, weakly lobate	Densely muricate; concentrated along periphery but not muricocarinate, nonspinose, normal perforate	4	Gradually	Inflated, subrectangular, tangentially longer than radially broad, meeting at nearly right angles, chamber contacts disjunct along peripheral margin, early chambers elevated slightly above plane of final whorl	Depressed, slightly curved, short	Depressed/ incised, radial	Small, deep	Umbilical-extraumbilical low arch extending towards peripheral margin + discrete small openings in some individuals	Thin lip & overhanging, rounded umbilical shoulder	0,35-0,55	
A. quetra *	Planoconvex, subquadrate, low trochospiral, lobate	Moderately to strongly muricate; concentration of muricae along peripheral margin (discontinuously muricocarinate), nonspinose, normal perforate	4	Gradually	Broadly subtriangular, moderately inflated on umbilical side, flattened and meeting at right angles, overlapping and tangentially longer than broad on spiral side, final chamber with high conical angle sometimes reduced in size	Curved	Depressed/ incised, curved to sinous, radial	Wide, deep	Umbilical-extraumbilical arch extending towards but not reaching periphery + discrete intercameral openings		0,5	
A. sibaiyaensis	Planoconvex, low trochospiral to sometimes planispiral, round to subround	Muricate, nonspinose, normal perforate	5-9	Gradually	Inflated, subtriangular to round on both sides	Depressed, radial	Depressed, radial	Narrow	Umbilical-extraumbilical, circular, arch-like opening extending to periphery	Lip to well developed flange	0,29	
A. wilcoxensis *	Planoconvex, elongate-oval peripheral outline, moderately lobate	Densely muricate on both sides; concentration of muricae along peripheral margin but non-carinate, nonspinose, normal perforate	4	Rapidly	Subangular to conical, inflated on umbilical side, lens-shaped to semicircular, overlapping on spiral side	Depressed, curved	Depressed, radial, weakly curved	Narrow, deep	Umbilical-extraumbilical, arch extending nearly to periphery + sutural openings	Thin lip	0,38	

Table 18. (cont.)

Species name	Test outline	Wall Texture	Chambers			Sutures		Umbilicus	Aperture	Apertural features	Size (mm)	Age
			# of chamber	Increase in size	Chambers	Spiral	Umbilical					
A. boudreauxi	Planoconvex, subcircular, low trochospiral, subacute periphery	Robust, heavily calcified, wall with blocky fused muricae	4,5-5	Rapidly	Radially compressed and appressed	Slightly depressed or flat	Depressed, straight, radial	Narrow, deep	Umbilical-extraumbilical, low arch		0,28	Early-Middle Eocene
A. bullbrooki	(Sub)quadrate, low trochospiral; rounded to subangular in edge view	Strongly muricate- giving impression of pseudocarina but not concentrated on circum-umbilical part, nonspinose, normal perforate	4	Gradually	Lunate shaped on spiral side; inflated, moderately embracing, hemispherical; closely appressed and embracing	Weakly curved	Depressed, straight, radial	Narrow to moderately wide	Low, rimmed opening extending towards but not reaching the periphery		0,43	
A. collactea	Biconvex but more inflated umbilical side, compct, low trochospiral, rounded to subangular peripheral margin	Densely muricate on both sides, nonspinose, normal perforate	5	Slowly	Subangular, equal sized	Radial, straight to weakly curved	Radial, straight to weakly curved	Narrow, deep	Low, arched slit along base of last chamber + minute intercameral openings at chamber junctions		0,18-0,25	
A. cuneicamerata	Low trochospiral, loosely coiled	Densely muricate umbilical side, weakly muricate spiral side, no concentration of muricae on circum-umbilical part, nonspinose, normal perforate	5-6	Gradually	Moderately inflated, tendency to develop angulate & disjunct chamber seperation; chambers of last whorl lunate with ante- & penultimate chamber often wedge-shaped (cuneiform)	Straight to weakly curved, tangential to periphery	Depressed to moderately incised, straight, radial	Wide, deep	Umbilical-extraumbilical extending towards but not reaching periphery, relict apertures of ante- & penultimate chambers	Distinct, circumumbilically extending apertural lips connected to relatively broader lip of final chamber	0,41	
A. mcgowrani	Moderate trochospiral, compact, weakly lobate	Densely muricate; conical muricae concentrated around last chamber but not fused to muricocarina, nonspinose, normal perforate	4 (rarely 3-4,5)	Gradually	Wedge-shaped or triangular on umbilical side, subrectangular or ovoid on spiral side, final chamber oval in umbilical view, twice as long as high, subrounded to angular in edge view	Incised, radial to weakly curved, intruded by slender muricae	Deeply incised, distinct, radial, intruded by slender muricae	Deep	Umbilical-extraumbilical	Common bullae	0,25-0,30	
A. praetopilensis	High anguloconical, low trochospiral, subacute margin	Strongly muricate, nonspinose, normal perforate	3,5-4	Rapidly	Juxtaposed, inflated, tangentially longer than radially broad; last chamber distinctly disjunct, cuneate or mitriform with circumperipheral muricae	Radial to weakly curved	Depressed, radial	Wide, deep	Extends towards periphery, supplementary apertures between last 2 chambers	No circumumbilical rim, aperture weakly rimmed	0,38	
A. primitiva	Subangular, robust, compact, subquadrate	Coarsely muricate, often with relatively smooth umbilical face to final chamber, normal perforate, nonspinose	3-4	Rapidly	Triangular on umbilical side, arranged at distinct right angles to each other, tangentially longer than broad on spiral side	Curved, generally obscured by muricate ornament	Incised, distinct, straight	Narrow, deep	Umbilical-extraumbilical, interiomarginal, asymmetrically placedat the base of last chamber		0,29	
A. pseudosubsphaerica	Subspherical, high trochospiral, compact, circular, slightly lobate	Weakly muricate, cancellate on spiral side with large, bladed muricae on umbilical side, normal perforate, nonspinose	4-6	Slowly	Moderately inflated, radially compressed	Depressed, wide		Wide, open, covered by final chamber	Slit-like or low, broad arch		0,19	
A. puntocarinata	Subacute with distincly punctate pseudocarina, low trochospiral	Strongly muricate; concentrated on umbilical shoulders, normal perforate, nonspinose	4	Gradually	Inflated, wedge-shaped, longer axially than radially broad	Radial to weakly curved	Incised, radial to only slightly curved	Wide, open, deep	Low arch extending towards but not reaching periphery	Distinct lip, no circumumbilical rim	0,33	
A. rohri	Subrounded to truncate, low trochospiral	Densely muricate, normal perforate, nonspinose	5 (less commonly 6)	Gradually	Rounded to subangularon umbilical side, hemispherical to wedge sahaped on spiral side; final chamber wedge-shaped & with disjunctly separated from antepenultimate chamber	Depressed, straight to weakly curved	Depressed, weakly curved	Narrow, deep	Umbilical-extraumbilical arch extending towards periphery + distinct, rimmed supplementary apertures at base of antepenultimate and final chambers	Muricate umbilical shoulders	0,37	Middle Eocene
A. topilensis	Planoconvex, subquadrate, lobate	Densely muricate, normal perforate, nonspinose	3,5-4,5	Rapidly	Disjunct, cuneate or mitriform ante- & penultimate chambers strongly flattened along peripheral margin; elongate, lunate/ semicircular on spiral side	Depressed, curved	Strongly incised, radial, straight to weakly curved	Narrow, deep	Umbilical-extraumbilical arch, raised + supplementary apertures bordered by raised rims	Thin lip	0,34	
A. echinata	Biconvex, compact, rounded axial periphery, weakly to moderately lobate	Moderately to coarsely muricate, normal perforate, nonspinose	3,5-4	Rapidly	Globular, last chamber usually kummerform & connected to bulla	Weakly depressed to indistinct, radial	Weakly to moderately depressed, radial	Often covered by bullae	Variable in size, shape, position and number but usually a single low arched opening directed to umbilicus	Bullae, narrow lip	0,3	Middle-Late Eocene
A. medizzai	Biconvex, quadrate to subcircular, weakly to moderately lobate, rounded periphery	Finely muricate, normal perforate, nonspinose	4-5	Moderately	Globular, rarely kummerform	Moderately depressed, radial	Moderately depressed, radial	Narrow in more compact specimens, shallow & broad in evolute forms	Small, often indistinct low umbilical to slightly extraumbilical arch		0,16-0,20	

***Acarinina boudreauxi* Fleisher, 1974**

Plate 4, Figure 1

1974 *Acarinina boudreauxi* Fleisher. p. 1112, pl. 11, figs. 2-5.

2006 *Acarinina boudreauxi* Pearson *et al*. p. 273, pl. 9.5, figs. 9-16.

Remarks: This species is distinguished from *Acarinina bullbrooki* by its smaller size and subacute periphery.

In the Karaburun MSS (Sample no. 9); one of the specimens is refered as *Acarinina boudreauxi*/*puntocamerata*. This form is thought to be a transitional form between these species. The chambers of the form are somehow spherical, whereas the periphery is rounded and the keel is distinct.

Geographic Distribution: Probably wide spread; Indian Ocean, DSDP Site 219, Arabian Sea.

Occurrence: Karaburun MSS, Sample no. 15; İstafan MSS, Sample no. 2-4, 7, 11; Sinay-Karasu MSS, Sample no. 4, 5, 9, 12, 14.

***Acarinina bullbrooki* (Bolli, 1957)**

Plate 4, Figures 2-3

1957 *Globorotalia bullbrooki* Bolli. p. 167, pl. 38, figs. 5a-b (type reference).

1949 *Globorotalia (Truncorotalia) crassata* (Cushman) var *densa* (Cushman). Cushman and Bermudez, p. 38. pl. 7, figs. 10-12.

1953 *Globorotalia crassaformis* Subbotina. p. 290, pl. 21, figs. 2-7.

1977 *Acarinina densa* (Cushman). – Berggren, p.259, chart no: 12.

1991 *Acarinina matthewsae* (Blow). - Huber, p.439, pl. 3, figs. 3, 4.

1992 *Acarinina matthewsae* (Bolli). - Berggren, p. 563, pl. 2, figs. 7, 8.

2000 *Acarinina bullbrooki* (Bolli). - Sztrakos, p. 121, pl. 20, figs. 10-11.

2002 *Acarinina bullbrooki* (Bolli). - Galeotti *et al*., p. 364, pl. 2, figs. 1-3.

2004 *Acarinina matthewsae* (Bolli). - Pearson *et al*., p. 37, pl. 2, figs. 5, 6.

2006 *Acarinina bullbrooki* (Bolli). - Pearson *et al*., p. 274, pl. 9.6, figs. 1-16.

2011 *Acarinina bullbrooki* (Bolli). - Zakrevskaya *et al.*, p. 777, figs. 14 f-g.

2012 *Acarinina bullbroolki* (Bolli). - Robertson *et al*., p. 273, fig. 6s.

Remarks: *Acarinina bullbrooki* is called for the acarininids having a quadrate outline, mostly subangular edge view and lunate shaped - appressed chambers. The forms with more rounded outline, like the ones in Galeotti *et al.* (2002), are included in *A.boudreauxi*.

In the Karaburun section (sample no. 8, 9); some acarininids are defined as *Acarinina* cf. *bullbrooki*. These forms are thought be transitional forms. The chambers on their spiral side are subacute, whereas their apertures are narrower than *Acarinina soldadoensis* or *Acarinina angulosa*. On the other hand, the chambers on spiral side are not totally rectangular, but the edge view is somehow acute, which is supposed to be a transitional property between *Acarinina pseudotopilensis* and *Acarinina bullbrooki*. Therefore, these forms are transitional forms in the evolution of *Acarinina bullbrooki* or they are the juveniles of this species.

Geographic Distribution: Northwest Atlantic Ocean, Trinidad, Marshall Islands, western Pacific Ocean, Morocco, Cuba, south central Puerto Rico, California, Alabama, New Zeland, Tanzania, South Indian Ocean, North Caucasus.

Occurrence: Karaburun MSS, Sample no. 15; İstafan MSS, Sample no. 1-8, 10-14, 17; Sinay-Karasu MSS, Sample no. 3-5, 8, 9.

Acarinina coalingensis (Cushman and Hanna, 1927)

Plate 4, Figure 4

1927 *Globigerina coalingensis* Cushman and Hanna. p. 219, pl. 14, fig. 4.

1947 *Globoquadrina primitiva* Finlay. p. 291, pl. 8, figs. 129-134.

1953 *Acarinina triplex* Subbotina. p. 230, pl. 23, figs. 1-5.

1969b *Acarinina coalingensis* (Cushman and Hanna). - Berggren, p. 152, pl. 1, figs. 27-29.

1979 *Acarinina triplex* Blow. p. 963, pl. 97, figs. 8, 9.

1991b *Acarinina coalingensis* (Cushman and Hanna). Huber, p. 439, pl. 3, fig. 2.

1992 *Acarinina coalingensis* (Cushman and Hanna). Berggren, p. 563, pl. 2, fig. 3.

1993 *Acarinina triplex* Pearson *et al.* pl. 1, figs. 11-12.

1995 *Acarinina triplex* Lu and Keller. pl. 2, figs. 4-5.

1999 *Acarinina coalingensis* (Cushman and Hanna). - Olsson *et al.*, p. 47; pl. 39, figs. 1-16.

2006 *Acarinina coalingensis* Pearson *et al*. p. 276, pl. 9.7, figs. 1-16.

2008 *Acarinina coalingensis* (Cushman and Hanna). - Handley *et al.*, p. 20, text fig. 2.8.

Remarks: *Acarinina coalingensis* has a compact test with 3 rapidly enlarging chambers. It differs from *A. pseudotopilensis* and *A. primitiva* by its subglobular, compact test structure.

Geographic Distribution: South Atlantic Ocean, Antaractic Ocean, Trinidad, Kerguelen Plateau, Indian Ocean, New Zeland, northern Caucasus, Austria, Tanzania.

Occurrence: Karaburun MSS, Sample no. 7, 12; Ayazlı MSS, Sample no. 11.

Acarinina collactea (Finlay, 1939)

1953 *Acarinina rotundimarginata* Subbotina. p. 311, pl. 25, figs. 1-3.

1939 *Acarinina collactea* Finlay. p. 327. pl. 29, figs. 164-165.

2002 *Acarinina rotundimarginata* Galeotti *et al*. p. 362, pl. 1, figs. 12-13.

2006 *Acarinina collactea* Pearson *et al.* p. 278, pl. 9.8, figs. 1-16.

Remarks: *Acarinina collactea* is a small acarininid with 5 chambers closely packed together. It is indicated that there are also found tetrathalamous individuals. It has a rounded and asymmetrically biconvex appearance with a more convex umbilical side in the edge view. It is the synonym of *A.rotundimarginata* Subbotina that is described in the USSR stratigraphy (Subbotina, 1953; Galeotti *et al*., 2002). In the İstafan Section, the described specimens have the typical edge view appearance and chamber shape of the species. However, they have 4-4,5 chambers rather than 5. Therefore, it is preferred to use the form as *Acarinina* cf. *collactea.*

In the Karaburun MSS (sample no. 15); one of the investigated specimens is referred as *Acarinina collactea*/*medizzae*. This form is supposed to be a transitional form between these two species. The edge view of the form is subacute as in *Acarinina collactea*, whereas the aperture of the form is indistinct, which makes a relation with *Acarinina medizzae*. Therefore regarding to the descandance of *Acarinina medizzae* from *Acarinina collactea* (Pearson *et al.*, 2006), this transitional form is named as *Acarinina collactea*/*medizzae* in this study.

Geographic Distribution: New Zeland, Denmark, India, California, Tanzania, north Caucasus, Nigeria, Trinidad, southwest Pacific Ocean, southern Indian Ocean.

Occurrence: İstafan MSS, Sample no. 1-6, 14; Sinay-Karasu MSS, Sample no. 5, 15, 21.

Acarinina cuneicamerata (Blow, 1979)

Plate 4, Figure 5

1979 *Globorotalia (Acarinina) cuneicamerata* Blow. p. 924. pl. 146, figs. 6-8; pl. 153, figs. 1-4; pl. 156, figs. 1-2; pl. 165, figs. 4, 7; pl. 203, fig. 5.

1979 *Globorotalia (Acarinina)* sp. ex interc. *G. (A.). decepta* (Martin) and *G. (A.) cuneicamerata* n. sp. Blow. p. 924, pl. 154, figs. 6, 7.

2006 *Acarinina cuneicamerata* Blow. - Pearson *et al.*, p. 281, pl. 9.9, figs. 1-16.

Remarks: The acarininid species with 5 wedge-shaped, angular chambers are classified as *A. cuneicamerata.* It is one of the larger acarininids within the studied samples. It is differentiated from the other acarininids with the angular chambers rather than the rounded chambers.

Geographic Distribution: Equatorial Atlantic Ocean, northwest Pacific Ocean, Tethys, India, Indian Ocean.

Occurrence: İstafan MSS, Sample no. 4, 7.

Acarinina esnaensis (Leroy, 1953)

Plate 4, Figure 6

1953 *Globigerina esnaensis* Leroy. p. 31, pl. 6, figs. 8-10.

1956 *Truncorotalia esnaensis* (Leroy). – Said and Kenaway, p. 151, pl. 6, figs. 7a-b.

1957 *Globorotalia esnaensis* (Leroy). – Loeblich and Tappan, p. 189, pl. 61, figs. 1a-2c, 9a-c; pl. 57, figs. 7a-c.

1959 *Globigerina esnaensis* Leroy. – Nakkady, p. 461, pl. 3, figs. 2a-c.

1963 *Globigerina esnaensis* Leroy. – Gohrbandt, p. 49, p. 2, figs. 19-21.

1965 *Globigerina esnaensis* Leroy. – McGowran, p. 61, 63, pl. 6, fig. 5, text-fig. 10.

1970 *Globorotalia esnaensis* (Leroy). – Samanta, p. 624, pl. 95, figs. 7-8.

1971 *Globorotalia* (*Acarinina*) *esnaensis* (Leroy). – Jenkins, p. 82, pl. 3, figs. 84-86.

1977 *Acarinina esnaensis* (Leroy). – Berggren, p. 249, chart 10.

1991 *Acarinina esnaensis* (Leroy). – Huber, p.439, pl. 1, figs. 13-15.

2006 *Acarinina esnaensis* (Leroy). – Pearson et al., p. 286, pl. 9.11, figs. 1-12.

Remarks: This species is a 4-4,5 chambered acarinid. Its elongated test and gradually increasing chamber size are distinguishing factors with respect to the quadrate test and equidimentional chambers of A. interposita.

Geographic Distribution: Egypt, Australia, Alabama, Virginia, Denmark, Spain, New Zeland, south Indian Ocean, Maud Rise, north Caucasus, western Turkmenia, Tanzania.

Occurrence: Erfelek MSS, Sample no. 46, 50, 69, 87; Erfelek 1 MSS, Sample no. 40.

Acarinina esnehensis (Nakkady, 1950)

1950 *Globigerina cretacea* d'Orbigny var. *esnehensis* Nakkady. p. 689, pl. 90, figs. 14-16.

1979 *Muricoglobigerina esnehensis* (Nakkady). – Blow, p.1127, pl. 109, figs. 1-7.

2006 *Acarinina esnehensis* (Nakkady). – Pearson *et al*., p 289, pl. 9.12, figs. 1-16.

2012 *Acarinina esnehensis* (Nakkady). – Gasinsky *et al*., p. 849, text-fig. 5C-D, J-K.

Remarks: *Acarinina esnehensis* is one of the 5-7 chambered species in the Early Eocene. In studied samples, this form is characterized by 5 chambers in its last whorl. Among the 5-chambered Early Eocene acarinids, this species is loosely coiled with respect to *A. pentacamerata* and its chambers show a lateral compression that distinguishes the form from *A. cuneicamerata* whose chambers are subtriangular to cuneiform.

Geographic Distribution: Egypt, Shatsky Rise, Trinidad, New Zeland, Pakistan, Germany, Austria.

Occurrence: Erfelek MSS, Sample no. 56, 61, 63.

Acarinina interposita Subbotina, 1953

Plate 4, Figure 7

1953 *Acarinina interposita* Subbotina. p. 231, pl.23, figs. 6 a-c.

1979 *Globorotalia (Acarinina) interposita* (Subbotina). Blow, p. 931-933, pl.156, figs. 7-9.

1988 *Acarinina interposita* Subbotina. - Krasheninnikov et al. p. 96, pl. 8, figs. 4-6.

2006 *Acarinina interposita* Subbotina. - Pearson *et al.* p. 290, pl. 9.11, figs. 13-19.

Remarks: *Acarinina interposita* has 4-4,5 slowly increasing chambers. Chambers are generally globular. It is differentiated from *A. wilcoxensis* by the shape of its chambers and their slow increase in size. It differs from *A. soldadoensis* by its tighter coiling.

Geographic Distribution: Tethys, northern Caucasus, DSDP Site 277, North Atlantic Ocean.

Occurrence: Erfelek 1 MSS, Sample no. 50, 54; Karaburun MSS, Sample no. 8-9.

Acarinina medizzai (Toumarkine and Bolli, 1975)

1975 *Globigerina medizzai* Toumarkine and Bolli. p. 77, pl. 6, figs. l-8; pl. 5, figs. 8, 10, 13-15, 17, 19-22.

1985 *Globigerina medizzai* Toumarkine and Lutherbacher. . p. 150, figs. 41.l-6, 8, 9.

1991 *Acarinina medizzai* Toumarkine and Bolli. – Nocchi *et al*., p. 266, pl. 4, fig. 23.

1988 *Acarinina medizzai* Toumarkine and Bolli. – Spezzaferri, p. 177, pl. 1, figs. 12a-b.

2004 *Acarinina medizzai* Toumarkine and Bolli. – Wade, p. 29, pl. 2, figs. a, b, q.

2006 *Acarinina medizzai* Toumarkine and Bolli. - Pearson *et al*., p. 293, pl. 9.14, figs. 1-15.

Remarks: *Acarinina medizzai* has 4-6 chambers moderately increasing in size. It has a subcircular, biconvex outline. It is smaller and low trochospiral with respect to *A. collactea.*

Geographic Distribution: Italy, northern Caucasus, ODP Hole 918D, Atlantic Ocean.

Occurrence: Sinay-Karasu MSS, Sample no. 8-9.

Acarinina nitida (Martin, 1943)

1943 *Globigerina nitida* Martin. p. 115, pl. 7, fig. la-c.

1953 *Acarinina acarinata* Subbotina. p. 229, pl. 22, figs. 4, 5, 8, 10.

1970b *Acarinina acarinata* Subbotina. - Shutskaya, p.118, 228, pl. 27, fig. 13a-c.

1973 *Acarinina acarinata Subbotina*. - Krasheninnikov and Hoskins, p. 116, pl. 1, figs. 1-3.

1979 *Globorotalia (Acarinina) acarinata acarinata* (Subbotina). – Blow. p. 904, fig. 7.

1999 *Acarinina nitida* (Martin). – Olsson *et al.*, p. 48; pl. 12, figs. 1-3; pl. 41, figs. 1-16.

2011 *Acarinina nitida* (Martin). – Nguyen *et al.*, pl. 2, fig. 2.

Remarks: *Acarinina nitida* is observed as a compact form mostly with 5 chambers. Its radially compressed chambers rapidly increase in size. The test of this species is subrounded to subquadrate.

Geographic Distribution: California, northern Caucasus, Pacific Ocean, Tanzania, Trinidad.

Occurrence: Kaymakam Kayası MSS, Sample no. 31, 37.

Acarinina pentacamerata (Subbotina, 1947)

Plate 4, Figures 8-10

1947 *Globorotalia pentacamerata* Subbotina. p. 128-129. pl. 7, figs. 12-14; 15-17.

1953 *Acarinina pentacamerata* Subbotina. p. 301, pl. 23, fig. 8; p. 307, pl. 24, figs. 1-9.

1956 *Acarinina pentacamerata* Shutskaya. pl. 3, figs. 6a-c.

1965 *Acarinina pentacamerata* Hillebrandt. p. 344, pl. 5, figs. 10a-c.

1969 *Acarinina pentacamerata* Berggren. p. 124, pl. 1, figs. 24-26.

1979 *Globorotalia (Acarinina) camerata* (Khalilov). Blow, p. 917, pl. 135, fig. 6; pl. 156; figs. 5-6.

1985 *Acarinina pentacamerata* Tourmakine and Luterbacher. p. 116, text- figs. 17.4-5.

1991 *Acarinina pentacamerata* Huber. p. 439, pl. 2, figs. 6-8.

2002 *Acarinina pentacamerata* Galeotti *et al.* p. 364, pl. 2, fig. 9.

2006 *Acarinina pentacamerata* Pearson *et al.* p. 299, pl. 9.15, figs. 1-16.

2007 *Acarinina pentacamerata* Rincon *et al.* p. 289, pl. 3, fig. 5.

Remarks: *Acarinina pentacamerata* is a form with rounded, weakly lobate periphery. There are 5 chambers in its final whorl; inflated and gradually increasing in size. The edge view has a rounded, biconvex appearance.

Geographic Distribution: Wide spread except high Austral latiudes; Caucasus, Ukraine, Egypt, Italy, Atlantic Ocean, Spain, Germany, Pakistan, northwest Pacific Ocean, northeast Azerbaidjan.

Occurrence: İstafan MSS, Sample no. 1, 9; Karaburun MSS, Sample no. 2, 3, 5, 7, 9-12, 15, 16, 19; Sinay-Karasu MSS, Sample no. 7, 8.

***Acarinina* cf. *praetopilensis* (Blow, 1979)**

1979 *Globorotalia* (*Truncorotaloides*) *topilensis praetopilensis* Blow. p. 1043, pl.155, fig. 9; pl. 203, figs. 1-2.

2000 *Truncorotaloides praetopilensis* Sztrakos. p. 123, pl.21, figs. 11-12.

2004 *Acarinina praetopilensis* (Blow). - Pearson *et al.* p. 37, pl. 2, figs. 7-9.

2004 *Acarinina punctocarinata* (Blow). - Wade, p. 28, pl. 1, figs. g-i.

2006 *Acarinina punctocarinata* (Blow). - Pearson *et al.* p. 301, pl. 9.16, figs. 1-16.

Remarks: For the recorded forms in the present study, the typical distinct disjunction of the last chamber hasn't totally developed. However, the chambers aren't as close as the ones in *A.bullbrooki.* Therefore, it is preferred to evaluate the form as *Acarinina* cf. *praetopilensis.*

Geographic Distribution: Wide spread around Tethys and Atlantic Oceans, Tanzania Drilling Project Site 2/9/CC.

Occurrence: İstafan MSS, Sample no. 4, 6, 7, 12.

Acarinina primitiva (Finlay, 1947)

Plate 4, Figures 11-16

1947 *Globoquadrina primitiva* Finlay. p. 291, pl.8, figs. 129-134.

1952 *Globigerina primitiva* (Finlay). Brönnimann, p. 11, pl. 1, figs. 10-12.

1961 *Globigerina primitiva* (Finlay). Hornibrook, p. 148.

1965b *Pseudogloboquadrina primitiva* (Finlay). Jenkins, p. 1124-1125, fig. 9.

1971 *Globigerina primitiva* (Finlay).- Postuma, p. 154, figs. 1-7.

1979 *Globorotalia* (*Acarinina*) *primitiva* (Finlay). Blow, p. 949, pl.143, figs. 6-9.

1990 *Acarinina primitiva* (Finlay).- Stott and Kennett, p. 559, pl. 6, figs. 11-12.

1993 *Acarinina primitiva* (Finlay).- Pearson *et al.*, pl. 1, figs. 19.

1995 *Acarinina primitiva* (Finlay).- Basov, p. 165, pl. 1, figs. 11-13.

2006 *Acarinina primitiva* Pearson *et al.* p. 302, pl. 9.17, figs. 1-16.

Remarks: *Acarinina primitiva* has a strongly muricate test with 3-4 compact chambers. It differs from other acarininds by its triangular chamber shape and flattened last chamber.

Geographic Distribution: New Zeland, South Indian Ocean, Subantarctic Ocean; less common in Caribbean, Atlantic and Indo-Pacific.

Occurrence: Karaburun MSS, Sample no. 2-6, 8, 9, 11-13, 15; Sinay-Karasu MSS, Sample no. 11; Erfelek MSS, Sample no. 88, 90, 93.

Acarinina pseudotopilensis Subbotina, 1953

Plate 4, Figure 17

1953 *Acarinina pseudotopilensis* Subbotina, p. 227, pl. 21, figs. 8a-c, 9a-c; pl. 22, figs. 1a-3c.

1960 *Globorotalia pseudotopilensis* (Subbotina). Reyment, p. 81, 82, pl. 15, figs. 14a-c, pl. 15,figs. 15-17, pl. 16, fig. 1a,b.

1975 *Globorotalia pseudotopilensis* (Subbotina). Lutherbacher, p. 65, pl.3, figs. 4-9.

1993 *Acarinina pseudotopilensis*Subbotina. Pearson and others, p. 124, pl.1, figs. 13-15.

2006 *Acarinina pseudotopilensis* Pearson *et al*. p. 305, pl. 9.18, figs. 1-16.

Remarks: *Acarinina pseudotopilensis* has triangular to wedge shaped 3,5-4 chambers in its last whorl. It is one of the large acarininids. The outline is more triangular and chambers are more disjunct with respect to *A. esnaensis* and *A. wilcoxensis*, whereas the disjunction isn't as obvious as in *A. praetopilensis, A. topilensis, A. rohri* and *A. quetra.*

Geographic Distribution: Caribbean, New Zeland, North and South Atlantic, Indo-Pacific, Pakistan, Nigeria, Germany, Denmark, Italy, Austria, Northern Caucasus.

Occurrence: Karaburun MSS, Sample no. 1-6, 8-12, 14, 15; Ayazlı MSS, Sample no. 11; Sinay-Karasu MSS, Sample no. 6, 9; Erfelek MSS, Sample no 55, 61, 64, 67, 71-73, 75, 76, 78, 80, 81, 83, 88, 90, 95; Erfelek-A MSS, Sample no 14; Kaymakam Kayası MSS, Sample no 39; Kaymakam Kayası-A MSS, Sample no 1.

Acarinina punctocarinata Fleisher, 1974

1974 *Acarinina punctocarinata* Fleisher, p. 1014, pl. 3, figs. 4-8.

1953 *Globorotalia crassaformis* Galloway and Wissler. - Subbotina, p. 223, pl. 21, figs. 5a-c.

2006 *Acarinina punctocarinata* Fleisher - Pearson *et al*. p. 273, pl. 9.5, figs. 1-8.

Remarks: *Acarinina punctocarinata* has 4 wedge-shaped chambers in its final whorl. Being longer axially and broader radially is an important property. Another distinguishing feature of the form that is used to differentiate the form from *A.bullbrooki* is the tangential elongation and semi- rectangular shape of its chambers.

In studied samples, some of the forms are described by more rounded outline, non-compressed chambers and having smaller ultimate chamber with respect to the penultimate one. They are called *Acarinina* cf. *punctocarinata* in the present study.

Geographic Distribution: Wide spread from tropical to austral regions; North Caucasus, Arabian Sea.

Occurrence: İstafan MSS, Sample no. 1, 2, 6.

Acarinina quetra (Bolli, 1957)

Plate 4, Figures 18-19

1957 *Globorotalia quetra* Bolli. p.79, pl. 19, fig. 1-6.

1952 *Globorotalia* (*Acarinina*) *quetra* Bolli. – Hillebrandt, p.144, pl. 14, fig. 2a-c.

1974 *Acarinina quetra* Bolli. – Fleisher, pl. 3, fig. 3.

1975 *Globorotalia quetra* Bolli. - Stainforth *et al*., p.221, text-figs. 80.1-6.

1977 *Acarinina quetra* Bolli. – Berggren, p.251, chart no. 10.

1979 *Globorotalia* (*Truncorotaloides*) *quetra* Bolli. – Blow, p. 1034-1036, pl. 122, figs. 4, 7-9; pl. 200, figs. 5, 6; pl. 123, figs. 6-9; pl. 202, figs. 1-6; pl. 129, fig. 5; pl. 132, figs. 7-9; pl. 201, figs. 4-6; pl. 140: fig. 4.

1985 *Morozovella quetra* Bolli. - Snyder and Waters, p. 448, pl. 9, fig. 4-6.

2000 *Acarinina quetra* Bolli. - Warraich *et al*., p.193, figs. 17.13-15.

2001 *Acarinina quetra* Bolli. - Warraich and Ogasawara, p.29, figs. 7.4-6.

2006 *Acarinina quetra* Bolli. - Pearson *et al*., p.309, pl. 9.19, figs. 1-16.

Remarks: *Acarinina quetra* is distinguished by its subquadrate, planoconvex test and high conical angle of its final chamber. It has 4 chambers in its last whorl which are lens shaped on spiral side and subtriangular in shape on the umbilical side. Its umbilicus is relatively wide and deep.

Geographic Distribution: Trinidad, Germany Pakistan, Arabian Sea, Atlantic Ocean, Shatsky Rise

Occurrence: Erfelek Section, sample no. 107, 115

***Acarinina soldadoensis* (Bronnimann, 1952)**

Plate 4, Figure 20

1952 *Globigerina soldadoensis* Bronnimann, p. 7, 9, pl. 1, figs. 1-9.

1962 *Globorotalia* (*Acarinina*) *soldadoensis* (Bronnimann). Hillebrandt, p.142, pl.14, figs.5-6.

1971b *Acarinina soldadoensis* (Bronnimann). Berggren, p. 76, pl. 5, figs. 1-3.

1979 *Muricoglobigerina soldadoensis soldadoensis* (Bronnimann). Blow, p. 1120, pl.98, figs.1-3; pl. 107, figs. 1-5; pl. 109, fig. 8.

1999 *Acarinina soldadoensis* (Bronnimann). – Olsson *et al.*, p. 50; fig. 20; pl. 15, figs. 4, 7, 8; pl. 42, figs. 1-16.

2006 *Acarinina soldadoensis* (Bronnimann). – Pearson *et al.*, p. 318; pl. 9.3, figs. 1-10.

2007 *Acarinina soldadoensis* (Bronnimann). – Luciani *et al.*, p. 206, pl. 1, figs. 3.

2011 *Acarinina soldadoensis* (Bronnimann). – Nguyen *et al.*, pl. 2, figs. 4, 6.

Remarks: *Acarinina soldadoensis* is one of the elongate acarininds with 4 or 5 chambers on last whorl. In our samples, 5 chambers bearing forms have not been identified. Its umbilicus is wide. The main difference of *A. soldadoensis* and *A. angulosa* is the disjunt and angular chambers of *A.angulosa*. Its edge view is more globular and its umbilicus is wider with respect to *A. esnaensis*, *A. interposita* and *A. wilcoxensis*, of which spiral side is relatively flat and chambers are more closely arranged.

Geographic Distribution: Trinidad, New Zeland, Kerguelen Plateau, Southern Indian Ocean, Tanzania, South Atlantic Ocean, Maud Rise, Azerbaidjan.

Occurrence: Ayazlı MSS, Sample no. 1, 4, 9; Erfelek MSS, Sample no. 100; Karaburun MSS, Sample no. 2, 6, 12, 14, 15; Kaymakam Kayası MSS, Sample no. 35.

Acarinina wilcoxensis (Cushman and Ponton, 1932)

Plate 5, Figure 1

1932 *Globorotalia wilcoxensis* Cushman and Ponton, p. 71, pl. 9, figs. 10 a-c.

1944 *Globorotalia wilcoxensis* Cushman, p. 15, pl. 2, figs. 14, 15 a, b.

1957a *Globorotalia wilcoxensis* Bolli, p. 79, pl. 19, figs. 7-9.

1960a *Globorotalia wilcoxensis* Berggren, p. 97-100, pl. 13, figs. 3a-4c.

1968 *Truncorotaloides (Acarinina) wilcoxensis* McGowran, pl. 3, fig. 1.

1971 *Globorotalia wilcoxensis* Postuma, p. 221.

1985 *Morozovella wilcoxensis* Snyder and Waters, p. 446, *pl. 10*, figs. 3-5.

1990 *Acarinina wilcoxensis berggreni* (El Naggar) Stott and Kennett, p. 560, pl. 4, figs. 5, 6.

1993 *Acarinina wilcoxensis* Lu and Keller**,** p. 102, pl. 2, figs. 14, 15.

2001 *Acarinina wilcoxensis* Warraich and Ogasawara**,** p. 33, figs. 8.4-6.

2006 *Acarinina wilcoxensis* Pearson *et al*., p. 320, pl. 9.23, figs. 1-16.

Remarks: *Acarinina wilcoxensis* 4 rapidly increasing chambers that is different than *A.interposita*. The chambers are lens-shaped. Moreover, *A. wilcoxensis* has more ovate periphery with respect to *A. interposita and A. esnaensis* and plano-convex outline instead of a globular test.

Geographic Distribution: Widespread in (sub)tropical areas; mid-Pacific Guyots, Alabama, Denmark, Austria, California, Pakistan, Shatsky Rise, South Atlantic Ocean, Egypt.

Occurrence: Erfelek 1 MSS, Sample no. 35, 39, 40, 47, 54; Karaburun MSS, Sample no. 2, 3, 6, 8, 9.

Genus *Igorina* Davidzon, 1976

Type species: *Acarinina tadjikistanensis* Bykova, 1953

The classification of the species of genus *Igorina* is summarized in Table 19.

Igorina broadermanni (Cushman and Bermudez, 1949)

Plate 5, Figures 2-7

1949 *Globorotalia (Truncorotalia) broadermanni* Cushman and Bermudez, 40, pl.7, figs. 22-24.

1957a *Globorotalia broadermanni* (Cushman and Bermudez).- Bolli,. p. 167, pl. 37, figs. 13a-c.

1957b *Globorotalia broadermanni* (Cushman and Bermudez).- Bolli, p. 80, pl. 19, figs. 13-15.

1961 *Pseudogloborotalia broadermanni* (Cushman and Bermudez).- Bermudez, p. 1340, pl. 16, fig. 7.

1979 *Globorotalia* (*Acarinina*) *broadermanni broadermanni* (Cushman and Bermudez).- Blow, p. 911, pl. 130, figs. 7-9; pl. 135, fig. 4; pl. 142, figs. 1-3; pl. 153, figs. 7, 8; pl. 179, figs. 3-5.

1985 *Acarinina broadermanni* (Cushman and Bermudez).- Synder and Waters, p. 446, pl. 6, figs. 1-3.

1993 *Morozovella broadermanni* (Cushman and Bermudez).- Pearson *et al.*, p. 125, pl. 1, fig. 21.

1995 *Igorina broadermanni* (Cushman and Bermudez).- Lu and Keller, p. 102, pl. 4, fig. 16.

2000 *Igorina broadermanni (*Cushman and Bermudez).- Warrick and others, p. 293, pl. 18, figs. 18-20.

2001 *Igorina broadermanni* (Cushman and Bermudez). - Warrick and Ogasawara, p. 17, figs. 4.1-3.

2004 *Igorina broadermanni* (Cushman and Bermudez).- Pearson *et al.*, p. 37, pl. 2,fig. 2.

2006 *Igorina broadermanni* (Cushman and Bermudez).- Pearson *et al.*, p. 384, pl. 12-2, figs. 1-12.

2011 *Igorina broadermanni* (Cushman and Bermudez).- Nguyen et al., pl. 1, fig. 5.

2011 *Igorina broadermanni* (Cushman and Bermudez).- Soldan et al., p. 265, figs. 4, 6.

Table 19. Classification of genus *Igorina* (* indicates the identified species in this study)

Species name	Test outline	Wall Texture	Chambers			Sutures		Umbilicus	Aperture	Size (mm)	Age
			# of chamber	Increase in size	Chambers	Spiral	Umbilical				
I. albeari	Moderately to strongly biconvex, circular, distinctly carinate	Cancellate, pustulose	6-8	Gradually	Trapezoidal in spiral side; triangular in umbilical side	Strongly recurved	Radial to weakly curved		Low interiomarginal, umbilical-extraumbilical arch, with thin lip	0.30-0.32	Paleocene
I. pusilla	Low trochospiral, biconvex, compressed, circular, slightly lobate	Cancellate, pustulose, perforate, smooth surface	5-6	Moderatelly	Compressed	Strongly curved, slightly depressed, radial	Radial, depressed	Narrow, shallow, open	Low interiomarginal, umbilical-extraumbilical arch, with narrow lip	0.24	Paleocene
I. tadjikistanensis	Biconvex, ovate to subcircular, moderately lobate	Densely and finely praemuricate	5-7	Slowly	Triangular	Depressed, strongly recurved	Curved, depressed	Small, shallow	Low interiomarginal, umbilical-extraumbilical arch, with distinct lip	0.32	Paleocene
I. anapetes	Low trochospiral, subcircular, weakly lobate, planoconvex	Densely muricate, normal perforate, nonspinose	8-9	Gradually	Equidimensional, subtriangular	Flush with test, radial	Nearly straight, radial	Broad and deep	Circum-umbilical low arching slit extending towards peripheral margin with thin lip	0.32	Eocene
I. broadermanni *	Low trochospiral, subcircular, weakly lobate, planoconvex to weakly biconvex	Muricate, normal perforate, nonspinose; circumumbilical muricate	6-7	Gradually	Broadly subquadrate to subrectangular in spiral view; equidimensional, broadly triangular in umbilical view	Curved and retorse at junction with peripheral margin	Depressed, radial	Narrow and deep	Low slit extending towards peripheral margin	0.33	Eocene
I. ladoensis *	Low trochospiral, subcircular, lobate, biconvex	Muricate, normal perforate, nonspinose	5,5-6	Gradually	Radially elongate, lunate, semicircular in spiral view; wedge-shaped in umbilical view	Recurved	Radial, straight, weakly incised	Narrowly open and deep	Low slit extending towards peripheral margin	0.21	Eocene

Remarks: *Igorina broadermanni* is weakly biconvex to planoconvex species with 6-7 equidimentional chambers.

Geographic Distribution: Cuba, Caribbean, Trinidad, Egypt, Tunisia, Pakistan, Armenia, Tanzania, Austria, Arabian Sea, South Atlantic Ocean, Pacific Ocean, Indo-Pacific, Tethys, Caucasus.

Occurrence: Karaburun MSS, Sample no. 4, 5, 7-12, 14, 15, 18, 19, 22; Sinay-Karasu MSS, Sample no. 4, 5; Erfelek MSS, Sample no. 45.

Igorina ladoensis (Mallory, 1959)

Plate 5, Figures 8-11

1959 *Globorotalia broadermanni* Cushman and Bermudez var. *ladoensis* Mallory, 253, pl.23, figs. 3 a-c.

1957b *Globorotalia broadermanni* Cushman and Bermudez, 1949.- Bolli, p. 80, pl. 19, figs. 13-15.

1962 *Globorotalia caylaensis* Gartner and Hay, p. 561, pl. 1, figs. 2a-c.

1979 *Globorotalia (Acarinina) ladoensis* Mallory.- Blow, p. 933-935, pl. 117, figs. 1-6.

1998 *Igorina ladoensis* (Mallory). - Lu *et al.*, p. 212, pl. 1, figs. 10-11.

2006 *Igorina ladoensis* (Mallory). - Pearson *et al.*, p. 388, pl. 12-3, figs. 1-16.

2011 *Igorina ladoensis* (Mallory). - Soldan *et al*., p. 265, figs. 3, 5.

Remarks: *Igorina ladoensis* differs from *I. broadermanni* by its more lobate and more biconvex test shape.

Geographic Distribution: Caribbean, California, Atlantic, Tethys, Trinidad, France, Tanzania.

Occurrence: Karaburun MSS, Sample no. 10-12.

Genus *Morozovella* McGowran in Lutherbacher, 1964

Type species: *Pulvinulina velascoensis* Cushman, 1925

The classification of the species of genus *Morozovella* is summarized in Table 20.

Table 20. Classification of genus *Morozovella* (* indicates the identified species in this study)

Species Name	Test		Wall	Chambers			Sutures		Umbilicus		Aperture	Apertural features	Size (mm)	Age
	Outline	Periphery	Wall Texture	# of Chambers	Increase in size	Chambers	Spiral	Umbilical	Shape	Periumbilical collar				
M. praeangulata *	Planoconvex, moderately lobate	Strongly muricate but not muricocarinate		5-6	Slowly	Tangentially elongate	Incised, weakly muricate, strongly recurved	Depressed/ incised, straight to weakly curved	Narrow, deep, open		Umbilical-extraumbilical, low apertural slit extends nearly to periphery	Distinct intraperiumbilical lip	0,32	Early Paleocene
M. acuta *	Planoconvex, conicotruncate, strongly lobate, acute	Distinctly muricocarinate, bounded by a thick flange	Minute, low spinose processes especially along peripheral border	4,5-5	Gradually	Last chamber possing 1/3 of the whorl	Distinct, strongly recurved, tangential, slightly depressed	Depressed, radial, distinct	Wide & open	Weakly to moderately well ornamented with muricae		Well developed triangular circumumbilical teeth	0,46	Late Paleocene
M. acutispira *	Biconvex due to the exceptional height of spire of initial whorl, lobate	Very large & projecting banded keel	Finely punctate	4-6	Rapidly	Petaloid, flattened along the peripheral margin	Curved, raised, ornamented by extention of strongly muricate keel	Depressed & radial, slightly curved	Narrow, deep		Umbilical-extraumbilical, interiomarginal, low arch			
M. angulata *	Rotaliform, angulo-conical, lobate, (sub)acute	Umbilical-extraumbilical, interiomarginal	Granular or subspinose, very finely perforate	4-6	Rapidly	Early chambers slightly elevated, anguloconical chambers in last whorl	Strongly recurved	Depressed & radial, straight	Narrow, deep	Weak	Umbilical-extraumbilical, interiomarginal, low arch	Weakly developed lip	0,35	
M. apanthesma	Planoconvex, umbilicoconvex, lobate	Weakly muricocarinate	Distinctly muricate umbilical side, coarsely perforate spiral side	4-5		Inflated to subangular on umbilical side -moderately convex, triangular in edge view	Slightly depressed, strongly curved	Depressed, radially curved	Narrow, deep		Umbilical-extraumbilical, interiomarginal	Narrow, continuous intraperiumbilical lip	0,23-0,45	
M. conicotruncata *	Truncated cone, moderately lobate, subcircular, flat to slightly convex spiral side	Peripheral muricocarina variable, generally fused on early chambers of last whorl	Densely covered with short & relatively thick spines	5-7	Very slowly	Subangular, inflated, close to one another, equidimentional; last chamber with smoother surface	Incised, distinctly curved	Incised, straight to weakly curved, radial	Narrow, deep		Umbilical-extraumbilical, interiomarginal, low arch slit extending to half way between umbilicus & periphery			
M. occlusa *	Planoconvex to low biconvex, nearly circular	Distinctly muricocarinate	Finely perforate, surface smooth except for thickened sutures on spiral side & peripheral keel, umbilical side granular	4-6 (rarely up to 8)	Gradually	With coarsely muricate suture between ultimate and penultimate chamber	Elevated & beaded, tangentially curved	Depressed, radial	Narrow, deep	Circular, subacute, weakly to moderately muricate umbilical shoulder	Umbilical-extraumbilical, interiomarginal	Distinct lip	0,45	
M. pasionensis	Low umbilico-convex, distinctly lobate	Heavily keeled	Thin, completely covered by short spines	5-7 (sometimes up to 10)	Gradually	Generally equidimentional	Raised and beaded, curved	Depressed, radial	Wide & shallow	Weakly developed	Low slit extending along peri-intraumbilical margin to peripheral margin of last chamber		0,5	
M. velascoensis *	Planoconvex, nearly circular, subacute, robust, moderately lobate	Distinctly muricocarinate except spiral chamber surfaces, finely perforate		6-7 (rarely 8)		Anguloconical	Raised and beaded	Depressed, radial, moderately to strongly curved	Moderately open	Adumbilical or circum-umbilical rim of fused muricae	Umbilical-extraumbilical, low apertural slit extends nearly to periphery			

Table 20. (cont.)

Species Name	Test		Wall	Chambers			Sutures		Umbilicus		Aperture	Apertural features	Size (mm)	Age
	Outline	Periphery	Wall Texture	# of Chambers	Increase in size	Chambers	Spiral	Umbilical	Shape	Periumbilical collar				
M. aequa *	Subquadrate, planoconvex, moderately lobate	Muricocarinate	Covered with muricae especially on umbilical shoulder & along margin	4 (less commonly 5)	Rapidly	Angular-conical, somewhat imbricated	Curved, raised	Straight, radial	Narrow		Umbilical-extraumbilical, low apertural slit extends nearly to periphery			Late Paleocene - Early Eocene
M. gracilis *	Very low trochospiral, planoconvex to moderately biconvex, lobate	Well developed muricocarinae	Muricae on umbilical surface, weakly muricate spiral side except concentration along sutures and peripheral margin, distinctly spinose	5-6	Rapidly	Equidimentional, angular, inflated; non-muricate & cuneiform last chamber	Strongly curved, distinctly muricocarinate except for last 2 chambers	Depressed, radial, straight	Narrow, deep, open		Umbilical-extraumbilical, interiomarginal, low arch extending towards, but not to margin		0,5	
M. subbotinae *	Planoconvex to weakly biconvex, lenticular, acute, moderately lobate	Strongly, thickly keeled	Generally covered with muricae on umbilical side, relatively smooth spiral side	4-4,5	Rapidly	Trapezoidal chambers on spiral side	Incised, weakly recurved, tangential	Incised, weakly recurved	Narrow, deep, open		Umbilical-extraumbilical, low apertural slit extends nearly to periphery	Weak lip	0,36	
M. allisonensis	Biconvex to mildly planoconvex, low to medium trochospiral, subcircular, weakly to non-lobate	Weakly muricate keel	Muricate, nonspinose, normal perforate	5-9	Gradually	Flattened to moderately inflated, triangular on umbilical side, trapezoidal to subquadrate on spiral side	Raised to slightly depressed, strongly to weakly curved, radial, muricate	Depressed, straight to slightly curved, radial	Small, deep	Unornamented, rounded umbilical shoulders	Umbilical-extraumbilical, low arch to subcircular, extends to periphery		0,35-0,40	Early Eocene
M. edgari *	Low to moderately conical trochospiral, weakly lobate	Weakly developed peripheral muricocarina	Muricate, nonspinose, normal perforate, concentration of pustules decreasing towards terminal chambers	5-6	Gradually	Early chambers raised, cuneiform-shaped chambers in last whorl, trapezoidal on spiral side	Distinctly curved	Weakly incised, straight, radial	Narrow & deep		Umbilical-extraumbilical, low apertural slit extends nearly to periphery		0,21	
M. formosa *	Planoconvex, subcircular, moderately lobate	Strongly muricate keel	Muricate, nonspinose, normal perforate, muricae scattered on early chambers of last whorl	6-6,5 (rarely 7-8)	Gradually	Triangular, inflated & subangular on umbilical side, trapezoidal with curved margins on spiral side	Slightly elevated, strongly curved, nearly radial, muricate	Moderately depressed, weakly curved to straight, radial	Moderately wide, deep, open		Umbilical-extraumbilical, low apertural slit extends nearly to periphery		0,65	
M. lensiformis *	Weakly biconvex, low trochospiral, tightly coiled, subquadrate to subcircular, weakly lobate	Peripheral muricocarina often obscured by fusion of muricae along margin	Muricate, nonspinose, normal perforate, granular/sugary texture	4-4,5	Rapidly	Elevated early chambers often obscured by muricate growth	Moderately to strongly muricate and (re)curved	Slightly depressed, straight to slightly curved	Narrow		Umbilical-extraumbilical, low apertural slit extends nearly to periphery		0,40-0,55	
M. marginodentata *	Biconvex, low trochospiral, oval to subcircular, lobate, peripheral compression on umbilical side	Thick and strongly fimbriate muricocarina	Densely muricate on both sides, nonspinose, normal perforate	4-4,5	Rapidly	Moderately inflated, chambers depressed towards periphery on umbilical side; flat, lense-shaped to semicircular on spiral side	Elevated, curved, strongly muricate	Depressed, straight to slightly curved, radial	Narrow & deep		Umbilical-extraumbilical, low apertural slit extends nearly to periphery		0,43	
M. aragonensis *	Planoconvex, tightly coiled, nearly circular, weakly lobate	Strong/thick peripheral muricocarina	Muricate, nonspinose, normal perforate, blunt-tipped muricae scattered over chambers on umbilical side	5-7		Triangular and inflated on umbilical side, trapezoidal to lozenge shaped on spiral side; generally smooth last chamber	Raised or flush, strongly curved, muricate/beaded, forming acute angle with periphery	Moderately depressed, straight to slightly sinous	Narrow, deep	Rimmed by rounded tips at circumumbilical chamber confluence	Umbilical-extraumbilical, low apertural slit extends nearly to periphery		0,6	Early-Middle Eocene
M. caucasica	Planoconvex, subcircular, moderately lobate	Strongly muricate/beaded keel	Muricate, nonspinose, normal perforate	6-8 (less commonly 5, 9 or 10)	Gradually	Triangular on umbilical side, trapezoidal to subquadrate on spiral side, early chambers slightly raised above test surface	Depressed, straight, radial	Depressed, straight, radial	Large, open & deep	Strongly ornamented by fused muricae	Umbilical-extraumbilical, low apertural slit extends nearly to periphery		0,40-0,60	
M. crater *	Planoconvex, lobate	Well developed muricocarinae	Muricate, nonspinose, normal perforate	4,5-5	Slowly	Equidimentional	Strongly limbate, curved, heavily beaded	Weakly curved to radial	Wide & deep	Thickened circumumbilical rim of elevated chamber shoulders	Umbilical-extraumbilical, low apertural slit extends nearly to periphery	Thin lip	0,53	

Morozovella acuta (Toulmin, 1941)

Plate 5, Figure 12

1941 *Globorotalia wilcoxensis* Cushman and Ponton var. *acuta* Toulmin, p. 608, pl. 82, figs. 6-8.

1957a *Globorotalia acuta* (Toulmin) – Loeblich and Tappan, p. 185, pl. 47, figs. 5a-c; pl. 55, figs. 4a-5c.

1964 *Globorotalia acuta* (Toulmin) – Luterbacher, p.686-689, text-figs. 101a-c, 102a-104c.

1970a *Globorotalia velascoensis acuta* (Toulmin) – Shutskaya, p. 119-120, pl. 27, figs. 11a-c; pl. 28, figs. 4a-c; pl. 29, figs. 9a-c.

1971 *Globorotalia* (*Morozovella*) *acuta* (Toulmin) – Jenkins, p. 106, pl. 9, figs. 205-207.

1985 *Morozovella acuta* (Toulmin). – Toumarkine and Luterbacher, p. 111, text-fig. 14.

1991 *Morozovella acuta* (Toulmin). – Van Eijden & Smit, p. 113.

1999 *Morozovella acuta* (Toulmin). – Olsson *et al*., p. 55, pl. 45, figs. 1-14.

2009 *Morozovella acuta* (Toulmin). – Obaidalla *et al*., p. 4, pl. 2, figs. 7-8.

2010 *Morozovella acuta* (Toulmin). – Gebhardt *et al*., p. 414, text-fig. 3.11.

Remarks: This morozovellid species is a plano-convex form with strongly convex umbilical side and its umbilical ridges are developed as in Paleocene form *M. velascoensis* and Eocene species *M. aragonensis, M. caucasica* and *M. crater*. However, the number of chamber in its last whorl and shape of the chambers are totally different than in those forms. *Morozovella acuta* has 5 chambers in its last whorl in contrast to higher number of chambers in *M. aragonensis, M. caucasica* and *M.velascoensis*. Chambers, which increase gradually in size, are hemispherical on spiral side in contrast to trapezoidal chambers of *M.velascoensis*, crescentic to triangular chambers of *M.aragonensis*, trapezoidal to subquadrate chambers of *M.caucasica* and elongated chambers of *M. crater*. The test of *Morozovella acuta* is lobate. The species has a wide and open umbilicus and umbilical-extraumbilical aperture. However, well developed triangular teeth haven't been observed as indicated by Olsson *et al.* (1999).

Geographical Distribution: Alabama, Maryland, New Jersey, Virginia, Mexico, Trinidad, Crimea, New Zeland, Morocco, Italy, Tanzania, Nigeria.

Occurrence: Erfelek MSS, Sample no. 43.

Morozovella acutispira (Bolli and Cita, 1960)

1960 *Globorotalia acutispira* Bolli and Cita. p. 15, pl. 33, figs. 3a-c.

1970b *Globorotalia* sp. aff. *G. acutispira* Bolli and Cita. – Shutskaya, p.118-120, pl. 25, figs. 7-c.

1984 *Globorotalia* (*Morozovella*) *occlusa acutispira* Bolli and Cita. – Belford, p. 9, pl. 17, figs. 14-21.

1999 *Morozovella acutispira* (Bolli and Cita). – Olsson, p. 55, pl. 45, figs. 1-14.

2010 *Morozovella acutispira* (Bolli and Cita). – Gebhardt *et al*., p. 414, text-fig. 3.12.

Remarks: *Morozovella acutispira* is one of the biconvex morozovellids with a lobate outline and 5-6 chambers in its last whorl. Its more loosely coiling and lobate outline are differentiating features with respect to nearly circular outline of *M. occlusa.* This species has a narrow and deep umbilicus, which distinguished the form from *M. passionensis*, which has a planoconvex test.

In the Kaymakam Kayası MSS, one of the specimens from the last sample (Sample no. 45) has been defined as *Morozovella acutispira-occlusa.* This form has crescentic-subspherical spiral sutures as in *M. acutispira*; however its nearly circular outline looks like that of *M. occlusa*. Olsson *et al*. (1999) mentioned both species as sister species that are related to each other. Therefore, the observed species is thought to be a transition between *M. acutispira* and *M. occlusa.*

Geographical Distribution: Crimea, New Guinea, Italy, Nigeria.

Occurrence: Kaymakam Kayası MSS, Sample no. 31.

Morozovella aequa (Cushman and Renz, 1942)

Plate 5, Figures 13-15

1942 *Globorotalia crassata* (Cushman) var. *aequa* Cushman and Renz, p. 12, pl. 3, fig. 3a-c.

1949 *Globorotalia (Truncorotalia) crassata* (Cushman) var. *aequa* Cushman and Renz.- Cushman and Bermudez, p. 37, pl. 7, figs. 7-9.

1957a *Globorotalia aequa* Cushman and Renz.- Bolli, p. 74, pl. 17, figs. 1-3; pl. 18, figs. 13-15.

1957a *Globorotalia aequa* Cushman and Renz.- Loeblich and Tappan, p. 186, pl. 59, figs. 6a-c; pl. 64, figs. 4a-c.

1962 *Globorotalia (Truncorotalia) aequa aequa* (Cushman and Renz).- Hillebrandt, p. 133-134, pl. 13, figs. 1a-c.

1975b *Globorotalia aequa* Cushman and Renz.- Luterbacher, p. 64, pl. 2, figs. 22-24.

1985 *Morozovella aequa* (Cushman and Renz). - Snyder and Waters, p. 446, pl. 7, figs.

5-7.

1985 *Morozovella aequa* (Cushman and Renz).- Toumarkine and Luterbacher, p.113, figs 15. 1-3.

1990 *Morozovella aequa* (Renz & Cushman).- Stott & Kennett, p. 560 pl. 6, figs. 13-15.

1995 *Morozovella aequa* (Renz & Cushman).- Lu & Keller, p. 102 pl. 1, figs. 15.

1997 *Morozovella aequa* (Renz & Cushman).- Berggren and Norris, p. 103 Plate 16, figures 22-24

1999 *Morozovella aequa* (Cushman and Renz). - Olsson *et al.*, p. 57; p. 15, figs. 11, 12, 15; pl. 47, figs. 1-16.

2006 *Morozovella aequa* (Cushman and Renz).- Pearson *et al.*, p. 345, pl. 11-1, figs. 1-8.

2007 *Morozovella aequa* (Cushman and Renz). - Luciani *et al.*, p. 206, pl. 1, figs. 4, 7, 8.

2008 *Morozovella aequa* (Cushman and Renz). - Handley *et al.*, p. 20, text fig. 2.7.

2011 *Morozovella aequa* (Cushman and Renz). - Nguyen *et al.*, pl. 1, fig. 7.

2012 *Morozovella aequa* (Cushman and Renz). – Robertson *et al.*, p. 273, fig. 6p.

Remarks: *Morozovella aequa* differs by its relatively loosely coiled chambers with other morozovellids. The last chamber of the form almost equals to the half of the test size.

In the Kaymakam Kayası MSS, one of the specimens from the last sample (Sample no. 45) has been defined as *Morozovella apanthesma-aequa.* This form is a 5-chambered specimen resembling to *M. apanthesma*. On the other hand, the plano-convex test with broader pen-ultimate and ultimate chambers looks like the chambers of *M. aequa*. As *M.aequa* is mentioned to evolve from *M. apanthesma,* this specimen is evaluated as a *M. apanthesma-M. aequa transition.*

Geographic Distribution: Trinidad, Cuba, Italy, Mexico, New Jersey, Trinidad, Australia, Pacific Ocean, Tanzania, New Zeland, South Atlantic Ocean, North Caucasus.

Occurrence: Karaburun MSS, Sample no. 2, 8; Ayazlı MSS, Sample no. 4, 5, 9; Erfelek MSS, Sample no. 43; Kaymakam Kayası-A MSS, Sample no. 4.

Morozovella angulata (White, 1928)

Plate 5, Figures 16-17

1928 *Globigerina angulata* White. p. 27, fig. 13.

1937 *Globorotalia angulata* (White). – Glaessner, p. 383, pl. 4, figs. 35a-c; 37a-c.

1953 *Globorotalia angulata* (White). – Bykova, p. 82-86, text-figs. 7a-11c.

1956 *Globorotalia angulata* (White). – Shutskaya, p. 92, 93, pl. 3, figs. 2a-c, text-fig. 1.

1957a *Globorotalia angulata* (White). – Bolli, p. 74, pl. 17, figs. 7-9.

1957a *Globorotalia angulata* (White). – Loeblich and Tappan, p. 187, pl. 50, figs. 4a-c; pl. 64, figs. 5a-c.

1960 *Globorotalia angulata* (White). – Olsson, p. 44, pl. 8, figs. 14-16.

1962 *Globorotalia (Truncorotalia) angulata* (White). – Hillebrandt, p. 131, 132, pl. 13, figs. 14a- 15c.

1968 *Truncorotaloides (Morozovella)* angulatus (White). – Mc Gowran, p. 190, pl. 1, figs. 13-18.

1979 *Globorotalia* (*Morozovella*) *angulatus* (White). – Blow, p. 984, pl. 86, figs. 7-9; pl. 87, fig. 1.

1985 *Globorotalia angulata* (White). – Toumarkine and Luterbacher, p. 111, text-figs. 14:5a-c, 6a-c.

1999 *Morozovella angulata* (White). – Olsson *et al.*, p.58, fig. 23, pl. 48, figs. 1-16.

2009 *Morozovella angulata* (White). – Obaidalla *et al*., p. 4, pl. 1, figs. 4-5.

2011 *Morozovella angulata* (White). – Sprong *et al*., p. 179, pl. 1, figs. 5-6.

2012 *Morozovella angulata* (White). – Birch *et al.,* p. 378, fig. 3.7-8.

Remarks: *Morozovella angulata* is one of the morozovellids on which the peripheral muricocarina is developed. This property distinguishes *M. angulata* from *M. praeangulata.* It has a conical test with flat spiral side and convex umbilical side.

Geographic Distribution: Mexico, Caucasus, Turkmenia, Trinidad, New Jersey, Alabama, Italy, Australia, Shatsky Rise.

Occurrence: Erfelek MSS, Sample no. 43, 44; Erfelek 1 MSS, Sample no. 26, 29, 32.

***Morozovella aragonensis* (Nuttall, 1930)**

Plate 5, Figures 18-20; Plate 6, Figure 1

1930 *Globorotalia aragonensis* Nuttall, 288, pl. 24, figs. 6-8; 10-11.

1937 *Globorotalia aragonensis* Nuttall.- Glaessner, p. 10, pl. 1, figs. 5a-c.

1949 *Globorotalia (Truncorotalia) aragonensis* Nuttall.- Cushman and Bermudez, p. 38, pl. 7, figs. 13-15.

1953 *Globorotalia aragonensis* Nuttall.- Subbotina, p. 215, pl. 18, figs. 6a-c.

1957a *Globorotalia aragonensis* Nuttall.- Bolli, p. 75, pl. 18, figs. 7-9.

1961 *Pseudogloborotalia aragonensis* **(**Nuttall).- Bermudez, p. 1338-1340, pl. 6, figs. 5a-c.

1974 *Morozovella aragonensis aragonensis* (Nuttall).- Fleisher, p. 1029, pl. 14, fig. 11.

1979 *Globorotalia (Morozovella) aragonensis* (Nuttall).- Blow, p.990, pl. 134, fig. 6.

1985 *Globorotalia aragonensis* Nuttall.- Toumarkine and Luterbacher, p. 112, text-figs. 16. 4a-c.

1993 *Morozovella aragonensis* (Nuttall). - Pearson *et al.*, p. 124, pl. 2, figs. 1-3.

2000 *Morozovella aragonensis* (Nuttall).- Warrick and others, *p. 293, pl. 17.6*, figs. 11-12.

2001 *Morozovella aragonensis* (Nuttall).- Warrick and Ogasawara, *p. 37.*

2004 *Morozovella aragonensis* (Nuttall). - Pearson *et al.*, p. 37, pl. 2, fig. 12.

2006 *Morozovella aragonensis* (Nuttall). - Pearson *et al.*, p. 349, pl. 11-3, figs. 1-16.

2011 *Morozovella aragonensis* (Nuttall). - Zakrevskaya *et al.*, p. 777, figs. 14 a-b.

Remarks: *Morozovella aragonensis* has a nearly circular, compact periphery. It is a robust morozovellid. The test of *Morozovella aragonensis* is planoconvex, possessing 5-7 chambers in its last whorl.

Geographic Distribution: Caribbean, Caucasus, Meditterranean, Mexico, Trinidad, Italy, Equatorial and South Atlantic Ocean, Cuba, Indian Ocean, Pakistan, Tanzania, Pacifix Ocean.

Occurrence: Karaburun MSS, Sample no. 15, 18, 19, 22; Erfelek-A MSS, Sample no. 14; Kaymakam Kayası-A MSS, Sample no. 15.

Morozovella conicotruncata (Subbotina, 1953)

Plate 6, Figures 2-3

1947 *Globorotalia conicotruncata* Subbotina. p. 115, pl. 4, figs. 11-13.

1953 *Acarinina conicotruncata* (Subbotina). p. 220, pl. 20, figs. 5a-b, 6a-c, 7a-c, 8a-c.

1964 *Globorotalia conicotruncata* Subbotina.- Luterbacher, p. 660, text-figs. 46-49.

1971b *Morozovella conicotruncata* (White). – Berggren, p. 74, pl. 4, figs. 8-14.

1975a *Globorotalia conicotruncata* Subbotina.- Luterbacher, p. 726, pl. 1, figs. 6,7.

1983 *Globorotalia conicotruncata* Subbotina.- Pujol, p. 645, pl. 2, fig. 8.

1985 *Morozovella conicotruncata* (White). – Snyder and Waters, p. 446, pl. 8, figs. 4-6.

1999 *Morozovella conicotruncata* (Subbotina). – Olsson *et al*., p. 60, pl. 11, figs. 10-15; pl. 50, figs. 1-15.

Remarks: This morozovellid, which is another species having initial muricocarina development, has a test with a truncated conical shape, which is different than the angulo-conical test of *M. angulata*. This test shape resembles that of *M. velascoensis*, however the shape of the chambers are different for these two species.

Geographic Distribution: Caucasus, Atlantic Ocean, Shatsky Rise, Turkmenia, Italy, Guatemala.

Occurrence: Erfelek MSS, Sample no. 43; Erfelek 1 MSS, Sample no. 26.

Morozovella crater (Hornibrook, 1958)

Plate 6, Figure 4-6

1939a *Globorotalia crater* Finlay, 125.

1958 *Globorotalia crater* Hornibrook, 33, pl. 1, figs. 3-5.

1971 *Globorotalia (Morozovella) crater* Finlay.-Jenkins, 103, pl. 8, figs. 192-194.

2004 *Morozovella crater* (Finlay).-Pearson and others, 37, pl. 2, figs. 13-14.

2006 *Morozovella crater* (Finlay).-Pearson and others, 358, pl. 11.5, figs. 1-16.

Remarks: *Morozovella crater* is a plano-convex morozovellid with 4,5-5 chambers. The chamber enlargement is very slow. It has circumumbilical rim on its chamber shoulders like *M. aragonensis*, *M. caucasica* and *M. velascoensis*; however *M. crater* is differentiated from these forms by the smaller number of chambers in its last whorl.

Geographic Distribution: New Zeland, Shatsky Rise, Atlantic Ocean, Spain, California, Tanzania.

Occurrence: Karaburun MSS, Sample no. 2, 3, 6, 7, 9, 11, 12, 14, 15, 19, 22; Sinay-Karasu MSS, Sample no. 1, 4, 7; Kaymakam Kayası-A MSS, Sample no. 8.

Morozovella edgari (Premoli Silva and Bolli, 1973)

Plate 6, Figure 7-10

1973 *Globorotalia edgari* Premoli Silva and Bolli, p. 526, pl. 7, figs. 10-12; pl. 8, figs. 1-12.

1979 *Globorotalia* (*Morozovella*) *finchi* Blow, p. 999, pl. 99, figs. 6-11.

1985 *Morozovella edgari* Premoli Silva and Bolli. – Toumarkine and Luterbacher, p. 114, text-figs. 15.6a-c.

2001 *Morozovella edgari* Premoli Silva and Bolli. – Kelly *et al*., p. 509, text-fig. 1D-F, 3C

2006 *Morozovella edgari* Premoli Silva and Bolli. – Pearson et al., p. 362, pl. 11.6, figs. 1-16.

Remarks: This species is one of small sized morozovellids. Morozovella edgari has a lobate test with 5-6 chambers in its last whorl. The chambers are mostly elongated on the spiral side and triangular on the umbilical side. The umbilicus of this species is narrow and deep and its aperture extends nearly to the periphery. The edge view of this form is biconvex, which makes a resemblance with Morozovella lensiformis; however the size of their test, the number of chambers in their last whorl and the distribution of their muricate are dissimilar.

Geographical Distribution: DSDP Site 152 (Caribbean Sea), Allison Guyot and Shatsky Rise (Pacific Ocean).

Occurrence: Erfelek MSS, Sample no. 45, 47, 48.

Morozovella formosa (Bolli, 1957b)

Plate 6, Figure 11

1957b *Globorotalia formosa formosa* Bolli, p. 76, pl. 18, figs. 1-3.

1964 *Globorotalia formosa formosa* Bolli. – Luterbacher, p. 694-696, text-figs. 118a-c, 119a-c; 120a-c.

1970 *Globorotalia formosa formosa* Bolli. – Samantha, p. 624, pl. 97, figs. 15, 16.

1971 *Globorotalia formosa* Bolli. – Postuma, p. 190, figs. on p. 191.

1971 *Morozovella formosa* (Bolli). – Berggren, pl. 5, figs. 15, 16.

1975 *Globorotalia formosa formosa* Bolli. – Stainforth *et al*., p. 184, text-figs. 48.1-6.

1975b *Globorotalia formosa formosa* Bolli. – Luterbacher, p. 65, pl. 5, figs. 16-18.

1979 *Globorotalia* (*Morozovella*) *formosa* (Bolli). – Blow, p. 1000, pl. 127, figs. 3, 4; pl. 134, figs. 7, 8; pl. 224, fig. 3, 4.

1985 *Globorotalia formosa formosa* Bolli. – Toumarkine and Luterbacher, p. 112, fig. 15.13.

1998 *Morozovella formosa* (Bolli). – Lu *et al.*, p. 212, pl. 1, figs. 6-8.

2000 *Morozovella formosa formosa* (Bolli). – Warraich *et al*., p. 293, fig. 17.21-23.

2001 *Morozovella formosa formosa* (Bolli). – Warraich and Ogasawara, p. 39, figs. 9.13-15.

2006 *Morozovella formosa* (Bolli). – Pearson *et al.*, p. 365, pl. 11.7, figs. 1-16.

Remarks: This is a robust form with a distinctly lobate test and 6-8 chambers in its last whorl. It has thought to be evolved from *M. gracilis*. The differences between *M. formosa* and *M. gracilis* are the increasing in the number of chambers in last whorl of *M. formosa*, larger test and wider umbilicus of this species.

Geographic Distribution: Trinidad, central Apennines (Italy), India, Pakistan, California, Cuba, South Atlantic Ocean.

Occurrence: Erfelek MSS, Sample no. 56.

Morozovella gracilis (Bolli, 1957b)

Plate 6, Figure 12

1957b *Globorotalia formosa gracilis* Bolli, 75-76, pl. 18, figs. 4-6.

1970b *Globorotalia formosa gracilis* (Bolli).-Shutskaya, 118-120, pl. 14, figs. 8a-c.

1971 *Globorotalia (Morozovella) gracilis* (Bolli).-Jenkins, 105, pl. 9, figs. 202-204.

1971b *Morozovella gracilis* (Bolli).- Berggren, 76, pl.5, figs. 7-8.

1985 *Morozovella formosa gracilis* (Bolli).-Snyder and Waters, 446-447, pl. 8, figs. 7-9.

1985 *Morozovella formosa gracilis* (Bolli).-Toumarkine and Luterbacher, 12, text-figs. 15:12a-c.

1991b *Morozovella gracilis* (Bolli).- Huber, 440, pl.4, fig. 8.

1995 *Morozovella gracilis* (Bolli).- Lu and Keller, 102, pl.1, fig. 9.

2006 *Morozovella gracilis* (Bolli).- Pearson *et al.*, p. 366, pl. 11.8, figs. 1-16.

2011 *Morozovella formosa-gracilis* (Bolli). - Nguyen *et al.*, pl. 2, figs. 7-8.

Remarks: This is a moderately biconvex morozovellid with 5-6 chambers in its last whorl. It has a smaller test and keel doesn’t well developed as in *M. formosa*, which evolved from the former species. In our samples, some of the 6 chambered specimens are thought to be transitional forms between *M. gracilis* and *M. formosa* because of having biconvex tests with wide umbilicus. These forms are identified as *Morozovella gracilis/formosa.*

Geographic Distribution: Trinidad, SW Crimea, Central Apennines, Italy, New Zeland, South Atlantic Ocean, Shutsky Rise, Tanzania, Egypt.

Occurrence: Ayazlı MSS, Sample no. 1, 4, 11; Erfelek MSS, Sample no. 47, 56.

Morozovella lensiformis (Subbotina, 1953)

Plate 6, Figures 13-18; Plate 7 Figures 1-5

1953 *Globorotalia lensiformis* Subbotina, 214, pl. 18, figs. 4 a-c; 5 a-c.

1962 *Globorotalia (Truncorotalia) lensiformis* Subbotina.- Hillebrandt, p. 136, pl. 13, figs. 12a-13c.

1971 *Morozovella lensiformis* (Subbotina).- Berggren, pl. 5, figs. 18-20.

1972 *Globorotalia lensiformis* Subbotina subsp. *carpatica* Samuel, p. 127-128, pl. 36, figs. 1a-2c.

1975 *Globorotalia lensiformis* (Subbotina).- Stainforth *et al.*, p. 200, text-figs. 1a-2c.

1979 *Globorotalia (Morozovella) lensiformis* Subbotina.- Blow, p. 1003-1005, pl. 125, figs. 6-9; pl. 126, figs. 1-3; pl. 128, figs. 1-9; pl. 129, figs. 1-3; pl. 134, figs. 1, 7; pl. 251, fig. 5.

1985 *Morozovella lensiformis* (Subbotina).- Synder and Waters, p. 460, pl. 9, figs. 1, 3.

2000 *Morozovella lensiformis* (Subbotina).- Warrick and others, *p. 293, figs. 17.7-9*.

2001 *Morozovella lensiformis* (Subbotina).- Warrick and Ogasawara, *p. 40, figs. 10.1-3*.

2006 *Morozovella lensiformis* Pearson *et al.*, p. 367, pl. 11.9, figs. 1-16.

Remarks: This is biconvex morozovellid with 4-4½ chambers in its last whorl. Its wall is densely muricate. The test shape and less number of chambers in the last whorl distinguish *M. lensiformis* from *M. aragonensis.*

Geographic Distribution: Widespread in (sub)trophical regions; South Atlantic Ocean, North Caucasus, Indo-Pacific, Pakistan, Austria, Germany, California, Pacific Ocean, New Zeland, Czechoslovalia.

Occurrence: Karaburun MSS, Sample no. 3-12, 14; Ayazlı MSS, Sample no. 11; Erfelek-A MSS, Sample no. 14; Kaymakam Kayası-A MSS, Sample no. 4, 8, 15.

Morozovella cf. _marginodentata_ (Subbotina, 1953)

1953 *Globorotalia marginodentata* Subbotina, p. 212, pl. 17, fig. 14; pl. 18, figs. 1a-3c.

1962 *Globorotalia* (*Truncorotalia*) *aequa marginodentata* Subbotina. – Hillebrandt, p. 135, pl. 13, figs. 9a-11.

1963 *Truncorotalia marginodentata marginodentata* Subbotina. – Gohrbandt, p. 62, pl. 6, figs. 4-6.

1964 *Globorotalia marginodentata* Subbotina. – Luterbacher, p. 673, text- figs. 75a-

84c.

1970 *Globorotalia marginodentata* Subbotina. – Samanta, p. 626, pl. 96, figs. 3, 4.

1971 *Morozovella marginodentata* Subbotina. – Berggren, p. 76, pl. 5, fig. 9.

1975a *Globorotalia marginodentata* Subbotina. – Luterbacher, p. 727, pl. 2, figs. 6a-c.

1975b *Globorotalia marginodentata* Subbotina. – Luterbacher, p. 65, pl. 4, figs. 4-6.

1979 *Globorotalia* (*Morozovella*) *subbotinae marginodentata* Subbotina. – Blow, p. 1024-1026, pl. 139, figs. 1-9; pl. 140, figs. 1-3.

1985 *Morozovella marginodentata* Subbotina. – Snyder and Waters, p. 460, pl. 8, figs. 13a-14c.

2000 *Morozovella marginodentata* Subbotina.–Warraich, Ogasawa and Nishi, p. 293, figs. 17.4, 5, 10.

2001 *Morozovella marginodentata* Subbotina.–Warraich and Ogasawa, p. 40, figs. 10.7-9.

2006 *Morozovella marginodentata* Pearson *et al.*, p. 368, pl. 11-10, figs. 1-16.

Remarks: The most important distinguishing feature of this species is its dense murication and the peripheral muricocarina on its wall. The specimen in our sample also represents this property. However, the test is more or less planoconvex rather than biconvex. This form is thought to be a transitional form between *Morozovella subbotinae* and *Morozovella marginodentata*; therefore it is mentioned as *Morozovella* cf. *marginodentata*.

Geographical Distribution: Austria, Germany, Italy, northern Caucasus, India, Pakistan, Mexico, Atlantic Ocean.

Occurrence: Ayazlı MSS, Sample no. 11.

***Morozovella occlusa* (Loeblich and Tappan, 1957)**

Plate 7, Figure 6

1957a *Globorotalia occlusa* Loeblich and Tappan, p. 191, pl. 55, figs. 3a-c; pl. 64, figs. 3a-c.

1964 *Globorotalia occlusa* Loeblich and Tappan – Luterbacher, p. 690, text-figs. 112a-114c.

1962 *Globorotalia* (*Truncorotalia*) *velascoensis occlusa* Loeblich and Tappan. – Hillebrandt, p. 139, pl. 13, figs. 22, 24, 25.

1971 *Globorotalia* (*Morozovella*) *occlusa* Loeblich and Tappan. – Jenkins, p. 106, pl. 9, figs. 208-210.

1979 *Globorotalia* (*Morozovella*) *occlusa* Loeblich and Tappan. – Blow, p. 1007, pl. 90, figs. 7, 10; pl. 95, figs. 7-10; pl. 96, figs. 1-3; pl. 213, fig. 6; pl. 214, figs. 1-6; pl. 215, figs.5, 6; pl. 103, figs. 4-6 and pl. 108, figs. 9, 10; pl. 118, figs. 1-7.

1979 *Globorotalia* (*Morozovella*) *occlusa* cf. *occlusa* Loeblich and Tappan. -Blow, p. 1007, pl. 92, figs. 5, 6.

1979 *Globorotalia* (*Morozovella*) *occlusa crosswickensis* Olsson. – Blow, p. 1011, pl. 88, figs. 1,2; pl. 213, figs. 1, 2; pl. 90, figs. 3-6; 8, 9; pl. 213, figs. 3-5; pl. 215, figs. 1-4.

1984 *Globorotalia* (*Morozovella*) *occlusa* (Loeblich and Tappan). – Belford, p. 9, pl. 17, figs. 6-14.

1999 *Morozovella occlusa* (Loeblich and Tappan). – Olsson *et al.*, p. 62; pl. 17, figs. 4-6; pl. 51, figs. 1-15.

2011 *Morozovella occlusa* (Loeblich and Tappan). – Nguyen *et al.*, pl. 2, fig. 1.

2012 *Morozovella occlusa* (Loeblich and Tappan). – Birch *et al.*, p. 378, fig. 3.1-2.

Remarks: This species is generally characterized by a low biconvexity, which distinguishes it from *Morozovella velascoensis*. Its circular outline is another distinguishing property. Olsson *et al*. (1999) mentioned that there are 4-6 (rarely up to 8) chambers in last whorl of the form. In our individuals mostly 6 chambers are observed. The chambers are trapezoidal on spiral side and triangular on umbilical side. The test is circular. Its umbilicus is narrow and deep and its aperture is an interiomarginal, umbilical-extraumbilical arch.

Geographical Distribution: Italy, Salzburg Basin, Mexico, Tanzania, New Zealand, Papua New Guinea, Shatsky Rise (NW Pacific Ocean), South Atlantic Ocean.

Occurrence: Ayazlı MSS, Sample no. 4, 5.

***Morozovella praeangulata* (Blow, 1979)**

Plate 7, Figure 7

1979 *Globorotalia* (*Acarinina*) *praeangulata* Blow, p. 942-944, pl. 82, figs. 5-6; pl. 83, fig. 6; pl. 84, figs. 1, 7; pl. 212, figs. 1, 2, 8.

1997 *Morozovella praeangulata* (Blow). – Berggren and Norris, p. 99, pl. 14, figs. 1, 4-6.

1999 *Morozovella praeangulata* (Blow). –Olsson *et al.*, p. 64, p. 53, figs. 1-13.

2012 *Morozovella praeangulata* (Blow). – Birch *et al.*, p. 378, fig. 3.7-8.

Remarks: This morozovellid is different than the more developed ones by lacking a muricocarina and therefore its periphery is not sharply acute in the edge view as in the other morozovellids. However, its wall is also strongly muricate. There are 5-6 chambers in its last whorl. The chambers are crescentic, elongated and overlapping the previous one in the spiral view, whereas they are triangular to trapezoidal in umbilical side with radial sutures. The sutures are incised on both sides.

Geographic Distribution: Trinidad, Shatsky Rise (NW Pacific Ocean), Turkmenia, Tadzhikistan.

Occurrence: Kaymakam Kayası MSS, Sample no. 31.

Morozovella subbotinae **(Morozova, 1939)**

Plate 7, Figures 8-11

1939 *Globorotalia subbotinae* Morozova, 80, pl. 2, figs. 16-17.

1943 *Globorotalia rex* Martin, p. 117, pl. 8, figs. 2a-c.

1949 *Globorotalia crassata* (Cushman).- Subbotina, p. 119, pl. 5, figs. 31-33.

1953 *Globorotalia crassata* (Cushman).- Subbotina, p. 211, 212, pl. 17, figs. 7a-c; pl. 17, figs. 13a-c.

1964 *Globorotalia subbotinae Morozova*. - Luterbacher, p. 676, text-figs. 85, 86, 89, 90.

1970a *Globorotalia subbotinae* Morozova.- Shutskaya, p. 119-120, pl. 13, figs. 6a-c; pl. 14, figs. 6a-c.

1971 *Globorotalia* (*Morozovella*) *aequa rex* Martin. - Jenkins, p. 101-102, pl. 7, figs. 180-182.

1985 *Morozovella subbotinae* (Morozova).- Synder and Waters, p. 442-443, pl. 9, figs. 10-12.

1985 *Morozovella subbotinae* (Morozova).- Toumarkine and Luterbacher, p. 112, text-figs. 15: 9a-c.

1993 *Morozovella subbotinae* (Morozova).- Lu and Keller, p. 123, pl. 4, fig. 19.

1998 *Morozovella subbotinae* (Morozova).- Lu *et al.,* p. 212, pl. 1, figs. 1-3.

1999 *Morozovella subbotinae* (Morozova). – Olsson *et al.*, p. 65, fig. 24; p. 54, figs. 1-12.

2001 *Morozovella subbotinae* (Subbotina).- Warrick and Ogasawara, *p. 41, figs. 10.16-18*.

2006 *Morozovella subbotinae* Pearson *et al.,* p. 370, pl. 11-1, figs. 9-16.

2007 *Morozovella subbotinae* (Morozova). – Luciani *et al.,* p. 206, pl. 1, figs. 5, 6.

2008 *Morozovella subbotinae* (Morozova). – Handley *et al*., p. 20, text fig. 2.6, 9.

2011 *Morozovella subbotinae* (Morozova). – Nguyen *et al.*, pl. 1, fig. 2.

2014 *Morozovella subbotinae* (Morozova). – Bornemann *et al*., p. 71, text fig. 2.1.

Remarks: *Morozovella subbotinae* differs from *Morozovella aequa* by more lobate test and more gradually increasing chamber size. It has 4-4,5 chambers in its last whorl. Its test is strongly muricocarinate.

Geographic Distribution: Widespread in (sub)trophical regions; Atlantic Ocean, Indo-Pacific and Tethys, Kazakhstan, Italy, India, Pakistan, Caucasus, Pacific Ocean, Sussex (UK),Tanzania, Crimea, Trinidad, Egypt, Austria.

Occurrence: Karaburun MSS, Sample no. 5, 6, 14; Ayazlı MSS, Sample no. 2, 4, 5, 11; Erfelek MSS, Sample no. 45, 47, 48; Kaymakam Kayası-A MSS, Sample no. 4, 8.

Morozovella velascoensis (Cushman, 1925)

Plate 7, Figures 12-14

1925 *Pulvinulina velascoensis* Cushman. p. 19, pl. 3, figs. 5a-c.

1928 *Globorotalia velascoensis* Cushman. – White, p. 281, pl. 398, figs. 2a-c.

1946 *Globorotalia velascoensis* Cushman. – Cushman and Renz, p. 47, pl. 8, figs. 13, 14.

1947 *Globorotalia velascoensis* Cushman. – Subbotina, p. 123, pl. 7, figs. 9-11; pl. 9, figs. 21-23.

1953 *Globorotalia velascoensis* Cushman. – Le Roy, p. 33, pl. 3, figs. 1-3

1956 *Globorotalia velascoensis* Cushman. – Haque, 1956, p. 181, pl. 24, figs. 2a-c.

1957a *Globorotalia velascoensis* Cushman. – Bolli, p. 76, pl. 20, figs. 1-4.

1957a *Globorotalia velascoensis* Cushman. – Loeblich and Tappan, p. 196, pl. 64, figs. 1a-2c.

1960 *Globorotalia velascoensis* Cushman. – Bolli and Cita, p. 391, pl. 35, figs. 7a-c.

1961 *Globorotalia velascoensis* Cushman. – Said and Kerdany, p. 330, pl. 1, figs. 10a-c.

1961 *Pseudogloborotalia velascoensis* Cushman. – Bermudez, p. 1349, pl. 16, figs. 11a-b.

1962 *Globorotalia* (*Truncorotalia*) *velascoensis velascoensis* Cushman. – Hillebrandt, p. 169, pl. 13, figs. 16-21.

1968 *Truncorotaloides* (*Morozovella*) *velascoensis* Cushman. – McGowran, pl. 2, fig. 1.

1970b *Globorotalia velascoensis* Cushman. – Shutskaya, p. 118-120, pl. 23, figs. 3a-c;

pl. 24, figs. 5a-c; pl. 25, figs. 5a-c; pl. 27, figs. 12a-c; pl. 29, figs. 8a-c.

1971 *Globorotalia* (*Morozovella*) *velascoensis velascoensis* Cushman. – Jenkins, p. 107, pl. 9, figs. 214-216.

1975a *Globorotalia velascoensis* Cushman. – Luterbacher, p. 726, pl. 1, figs. 8a,b.

1983 *Globorotalia velascoensis* Cushman. – Pujol, p. 644, pl. 3, fig. 9.

1979 *Globorotalia* (*Morozovella*) *velascoensis velascoensis* Cushman. – Blow, p. 1029, pl. 92, fig. 7; pl. 94, figs. 6-9; pl. 95, figs. 1,2; pl. 216, figs. 1-8; pl. 217, figs. 1-6; pl. 99, figs. 3,4.

1984 *Globorotalia* (*Morozovella*) velascoensis *velascoensis* Cushman. – Belford, p. 10, pl. 1, fig. 2; pl. 19, figs. 1-12.

1985 *Morozovella velascoensis* (Cushman). – Toumarkine and Luterbacher, p. 110, text figs. 13.

1998 *Morozovella velascoensis* (Cushman). – Lu *et al.*, p. 212, pl. 1, figs. 4, 5, 9.

1999 *Morozovella velascoensis* (Cushman). – Olsson *et al.*, p. 66; fig. 25; pl. 17, figs. 10-12, pl. 55, figs. 1-15.

2007 *Morozovella velascoensis* (Cushman). – Luciani *et al.*, p. 206, pl. 1, figs. 1, 2.

2008 *Morozovella velascoensis* (Cushman). – Handley *et al.*, p. 20, text fig. 2.5.

2011 *Morozovella velascoensis* (Cushman). – Nguyen *et al.*, pl. 1, fig. 6.

2012 *Morozovella velascoensis* (Cushman). – Robertson *et al.*, p. 273, fig. 6q.

Remarks: This morozovellid has a robust, strongly muricocarinate, planoconvex test with 6-8 chambers in its last whorl. With these properties, Olsson *et al.* (1999) and Pearson *et al.* (2006) mentioned it as a homeomorph of Early-Middle Eocene form, *Morozovella caucasica*. Pearson *et al.* (2006) distinguish these two species with the larger size, higher conical angle and more pronounced circumumbilical ornament of chamber shoulder of *Morozovella velascoensis*.

Geographic Distribution: Caucasus, Crimea, Italy, Salzburg Basin, Egypt, Pakistan, Tanzania, Trinidad, Mexico, New Zealand, Papua New Guinea, Shatsky Rise (NW Pacific Ocean), Rio Grande Rise (SW Atlantic Ocean).

Occurrence: Ayazlı MSS, Sample no. 4, 5.

Genus *Morozovelloides* Pearson and Berggren, 2006

Type species: *Globorotalia lehneri* Cushman and Jarvis, 1929

The classification of the species of genus *Morozovelloides* is summarized in Table 21.

Table 21. Classification of genus *Morozovelloides* (* indicates the identified species in this study)

Species name	Test outline	Wall Texture	Chambers			Sutures		Umbilicus	Aperture	Size (mm)	Age
			# of chamber	Increase in size	Chambers	Spiral	Umbilical				
M. bandyi *	Low trochospiral, planoconvex to lenticular outline, petaloid periphery	Muricate, normal perforate with smooth areas on the spiral side	4-5	Gradually	Imbricate, strong disjunction of long axes of the chambers in spiral view	Depressed, straight	Radial, straight to weakly reflexed at junction with peripheral margin	Moderately broad and deep	Low, flat, umbilical-extraumbilical arch, with a distinct lip; small supplementary apertures at the base of sutures between penultimate and antepenultimate chambers	0.28	Middle Eocene
M. coronatus	Low trochospiral, asymmetrically biconvex; umbilicoconvex, elongate, oval to subcircular, moderately lobulate outline	Normal perforate, with concentration of muricae around periphery and on umbilical shoulders of chambers	5-5,5	Gradually	Lens-shaped, trapezoidal to subtriangular or subquadrate in spiral side; subtriangular, weakly inflated in umbilical side	Curved, tangential to periphery in early part of last whorl, radial, straight in terminal part	Radial, straight to weakly reflexed at junction with peripheral margin	Wide and deep	Low arch extending nearly to the periphery and rimmed by a thickened margin	0.43	
M. crassatus	Low trochospiral, asymmetrically biconvex, elongate-oval to subcircular, weakly to moderately lobulate	Muricate, especially around periphery and umbilicus, often with smooth dorsal and ventral surfaces to chambers	5	Gradually	Lens-shaped, trapezoidal in spiral side; subtriangular, weakly inflated in umbilical side	Strongly curved, distinctly muricate	Depressed, radial straight, recurving near periphery	Closed or relatively narrow, deep	Low, umbilical-extraumbilical slit extending to the margin	0.30	
M. lehneri	Low trochospiral, biconvex, elongate, oval, strongly lobulate	Muricate, normal perforate, distinct blade-like or fimbriate peripheral muricocarina	5-9	Gradually	Weakly inflated, compressed on spiral side; radially elongate, slightly inflated subtriangular to wedge-shaped chambers on umbilical side	Depressed, straight	Weakly curved on early portion of final whorl, essentially straight, radial and depressed on later part	Closed to narrowly open	Low, umbilical-extraumbilical slit extending to periphery	0.36	

Morozovelloides bandyi (Fleisher, 1974)

1930 *Globorotalia crassata* (Cushman).-Cushman and Barksdale, 67-68, pl. 12, fig. 7a-b.

1939 *Globorotalia crassata* (Cushman).-Cushman, 74, pl. 12, fig. 19.

1953 *Globorotalia spinulosa* (Cushman).-Beckmann, 397-398, pl. 26, fig. 13.

1974 *Morozovella bandyi* Fleisher, 1034, pl. 14, figs. 3-8.

1993 *Morozovella crassata* (Cushman).-Pearson and others, pl. 2, figs. 4-6.

2006 *Morozovelloides bandyi* (Fleisher).-Pearson and others, 330, pl. 10.1, figs. 1-16.

Remarks: *M. bandyi* has a discontinuous muricocarina. It is a planoconvex to lenticular form with 4-5 chambers in its last whorl. This form is thought to be homeomorphic to *Morozovella aequa-M. subbotinae* group that belongs to Early Eocene.

Geographic Distribution: North America, South Atlantic Ocean, Arabian Sea.

Occurrence: Karaburun MSS, Sample no. 19.

Genus *Planorotalites* Morozova, 1957

Type species: *Globorotalia pseudoscitula* Glaessner, 1937

The classification of the species of genus *Planorotalites* is summarized in Table 22.

Table 22. Classification of genus *Planorotalites* (* indicates the identified species in this study)

Species name	Test outline	Wall Texture	Chambers			Sutures		Umbilicus	Aperture	Size (mm)	Age
			# of chamber	Increase in size	Chambers	Spiral	Umbilical				
P. capdevilensis *	Biconvex, subcircular, very weakly lobulate	Strongly muricate, normal perforate, nonspinose	6-8	Gradually	Trapezoidal in spiral side; subtriangular in umbilical side	Flush with test, distinctly curved and limbate	Distinct, straight, radial to slightly curved	Narrow and shallow	Low, umbilical-extraumbilical arch, with a distinct lip	0.25	Eocene
P. pseudoscitula *	Low trochospiral, oval to subcircular, weakly lobate, weakly biconvex	Weakly muricate, normal perforate, nonspinose	6-8	Gradually	Trapezoidal in spiral side; subtriangular in umbilical side	Flush with test, distinctly curved	Depressed, radial to slightly curved	Narrow and shallow	Low, umbilical-extraumbilical arch, with a distinct lip	0.25	

Planorotalites capdevilensis (Cushman and Bermudez, 1949)

Plate 7, Figure 15

1949 *Globorotalia* (*Globorotalia*) capdevilensis Cushman and Bermudez, p. 32, pl. 6, figs. 10-12.

1957a *Globorotalia renzi* Bolli, p. 168, pl. 38, figs. 3a-c.

1960 *Globorotalia renzi* Bolli. – Berggren, p. 53, pl. 1, figs. 16a,b.

1971 *Globorotalia renzi* Bolli. – Postuma, p. 208, figs. on p. 209.

1971 *Globorotalia* (*Planorotalites*) *renzi* Bolli. – Jenkins, p. 110, pl. 9, figs. 224-226.

1975 *Globorotalia renzi* Bolli. – Stainforth et al., p. 221, text-figs. 81.1-5.

1977 *Globorotalia* (*Globorotalia*) *capdevilensis* Cushman and Bermudez. – Cifelli and Belford, p. 103, pl. 1, figs. 13-15.

1985 *Globorotalia renzi* Bolli. – Snyder and Waters, p. 447, pl. 10, figs. 6,7.

1985 *Planorotalites renzi* (Bolli). – Toumarkine and Luterbacher, p. 118, figs. 20.1a-c.

2004 *Planorotalites* capdevilensis (Cushman and Bermudez). – Pearson et al., p. 36, pl. 1, figs. 22, 23.

2004 *Planorotalites capdevilensis* (Cushman and Bermudez.) – Wade, p. 28, pl. 1, figs. a-b.

2006 *Planorotalites capdevilensis* (Cushman and Bermudez). – Pearson et al., p. 392, pl. 12.4, figs. 1-16.

Remarks: The wall texture of this species more looks like the ones of acarininids with a stronger murication in contrast to *P. pseudoscitula,* which has weakly muricate wall. The test of the form is biconvex. It has very distinct sutures on spiral side. Although the shape of the chambers looks like the chamber shape of *P. pseudoscitula,* this species has a rapid increase in the chamber size.

Geographical Distribution: Cuba, Tanzania, Trinidad, Nigeria, Carpathians, northeast Atlantic Ocean, New Zeland, California.

Occurrence: Karaburun MSS, Sample no. 15; Sinay-Karasu MSS, Sample no. 6.

Planorotalites pseudoscitula (Glaessner, 1937)

Plate 7, Figure 16

1937 *Globorotalia pseudoscitula* Glaessner, *32, text*- figs. 3a-c.

1947 *Globorotalia pseudoscitula* Subbotina, p. 121-122, pl. 9, figs. 18-20.

1953 *Globorotalia pseudoscitula* Subbotina, p. 208, pl. 16, figs. 17a-c, 18a-c; pl. 17, figs. 1a-c.

1972 *Globorotalia pseudoscitula* Samuel, p. 193-194, pl. 51, figs. 2a-4c.

1973 *Globorotalia pseudoscitula* Schmidt and Raju, p. 181-182, pl. 1, figs. 3a-c, 4.

1976 *Planorotalites pseudoscitula* Hillebrandt, p. 345, pl. 4, figs. 14.

1977 *Planorotalites pseudoscitula* Berggren, p. 244, chart no. 3.

1979 *Globorotalia (Globorotalia) pseudoscitula* Glaessner (sensu lato).- Blow, 897, pl. 116, figs. 8-10; pl. 173, figs. 1-8.

1985 *Planorotalites pseudoscitula* Toumarkine and Luterbacher, p. 118, figs. 20.5-10.

1988 *Planorotalites pseudoscitula* Loeblich and Tappan, p. 477, pl. 518, figs. 6-8.

1993 *Planorotalites pseudoscitula* Lu and Keller, p. 114, pl. 5, figs. 5-7.

1995 *Planorotalites pseudoscitula* Lu and Keller, p. 100, pl. 6, figs. 15-17.

2006 *Planorotalites pseudoscitula* Pearson *et al.*, p. 393, pl. 12-5, figs. 1-16.

Remarks: This species is an easily recognizable form with weakly biconvex, weakly lobate, oval to subcircular outline bearing 6-8 chambers in its last whorl. It is differentiated by its carinate test and small size.

Geographic Distribution: Trophics to temperate regions; Pacific Ocean, Tanzania, Caucasus, South Atlantic Ocean, Indian Ocean, Spain, Israel, Jamaica.

Occurrence: Sinay-Karasu MSS, Sample no. 1, 8.

Genus *Praemurica* Olsson, Hemleben, Berggren and Liu, 1992

Type species: *Globigerina* (*Eoglobigerina*) *taurica* Morozova, 1961

The classification of the species of genus *Praemurica* is summarized in Table 23.

Praemurica inconstans (Subbotina, 1953)

Plate 7, Figures 17-18

1953 *Globigerina inconstans* Subbotina, p. 58, pl. 3, figs. 1-2.

1960 *Globigerina inconstans* Subbotina, text-fig. 1.

1961 *Globorotalia (Acarinina) inconstans* (Subbotina). – Leonov and Alimarina, pl. 3, figs. 1-3.

1964 *Globorotalia inconstans* (Subbotina). – Luterbacher, p. 650, figs. 19-23.

1970b *Acarinina inconstans inconstans* (Subbotina). – Shutskaya, p. 108, pl. 6, figs. 4, 5.

1979 *Globorotalia* (*Turborotalia*) *inconstans* (Subbotina). – Blow, p. 1080, pl. 71, figs. 6, 7; pl. 75, figs. 4-7; pl. 76, figs. 3, 6, 7, 10; pl. 77, fig. 1; pl. 81, figs. 1, 2; pl. 233, figs. 4, 5.

Table 23. Classification of genus *Praemurica* (* indicates the identified species in this study)

Species name	Test outline	Wall Texture	Chambers			Sutures		Umbilicus	Aperture	Size (mm)	Age
			# of chamber	Increase in size	Chambers	Spiral	Umbilical				
P. inconstans *	Subcircular to broadly elongate-oval, moderately lobate outline, peripheral margin rounded to weakly subangular, spiral side very strongly compressed, umbilical side convex	Finely cancellate, non-spinose, smooth	5-7	Rapidly	Spherical, closely packed together, rounded on spiral side, rounded or triangular on umbilical side, larger last chamber	Radial, straight to curved, weakly incised	Radial, curved	Shallow	Interiomarginal, umbilical-extraumbilical slit with distinct, lipped rim	0.35-0.45	Early Paleocene
P. pseudoinconstans *	Subcircular to slightly elongate, moderately lobate outline, biconvex with rounded peripheral margins	Weakly cancellate, finely and densely perforate	5-6	Gradually	Inflated, subglobular, slightly more embracing and appressed in umbilical side, last chamber sometimes slightly offset toward umbilicus	Radial, distinctly incised	Radial, distinctly incised	Widely open, moderately deep	High rounded arch, bordered by a narrow lip broadening toward umbilicus	0.33	
P. taurica	Subpolygonal lateral outline, strongly compressed along the growth axis	Weakly cancellate, finely perforate, smooth	5-6	Gradually	Globular to slightly ovoid, last chamber asymmetrical, flattened at apertural face and slightly shifted toward umbilical surface	Deep, straight	Deep, straight	Broad, wide, deep	Umbilical-extraumbilical low to high arch bordered by narrow, triangular lip	0.32-0.45	
P. uncinata *	Elongate-oval, plano-convex to moderately high spired, moderately lobate, axial periphery rounded to subangular	Weakly cancellate, finely spinose	5-8	Moderately	Trapezoidal on spiral side, subangular, inflated, laterally compressed on umbilical side	Incised, strongly recurved	Radial, depressed	Narrow, deep	Narrow interiomarginal, umbilical-extraumbilical arch extending to peripheral margin, secondary spiral apertures	0.35	

1992 *Morozovella inconstans* (Subbotina). – Berggren, p. 564, pl. 1, figs. 12-13.

1997 *Praemurica inconstans* (Subbotina). – Berggren and Norris, p. 97, pl. 13, figs. 1-6.

2009 *Praemurica inconstans* (Subbotina). – Obaidalla *et al*., p. 4, pl. 1, figs. 6-7.

2012 *Praemurica inconstans* (Subbotina). – Birch *et al.*, p. 378, fig. 3.17-22.

2013 *Praemurica pseudoinconstans* (Blow). – Arenillas and Arz, p. 242, text-fig. 5H-L.

Remarks: This form has a lobate outline with 5-7 chambers in its last whorl increasing rapidly in size. The observed specimens have generally 5 ½ chambers in the last whorl. The wall structure of the species looks like the ones of acarinids. The last chamber of this species is slightly loosely evolute. Chambers are spherical to trapezoidal on spiral side, triangular on umbilical side. Umbilical-extraumbilical aperture is observed.

Geographical Distribution: Texas, N Caucasus, central Apennines (Italy), Tanzania, Turkmenia, NW Azerbaidzhan, Trinidad, Kerguelen Plateau (Southern Indian Ocean), Weddell Sea (Antarctic Ocean), Shutsky Rise (NW Pacific Ocean)

Occurrence: Erfelek MSS, Sample no. 38, 40, 41.

***Praemurica pseudoinconstans* (Blow, 1979)**

1979 *Globorotalia* (*Turborotalia*) *pseudoinconstans* Blow. p. 1105, pl. 67, figs. 3-4; pl. 69, fig. 4.

1992 *Praemurica pseudoinconstans* (Blow). – Olsson *et al*., p. 202, pl. 6, figs. 1-8.

1999 *Praemurica pseudoinconstans* (Blow). – Olsson *et al*., p. 74, pl. 60, figs. 1-13.

2012 *Praemurica pseudoinconstans* (Blow). – Birch *et al.*, p. 378, fig. 3.23-25.

2013 *Praemurica pseudoinconstans* (Blow). – Arenillas and Arz, p. 242, text-fig. 5E-G.

Remarks: *Praemurica pseudoinconstans* is another species that we observed with 5 chambers in its last whorl. The increasing rate of chamber size is slower in *P. pseudoinconstans* with respect to *P. inconstans.*

Geographical Distribution: Alabama, Shatsky Rise, Tunisia, Spain.

Occurrence: Erfelek MSS, Sample no. 29, 30, 32-35, 36; Erfelek 1 MSS, Sample no. 17, 19, 20, 22; Kaymakam Kayası MSS, Sample no. 5-7, 9, 12.

***Praemurica uncinata* (Bolli, 1957a)**

1957a *Globorotalia uncinata* Bolli. p. 74, pl. 17, figs. 13-15.

1964 *Globorotalia uncinata* Bolli. – Luterbacher, p. 655, 656, 658; p. 653, figs. 30a-c;

p. 657, figs. 31a-c.

1966 *Globorotalia uncinata uncinata* Bolli. – El Naggar, p. 240, 693, pl. 18, figs. 1a-c; pl. 19, figs. 2a-c.

1970a *Acarinina inconstans uncinata* (Bolli). – Shutskaya, p. 110, pl. 6, figs. 1a-c, 2a-c, 3a-c.

1970b *Acarinina inconstans uncinata* (Bolli). – Shutskaya, p. 118-120, pl. 19, figs. 7a-c, 10a-c.

1978 *Globorotalia uncinata* Bolli. – Toumarkine, p. 692, 693, pl. 1, fig. 16.

1983 *Globorotalia uncinata* Bolli. – Pujol, p. 645, 652, pl. 2, fig. 1.

1999 *Praemurica uncinata* (Bolli). – Olsson *et al*., p. 76.; fig. 30; pl. 10, figs. 9-11; pl. 62, figs. 1-16.

2009 *Praemurica uncinata* (Bolli). – Obaidalla *et al*., p. 4, pl. 1, figs. 8-9.

2012 *Praemurica uncinata* (Bolli). – Birch *et al.*, p. 378, fig. 3.9-11.

Remarks: This species mostly has larger number of chambers in its last whorl (up to 8 chambers) with respect to other species of genus *Praemurica*. It is a planoconvex form and the chambers on the spiral side are trapezoidal in shape. This is the characteristic feature for this species.

Geographic Distribution: Trinidad, Texas, Italy, Egypt, Caucasus, Shatsky Rise, South Atlantic Ocean.

Occurrence: Erfelek MSS, Sample 20, 23-25.

4.2. PALEOCENE-EOCENE BENTHIC FORAMINIFERA

The taxonomy of the benthic foraminifera isn’t the primary purpose of this thesis. However, during the progress of the study, it is recorded that the abundance of the planktonic foraminifera are very low in the Erfelek Section, whereas the benthic foraminifera are highly abundant. Moreover, this section has been sampled in detail as the Erfelek 1 Section for the recognition of the Paleocene-Eocene boundary, on which the Benthic Foraminiferal Extinction Event (BFEE) becomes important. Therefore, taxonomy of the benthic foraminifera comes to be an essential study also for this thesis.

The benthic foraminiferal assemblage of the Erfelek 1 Section has been studied in detail. Forms with both calcareous and agglutinated walls were identified. The generic identifications were based on the definitions of Loeblich and Tappan (1988), whereas the explanations of Kaminski and Gradstein (2005) were used for the species descriptions of the agglutinated foraminifera**.** Besides these two key referances, the definitions of Berggren and Aubert (1976), Sztrakos (2000), Sztrakos (2005), Alegret and Ortiz (2007) and Webb (2007) were also utilized.

The observed taxa includes the “Velasco-type fauna” of Berggren and Aubert (1975), which are the bathyal and abyssal genera mainly consist of *Osangularia*, *Nuttallides, Aragonia, Pullenia, Anomalina, Gyroidinoides* and *Cibicidoides.* The species classification has not always been carried out since the identified morphological features of the specimens aren’t enough for defining a species. A total of 3 orders, 19 superfamilies, 30 families, 38 genera and 14 species were defined in the Erfelek 1 Section. Their taxonomy will be summarized as remarks in the next sections.

4.2.1. Calcareous Benthic Foraminifera

Phylum Protozoa

Order Rotaliida Delage & Hérouard, 1896

Superfamily Asterigerinacea d'Orbigny, 1839

Family Epistomariidae Hofker, 1954

Genus *Nuttallides* Finlay, 1939

Plate 8, Figure 1

Remarks: *Nuttallites* is a trochospirally coiled multilocular form with a lenticular, biconvex test and an imperforate keel. The recorded specimens have crescentic chambers on spiral side and subtriangular chambers on umbilical side. The chambers on the spiral side aren’t generally observed except the last whorl. The interiomarginal aperture extends nearly to keel of the form.

Occurrence: Erfelek 1 MSS, sample no. 11, 15, 25, 26, 31, 32, 33, 35, 38, 39

Superfamily Buliminacea Jones, 1875

Family Buliminidae Jones, 1875

Genus *Bulimina* d’Orbigny, 1826

Plate 8, Figures 2-3

Remarks: It is a triserial form with an elongate test. The septa are indistinct. This genus isn’t so common in the samples. Most of the observed specimens have a smooth surface, but also some spiny projections may be placed in the lower part of the chambers.

Occurrence: Erfelek 1 MSS, sample no. 25, 26, 33, 35, 36, 38, 48

Superfamily Cassidulinacea d'Orbigny, 1839

Family Cassidulinidae d'Orbigny, 1839

Genus *Globocassidulina* Voloshinova, 1960

Plate 8, Figure 4

Remarks: *Globocassidulina* is the only biserially enrolled form in the samples. The sutures are zigzag because of chamber's orientation. This genus is characterized by a globular test with a smooth surface. It is one of the rare forms in the section.

Occurrence: Erfelek 1 MSS, sample no. 39, 40

Superfamily Chilostomellacea Brady, 1881

Family Alabaminidae Hofker, 1951

Genus *Alabamina* Toulmin, 1941

Remarks: This form has a biconvex trochospiral test with a subangular periphery. It has a narrow and depressed umbilicus. Aperture of the genus *Alabamina* is an interiomarginal slit. The presence of a lip isn't identified in the studied specimens.

Occurrence: Erfelek 1 MSS, sample no. 36, 54

Family Gavelinellidae Hofker, 1956

Genus *Gyroidinoides* Brotzen, 1942

Plate 8, Figure 5

Remarks: *Gyroidinoides* is a planoconvex trochospiral form. The spiral side of the form is evolute and flat, whereas the umbilical side is involute and convex. It has a rounded and subacute periphery. A low interiomarginal aperture is observed that extends from the periphery to the umbilicus.

Occurrence: Erfelek 1 MSS, sample no. 19, 22, 23, 25, 33, 36, 38, 39, 40

Family Heterolepidae González-Donoso, 1969

Genus *Anomalinoides* Brotzen, 1942

Plate 8, Figures 6-7

Remarks: It is a low trochospiral, biconvex form with a rounded periphery. The chambers are inflated on spiral side and seperated with curved and depressed sutures. The sutures are radial and depressed on the umbilical side. One of the most distinguishing features is its low arch, interiomarginal aperture that extends on the spiral side.

Occurrence: Erfelek 1 MSS, sample no. 16, 23, 24, 26, 28, 31, 33, 35, 38, 40, 50

Family Oridorsalidae Loeblich and Tappan, 1984

Genus *Oridorsalis* Andersen, 1961

Plate 8, Figures 8-9

Remarks: *Oridorsalis* has a lenticular, low trochospiral test with a carinate periphery. The umbilical side is generally more convex in the observed specimens. Spiral side is evolute, however only the last whorl is clearly observed mostly in our samples, probably related to the preservation. Its sutures are radial and depressed on spiral side; radial and straight on umbilical side. The primary aperture of the genus is interiomarginal, extending from near the periphery almost to the closed umbilicus. The presence of both umbilical and spiral secondary apertures is mentioned in the definition of this form. However, they haven't been recognized in our specimens. *Oridorsalis* is one of the most common benthic foraminifera in the Erfelek 1 Section.

Occurrence: Erfelek 1 MSS, sample no. 15, 17, 20, 23, 24, 25, 26, 28, 33, 36, 38, 39, 40, 50

Family Osangulariidae Loeblich and Tappan, 1964

Genus *Osangularia* Brotzen, 1940

Plate 8, Figure 10

Remarks: Biumbonate, lenticular, trochospiral test of this genus has a carinate periphery. The spiral side is evolute with crescentic, triangular or trapezoidal chambers separated by oblique sutures. On the other hand, the umbilical side is involute with triangular chambers and radial, depressed sutures. Its aperture is areal with an acute angle to the base of the chamber face.

Occurrence: Erfelek 1 MSS, sample no. 20, 23, 24, 25, 32, 34, 35, 36, 38

Superfamily Loxostomatacea Loeblich & Tappan, 1962

Family Loxostomatidae Loeblich and Tappan, 1962

Genus *Aragonia* Finlay, 1939

Plate 8, Figures 11-12

Remarks: *Aragonia* is a biserial form. It has a marginal keel and a rhomboidal outline, which is mostly compressed in section. Its chambers increase rapidly in size. The sutures are elevated and thickened. The aperture is defined as a small opening at the base of the apertural face.

Occurrence: Erfelek 1 MSS, sample no. 17, 20, 23, 24, 25, 31, 38, 40, 43

Superfamily Nodosariacea Ehrenberg, 1838

Family Ellipsolagenidae A. Silvestri, 1923

Genus *Fissurina* Reuss, 1850

Plate 8, Figures 13-16; Plate 14, Figure 4

Remarks: *Fissurina* is distinguished with its rounded to ovale outline, which is mostly lenticular in section. It has a keeled periphery; keels may be more than one. The surface of the test has aligned puntuations. Its aperture is terminal, ovate to slitlike, within a slightly depressed fissure at the test apex.

Occurrence: Erfelek 1 MSS, sample no. 23, 24, 25, 33, 39, 43

Family Lagenidae Reuus, 1862

Remarks: All unilocular forms with hyaline wall are included to this family and the genus classification isn't described except the genus *Lagena.*

Occurrence: Erfelek 1 MSS, sample no. 23, 31, 3, 38, 39, 40

Genus *Lagena* Walker & Jacob, 1798

Plate 9, Figures 1-4

Remarks: This genus has a globular to ovate test. The aperture is terminal on a short neck. *Lagena* is defined to have longitudinal striae or costae; however these surface ornamentations is mostly missing on our specimens because of their poor preservation.

Occurrence: Erfelek 1 MSS, sample no. 26, 28, 32

Family Nodosariidae Ehrenberg, 1838

Genus *Dentalina* Risso, 1826

Plate 9, Figures 8-9

Remarks: The distinguishing feature of this genus is its slightly arcuate test. Its sutures are horizontal. It has a terminal aperture.

Occurrence: Erfelek 1 MSS, sample no. 26, 39

Genus *Nodosaria* Lamarck, 1812

Plate 9, Figure 10

Remarks: Test is elongate with globular to ovate chambers. Surface is smooth and unornamented. Aperture is terminal and produced on a neck.

Occurrence: Erfelek 1 MSS, sample no. 38

Undetermined nodosarids

Plate 9, Figures 5-7

Remarks: The uniserial, multicolular specimens with hyaline wall are defined under family Nodosariidae. Except *Dentalina* and *Nodosaria*, generic classification has not been carried out and these specimens are evaluated directly in family rank.

Occurrence: Erfelek 1 MSS, sample no. 12, 20, 23, 25, 29, 31, 32, 33, 38, 39, 40, 50

Family Vaginulinidae Reuss, 1860

Genus *Lenticulina* Lamarck, 1804

Plate 9, Figures 11-13

Remarks: *Lenticulina* has a planispiral, lenticular and biumbonate test. Its periphery is carinate. The last chamber may tend to flare or become uncoiled, which is sometimes noticed also in our specimens. The smooth surface of the form is mentioned to have sutural nodes or elevations; however these ornamentations aren't observed in our specimens.

Occurrence: Erfelek 1 MSS, sample no. 23, 25, 26, 28, 31, 32, 33, 39, 40, 48, 50

Genus *Neoflabellina* Bartenstein, 1948

Plate 9, Figures 14-15; Plate 14, Figure 6

Remarks: The palmate outline with truncate margins of this genus is its most distinguishing feature. The initial planispiral coiling is followed by a flaring stage and becomes uniserial in the final stage. The inverted V-shaped chambers, separated by elevated sutures are the important properties of this genus.

Occurrence: Erfelek 1 MSS, sample no. 26, 33, 48

Genus *Saracenaria* Defrance, 1824

Plate 9, Figures 16-17

Remarks: This genus is initially planispirally coiled like *Lenticulina*; however it is flaring with a triangular section view in the later stages. It has carinate margins and a radiate aperture.

Occurrence: Erfelek 1 MSS, sample no. 23, 24, 26, 32, 33, 40

Superfamily Nonionacea Schultze, 1854

Family Nonionidae Schultze, 1854

Genus *Nonion* de Montfort, 1808

Plate 9, Figure 18

Remarks: *Nonion* has a planispiral, rounded and biumbilicate test. The incised and curved sutures are one of its distinguishing features. The sutures are indistinct on some of the specimens in our samples. Aperture of this genus is a low interiomarginal and equatorial slit at the base of the arched apertural face, extending laterally nearly to the umbilici.

Occurrence: Erfelek 1 MSS, sample no. 20, 26, 28, 32, 40

Genus *Pullenia* Parker and Jones, 1862

***Pullenia coryelli* White, 1929**

Plate 9, Figure 19

Remarks: Test is planispirally involute with a globular to slightly compressed outline. Sutures are radial, flush to slightly depressed. The aperture of *Pullenia* is its most dintinguishing feature in our specimens, which is a narrow interiomarginal crescentic slit, extending across the periphery to the umbilici.

Occurrence: Erfelek 1 MSS, sample no. 15, 20, 24, 25, 32, 34

Superfamily Planorbulinacea Schwager, 1877

Family Cibicididae Cushman, 1927

Genus *Cibicides* de Montfort, 1808

Plate 10, Figures 1-2

Remarks: Test of *Cibicides* is trochospiral and planoconvex with a carinate and angular periphery. Its aperture is a low interiomarginal equatorial opening.

Occurrence: Erfelek 1 MSS, sample no. 20, 24, 29, 33

Genus *Cibicidoides* Thalmann, 1939

Plate 10, Figures 3-4

Remarks: The difference of this genus from *Cibicides* is its biconvex, lenticular test. Its periphery is also angular and carinate. The spiral side is coarsely perforated. Sutures are curved and limbate on the spiral side, straight and radial on the umbilical side. Aperture is a low, interiomarginal and equatorial arch at the base of the apertural face, on the periphery and above the keel of the previous whorl; bordered by a small lip.

Occurrence: Erfelek 1 MSS, sample no. 24, 26, 29, 32, 32, 35, 36, 38

Family *Planulinidae* Bermúdez, 1952

Genus *Planulina* d'Orbigny, 1826

Plate 10, Figures 5-6

Remarks: *Planulina* has a very low trochospiral, planoconvex test. Its periphery is truncated with an imperforate keel. Both sides are evolute. The chambers are arched and separated by thick, curved septa. Its aperture is an equatorial and interiomarginal arch.

Occurrence: Erfelek 1 MSS, sample no. 38, 39, 40, 50

Superfamily Pleurostomellacea Reuss, 1860

Family Pleurostomellidae Reuss, 1960

Genus *Ellipsoglandulina* Silvestri, 1900

Plate 10, Figures 7-8

Remarks: It is another uniserial genus. However, different than the nodosarids, the chambers of this genus is overlapping and increasing rapidly in size. The test is elongate and flaring. The final chamber is very large to cover up to 2/3 of the test. It has horizontal, depressed sutures. Aperture is terminal.

Occurrence: Erfelek 1 MSS, sample no. 22, 23, 24, 31, 38

4.2.2. Agglutinated Benthic Foraminifera

Order Astrorhizida Brady, 1881

Superfamily Ammodiscacea Reuss, 1862

Family Ammodiscidae Reuss, 1862

Genus *Ammodiscus* Reuss, 1862

Remarks: This genus has a bilocular test, on which the globular proloculus is followed by a planispirally coiled second chamber. Aperture is an arch at the open end of the second chamber. Three species of this genus are defined and the other unclassified members are named as *Ammodiscus* sp.

Occurrence: Erfelek 1 MSS, sample no. 11, 26, 28, 33, 39, 40, 50, 55

Ammodiscus cretaceous (Reuss, 1845)

Plate 10, Figure 9

Remarks: It is one of the large species with 8 to 11 whorls. The final 3 or 4 whorls are broader than the previous whorls. The test surface has fine radial striations, which is noticed in some of the specimens in our samples.

Bathymetry: Middle neritic to upper abyssal.

Occurrence: Erfelek 1 MSS, sample no. 50

Ammodiscus glabratus Cushman & Jarvis, 19287

Plate 10, Figures 10-11; Plate 14, Figure 1

Remarks: *Ammodiscus glabratus* is said to commonly be reported from flysch-type and abyssal agglutinated assemblages throughout the world (Kaminski and Gradstein, 2005). Its test is biconcave. The second chamber coiled in 10 whorls. The width is increasing slowly, but the thickness is increasing rapidly.

Bathymetry: Bathyal.

Occurrence: Erfelek 1 MSS, sample no. 35, 42, 50

Ammodiscus peruvianus Berry, 1928

Plate 10, Figures 12-14; Plate 14, Figure 7

Remarks: Test is medium to large, biconcave and elliptical in outline. Chamber slowly increases in size and has up to 8 whorls. The specimens with elliptical outlines are defined as *A. peruvianus* in our samples.

Bathymetry: Bathyal to abyssal.

Occurrence: Erfelek 1 MSS, sample no. 9, 26, 39, 40, 48, 50

Genus *Glomospira* Rzehak, 1885

Remarks: This genus is also a bilocular form. The proloculus is followed by a tubular chamber. This second chamber is streptospirally or irregularly coiled, followed by a planispiral coiling. Test is discoidal and the aperture is at the open end of the tube. Four species belonging to this genus are defined in this study and the rest is defined as *Glomospira* sp.

Kaminski and Gradstein (2005) defined a *Glomospira* acme for the Early Eocene. A *Glomospira* bloom is present during this interval. This acme is thought to be correlative along Tethys and North Atlantic; however its exact position depends on the trophic conditions (Giusberti *et al*., 2009).

Occurrence: Erfelek 1 MSS, sample no. 26, 33, 39, 40, 43, 46, 47

Glomospira charoides (Jones & Parker, 1860)

Plate 11, Figures 1-2

Remarks: The proloculus is followed by a trochospirally enrolled second chamber, coiled about a vertical axis. The last whorl may deviate from the axis of coiling. This species is one of the common species in our samples. It is a small form and easy to recognize because of the type of its coiling.

Glomospira charoides is indicated as a marker opportunistic species for the stressed environments with a high resistance to carbonate dissolution (Kaminski and Gradstein, 2005; Giusberti *et al*., 2009).

Bathymetry: Bathyal to abyssal.

Occurrence: Erfelek 1 MSS, sample no. 9, 15, 28, 33, 36, 38, 39, 40, 43, 55

Glomospira diffundens Cushman & Renz, 1946

Plate 11, Figure 3

Remarks: Glomospira diffundens is distinguished by its large size. Its second chamber initially has a glomospiral coiling that turns into planispiral in the last whorl. It is mentioned to have a wide geographic distribution in flysch-type assemblages like Ammodiscus glabratus (Kaminski and Gradstein, 2005).

Bathymetry: Bathyal to upper abyssal.

Occurrence: Erfelek 1 MSS, sample no. 26, 35, 39

Glomospira irregularis (Grzybowski, 1898)

Plate 11, Figures 4-5

Remarks: *Glomospira irregularis* differs from the other observed species of *Glomospira* by a coarser wall and streptospiral coiling.

Bathymetry: Bathyal to abyssal.

Occurrence: Erfelek 1 MSS, sample no. 33, 50, 55

Glomospira serpens (Grzybowski, 1898)

Remarks: This species is a larger form with a miliolid-like coiling and an oval test. It is rarely sporadically observed in a few samples.

Bathymetry: Bathyal to abyssal, rare in abyssal sediments.

Occurrence: Erfelek 1 MSS, sample no. 9, 41, 50

Superfamily Astrorhizacea Sandahl, 1858

Family Bathysiphonidae Avnimelech, 1952

Genus *Nothia* Pflaumann, 1964

Remarks: Test of this genus is elongate, tubular and may be branched. It is mentioned to be commonly compressed due to the preservation and therefore its inner cavity is completely flattened (Kaminski and Gradstein, 2005). Aperture of the genus is at the open end of the tube. 1 species of this genus is defined and the other specimens are described as *Nothia* sp.

Occurrence: Erfelek 1 MSS, sample no. 11, 22, 28, 31, 33, 38, 39, 40, 41, 43, 46, 47, 48, 50, 51, 54, 55

Nothia excelsa (Grzybowski, 1898), emend. Geroch & Kaminski, 1992

Plate 11, Figures 6-8; Plate 14, Figure 2

Remarks: The flattened, straight test is identified without any proloculus. Some specimens are observed to be branched in our samples. It is also one of the common species in the section.

Bathymetry: Bathyal to abyssal.

Occurrence: Erfelek 1 MSS, sample no. 9, 15, 23, 25, 26, 40, 42

Genus *Psammosiphonella* Avnimelech, 1952

Plate 11, Figure 9

Remarks: Psammosiphonella is another genus that is common in flysch-type and abyssal assemblages (Kaminski and Gradstein, 2005). Its test is straight and cylindrical. The diameter of the test is smaller with respect to Nothia. Aperture is at the open end of the tube.

Occurrence: Erfelek 1 MSS, sample no. 26, 31, 33, 35, 38, 39, 40, 41, 47, 48, 50, 51

Family Rhabdamminidae Brady, 1887

Plate 11, Figure 10

Remarks: Some of the specimens observed in the section are cylindrical forms like genus *Psammosiphonella*, however they are not straight but curved. No genus name is determined for these forms, but they are classified within this family in our samples.

Occurrence: Erfelek 1 Section, sample no. 28, 39.

Family Saccamminidae Brady, 1884

Genus *Placentammina* Thalmann, 1947

***Placentammina placenta* (Grzybowski, 1898)**

Plate 11, Figures 11-13; Plate 14, Figure 5

Remarks: The circular and mostly flattened test with a collapsed part (depression) in the center is the distinguishing feature for this species. Its terminal aperture is on a short neck.

Bathymetry: Bathyal.

Occurrence: Erfelek 1 MSS, sample no. 24, 40, 41, 47, 50

Superfamily Hippocrepinacea Rhumbler, 1895

Family Hippocrepinidae Rhumbler, 1895

Genus *Hyperammina* Brady, 1878

***Hyperammina dilatata* Grzybowski, 1896**

Plate 11, Figures 14-18; Plate 14, Figure 9

Remarks: This species has a unilocular, flask-shaped test. Test is often compressed. Aperture is a broad rounded opening at the end of a short neck.

Bathymetry: Bathyal to abyssal, rare in abyssal assemblages.

Occurrence: Erfelek 1 MSS, sample no. 24, 41, 43, 47, 48, 50, 55

Order Textulariida Delage & Herouard, 1896

Superfamily Hormosinacea Haeckel, 1894

Family Hormosinidae Haeckel, 1984

Plate 12, Figures 1-2

Remarks: Chambers are rectilinear to arcuate and aperture is terminal, single or multiple for this family. Two different genera are defined in this family. The forms with incomplete tests are mentioned at a family rank in this study.

Occurrence: Erfelek 1 MSS, sample no. 33, 40

Genus *Caudammina* Montanaro-Gallitelli, 1955

***Caudammina ovula* (Grzybowski, 1896) emend. Geroch, 1960**

Plate 12, Figures 3-5

Remarks: The unilocular test with a spheroidal or ovate chamber is classified in this species. This single chamber is assumed to be a part of a multilocular test, whose chambers are connected by thin stalons (Kaminski and Gradstein, 2005). Apertures are small tubular passages at one or both ends of the test.

Bathymetry: Bathyal to abyssal. More abundant in middle bathyal to abyssal assemblages.

Occurrence: Erfelek 1 MSS, sample no. 29, 39, 40, 41

Genus *Hormosina* Brady, 1879

Plate 12, Figure 6

Remarks: The multilocular, uniserial forms are defined as *Hormosina* sp. in the present study. The chambers are mostly cylindrical. These forms look like the nodosarids; however their walls are totally different.

Occurrence: Erfelek 1 MSS, sample no. 39, 41, 55

Genus *Kalamopsis* de Folin, 1883

***Kalamopsis grzybowskii* (Dylazanka, 1923)**

Plate 12, Figures 7-9; Plate 14, Figure 8

Remarks: The cylindrical, uniserial forms with tubular chambers are described as *Kalamopsis grzybowskii*. Aperture at the open end of the tube. These forms have internal septae, however in our samples mostly a single chamber belonging to this species is observed.

Occurrence: Erfelek 1 MSS, sample no. 11, 15, 22, 23, 24, 32, 33, 34, 39, 41, 43, 47, 54, 55

Superfamily Lituolacea de Blainville, 1827

Family Haplophragmoididae Maync, 1952

Genus *Haplophragmoides* Cushman, 1910

Plate 12, Figures 10-11

Remarks: Coarsely agglutinated, planispirally coiled forms are classified in this genus. The test is biumbilicate with somewhat flattened sides. Chambers inflated and margin lobulated. Aperture is an elongate equatorial slit at the base of the apertural face.

Occurrence: Erfelek 1 MSS, sample no. 17, 23, 24, 31, 33, 43, 47

***Haplophragmoides suborbicularis* (Grzybowski, 1896) emend. Kaminski and Gradstein, 2005**

Plate 12, Figure 12

Remarks: Test of this species is with a rounded periphery and circular in outline. It has 5-7 chambers in its final whorl. Sutures flush or depressed slightly. Aperture of this species is an oval interiomarginal opening that looks like the aperture of genus *Pullenia*.

Bathymetry: Bathyal.

Occurrence: Erfelek 1 MSS, sample no. 15, 26, 39, 50

Superfamily Rzehakinacea Cushman, 1933

Family Rzehakinidae Cushman, 1933

Genus *Rzehakina* Cushman, 1927

Plate 12, Figure 13

Remarks: Test is flattened ovate, planispirally coiled. Narrow elongate chambers are a half coil in length commonly partially overlapping earlier coils to result in a much thickened wall at the center of the sides. Aperture is terminal, rounded.

Occurrence: Erfelek 1 MSS, sample no. 48

Superfamily Spiroplectamminacea Cushman, 1927

Family Spiroplectamminidae Cushman, 1927

Genus *Spiroplectammina* Cushman, 1927

Plate 12, Figures 14-15; Plate 14, Figure 3

Remarks: The planispiral coiling followed by biserially arranged chambers is the distinguishing feature of this genus. Its aperture is a low arch at the inner margin of the final chamber.

Occurrence: Erfelek 1 MSS, sample no. 9, 28, 29, 32, 33, 35, 36, 39, 40, 43 55

Superfamily Textulariacea Ehrenberg, 1838

Family Eggerellidae Cushman, 1937

Genus *Dorothia* Plummer, 1931

Plate 12, Figures 16-17

Remarks: It has a robust test with a trochospiral early stage and biserially arranged chambers in the later stage. The test has nearly parallel sides and it is circular in section. Aperture is an interiomarginal slit.

Occurrence: Erfelek 1 MSS, sample no. 9, 11, 20, 24, 25, 28, 29, 33, 36, 38, 47, 50

Family Pseudogaudryinidae Loeblich and Tappan, 1985

Genus *Clavulinoides* Cushman, 1936

Plate 12, Figure 18

Remarks: *Clavulinoides* is the only genus with triaserially-to-uniserially arranged chambers in this study. Its carinate angles makes easy to identify this form. Aperture of this form is simple, interiomarginal in the triserial stage; terminal, areal and rounded in the uniserial stage.

Occurrence: Erfelek 1 MSS, sample no. 23, 24, 38

Superfamily Trochamminacea Schwager, 1877

Family Trochamminidae Schwager, 1877

Genus *Trochammina* Parker & Jones, 1859

Plate 12, Figure 19

Remarks: This genus has an irregular coiling changing from planispiral to slightly trochospiral or showing a glomospiral coiling. It is a multilocular form. The observed specimens have a large test mostly with globular chambers. Aperture is large, rounded, equatorial, lying against the previous whorl.

Occurrence: Erfelek 1 MSS, sample no. 9, 15, 19, 20, 23, 24, 25, 26, 28, 31, 33, 38, 39, 40, 50

4.3. UNDETERMINED FORAMINIFERA

Plate 13, Figures 1-5

Remarks: This form has a brittle test and its preservation is very poor in samples. The observed specimens are thought to be the cast of the original form. It has a trochospiral test with subacute-acute periphery and lobate outline. It is mostly loosely coiled. The chambers are semicircular to crescentic, sometimes overlapping the following chamber in spiral side and semicircular in umbilical side. Sutures are curved on both sides. The aperture is umbilical-extraumbilical with a wide umbilicus. Although a classification isn't defined for this form, it is considered to be planktonic foraminifera. This foraminifera is recorded close to the Paleocene-Eocene boundary on both sections.

Occurrence: Ayazlı MSS, sample no. 2; Erfelek 1 MSS, sample no. 26, 34, 37

CHAPTER 5

PALEOCENE – EOCENE BOUNDARY

5.1. INTRODUCTION

Recently, the interest on the studies for the determination of various Global Boundary Stratotype Section and Points (GSSPs) and the event stratigraphy for the stage boundaries are increasing. The International Commission on Stratigraphy (ICS) has established several subcommissions and working groups for the deciding the GSSP of different system, series or stages depending on some criteria such as the continuous sedimentation in the section with an adequate thickness of sediments, high sedimentation rate, absence of vertical facies change, absence of synsedimentary and tectonic disturbances, metamorphism and diagenetic alterations, presence of abundant and diversified fossil record, favourable facies for long range biostratigraphic correlations, being suitable for radiometric dating, magnetostratigraphy and chemostratigraphy, the accessibility of the section, permenant protection of the site and possibility to fix a permenant marker (Remane *et al.*, 1996; Molina *et al*., 2011).

For the Paleocene, three GSSPs have been ratified for Danian, Selandian and Thanetian stages (Molina *et al*., 2006; Schmitz *et al*., 2011). The GSSP for the base of the Danian Stage is in El Kef, Tunisia (Molina *et al*., 2006). The base of the Danian Stage has been defined by the first appearance of Paleogene foraminifera, such as FAD of *Globoconusa* at the base or within a few centimeters of the boundary clay in this location. (Figure 48). GSSPs for the Selandian and Thanetian stages have been recognized in the Zumaia, Spain (Schmitz *et al*., 2011). The base of the Selandian corresponds to the second radiation of the calcareous nannofossil group, the fasciculiths, whereas the Thanetian GSSP corresponds to the base of magnetochron C26n (Figure 48).

For the Eocene, the GSSP for the base of the Ypresian Stage has been choosen and ratified in Dababiya, Egypt. It is located at the base of a lithostratigraphic unit where the base of the so-called Carbon Isotope Excursion (CIE) is recorded. First appearances of planktonic foraminiferal species *Acarinina sibaiyaensis* and *Acarinina africana* and nannoplankton species *Discoaster anartios* are the second markers for this GSSP (Aubry *et al.*, 2007) (Figure 49). Lutetian GSSP is another ratified GSSP. It is recorded in the

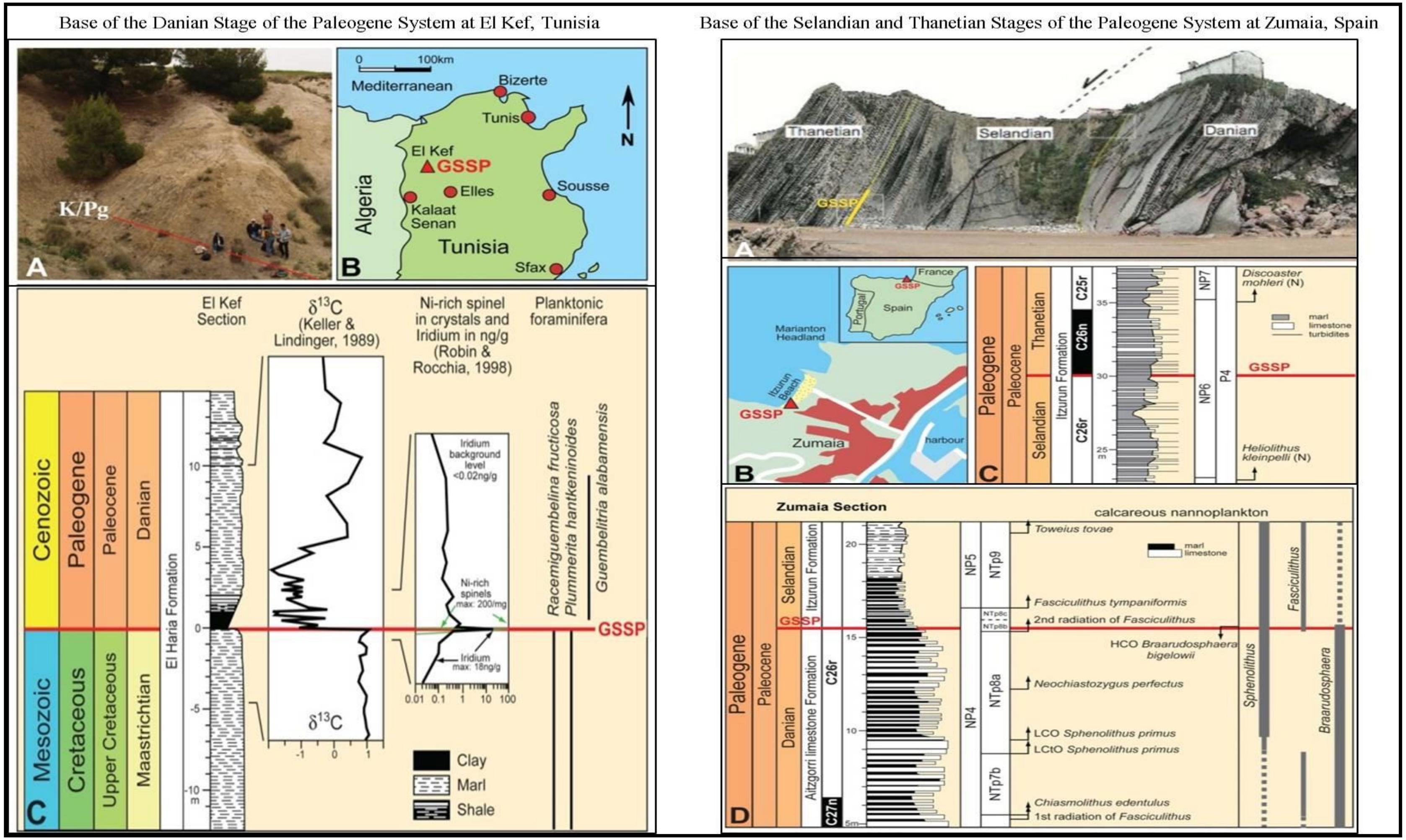

Figure 48 Paleocene GSSPs (Gradstein *et al.*¸ 2012)

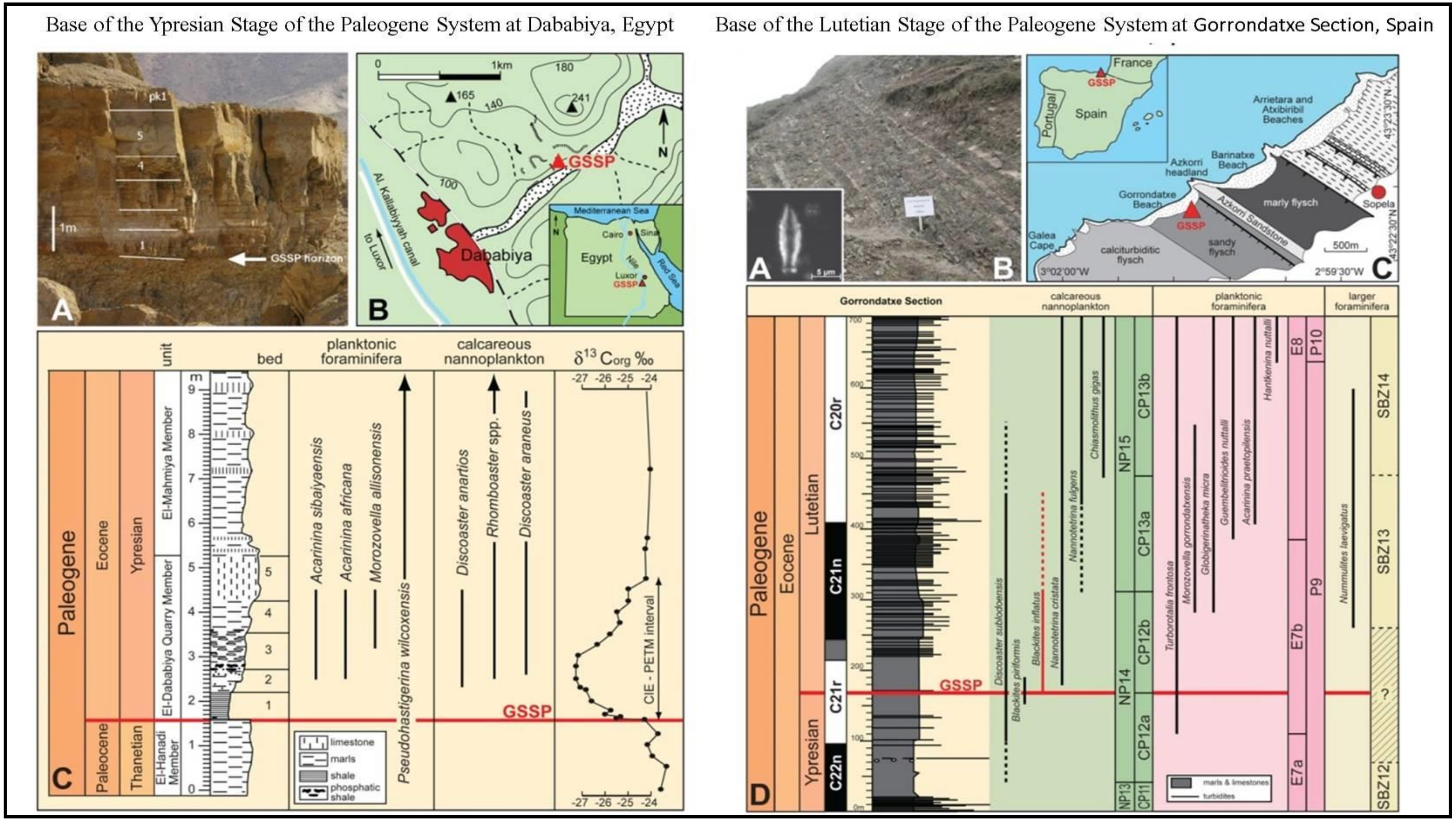

Figure 49. Eocene GSSPs (Gradstein *et al.*, 2012)

Gorrondatxe Section, Spain by the first appearance of calcareous nannofossil *Blackites inflatus* (Molina *et al.*, 2011) (Figure 49). GSSP for the base of the Bartonian Stage is in the Contessa highway section near Gubbio, Italy choosen by the last appearance of calcareous nannofossil *Reticulofenestra reticulata*, whereas the GSSP for the base of the Priabonian stage is in the Alano section, Italy, notified by the first appearance of the calcareous nannofossil *Chiasmolithus oamaruensis* (Gradstein *et al.*, 2012).

In this study, Paleocene is subdivided into two intervals as Lower and Upper Paleocene, while the Danian, Selandian and Thanetian stages are indirectly correlated with our planktonic foraminiferal zonation by using the literature (Olsson *et al*., 1999). On the other hand, the base of the Lutetian is recognized by the first appearances of hantkeninids or *Globigerinatheka subconglobata* and the base of the Priabonian is marked by the last appearance of the endemic Middle Eocene globigerinids. Lutetian-Bartonian boundary isn't defined and it is located within the *Globigerina eoceanica* Partial Range Zone, when the present data is correlated with the standard zonations (Berggren *et al*., 1995; Berggren and Pearson, 2005; Pearson *et al.*, 2006).

The most important boundary in this study is the Paleocene-Eocene boundary. As the Paleogene is a transitional period between the greenhouse world during the Cretaceous and the icehouse world during the Neogene, the climate changes during the Paleogene are of great interest. Paleocene-Eocene Thermal Maximum Event (PETM) is the most important event that has been was identified across the boundary with a negative shift in the carbon isotope (Carbon Isotope Excursion=CIE) and 4-8ºC increase in the global temperatures (Lu et al., 1998; Iakovleva et al., 2001; Cramer and Kent, 2005; Ortiz et al., 2008; Höntzch et al., 2011). Radiometric dating from the marine ash layers and orbital tuning of marine sediments provided the age of the onset of the CIE as 56.011–56.293 Ma (McInerney and Wing, 2011).

Many causes were presented for such an event, such as contribution of the release of methane from gas hydrates and terrestrial carbon sources obtained by the burning of peat and coal deposits (D'haenens *et al.*, 2012; Khozyem *et al.*, 2013). One possible cause of the "bolide summer" was indicated as an comet impact, marked by the increasing iridium anomalies reported at Zumaya, Spain and Goriska Brda Section, Slovenia (Cramer and Kent, 2005).

The dissolution interval at the onset of the PETM is one of the features that characterize the event worldwide and it is proposed to be caused by a progressive shoaling of the lysocline/CCD (Zachos *et al*., 2005).

Another global event across the boundary is the Benthic Foraminiferal Extinction Event (BFEE) (Thomas *et al.*, 1998). However, the exact position of BFEE is thought to be not clear in most of the PETM sections because of a Carbonate Dissolution Interval (CDI), along which only agglutinated benthics can be observed (Giusberti *et al*., 2009).

PETM is estimated as lasted in about 200 ka with different data changing between 120-220 ka (McInerney and Wing, 2011). The authors suggested different recovery times in different studies changing between 42 ka and 112 ka determined depending on the sedimentation rates of the sections.

5.2. CORRELATION OF THE PALEOCENE-EOCENE BOUNDARY SECTIONS AROUND THE WORLD

Numerous sections were studied all over the world in terms of the understanding of Paleocene and Eocene biostratigraphy with the emphasis on the Paleocene-Eocene boundary (Figure 50). Besides the GSSP in the Dababiya Section, Egypt; the most studied boundary sections are Zumaya, Alamedilla, Campo and Caravaca sections in Spain (Canudo *et al.*, 1995; Ortiz, 1995; Schmitz *et al*., 1997; Orue-Etxabarria, 2001; Molina *et al*., 2003; Alegret *et al*., 2009), Forada Section in Italy (Luciani, 2007), Untersberg Section in Austria (Egger *et al.*, 2005), Polish Outer Carpathians (Waskowska, 2011), Gebel Aweina Section in Egypt (Sperjer and Schmitz, 1998), Tunisia (Zili and Zaghbib-Turki, 2010; Stassen *et al*., 2012), Sokolovsky Quarry Section in Kazakhstan (Iakavlava *et al*., 2001). Besides the onshore studies, also many DSDP and ODP section were studied for investigating the boundary. Kaiho *et al*. (2006), Petrizzo (2007) and Takeda & Kaiho (2007) studied Shatsky Rise and Site 1209, Site 1210, Maud Rise and Allison Guyot. Bay of Biscay (N. Atlantic Ocean) was studied by Pardo *et al*. (1997).

The properties, such as the thickness of the studied intervals, number of samples used in different studies, lithologies on the boundary, thickness of the $CaCO_3$ dissolution zone and elevation of this zone from the boundary, vary in these sections (Table 24). But the common feature in these sections is the position of the boundary. It is mostly situated within a clayey interval and the studied samples were collected with very closed interval. The Paleocene-Eocene boundary sections around the world are discussed in the following sections. As mentioned in the first chapter, Introduction, one of the main purposes of this study is to delineate the Paleocene-Eocene boundary in the studied sections, to investigate paleontological characteristics such as the major changes in the diversity and/or abundance of foraminifera. The Erfelek and the Kaymakam Kayası sections are the sections on which the boundary is recognized by using the planktonic foraminifera. On the other hand, the boundary interval through the Erfelek Section was resampled with very narrow interval. In addition to the planktonic foraminifera, the benthic foraminiferal assemblages have been also analyzed in detail through the Erfelek 1 section. In order to understand the environmental conditions during this time interval, some XRD analyses (whole rock and clay minerals) have been carried out through the boundary.

5.2.1. Dababiya Section, Egypt

Dababiya Section is the GSSP section for the base of the Eocene (Dupuis *et al*., 2003; Berggren and Ouda, 2003; Ernst *et al.*, 2006; Aubry *et al.*, 2007). Here, the Paleocene-Eocene boundary was defined at the base of the Carbon Isotope Excursion (CIE).

The boundary is defined within the Esna Formation (Aubry *et al.*, 2007). The Paleocene-Eocene boundary is between the El Hanadi and Dababiya Quarry members of the Esna Formation marked by a clay level (Figure 51).

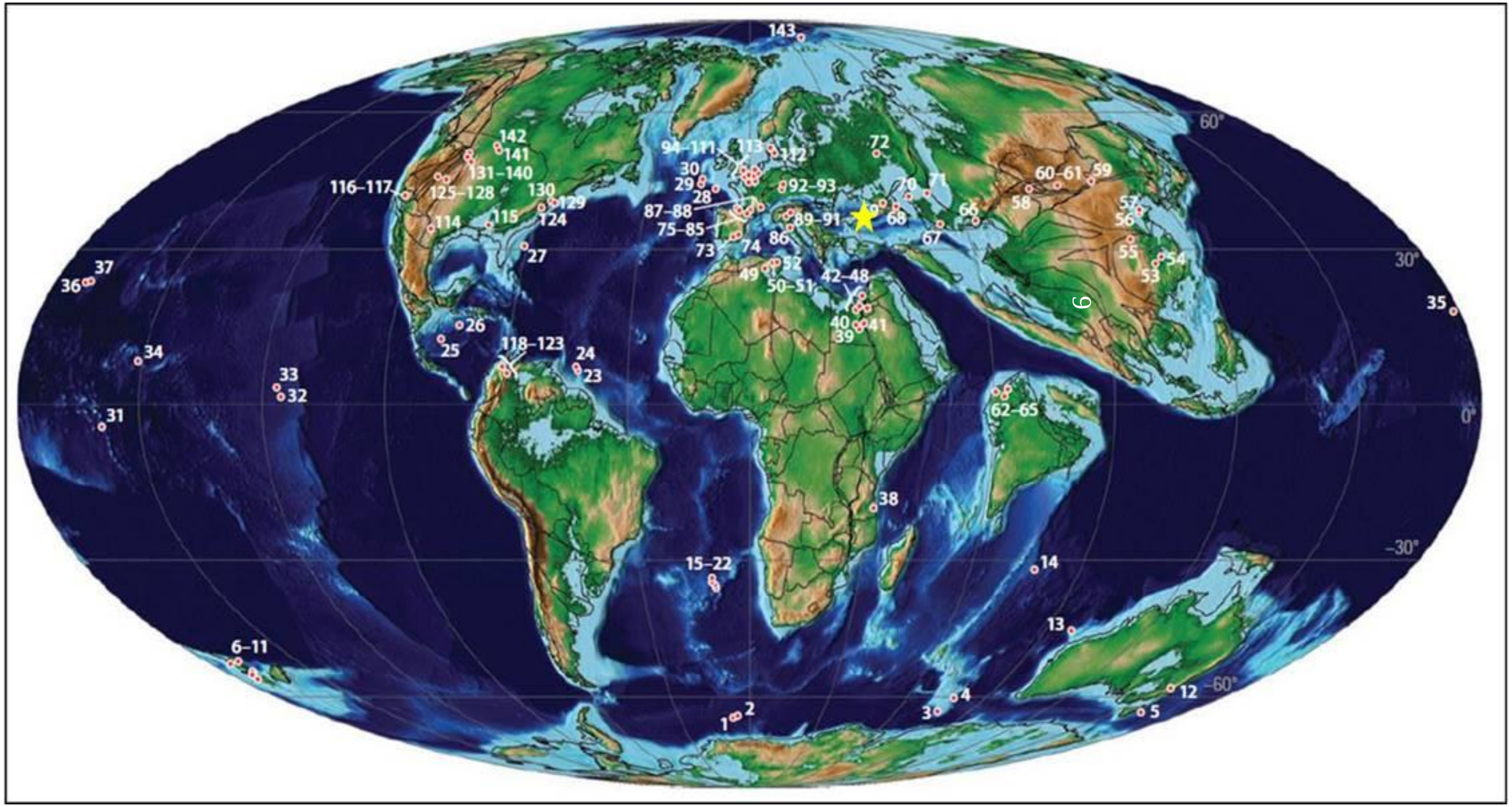

Figure 50. Global paleogeographic map for 56 Mya with marine and continental sites where the Paleocene-Eocene boundary interval has been studied. Yellow star indicates the possible position of the study area. Red circles are indicating the locations. Site numbers are keyed to Supplemental Table 1 of McInerney and Wing (2011).

Table 24. The statistics on the Paleocene-Eocene boundary sections around the world.

Name of the section	Location	Thickness of studied interval	Number of samples	Thickness of P5 Zone (m)		Lithology on the boundary	Thickness of $CaCO_3$ dissolution interval	Elevation of dissolution interval from P-E boundary	Reference
				Paleocene	Eocene				
Dababiya	Egypt	6.5 m	32	1.5	5	Clay		0 m	Ernst et al. (2006)
Wadi Nukhul	Egypt	330 cm	25	1.1	1.2	Clay	10 cm	0 m	Khozyem et al. (2013)
Sidi Nasseur	Tunisia	19 m	96	10	9	Shale	~80 cm	- 1.5 m	Stassen et al. (2012)
Wadi Mezaz	Tunisia	18 m	47	6.5	11.5	Shale	5 m	- 1.5 m	Stassen et al. (2012)
Contessa Road	Italy	90 cm	33			Marl	13 cm	-5 cm	Guisberti et al. (2009)
Forada	Italy	17 m	102			Clay marl	40-50 cm	0 m	Luciani et al. (2007)
Alamedilla	Spain	32 m		7.5	6	Clay	~50 cm	0 m	Molina et al. (1999)
Zumaya	Spain	42 m		13	19.5	Clay	4 m	0 m	Molina et al. (1999)
Trabakua Pass	Spain	26 m	146	9		Clay	3 m	-1.2 m	Bolle et al. (1998)
Ermua	Spain	45 m	90	5		Clay	25 m	-15 m	Bolle et al. (1998)
Campo	Spain	270 m	119	120		Calcareous lutite			Orue-Etxebarria et al. (2001)
Untersberg	Austria	40 m	27 (19 for forams)	4	29	Marly claystone	6 m	0 m	Egger et al. (2005)
ODP Site 689	S Atlantic Ocean	5 m	154	0.60	4.4	Ooze/chalk	20 cm	0 m	Kelly et al. (2012)
ODP Site 690	S Atlantic Ocean	5.11 m		0.59	4	Ooze/chalk	17 cm	1 cm	Kelly et al. (2012)
ODP Site 738	Antarctic Indian Ocean	Total of ~100 m with 30% recovery	67	Upper part of AP4 Zone correlated with M.velascoensis Zone = 15 m		Clay	< 20 cm	0 m	Lu and Keller (1993)
ODP Site 1209	Pacific Ocean	60 cm	82	0.15	1.2	Clay	$\delta 13C\downarrow = 6$ cm	0 m	Petrizzo (2007)
ODP Site 1210		60 cm		0.125	1.2		$\delta 13C\downarrow = 7$ cm		

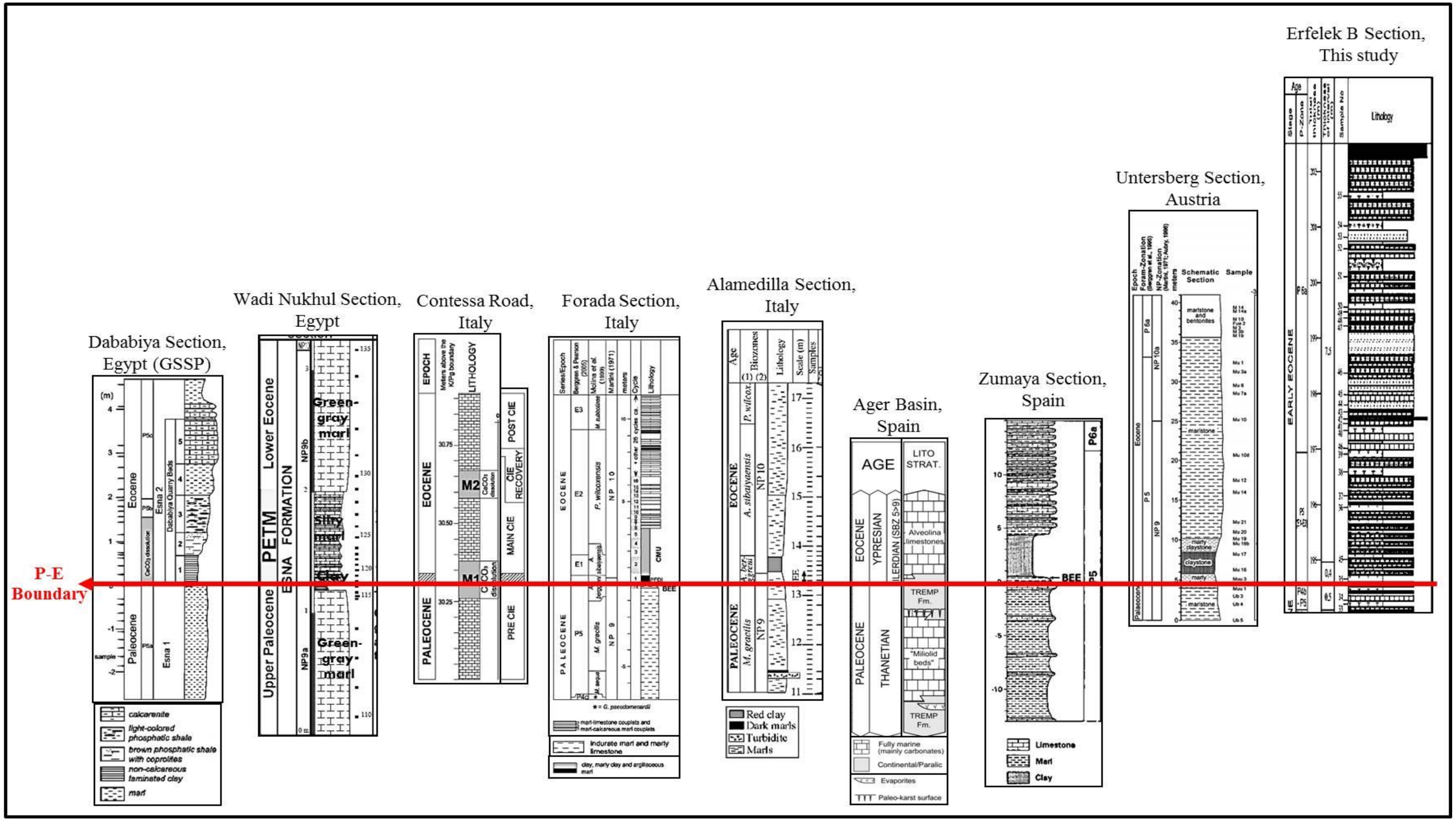

Figure 51. Lithological correlation of the boundary sections (Ernst *et al*., 2006; Khozyem *et al*., 2013; Giusberti *et al*., 2009; Luciani *et al*., 2007; Alegret *et al*., 2009; Schmitz *et al*., 1997; Egger *et al*., 2005).

5.2.1.1. Planktonic Foraminifera Studies

Many different biozonations have been established for the Paleocene-Eocene interval based on the first or last occurrences of the planktonic foraminifera (Bolli, 1957; Blow, 1979; Berggren and Miller, 1988; Berggren *et al*., 1995; Arenillas and Molina; 1996; Molina *et al*., 1999; Olsson *et al*., 1999; Berggren and Pearson, 2005; Pearson *et al*., 2006) (Figure 52).

Studying the GSSP for the base of Eocene in Dababiya Section, Egypt; Berggren and Ouda (2003) reported that the first occurrence of *Acarinina wilcoxensis* can be used as a marker for the correlation of the boundary. An excursion taxa related to carbon isotope excursion was mentioned by Aubry *et al*. (2007). *Acarinina africana, Acarinina sibaiyaensis* and *Morozovella allisonensis* belong to these short ranging taxa. In the Dababiya Section, the planktonic foraminiferal assemblage is mostly said to be absent or rare except the 30% of the total range of the CIE/PETM interval. However, the authors mentioned a high abundance of the excursion taxa in a 1 m thick interval, which also has high clay content.

Ernst *et al*. (2006) indicated the dominancy of *Morozovella* and *Subbotina* species during Late Paleocene. For the acarininids, the Paleocene taxa weren't abundant as much as morozovellids and subbotinids. However, during the lower CIE interval with the absence of benthics and other planktonic foraminifera, acarininids were observed with a peak in their abundance mainly with the dominancy of *Acarinina sibaiyaensis*. Middle CIE was marked by the appearance of *Morozovella allisonensis* and the shallow-dwelling *Morozovella* and *Acarinina* species were dominated in this interval. The diversity increases during the upper CIE with a decrease in acarininids and an increase in morozovellids and subbotinids. Especially the deep-dwelling taxa were abundant during the upper- and post-CIE intervals.

5.2.1.2. Benthic Foraminifera Studies

Benthic foraminiferal extinction event (BFEE) is an important global event on the Paleoene-Eocene boundary. Therefore, the planktonic foraminiferal biozonations of the Dababiya Section are also correlated with benthic foraminiferal events (Alegret *et al.*, 2005; Alegret and Ortiz, 2007).

The benthic foraminifera indicate the outer shelf environment represented by a common Midway – type fauna. The boundary is marked with the last occurrences of *Angulogavelinella avnimelechi*, *Anomalinoides aegyptiacus* and *Neobulimina farafraensis* by Alegret et al. (2005). Alegret and Ortiz (2007) also record the last occurrence of *Angulogavelinella avnimelechi* at the base of CIE and correlated it with the main phase of benthic foraminiferal extinction in the deep water. Ernst et al. (2006) mentioned an extinction rate of 40-65 % for the cosmopolitan deep sea benthic foraminifera of Paleocene, which was thought to be related to an unconformity or carbonate dissolution interval. Aubry et al. (2007) also mentioned an extinction of 50% of the Paleocene deep water benthic foraminifera, such as *Stensioeina beccariiformis, Angulogavelinella avnimelechi, Aragoniavelascoensis, Neoflabellina jarvis, Osangularia velascoensis* and *Pullenia coryelli*.

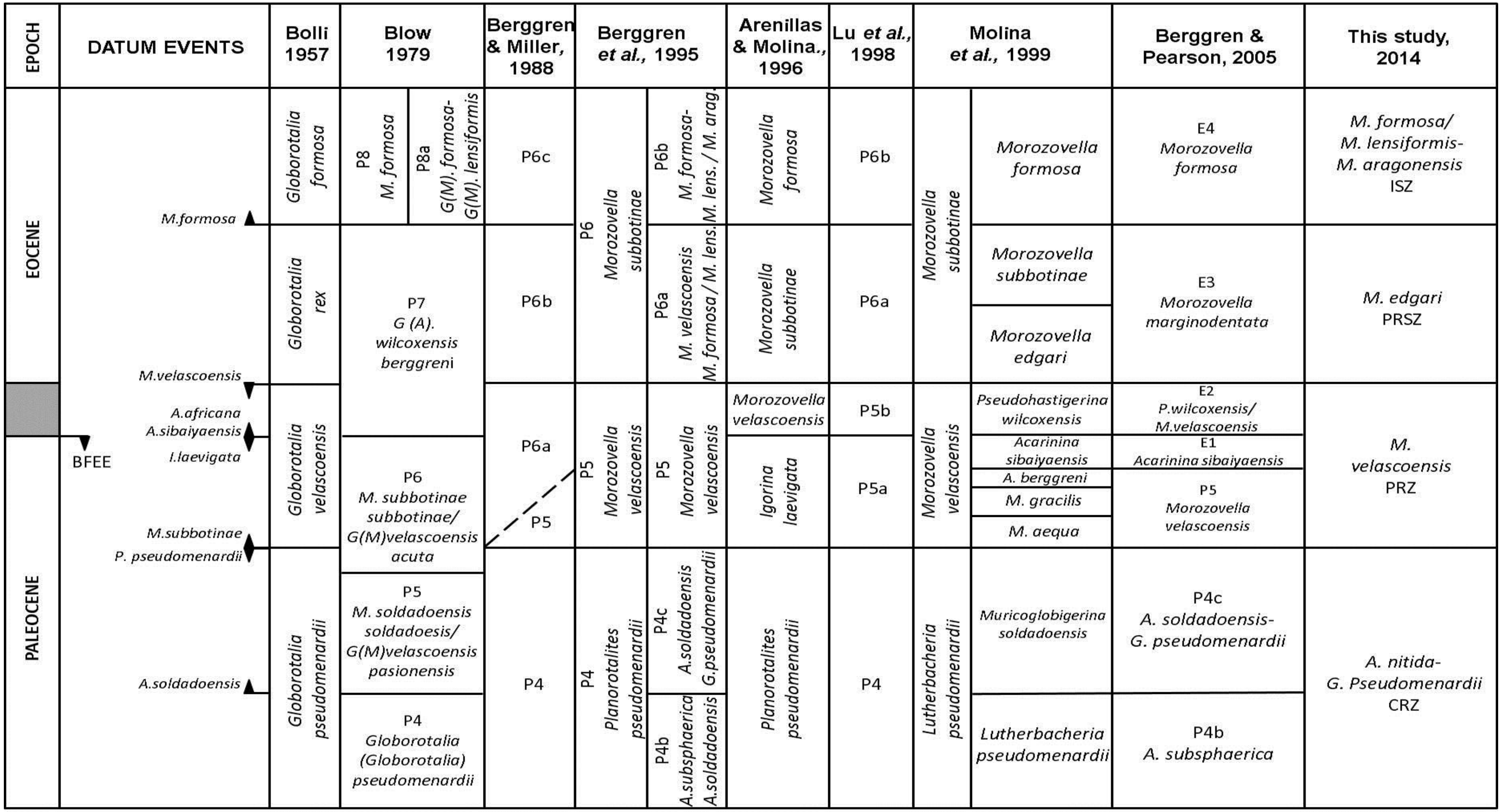

Figure 52. Comparison of different biozonations for the Paleocene-Eocene transition.

This portant turnover was stated to be just before the onset of the carbon isotope excursion.

Because of the dissolution, the lower part of the CIE interval is barren of fossils with the exception of an acme of the agglutinated foraminifera at the lower part of DQB 1 and the high abundance of a few other calcareous benthic species in the upper parts of this interval (Ernst *et al*., 2006; Alegret and Ortiz, 2007). This low diversity-high abundance of foraminifera was evaluated as the presence of a stressed environment with eutrophic conditions and anoxia.

The benthic recovery is said to be placed 2.5 m above the Paleocene-Eocene boundary in this section (Alegret and Ortiz, 2007). There are also a number of diversified small sized calcareous benthic species after the dissolution interval at the base of Eocene (Alegret *et al*., 2005; Ernst *et al.*, 2006). Extremely high abundance of *Lenticulina* spp. and buliminids during lower Eocene shows the presence of abundant food supply and/or low oxygenation. On the other hand, among the agglutinated benthic foraminifera, especially trochamminids, *Bathysiphon* spp., *Recurvoides* spp. and *Haplophragmoides* spp., are more abundant all through the section. They are opportunistic taxa and their high abundance is thought to express the environmental stress conditions with low oxygen and changes in food supply. Furthermore, the agglutinated forms are more abundant than the calcareous benthics during the PETM. In this study, along the interval that is almost barren of benthic foraminifera ($CaCO_3$ dissolution interval), genus *Acarinina* has a peak in abundance.

Alegret and Ortiz (2007) similarly studied the same section for investigating the causes of benthic foraminifera extinction from bathyal and abyssal depths. The authors mentioned about the high relative abundance of agglutinated benthic foraminifera probably because of the calcium carbonate dissolution with the onset of CIE. They also stated that dissolution can’t be the only mechanism for the low abundance of calcareous benthics when the presence of diversified acarininid taxa is considered within CIE interval.

5.2.1.3. Mineralogical Studies

The most important studies emphasize the mineralogical changes and sudden shifts in the isotope values; especially the $\delta^{13}C$ isotope, along the Paleocene-Eocene boundary.

GSSP section of Paleocene-Eocene boundary was studied by Ernst *et al*. (2006). As the illite-smectite mixed-layer minerals were said to be dominated along the section, chlorite-smectite mixed-layers had a peak and quartz content was said to be at its highest values during the lower part of CIE in this section. The authors mentioned a concentration of fish remains and high potassium values. In terms of the clay mineral contents, the domination of illite-smectite was inferred as the presence of warm and arid climate with the fluctuating humidity levels. Oppositely, the smectite content was progressively decreasing during the upper part of CIE. Post-CIE values indicated an increase in kaolinite with low amounts of chlorite and illite. The authors commented on the increase of kaolinite during the PETM related to the global warming and humidity. The authors also commented on the $\delta^{13}C$ isotope data and evaluated the sudden shift of $\delta^{13}C$ by an unconformity with the absence of low stand (LST) deposits in the section.

The Dababiya Quarry Core (DQC) Section, a second section near the GSSP, was examined in terms of the mineralogical and geochemical changes in Dababiya, Egypt (Soliman *et al*., 2011). The mineralogical analyses showed a carbonate dissolution interval at the base of Eocene and an abrupt increase in illite, chlorite-smectite mixed layer and kaolinite just above this dissolution interval with the beginning of PETM. Soliman *et al*. (2011) also mentioned an enrichment of fish remains about 30-45 cm above the P/E boundary which is related with the potassium concentrations in this interval.

5.2.2. Wadi Nukhul Section, Sinai, Egypt

Close to the GSSP section of the Paleocene-Eocene boundary, Wadi Nukhul Section is in the more distal part of the basin, i.e. the upper bathyal environment with a 500-600 m paleodepth (Khozyem *et al*., 2013). Upper Paleocene-Lower Eocene deposits are included to Esna Formation. In this section, the base of the Eocene is represented with the 10 cm thick clay-rich interval (Figure 51). The authors studied the calcareous nannoplanktons and mineralogical content of this section and noticed the carbonate dissolution within the clay-rich unit at the boundary. Moreover, the sudden decrease of $\delta^{13}C$ with the sudden change in the lithology is evaluated as a hiatus on the boundary.

5.2.2.1. Mineralogical Studies

In this section, the base of Eocene is a condensed clay rich layer that is a dissolution interval, barren of fossil content (Khozyem *et al*., 2013). However, the authors mentioned an increased in the fish remains, especially during the lower parts of PETM; just above the P/E boundary. This is explained by the increase in eutrophic conditions with highest potassium values and increase in the primary productivity correlated to the Transgressive System Tracts (TST).

The negative shift in the $\delta^{13}C$ isotope, decrease in calcite and smectite values and the increase in kaolinite, phylosilicates and quartz values are mentioned along the PETM interval. This is related to the short period of warm and humid conditions on the Paleocene-Eocene boundary, which is mentioned as Paleocene-Eocene Thermal Maximum (PETM). The variables turned into their original pre-PETM values after the PETM interval. Furthermore, the authors stated that there is a hiatus through most of the sections where the boundary has been examined and this hiatus can be marked by the abrupt change of the isotopic and mineralogic values.

5.2.3. Qreiya (Gebel Abu Had) Section, Upper Nile Valley, Egypt

The boundary is in the lower part of the Esna Formation (Esna Shale) like the other sections in Egypt (Berggren and Ouda, 2003). In the Qreiya Section, the uppermost Paleocene corresponds to the Esna Shale 1, whereas the PETM interval corresponds to the basal part of the Esna Shale 2. P5b Subzone is correlated with the PETM interval.

5.2.3.1. Planktonic Foraminifera Studies

For the planktonic foraminiferal assemblage, the diversification of acarininids and igorinids is observed just below the CIE interval (Berggren and Ouda, 2003). By the onset of CIE, the authors observed the decrease in abundance, diversity and size of the specimens. The lowermost part of the CIE interval consists of 30 cm thick clayey dissolution interval that is lack of foraminifera and rich in fish fragments. This level is also correlated with the clayey horizon of the Dababiya Quarry Beds. The laminated phosphatic shales with the first occurrence of *Acarinina sibaiyaensis* with low abundance of morozovellids and common fish fragments overlie the clayey interval. In the uppermost part of the CIE interval, the acarininids decrease in abundance, while the abundance of morozovellids and subbotinids increase especially in the calcarenite levels.

5.2.3.2. Benthic Foraminifera Studies

By means of the benthic foraminifera, both neritic water Midway fauna and deep water Velsco fauna are present below the boundary (Berggren and Ouda, 2003). The benthic foraminifera were extinct with the onset of the PETM and reappear in the uppermost part of the CIE interval.

5.2.4. North Gunna Section, Western Desert, Egypt

Covering an interval from Maastrichtian to Early Eocene, the Paleocene-Eocene boundary takes place within the Esna Formation along this section (Abdel-Kireem and Samir, 1995). The lowermost part of the Esna formation is at the top of the Paleocene *Morozovella velascoensis* Zone and the base of the Eocene section of the formation is marked with the *Morozovella subbotinae* Zone.

5.2.5. Sidi Nasseur and Wadi Mezaz Sections, Tunisia

Late Paleocene-Early Eocene is within the El Haria Formation, consists of dark gray shales and marls, in Sidi Nasseur and Wadi Mezaz sections (Stassen *et al*., 2012). The boundary is within a shale unit in both sections.

5.2.5.1. Benthic Foraminifera Studies

Stassen *et al*. (2012) studied Sidi Nasseur and Wadi Mezaz sections in Tunisia to observe the faunal changes in the shallow marine benthic foraminifera. In this study, the authors discussed the pre-PETM, PETM and post-PETM intervals. They suggested a diversified benthic fauna before the PETM with a rich calcareous and agglutinated benthic assemblage, whereas the planktonic foraminiferal diversity was poor. On the other hand, agglutinated benthic foraminifera and deep dwelling lagenids and buliminids became dominant during the PETM, which is stated to indicate the dysoxic, stressed conditions on the onset of PETM. The post-PETM taxa contains calcareous benthic taxa, such as *Lenticulina* species, and agglutinated taxa is rare in this interval. The authors also mentioned the sedimentation rates.

5.2.6. Contessa Road Section, Italy

Giusberti *et al.* (2009) examined a 90 cm thick interval across the Paleocene-Eocene boundary in terms of the main faunal events in benthic foraminiferal assemblage and environmental conditions in the Contessa Road Section. In this interval, there are 2 marl units, which are mentioned to show $CaCO_3$ dissolution. The Paleocene-Eocene boundary is within the first marl unit.

5.2.6.1. Benthic Foraminifera Studies

Giusberti *et al*. (2009) studied the benthic foraminifera across the boundary with 24 samples from a 90 cm thick section at Contessa Road, Italy (Figure 51). The authors distinguished 8 benthic foraminiferal assemblages in this section. The Paleocene pre-extinction assemblage is the lowermost one, consisting of a highly diversified taxa indicating low oxygen and high food supply conditions. Just below the P/E boundary, peak of Paleocene extinction taxa is observed with an increase in *Cibicidoides* spp. and anomalinids. An important duration is the $CaCO_3$ dissolution interval within the first marl unit, of which the assemblage is dominated by *Glomospira* spp., followed by a domination of buliminids and genus *Oridorsalis* at the top of this marl. The increase in the abundance of opportunistic *Nuttallides* is evaluated by the presence of oligotrophic environmental conditions with low food supply. The glomospira-peak has also been indicated in the second marl unit representing another $CaCO_3$ dissolution interval. The assemblage is dominated by the buliminids and lenticulinids during the post-CIE inverval that shows the unstable sea floor conditions with increasing food supply.

5.2.6.2. Mineralogical Studies

Giusberti *et al*. (2009) marked the $CaCO_3$ dissolution in a 12 cm thick marl unit, where the calcite percentage decreases down to 33% and the quartz content increases to 9% at the base of CIE. In this interval, the quartz content increases conversely and barite content also increases progressively. The carbon isotope has a negative shift at the uppermost part of this marl unit, stays low during the main CIE interval and shows a positive shift after the CIE, where the authors called as CIE recovery interval.

5.2.7. Forada Section, Italy

The Forada section is a deep water hemipelagic section considered to be close to continental depositional settings (Agnini *et al.*, 2007). Scaglia Rossa Formation is studied in this section across the boundary (Figure 51, Table 24). A clay marl unit is recorded at the

Paleocene-Eocene Boundary that is at the base of thin (about 0.5 m thick) marl within the uppermost part of P5 biozone. This marl is overlain by 3.4 m thick clay marl unit of which the $CaCO_3$ content changes between 0-42% and the quartz content increases controversially. The Paleocene-Eocene boundary coincides with the benthic foraminiferal extinction event.

5.2.7.1. Planktonic Foraminifera Studies

The planktonic foraminiferal turnover of the PETM event was investigated through the Forada section, northern Italy (Luciani *et al*., 2007). In this study, the Paleocene-Eocene boundary is in the uppermost part of the P5 Zone and it doesn't coincide with the P5-E1 zone boundary, which is 40-50 cm above this interval. The paleoenvironmental changes and their correspondence to the carbon isotope excursion were discussed and main planktonic foraminiferal changes during the inferred paleoenvironmental conditions were indicated. The authors examined an increase in the species composition and relative abundance of genus *Acarinina* and pointed out the similarity all around the Tethys. In this study, *Morozovella, Acarinina* and *Igorina* are indicated as surface dwellers reflecting the warm oligotrophic water conditions, whereas *Subbotina, Parasubbotina, Globanomalina* and *Planorotalites* are deep water genera indicating the cold and eutrophic oceans.

5.2.8. Zumaya Section, Spain

Zumaya section is the second most supported section among the candidate sections for the determination of the GSSP of the base of the Eocene (Aubry *et al.*, 2007). This deep marine section mainly consists of marls and calcitic sandstones. The Paleocene-Eocene boundary is at the base of 4 m thick clay layer. Acarininid peak and carbon isotope excursion is within this clay layer, of which the base is marked by the benthic foraminiferal excursion event.

5.2.8.1. Planktonic Foraminifera Studies

The Late Paleocene is indicated with a 25-40% abundance of the warm water taxa in this section (Pardo *et al.*, 1999). There are two peaks in the warm/cool ratio at the base of the Eocene; one of which is coinciding with the acarininid incursion and the other peak is the result of the increase in the abundance of morozovellids and igorinids. Molina *et al.* (1999) recognized the dominance of the morozovellids in the Eocene part of this section.

5.2.9. Alamedilla Section, Spain

Upper Paleocene sequence of the Alamedilla Section is mainly composed of marls that are followed by a 30 cm thick red clay layer (Molina *et al*., 1999; Alegret *et al*., 2009). The base of this clay layer marks Paleocene-Eocene boundary and the benthic foraminiferal extinction event. The Eocene sequence consists of marly limestones in this section.

5.2.9.1. Planktonic Foraminifera Studies

Lu *et al.* (1998) sampled the Alamedilla section, which is spanning 2.5 Myr across the boundary. Their planktonic foraminifera zonation covers P4-P6b interval (Figure 51, 52). In this study, planktonic foraminifera were separated into different morpho-guilds within each genera and the life span of each morpho-guild has been discussed. The authors concluded that there was a saltation event near PETM bounded by two stasis intervals. Paleocene was evaluated by a *Morozovella*-dominated assemblage whereas Early Eocene became *Acarinina*-dominated. Pardo *et al.* (1999) mentioned the dominance of the warm water taxa up to about 70% during the Late Paleocene, such as acarininids, morozovellids and igorinids. The authors mentioned an increase in warm/cool ratio coinciding with the clay layer and benthic foraminiferal extinction event. Molina *et al.* (1999) mentioned an Acarinina peak following the dissolution interval in the clay layer coinciding with the carbon isotope excursion.

5.2.10. Tremp-Graus Basin, Spainish Pyrenees

Pujalte *et al*. (2014) studied 5 different sectors from south east to northwest in this basin, which comprises continental to shallow marine facies during Danian-Early Ilerdian. Esplugafreda and Claret sectors are in the landward of the basin, whereas Serraduy Sector is a transitional sector and Campo and Ferrera sectors are placed seaward.

In this basin, the Paleocene-Eocene boundary takes place within the Claret Formation. The authors suggested a sea level fall and formation of the incised valleys before the PETM. This pre-PETM sea-level fall is said to take place also in other basins in southern Pyrenees, North Sea area, Australian Alps and Egypt. A transgression was observed in the basin after this sea-level fall from Late Thanetian to Ilerdian and the whole basin is covered by a marine Ilerdian sequence after the PETM.

5.2.11. Trabakua Pass and Ermua Sections, Spain

The Trabakua Pass Section is another candidate for the GSSP of the Paleocene-Eocene boundary (Bolle *et al*., 1998). It is a 26 m thick hemipelagic section. The section mainly consists of limestone-marl alternation that is interrupted by 3 m thick greenish to reddish clay layers in the middle part of the section. Ermua Section is correlated with the Trabakua Pass Section by Bolle *et al*. (1998). This is a 45 m thick turbiditic section, principally including coarse grained sandy calcarenites that are rich in detrital materials changing into hemipelagic marls towards the top of the section.

5.2.11.1. Planktonic Foraminifera Studies

The Trabakua Pass Section covers P4-P7 zones (Bolle *et al*., 1998). The Paleocene-Eocene boundary in the Trabakua Pass Section is placed 1.2 m above of a clay layer and it coincides with the P5-P6 zone boundary in this study, marked by the last occurrence of *Morozovella velascoensis*. The Ermua section covers the interval from P4 Zone to P6b

Subzone. The Paleocene-Eocene boundary is within a clayey layer, coinciding with the P5-P6 zone boundary (Bolle *et al*., 1998).

Oure-Etxebarria *et al*. (2001) correlated these two sections with the Campo Section. They used the siliciclastic intercalations in the sections, first appearance datum of calcareous nannoplankton *Discoaster multiradius* and last appearance datum of planktonic foraminifera *Morozovella occlusa* as the reference datums to define the lower and upper boundaries of the P5 Zone in this study.

5.2.12. Untersberg Section, Austria

Untersberg Section is a 40 m thick section covering P5-P6a zones (Egger *et al*., 2005) (Figure 51, Table 24). This section comprises the bathyal slope deposits belonging to Gosau Group. The Paleocene sequence consists of marlstones. The Paleocene-Eocene boundary is within the 2 m thick marly claystone unit. The lithology grades into claystone to marly claystone. The section was studied in terms of planktonic and benthic foraminifera, calcareous nannoplanktons and radiolaria, besides the bulk rock and clay mineral compositions.

5.2.13. Jaisalmaer Basin, Rajasthan, India

The boundary has been studied through Tanot-1 well by Kalia and Banerjee (1995) and Kalia and Kintso (2006). Paleocene-Eocene sequence is represented by inner-middle shelf deposits. The boundary is located within the Laki Formation at the base of a 3 m-thick sandy-clay horizon, which is overlain by marls rich in planktonic foraminiferal excursion taxa.

5.2.13.1. Planktonic Foraminifera Studies

The base of Eocene is marked with P5b Subzone limited by the total ranges of *Acarinina sibaiyaensis, Acarinina africana, Morozovella allisonensis* and *Morozovella rajasthanensis*. The upper part of this interval is rich in an acarininid-dominated planktonic foraminiferal assemblage (Kalia and Kinstso, 2006).

5.2.14. Kaurtakapy Section, Kazakhstan

Being a shallow epicontinental sea in the northern branch of the Neotethys Ocean, 23 m thick section has been studied in Kazakhstan (Pardo *et al.*, 1999) and the sequence, consisting of sandy chalks followed by sandy marls and marls, has been sampled. The Paleocene-Eocene boundary is at the top of the 10 cm thick brown clay layer, which comprises abundant fish debris and marcasite nodules.

5.2.14.1. Planktonic Foraminifera Studies

Pardo *et al.* (1999) studied an interval including 3 biozones from P4 to P6. The dominance of subbotinids, cold water indicators, with an average of 40-50 % through the Late Paleocene-Early Eocene interval is recorded in the section. This is thought to be related with the location of the section. The authors mentioned an increase in acarininids in the uppermost part of P5a Subzone that is the uppermost Paleocene, where the abundance of morozovellids and subbotinids decreases. On the other hand, within P5b Subzone, there is a sharp increase in the abundance of warm water dwellers, such as *Acarinina africana, Acarinina sibaiyaensis, Igorina convexa, Morozovella velascoensis* and *Morozovella gracilis*, while the abundance of cold water subbotinids decreases.

5.2.15. ODP Site 738, Kerguelen Plateau, Antarctic Indian Ocean

This section forms by the 30% recovery of 10 cores (core 4R to 14R) with a total thickness of ~100 m (Lu and Keller, 1993). The main lithology of the cores is calcareous nannofossil-foraminiferal chalk. The authors observed a 20 cm thick clay layer and mentioned carbonate dissolution at the base of the clay near the boundary. The Paleocene-Eocene boundary is between AP4 and AP5 zones in this study. The authors evaluated the sudden change in the lithology from chalk to clay as a hiatus in the boundary.

5.2.15.1. Planktonic Foraminifera Studies

The AP4 Zone is correlated with the total interval of P4 to P6a zones of Berggren and Miller (1998) and *P.pseudomenardii* and *M.velascoensis* Zone of Toumarkine and Luterbacher (1985). Therefore, marked by the last occurrence of *Morozovella velascoensis*, the boundary should be at a lower position with respect to the recent studied after Berggren *et al*. (1995).

5.2.16. ODP Sites 689 and 690, Weddell Sea, S Atlantic Ocean

These bathyal sections, consisting of foraminifer-nannofossil ooze and chalk, are located in the Maud Rise, South Atlantic Ocean (Kelly *et al*., 2012). The faunal analyses of the benthic foraminifera record a mid-bathyal environment for ODP Site 689 and a lower-bathyal environment for ODP Site 690.

5.2.16.1. Planktonic Foraminifera Studies

Kelly *et al*. (2012) evaluated the boundary from ODP sites 689 and 690 in the Weddell Sea (South Atlantic). They compared the relative abundance of morozovellids, robust acarininids and subbotinids. The robust acarininids had a peak at the base of the CIE interval, where the subbotinids decline. On the other hand, a morozovellids acme was observed in the uppermost part of the CIE. Another observation is the peaks of the abundance of *Globanomalina australiformis*, one of which is during the middle part of CIE and the other is at the base of post-CIE interval. A subbotinid acme was examined also during the post-CIE interval.

5.2.16.2. Mineralogical Studies

The $CaCO_3$ dissolution is recognized in both sites (Kelly *et al*., 2012). However, the decrease is smaller (90% to 82%) in Site 689, whereas the carbonate content decreases to ~60% in Site 690.

5.2.17. ODP Sites 1209 and 1210, Shatsky Rise, Pacific Ocean

These two ODP Sites contain Late Paleocene-Early Eocene deposits (Petrizzo, 2007). The Paleocene sequence consists of yellowish brown calcareous ooze. 2 mm thick dark brown clay seam overlies the calcareous ooze and is followed by the lowermost Eocene clay-rich ooze.

5.2.17.1. Planktonic Foraminifera Studies

Petrizzo (2007) investigated the boundary in the Shatsky Rise, Pacific Ocean along these ODP sections. In this study, P5 Zone is defined between the last appearance of *Globanomalina pseudomenardii* and the first occurrence of *Acarinina sibaiyaensis*. E1 and E2 zones aren't defined separately, but a combined zone is defined to the interval between the first occurrence of *Acarinina sibaiyaensis* and the last appearance of *Morozovella velascoensis.* Different than the other P-E boundary sections, there is an increase in the abundance of morozovellids and a decrease in the abundance of the acarininids and subbotinids during the PETM interval in the Shatsky Rise. The increase in the morozovellids, related to the presence of oligotrophic environments in the high latitudes during the onset of PETM, is due to the 45% increase of *M.velascoensis* and 5% increase of *M.aequa* and *M.subbotinae*.

5.3. PALEOCENE–EOCENE BOUNDARY ALONG THE ERFELEK 1 SECTION

5.3.1. Effects of the paleogeography of the region during the Paleocene-Eocene transition

As the Paleocene-Eocene boundary is one of the most important boundaries commonly studied, the most important boundary sections are located around the Tethys Belt (Schmitz *et al*., 1997; Egger *et al*., 2005; Ernst *et al*., 2006; Luciani *et al*., 2007; Alegret *et al*., 2009; Giusberti *et al*., 2009; Khozyem *et al*., 2013) (Figures 50, 53a).

For the Black Sea realm, Nikishin *et al*. (2011) studied the Late Paleozoic-Cenozoic evolution of the Black Sea and prepared the recent reconstructions for the paleogeography of the region (Figure 53b). Unfortunately, although our data confirms the marine conditions in the region until the Middle Eocene; especially the western part of the Turkish Black Sea coast is located on the region shown as "orogenic area, thrust belts, eroded highlands undivided" and the central part is located on the boundary of the flyschoidal zone by Nikishin *et al*. (2011). This can be related with the resolution of the charts or the deficiency of data from the Turkish Black Sea coasts. On the other hand, the reconstructions show that our study area is located in a region that has affected by the regional tectonics with respect to other Tethys sections, depending on the development of the Western and Eastern Black Sea basins and compressional regime in the Pontides related with the subduction of the Neotethys Ocean. Therefore, more unstable paleoenvironmental conditions have maintained in the region, which is reflected to the faunal and mineralogical changes along the boundary.

5.3.2. Planktonic Foraminifera Studies

As discussed in the previous sections, many different zonations have been established in the Paleocene-Eocene boundary interval (Lu *et al*., 1998; Molina *et al*., 1999; Pardo *et al*., 1999; Berggren and Ouda, 2003; Ernst *et al*., 2006; Aubry *et al*., 2007; Kalia and Kintso, 2006; Luciani *et al*., 2007; Petrizzo, 2007; Kelly *et al*., 2012) (Figure 52). Most of these studies define the boundary by the first appearance of *Acarinina sibaiyaensis.*

In the present study, the excursion taxa, such as *Acarinina sibaiyaensis*, *Acarinina africana* and *Morozovella allisonensis*¸ are not recognized. Therefore, throughout a detailed sampling of the Erfelek Section, the Paleocene-Eocene boundary is studied in the Erfelek 1 Section within the *Morozovella velascoensis* Zone by the first appearance of the *Acarinina wilcoxensis* (Figure 54). This marker bioevent, first appearance of this species, has also been suggested by Berggren and Ouda (2003) for the determination of the boundary.

For the uppermost Paleocene-lower Eocene part of the Erfelek 1 Section, the planktonic foraminiferal abundance is relatively very low with respect to benthic foraminifera. Contrary to the most of the Tethys sections, along which the planktonic foraminiferal assemblage is dominated by warm water taxa – acarininids and morozovellids – the planktonic foraminifera are dominated by subbotinids in the Erfelek 1 Section (Lu *et al*., 1998; Molin *et al*., 1999; Pardo *et al*., 1999; Kelly *et al*., 2012) (Figure 55). The dominance of the subbotinids has also been recognized in the Kaurtakapy Section,

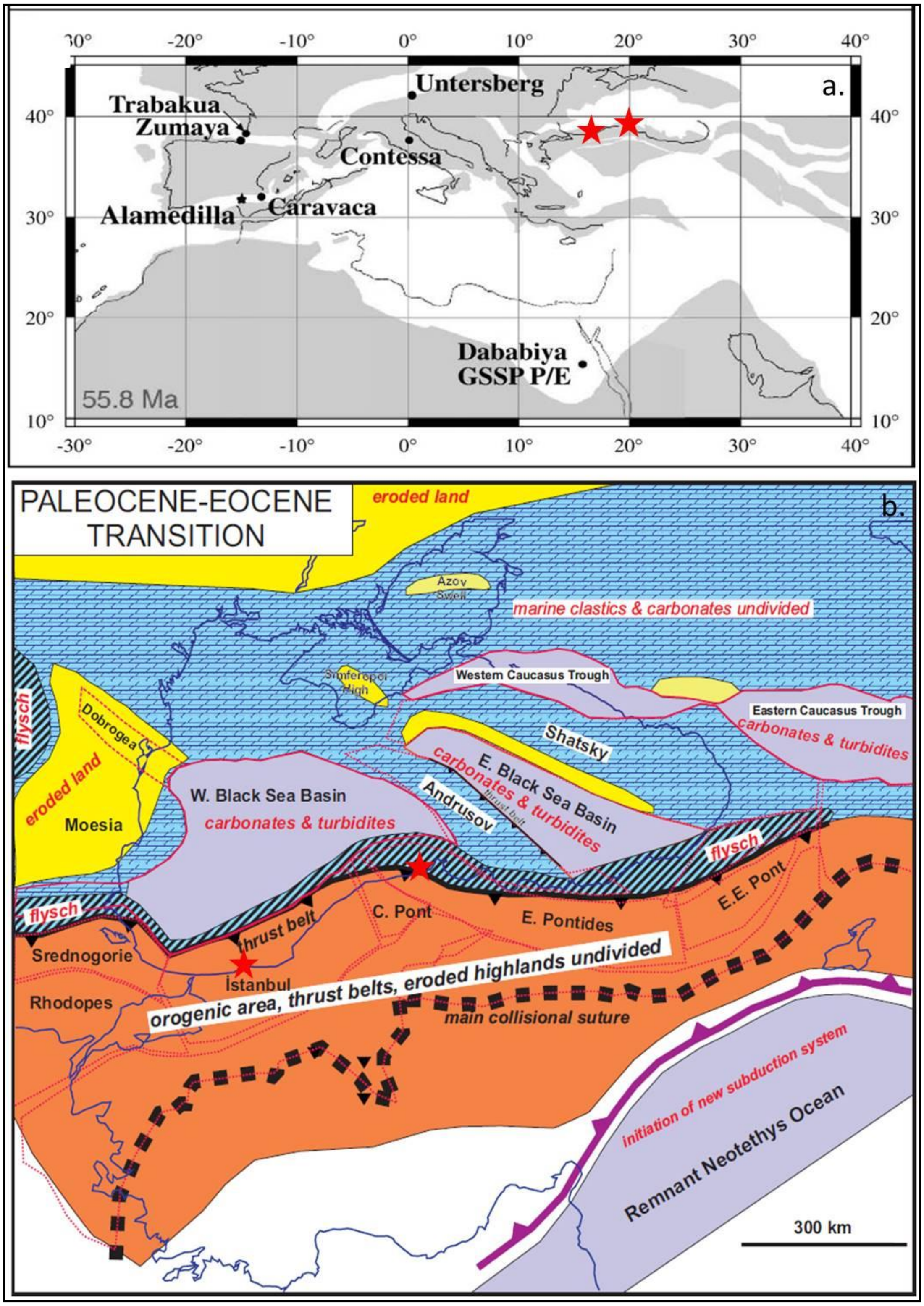

Figure 53. Paleogeographical map for the Paleocene-Eocene boundary (Red stars: possible locations for the sections studied in this thesis). **a.** Paleogeographical reconstruction modified from Hay *et al.* (1999). (GSSP: Global Stratotype Section and Point) (Alegret *et al*., 2009); **b.** Paleocene/Eocene transition paleogeographic/paleotectonic map of Black Sea region (Nikishin *et al*., 2011).

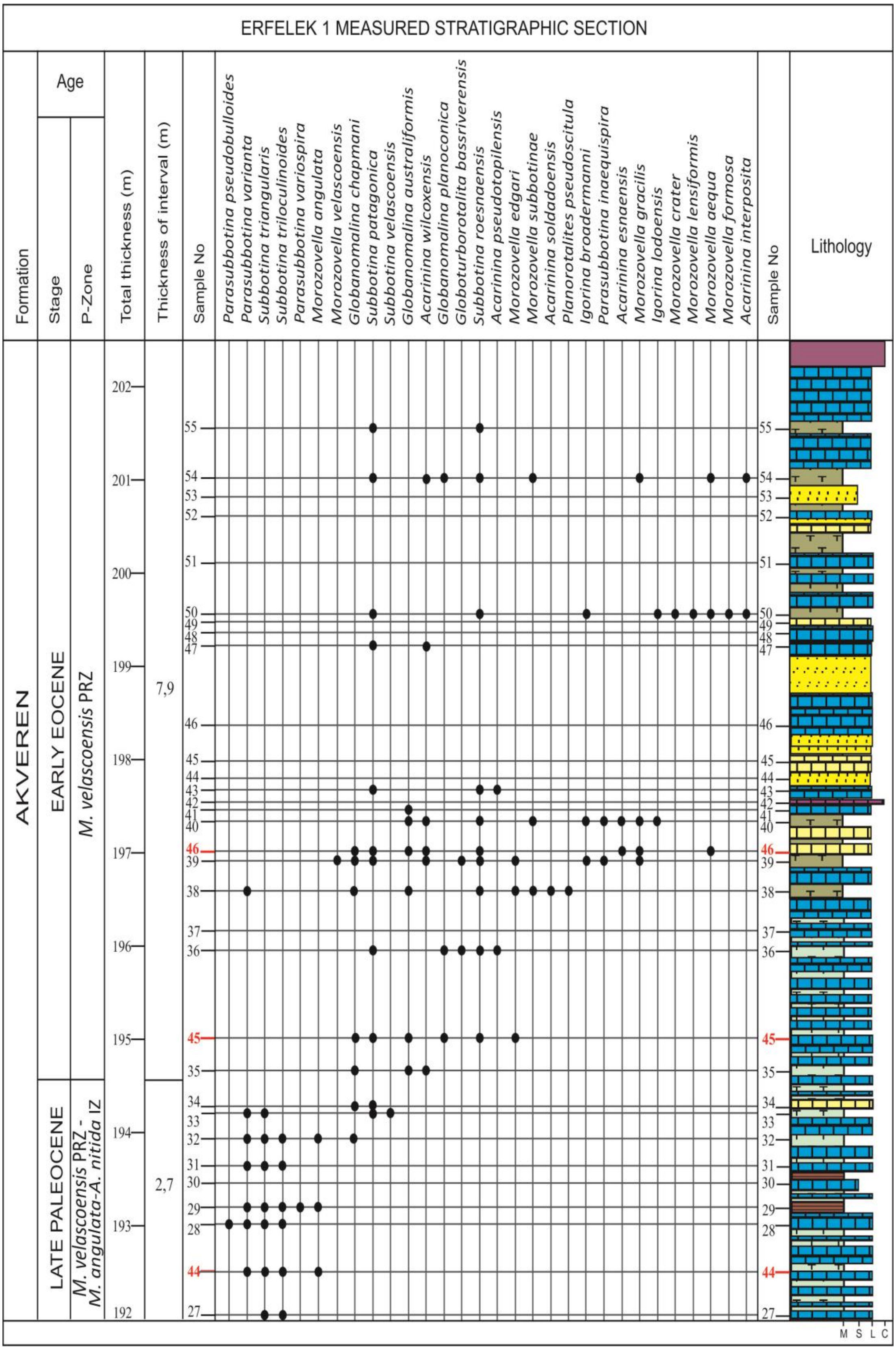

Figure 54. Planktonic foraminiferal distribution chart of the Erfelek 1 Section.

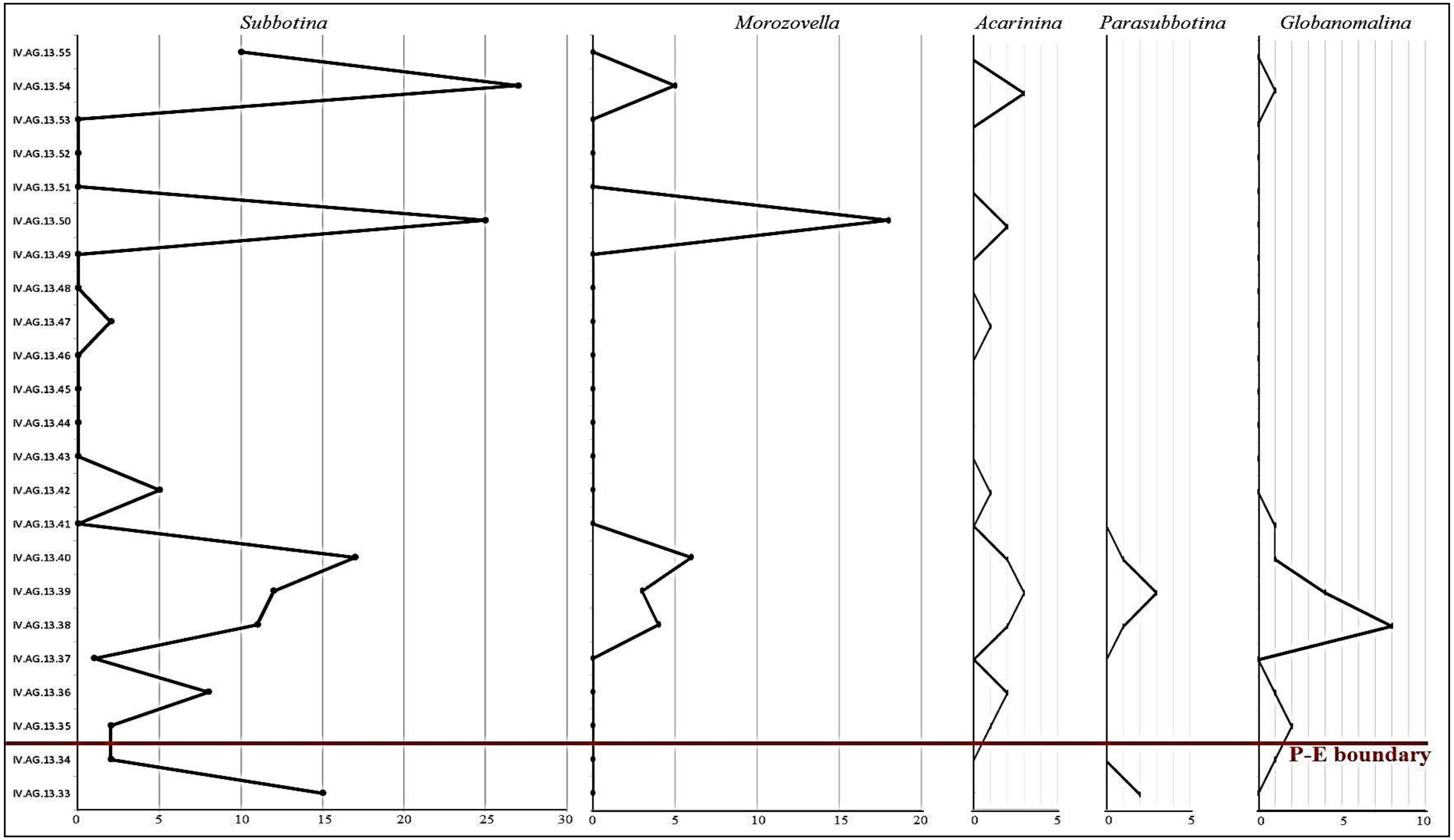

Figure 55. Relative abundance of the planktonic foraminifera along the Paleocene-Eocene boundary in the Erfelek 1 Section.

Kazakhstan (Pardo *et al*., 1999). Subbotinids are mentioned as the cool water indicatorsreflecting the deeper, eutrophic environments (Pardo *et al*., 1999; Luciani *et al*., 2007). Therefore, the paleogeographic position of the Erfelek 1 Section is thought to be in a cooler belt with respect to the Tethys sections and can be correlated with the Kaurtakapy Section.

Moreover, as the dominancy of the subbotinids marks the cool water conditions, the absence of the excursion taxa (*Acarinina sibaiyaensis*, *Acarinina africana* and *Morozovella allisonensis*) and rareness of planktonic foraminifera are thought to be related to the unsuitable cooler climatic conditions. Although the sampling interval is narrower in the Erfelek 1 Section with respect to that of the Erfelek Section, the sampling interval still might not be enough to record this very narrow interval for their FAD and LAD of these excursion taxa.

When the relative abundance of the genera is investigated, the abundance of the subbotinids decreases below the boundary, increases again above the boundary (Figure 55). This genus is mentioned to be low abundant during the PETM until the upper CIE interval (Berggren and Ouda, 2003; Ernst *et al*., 2006; Petrizzo *et al*., 2007; Kelly *et al.*, 2012). Although the exact position for the CIE and PETM isn't distinct in the Erfelek 1 Section because of the absence of the carbon isotope data, the peak of the genus above Sample 49 is thought to be correlated with the upper and/or post-PETM interval (Figure 55).

The acarininids, an important warm water indicating taxa, has been recognized to have a peak above the boundary with the appearance of the excursion taxa within the dissolution interval (Lu *et al*., 1998; Pardo *et al*., 1999; Berggren and Ouda, 2003; Ernst *et al*., 2006; Aubry *et al*., 2007; Kalia and Kintso, 2006; Kelly *et al*., 2012). The acarininid peak coincides with the interval that is barren of other foraminifera. However, the increase in the abundance of the fish fragment is in this dissolution interval (Ernst *et al*., 2006; Khozyem *et al*., 2013). The abundance of the morozovellids, another warm water indicator, is mentioned to decrease during the peak of the acarininids at the base of the CIE (Pardo *et al*., 1999; Ernst *et al*., 2006). Kelly *et al*. (2012) recorded the peak of globanomalinids with the increase in *Globanomalina australiformis* during the middle CIE and post-CIE intervals. In the Erfelek 1 Section, there are two peaks in the abundance of acarininids and globanomalinids, which are the warm water dwellers, just above the boundary (Samples 35-41). Morozovellids are absent during the first peak; however their abundance also increases parallel to the second peak in acarininids and globanomalinids (Figure 55). Pardo *et al.* (1999) mentioned the increase in the abundance of morozovellids following the increase in the abundance of acarininids in the Zumaya Section, which is perfectly matched with our data. The abundance of morozovellids is also increasing in the upper parts of the *Morozovella velascoensis* Zone. The recorded increase in the abundance of fish fragments is towards the middle part of this zone (Sample 40) in the Erfelek 1 Section and does not corresponds to the global data as this increase should be at the base of the Eocene (Figure 56). On the other hand, this increase is correlatable with the interval along which the calcite content decreases which is suitable with the global data (Ernst *et al*., 2006; Khozyem *et al*., 2013).

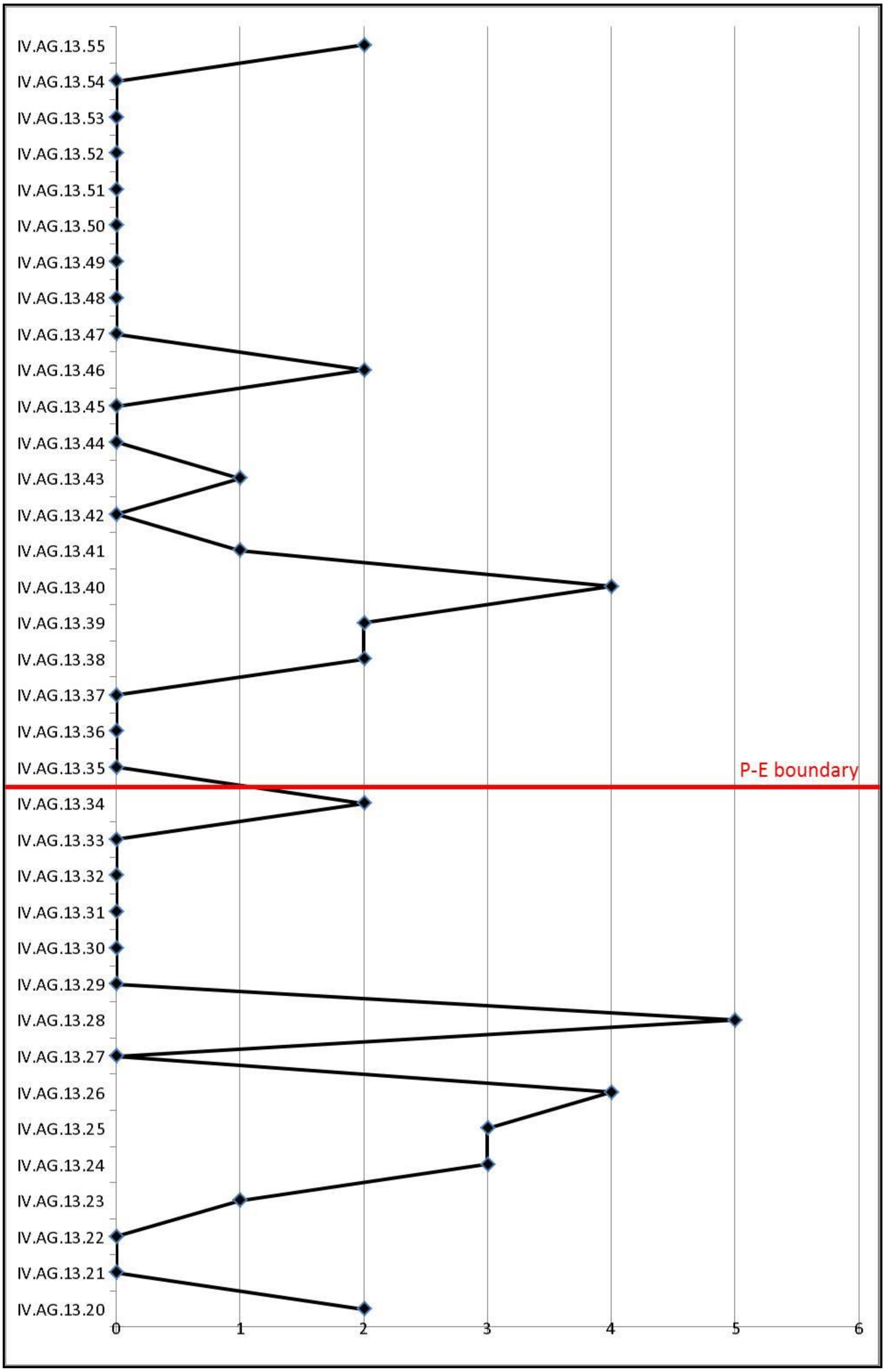

Figure 56. Fish teeth abundance chart of the Erfelek 1 Section.

In terms of the diversity and relative abundance of the planktonic foraminiferal assemblage, a sharp decrease is recognized along the boundary with respect to the rest of the section (Samples 34-37). This interval is thought to be correlated with the dissolution interval.

5.3.3.Benthic Foraminifera Studies

The benthic foraminiferal assemblage includes the taxa with both calcareous and agglutinated walls along the section (Figure 57). The diversity of both groups increases during the Late Paleocene with respect to the lower parts of the section. The high diversity of the pre-PETM calcareous and agglutinated taxa is also recognized by Stassen *et al*. (2012) in Sidi Nasseur and Wadi Mezaz sections (Tunisia) and by Giusberti *et al*. (2009) in Contessa Road Section (Italy). Giusberti *et al*. (2009) recognized the higher abundance of the genus *Cibicidoides* spp. below the boundary. This species is abundant during the Paleocene in the Erfelek 1 Section and disappears above the boundary (Sample 38).

Ernst *et al.* (2006) and Aubry *et al.* (2007) also mentioned %40-65 extinction for the benthic foraminifera with the onset of the PETM. The boundary is marked with the extinction of Paleocene deep water benthic foraminifera, such as *Stensioeina beccariiformis, Angulogavelinella avnimelechi*, *Aragonia velascoensis*, *Neoflabellina jarvis, Osangularia velascoensis* and *Pullenia coryelli* (Aubry *et al*., 2007). Most of these species have not been recognized in our section. However, the extinction of *Pullenia coryelli* is compatible to the data of Aubry *et al*. (2007), which is recoded just before the boundary (Sample 34) in this study.

Both diversity and relative abundance of the benthic assemblage decrease during the uppermost Paleocene-lowermost Eocene interval (Samples 34-37) in the Erfelek 1 Section, parallel to the decrease in the abundance and diversity of the planktonic foraminiferal assemblage. This interval is thought to be correlated with the carbonate dissolution interval.

The abundance of the agglutinated benthic foraminiferal is relatively higher than the abundance of the calcareous benthic foraminifera in this interval, which is conformable with results of Stassen *et al*. (2012) and Giusberti *et al*. (2009). The recovery of the forms is recorded after this interval through the rest of the section.

PETM taxa are recorded to be dominated by agglutinated benthic foraminifera, especially *Glomospira* spp., and deep dwelling lageninids and buliminids because of the stressed conditions (Stassen *et al*., 2012; Giusberti *et al*., 2009). However, the high abundance of the lageninids and buliminids isn't recognized in the Erfelek 1 Section.

Post-PETM interval is characterized by dominance of *Lenticulina* spp., whereas the agglutinated benthic foraminifera are said to decrease their abundance (Stassen *et al.*, 2012). The high abundance of the genus *Lenticulina* spp., which indicates the low oxygen and/or high food supply conditions that show the eutrophism, hasn't been recorded in our study. However, the high abundance of the planktonic foraminiferal genus *Subbotina* has already shown the eutropic conditions in the Erfelek 1 Section.

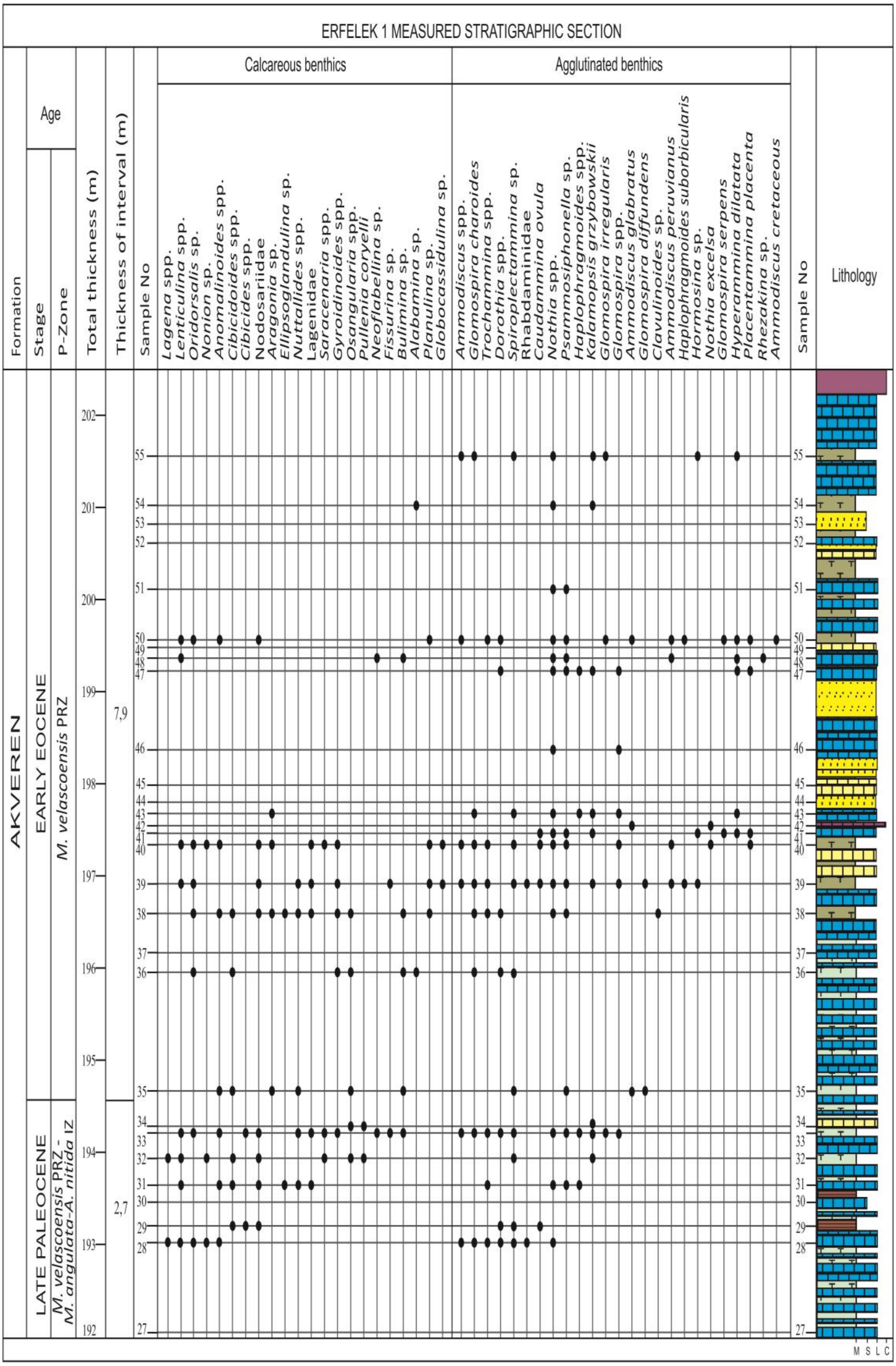

Figure 57. Benthic foraminiferal distribution chart of the Erfelek 1 Section.

5.3.4. Mineralogical Studies

The Akveren Formation, which contains the limestone-marl alternations with some calcitubiditic levels, is studied in the Erfelek 1 Section. Limestone is the dominated lithology along the Paleocene-Eocene boundary. Höntzch *et al.* (2011) mentioned that the hyperthermal-related CIEs always occur within marl beds. Also, most of the studied boundary sections contain a clayey level at the base of the Eocene. Therefore, as our section is limestone dominated and no clayey horizons are recognized in the field studied, the Erfelek 1 Section shows a difference from the other boundary sections.

The mineral content of the samples are evaluated by the XRD analyses from the bulk rock (Figure 58). The samples mainly include quartz, feldspar, clay and calcite. The dominant mineral in most of the samples is calcite, verifying the dominance of the limestone domination in the field study.

The boundary studies mentioned $CaCO_3$ dissolution at the PETM interval (Giusberti *et al*., 2009; Soliman *et al*., 2011; Kelly *et al*., 2012; Khozyem *et al.*, 2013). The amount of this dissolution changes for different sections. For example, the $CaCO_3$ content decreases only to 82-90% at ODP Site 689, Weddell Sea (Kelly *et al.*, 2012), whereas this content diminishes up to 0-42% in Forada Section (Agnini *et al*., 2007). In the Erfelek 1 Section, 91% to 51% just above the boundary (Figure 58). A second, more drastic decrease up to 27% is recorded above this level (Sample 39).

Agnini *et al*. (2007) and Luciani *et al*. (2007) realized a major increase in relative abundance of phyllosilicates/quartz and a corresponding major decrease of calcite at the base of the Eocene. This is also conformable to our data (Figure 59).

The clay minerals of the Erfelek 1 Section contain smectite, chlorite, illite and kaolinite. Most of the boundary studies indicate an increase in kaolinite percentage during the PETM interval, while the percentage of the other clay minerals decreases (Ernst *et al.*, 2006; Khozyem *et al.*, 2013). In the Erfelek 1 Section, the percentage of all clay minerals is decreasing in the uppermost Paleocene (Sample 34) and increasing passing the boundary (Sample 35) (Figure 60). The clay concentrations continue to fluctuate during the Early Eocene.

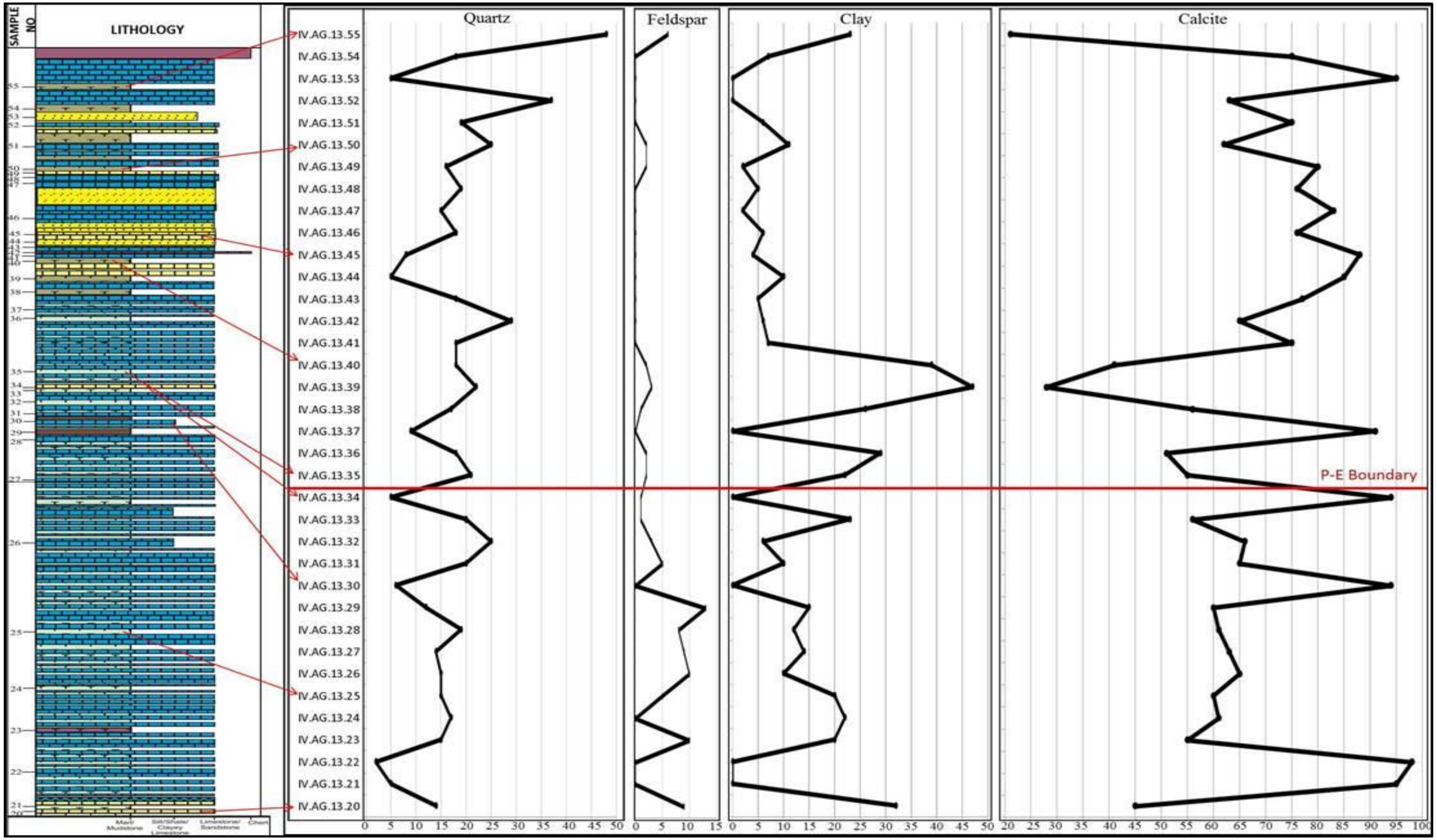

Figure 58. XRD results of the bulk rock in the Erfelek 1 Section.

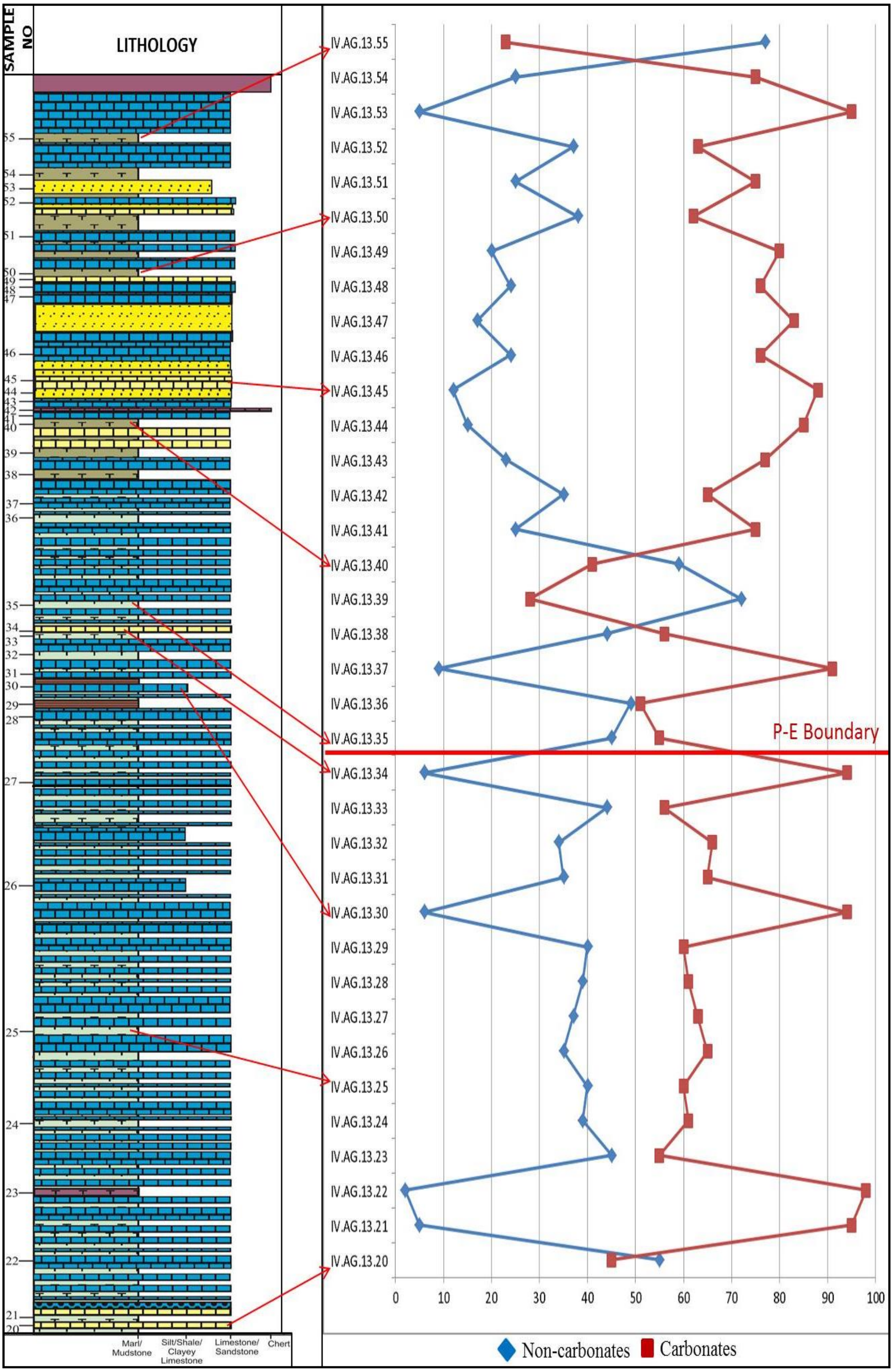

Figure 59. Percentage of carbonates and non-carbonates in the Erfelek 1 Section.

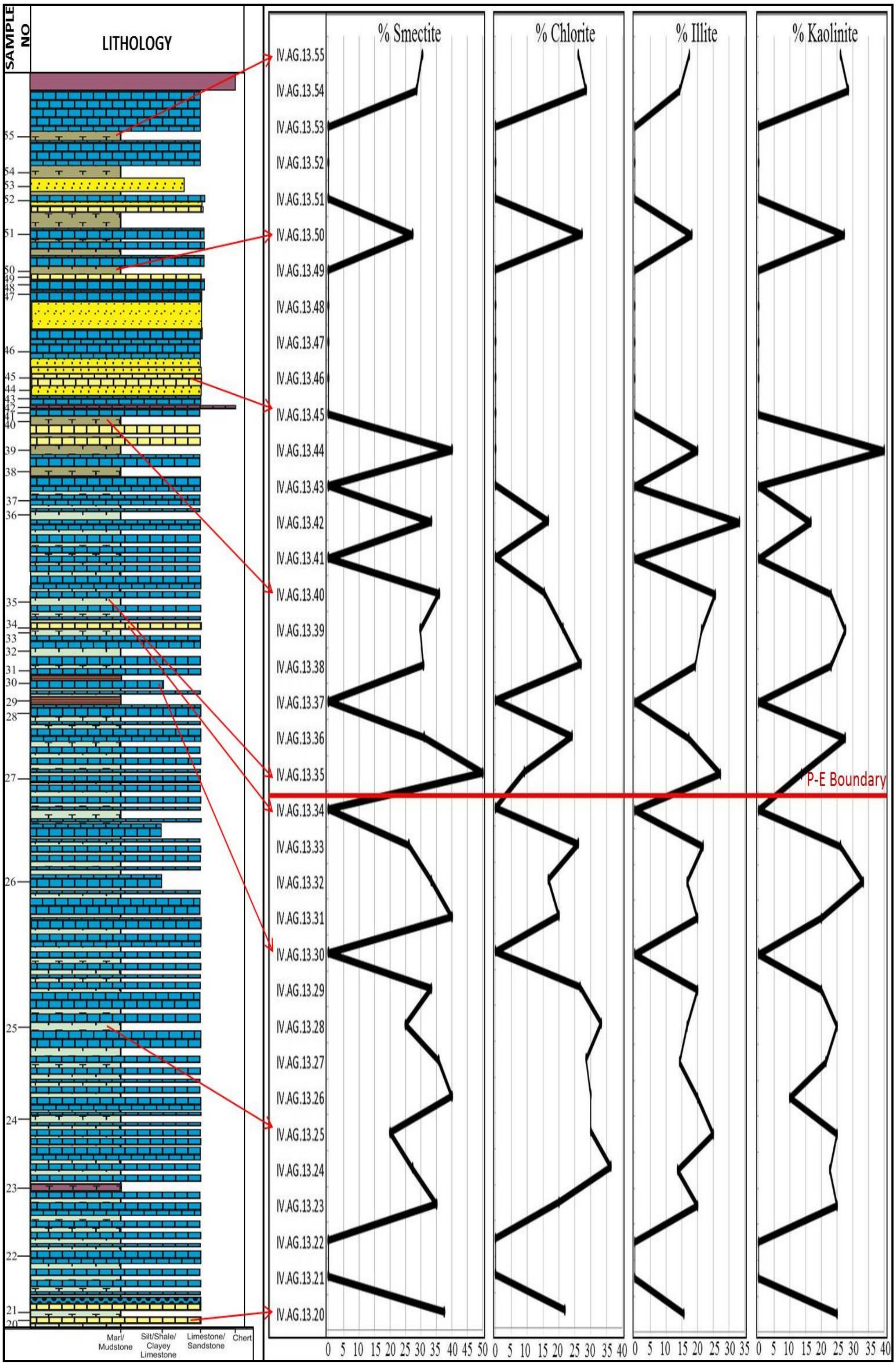

Figure 60. Percentage of clay minerals in total clay in the Erfelek 1 Section.

Khozyem *et al*. (2013) indicated that being the weathering or hydrothermal alteration products, the clay minerals represent the continental morphology, tectonic activities, sea level fluctuations and climatic conditions. For example illite and chlorite reflects the dry, arid to semiarid, cool to temperate climates; whereas smectite shows warm arid to temperate climate characterized by altering humid and dry seasons. Kaolinite forms during warm and humid climate. In our section, kaolinite, which is a warm and humid climate indicator, shows a nearly parallel change with the other clay minerals that are the cool and/or arid climate indicators (Figure 60). This could be evaluated by the regional tectonics that has overprinted the mineralogical record. These clay minerals should be originated from the different source areas which were uplifted due to regional tectonic activities, which are thought to be an evidence for the disconnection of the Mediterranean and the Crimean-Caucasus realms by the Middle Eocene and its effects at the Black Sea region.

CHAPTER 6

DISCUSSIONS AND CONCLUSIONS

6.1. DISCUSSION

6.1.1. Biostratigraphy

Located on the northern branch of the Neotethys Ocean, the paleogeographical position of the Black Sea region makes it an important bridge between the Mediterranean and the Crimean-Caucasus realms. Although the main disconnection of Paratethys from the Mediterranean was after the Oligocene, the discrepancies between their stratigraphies and biostratigraphies were recorded from the Middle Eocene and several endemic taxa were appeared in the Crimean-Caucasus realm (Rögl, 1998, 1999; Steininger and Wessely, 2000; Popov *et al.*, 2006; Batı *et al.*, 2009).

One of the most important groups that these discrepancies have been recorded is the planktonic foraminifera. It is an ideal fossil group for biostratigraphy, paleoclimatology and paleoenvironmental studies in terms of their high abundance in the rock due to their small size, high species diversity due to rapid evolution and their widespread geographic distribution of the taxa. Recording the evolution of Paleogene planktonic foraminifera is essential for emphasizing the regional changes.

The difficulties in the taxonomical studies are resulted from the new classification based on the type of the wall. The wall textures have not been preserved in most of the specimens. In this manner, the other morphological features of the species are used for their classification.

Thirteen biozones and four subzones are defined in this study for the Paleocene-Eocene interval (Figure 61). These zones are **(1)** *Parvularugoglobigerina eugubina-Praemurica uncinata* Interval Zone (with *Subbotina triloculinoides-Praemurica inconstans* Interval Subzone and *Praemurica inconstans-Praemurica uncinata* Interval Subzone) and **(2)** *Praemurica uncinata-Morozovella angulata* Interval Zone for the Early Paleocene; **(3)** *Morozovella angulata-Acarinina nitida* Interval Zone and **(4)** *Acarinina nitida-Globanomalina pseudomenardii* Concurrent Range Zone for the Late Paleocene; **(5)** *Morozovella velascoensis* Partial-range Zone for the Late Paleocene-Early Eocene; **(6)** *Morozovella subbotinae* Partial-range Zone (with *Morozovella edgari* Partial-range Subzone and *Morozovella* formosa/Morozovella *lensiformis-Morozovella aragonensis* Interval Subzone), **(7)** *Morozovella aragonensis - Morozovella formosa* Concurrent - range Zone,

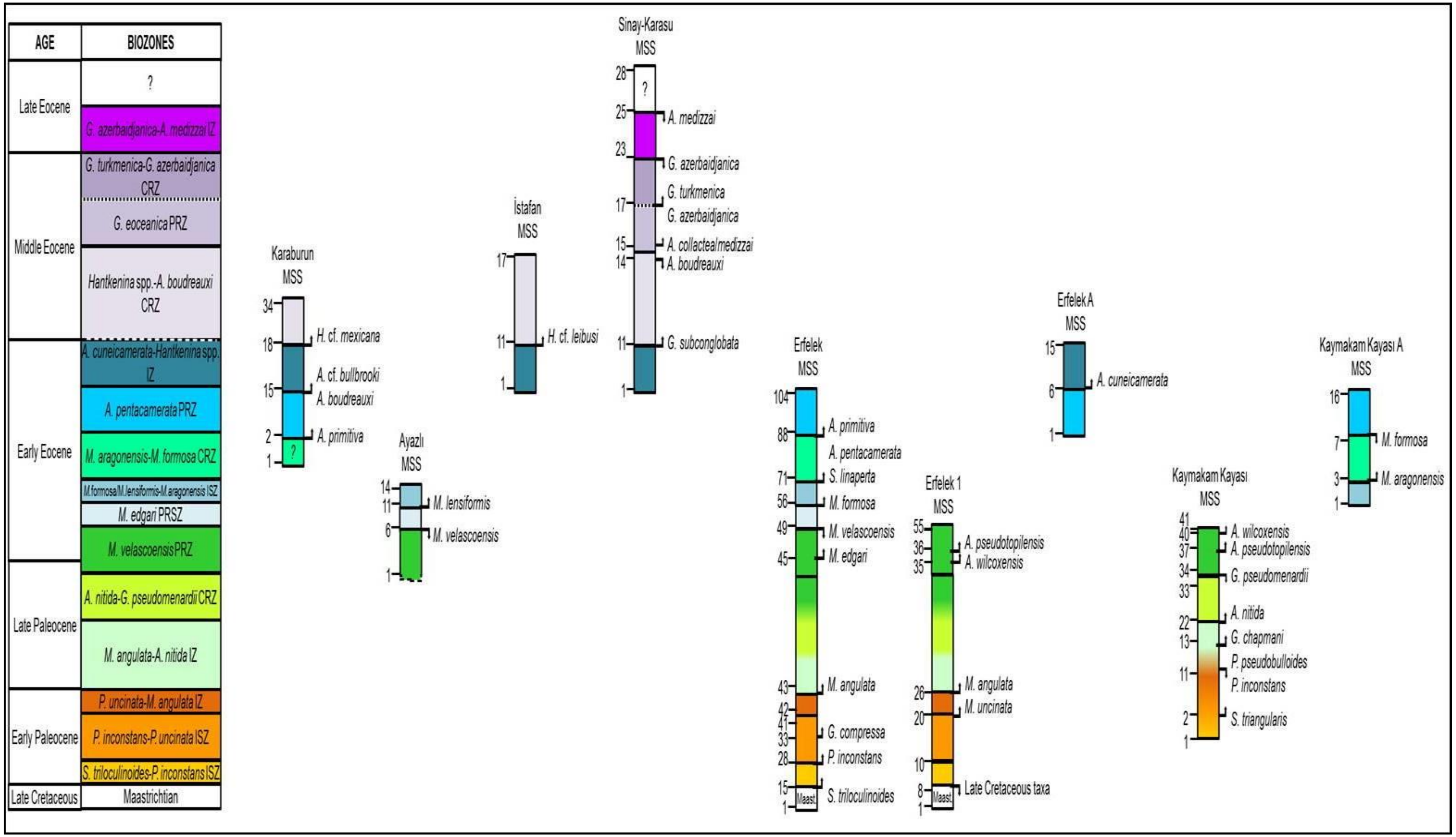

Figure 61. Correlation of the biozonations along each measured section.

(8) *Acarinina pentacamerata* Partial-range Zone and **(9)** *Acarinina cuneicamerata-Hantkenina* spp. Interval Zone for the Early Eocene and **(10)** *Hantkenina* spp.-*Acarinina boudreauxi* Concurrent-range Zone, **(11)** *Globigerina eoceanica* Partial-range Zone and **(12)** *Globigerina turkmenica-Globigerina azerbaidjanica* Concurrent-range Zone for the Middle Eocene and **(13)** *Globigerina azerbaidjanica-Acarinina medizzai* Interval Zone for the Late Eocene. Some of these zones and subzones, especially the zones in the upper Early Eocene, are recorded in many sections from east to west. On the other hand, Paleocene is recorded in Erfelek, Erfelek 1 and Kaymakam Kayası sections, whereas the most complete Middle-Upper Eocene sequence has been recognized in the Sinay-Karasu Section.

6.1.2. Paleoenvironmental conditions

In terms of establishing the biostratigraphy, the absence of some zone marker species used in the standard biozonations and long ranges of some species defined in our sections are the main problems in this study. For example, Late Paleocene is recorded in Erfelek, Erfelek 1 and Kaymakam Kayası sections. The benthic foraminiferal assemblage is dominant than the planktonic foraminifera during the Late Paleocene. Moreover, although the zone markers are mostly acarininids and morozovellids in the standard biozonations, our sections mainly consists of subbotinids, whereas the others are very rare or sporadic in the samples. As a result, regional biozones have been needed when it is impossible to define the standard biozonation because of the absence of the index species.

The life strategies of the planktonic foraminifera are known to change with the changing environmental conditions (Premoli Silva and Sliter, 1994; 1999; Petrizzo, 2002) (Table 25).

Table 25. Life strategies of the planktonic foraminifera with respect to different paleoenvironmental conditions (Premoli Silva and Sliter (1994, 1999)).

Life strategy	r-selected opportunists	K-selected specialists	r/K intermediate forms
Environment	Eutrophic waters	Oligotrophic waters	Mesotrophic waters
Water temperature	Cooling	Warming	Intermediate
Nutrient availability	Rich in nutrients	Low nutrient content	Intermediate
Surface to deep gradient	Decreasing	Increasing	Intermediate
Thermocline	Weakening	Strong	Intermediate
Size of individuals	Small-sized	Large-sized	Intermediate
Reproduction rate	Fast	When conditions are suitable	Intermediate
Population density	Rapidly increasing	Slowly increasing	Intermediate

For the Paleocene-Eocene planktonic foraminifera, the acarininids and the morozovellids are recorded as the warm water surface dwellers, while the subbotinids reflect the cooler and deeper in the water column (Luciani *et al*., 2010) (Figure 62). Therefore, the dominance of the subbotinids and scarcity of the others within the Upper Paleocene successions is the indicator for the presence of a cooler belt around the Sinop Region.

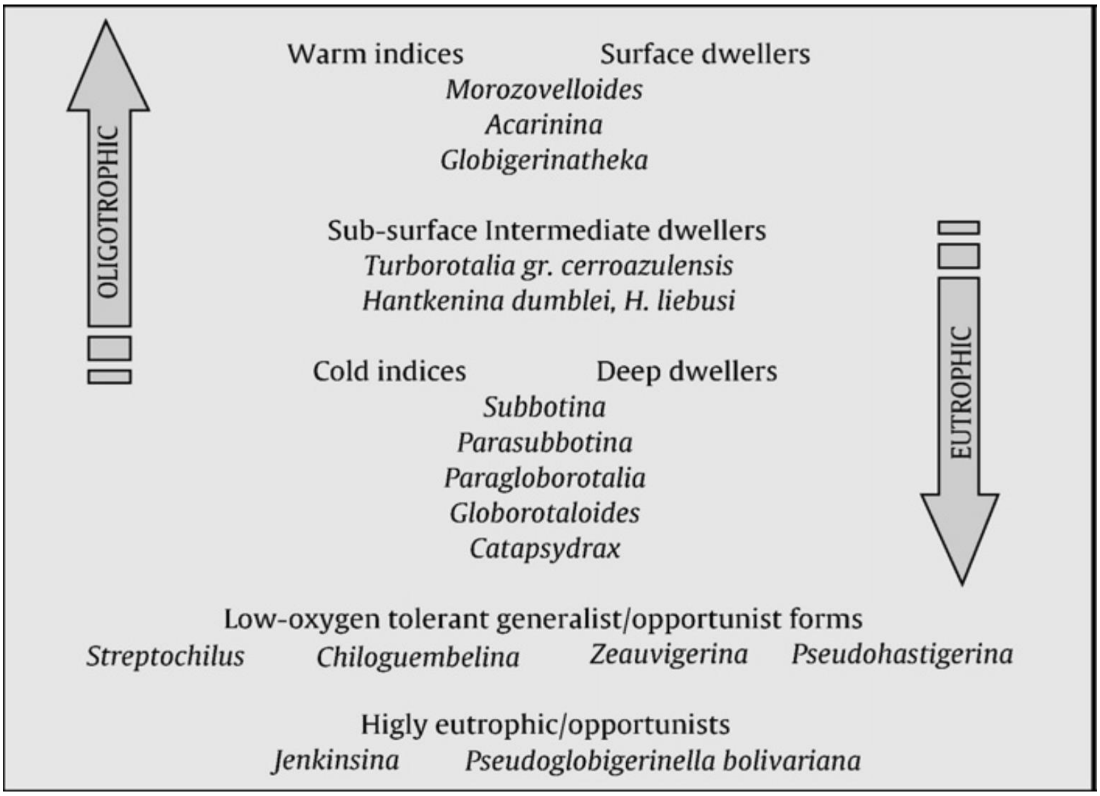

Figure 62. The life strategies of the Eocene planktonic foraminiferal taxa (Luciani *et al*., 2010).

The recent biozonations around the Paleocene-Eocene boundary defined the base of the Eocene (E1 of Berggren and Pearson, 2005) with the first appearances of 3 species; *Acarinina africana*, *Acarinina sibaiyaensis* and *Morozovella allisonensis*, which are indicated as the “planktonic foraminifera excursion taxa” (PFET) (Kelly *et al.*, 1996, 1998). When the geographical distribution of these excursion taxa is considered, the Tethys belt and some ODP sites around Atlantic and Pacific Oceans gain importance (Figure 63).

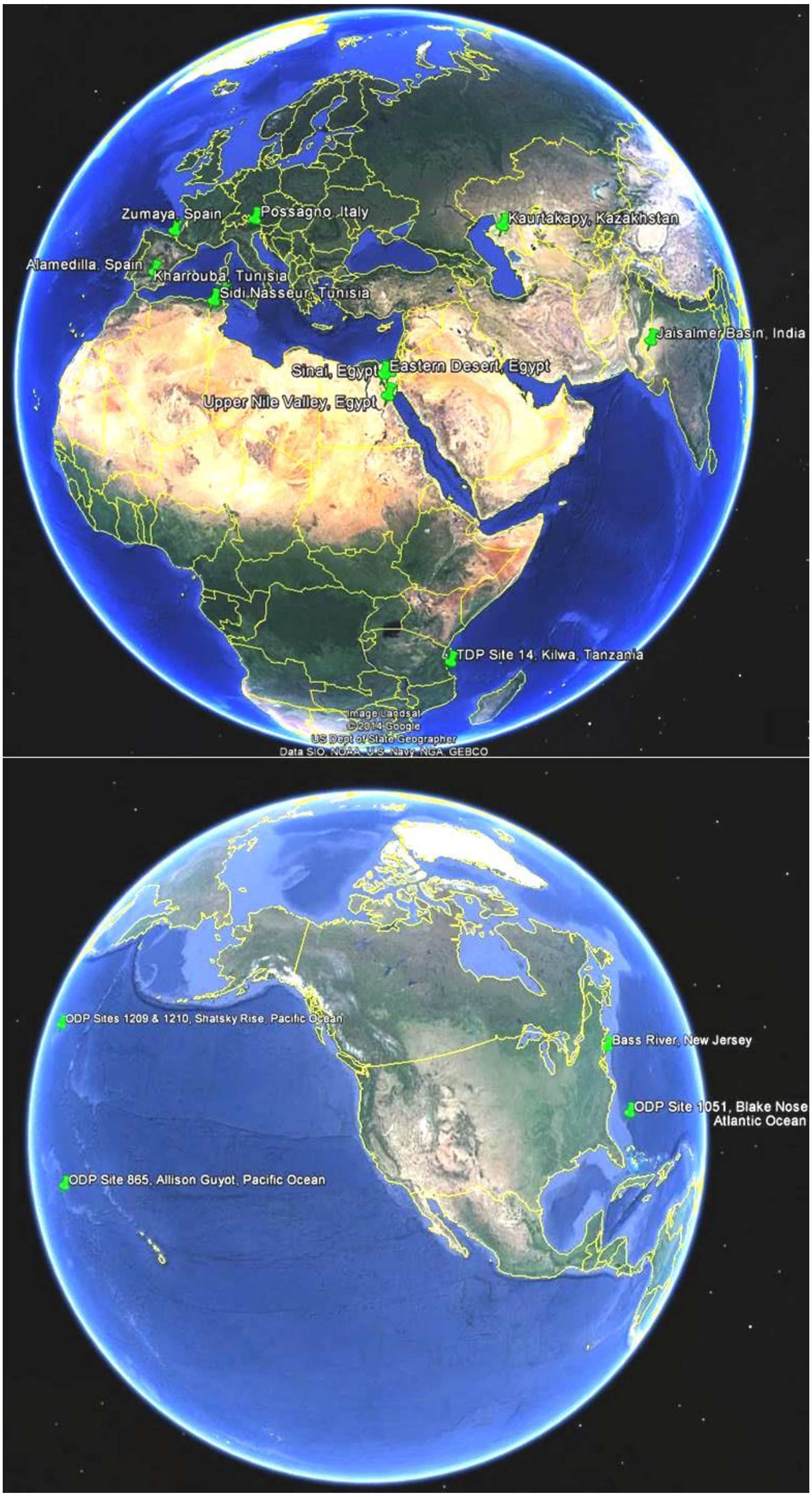

Figure 63. Geographical distribution of the excursion taxa (*Acarinina sibaiyaensis*, *Acarinina africana*, *Morozovella allisonensis*). Green pins show the locations that the excursion taxa are recorded.

Kelly *et al.* (1996) recorded that the excursion taxa shifted to deeper depth-habits because of the sudden warming of oceanic deep waters and diminishing of the thermocline. Morover, Kelly *et al.* (1998) established a model for the evolution of *Morozovella allisonensis* from *Morozovella velascoensis* and evolution of *Acarinina sibaiyaensis* from *Acarinina soldadoensis.* The authors commented that the restricted patchy distribution of *M. velascoensis* said to give raise the appearance of *M. allisonensis* by the deepening of the euphotic zone by the onset of oligotrophic conditions during the PETM. On the other hand, acarininids were said to be more tolerant to the environmental changes with respect to the morozovellids, so that they also existed during the scarcity of morozovellids and no distributional restriction was needed for their evolution.

The excursion taxa haven't been recorded in this study. One of the possible reasons is that the sampling interval can still be wider in the Erfelek 1 Section for sampling such a small stratigraphical interval. On the other hand, the most important reason is though to be the presence of a cooler paleoenvironment and eutrophic conditions in the studied area during the Late Paleocene-earliest Eocene, which is notified by the relative dominancy of the subbotinids with respect to other genera. This can be explained by the unsuitable paleoenvironmental conditions for the evolution of the excursion taxa from their ancestors in this region. The similar situation has also been recorded during the latest Middle Eocene, where the existence of the Crimean-Caucasus realm's endemic species, such as *Globigerina turkmenica* and *Globigerina azerbaijanica*, has been identified in the studied sequence. On the other hand, warm water indicator genera, such as *Morozovelloides, Acarinina* and *Globigerinatheka*, are missing or relatively low abundant during this interval. The preferred change in the abundance and diversity of the genera caused by the environmental factors can be as a result of the development of different subbasins in the Black Sea after the Cretaceous. Therefore, there should be a connection in the studied area with the northern realms that maintains the cooler paleoenvironments to affect the life strategies and abundance/ diversification of the assemblage.

6.1.3. Paleocene-Eocene Boundary

6.1.3.1. Lithostratigraphy

There are a limited number of studies covering the Paleocene-Eocene boundary around the Black Sea region. Lithologically, the boundary has been placed in different positions. For example, Gedik and Korkmaz (1984) placed the boundary on the boundaryof Akveren and Atbaşı formations, whereas Gedik *et al*. (1983) and Uğuz and Sevin (2008) placed the boundary within the Atbaşı Formation. On the other hand, Sunal and Tüysüz (2002) and Tüysüz *et al*., (2004, 2012) located the boundary on the boundary of the Atbaşı and the Kusuri formations (Figures 4,5).

The Paleocene-Eocene boundary has been recorded in two different sections around Sinop region; Erfelek and Kaymakam Kayası sections. In both sections, the Paleocene-Eocene boundary is inside the Akveren Formation. Therefore, the present data show a need for the revision of the formation ages at least for the Central Black Sea region.

6.1.3.2. Faunal changes

Recently, the event stratigraphy and the determination for the GSSP for different stages become interesting subjects for the researchers. The most important boundary in this study is Paleocene-Eocene boundary, which has a worldwide importance in terms of Paleocene Eocene Thermal Maximum (PETM) and benthic foraminifera extinction event (BFEE) (Lu *et al.*, 1998; Iakovleva *et al.*, 2001; Ortiz *et al.*, 2008; Höntzch *et al*., 2011). The boundary studies mostly include the extinction events in benthic foraminifera, the examination of the changes in $\delta^{13}C$ and clay minerals (Ernst *et al.*, 2006; Khozyem *et al.*, 2013).

As discussed above, the marker species for the base of the Eocene aren't recorded in this study. However, the Paleocene-Eocene boundary is determined by the first appearance of *Acarinina wilcoxensis* in the Erfelek 1 Section and by the first appearance of *Acarinina pseudotopilensis* in the Kaymakam Kayası Section. The abundance and diversity of the planktonic foraminifera are very low in these sections. The subbotinids are more abundant with respect to acarininids and morozovellids. On the other hand, an opposite situation has been recognized in most of the boundary sections around the Tethys, whereas the dominancy of the subbotinids was recorded in the Kaurtakapy Section, Kazakhstan related to the cold water conditions (Pardo *et al*., 1999).

Besides the planktonic foraminiferal biozonation, the benthic foraminiferal taxonomy and both bulk rock and clay mineralogy have been studied across the Paleocene-Eocene boundary in the Erfelek 1 Section. In this section, contrary to the low abundance and diversity of the planktonic foraminifera, numerous benthic foraminifera with both calcareous and agglutinated walls are recorded.

50% of the Paleocene deep water benthic foraminifera are mentioned to be extinct during the PETM (Aubry *et al*., 2007; Giusberti *et al*., 2009; Stassen *et al*., 2012). BFEE was marked by the last occurrence of *Stensioeina beccariiformis* in this section. This species isn't defined in our study. However, among the extinct taxa of the authors, the last occurrence of *Pullenia coryelli* is in the uppermost part of the Paleocene in the Erfelek 1 Section.

In addition to these data, there is also an increase in the abundance of the fish teeth that fits with the interval on which the decrease in the calcite content is recorded. This parallelism between the increase in the fish abundance and calcite dissolution is suitable with the global data (Ernst *et al*., 2006; Khozyem *et al*., 2013). However, in our study this interval is about 2 meters above the P-E boundary, whereas the peaks are just above the boundary in the other studies (Ernst *et al*., 2006; Khozyem *et al*., 2013). This can be explained by the higher sedimentation rates caused by the flyshoidal systems that are present in our study area.

6.1.3.3. Mineralogical changes

XRD studies have been carried out across the Paleocene-Eocene boundary. Both bulk rock and clay mineralogy is studied in the Erfelek 1 Section. The mentioned total dissolution of the $CaCO_3$ isn't recorded in this study (Giusberti *et al*., 2009; Soliman *et al*., 2011; Kelly *et al*., 2012; Khozyem *et al.*, 2013). However, the calcite content decreases from 91% to 51% just above the boundary and a more drastic decrease up to 27% is recorded above this level. A major increase in the relative abundance of phyllosilicates/quartz and a corresponding major decrease of calcite are also recorded at the base of the Eocene as mentioned also by Agnini *et al*. (2007) and Luciani *et al*. (2007).

On the other hand, in terms of the clay mineralogy, an increase in kaolinite percentage has been recorded during the PETM interval in most of the boundary studies, whereas the percentage of the other clay minerals decreases (Ernst *et al.*, 2006; Khozyem *et al.*, 2013). In the Erfelek 1 Section, there is a fluctuation in the percent of the clay minerals, which show a parallel trend all across the section. Their percentage is decreasing in the uppermost Paleocene and increasing passing the boundary. Therefore, the clay mineralogy in the Erfelek 1 Section isn't suitable to the global data, which is connected with the tectonic activity in the region causing the origination of these clay minerals from the different sources. In most of the boundary sections, the boundary is within marly sediments on which the clay content peaks just at the boundary (Figure 51). However, the boundary is within a carbonate dominated lithology in the Erfelek Section. Both the lithology and the content of the clay minerals is thought to indicate the possible allogenic carbonate transportation from the elevated parts of the basin.

A correlation of the faunal and mineralogical changes across the Paleocene-Eocene boundary is summarized in Figure 64 for the Erfelek 1 Section.

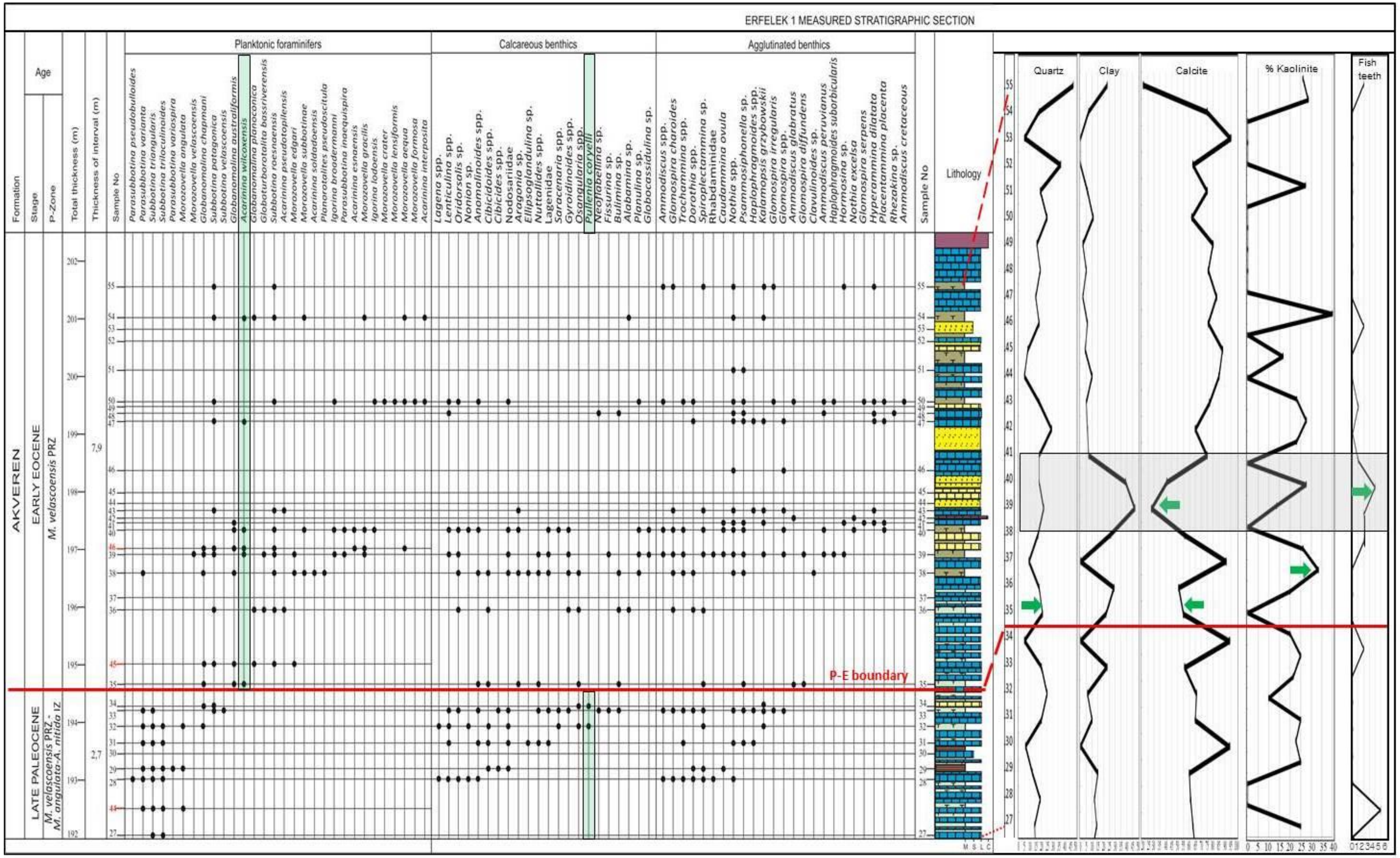

Figure 64. Correlation of the faunal and mineralogical changes across the Paleocene-Eocene boundary in the Erfelek 1 Section.

6.1.4. Middle and Late Eocene Interval

Three stratigraphical sections have been measured covering the Middle Eocene. The Karaburun and the İstafan sections are completed within the Lutetian, whereas the Sinay-Karasu Section continues up to Upper Eocene.

Because of the absence of the Middle Eocene index species, 3 zones have been defined in this interval, two of which is the chronostratigraphical equivalent of the combined Mediterranean zones. E8 and E9 zones of Berggren and Pearson (2005) coincides with the *Hantkenina* spp.-*Acarinina boudreauxi* Concurrent-range Zone defined in this study, whereas E10, E11 and E12 zones of the same authors are the equivalent of our *Globigerina eoceanica* Partial-range Zone.

The discrepancies, such as differences in stratigraphical ranges and presence/absence of the marker species of the Middle and Late Eocene between the Mediterranean and Crimean-Caucasus fauna have been documented (Batı *et al.*, 2009) (Figure 65). Therefore, the most important modification in the biozonation has needed to be made for the Middle and Upper Eocene. The zone marker planktonic foraminiferal species of the Middle and Upper Eocene Mediterranean biozonation, such as *Hantkenina nuttalli, Globigerinatheka kugleri, Morozovella lehneri, Orbulinoides beckmanni, Morozovella spinulosa, Truncorotaloides rohri* and *Globigerinatheka semiinvolutina,* have not been recorded in this study. The index species used in the biozonation of the Middle and Upper Eocene Crimean-Caucasian biostratigraphic scheme, such as *Hantkenina alabamensis*, *Hantkenina dumblei, Globigerinatheka index, Hantkenina australiformis, Subbotina praebulloides* and *Globigerinatheka tropicalis,* have also been absent in our samples.

Orbulinoides beckmanni Zone (P13 Zone of Berggren *et al.* (1995) and E12 Zone of Berggren and Pearson (2005) is an important taxon range zone in the Mediterranean biozonation defined by the short stratigraphical range of the nominate taxon. This interval is also related with the Middle Eocene Climatic Optimum (MECO) event. However, this species is recorded neither in this study nor in the previous studies in the Black Sea and Crimean-Caucasus realms (Akhmetiev and Beniamovski, 2003; Beniamovski, 2001; Akhmetiev and Beniamovski, 2006; Batı *et al.*, 2009; Zakrevskaya *et al.*, 2011; Beniamovski, 2012). Edgar *et al.* (2010) mentioned the environmental control on the biogeographical distribution of this species and commented on its restriction to the tropical and warm mid-latitudes (Figure 66). Therefore, the environmental restriction for the distribution of *Orbulinoides beckmanni* should be the reason for the absence of this form in the study area.

When the Middle Eocene planktonic foraminifera assemblage in each section are compared, the Karaburun Section includes diversified morozovellids and acarininids besides subbotinids, hantkeninids, globanomalinids and pseudohastigerinids, whose diversification are less than morozovellids and acarininids. On the other hand, the Middle Eocene succession in the İstafan and the Sinay-Karasu sections are dominated by the subbotinids and globigerinids, whereas the diversity and abundance of the acarininids, turborotalids and hantkeninids are lower. When the life strategies of these genera are considered, morozovellids and acarininids ar the warm water indicators iving in the surface waters,

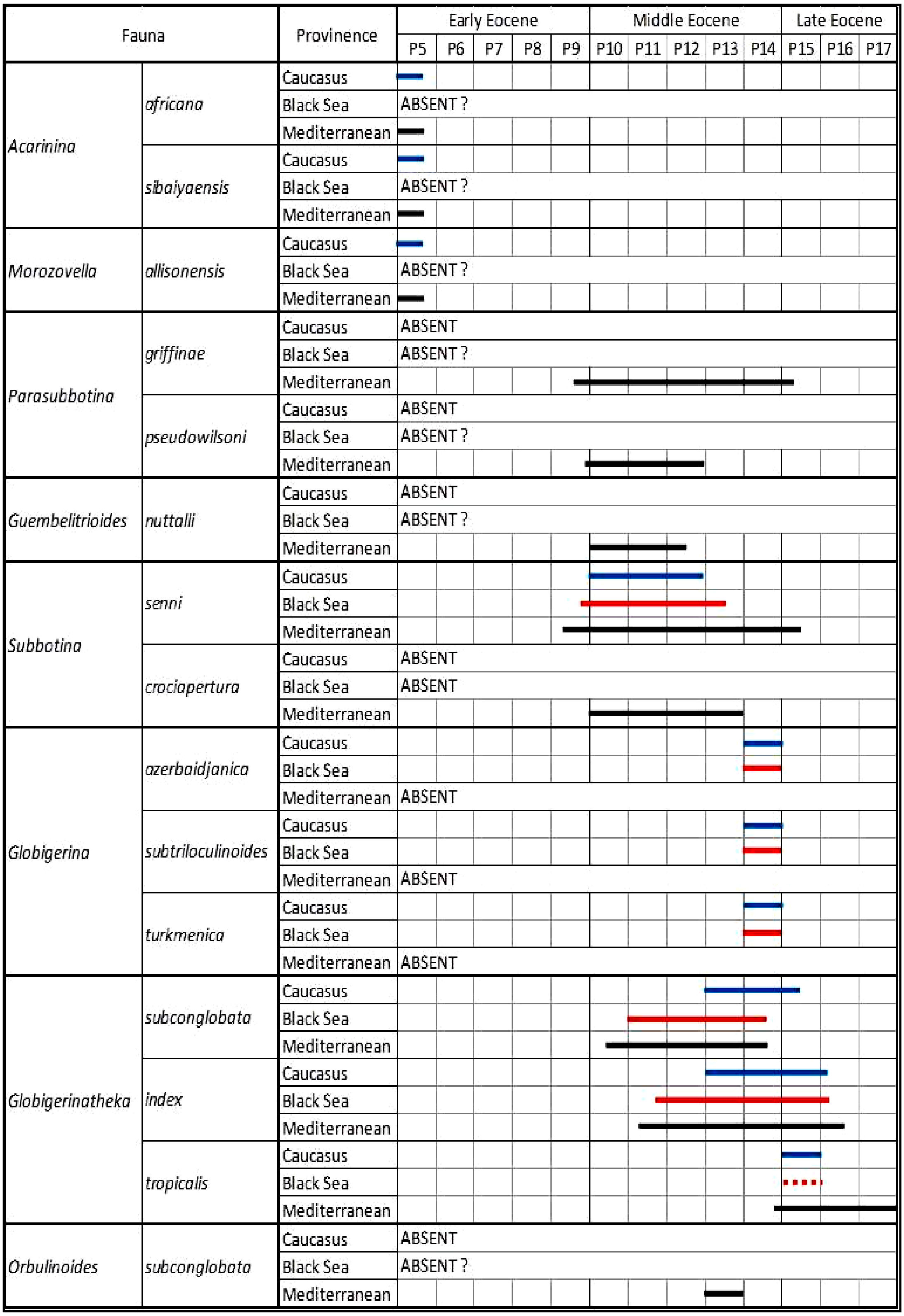

Figure 65. Discrepancies in the stratigraphical ranges of the Eocene planktonic foraminifera between Caucasus-Black Sea-Mediterranean realms (modified from Batı *et al*., 2009).

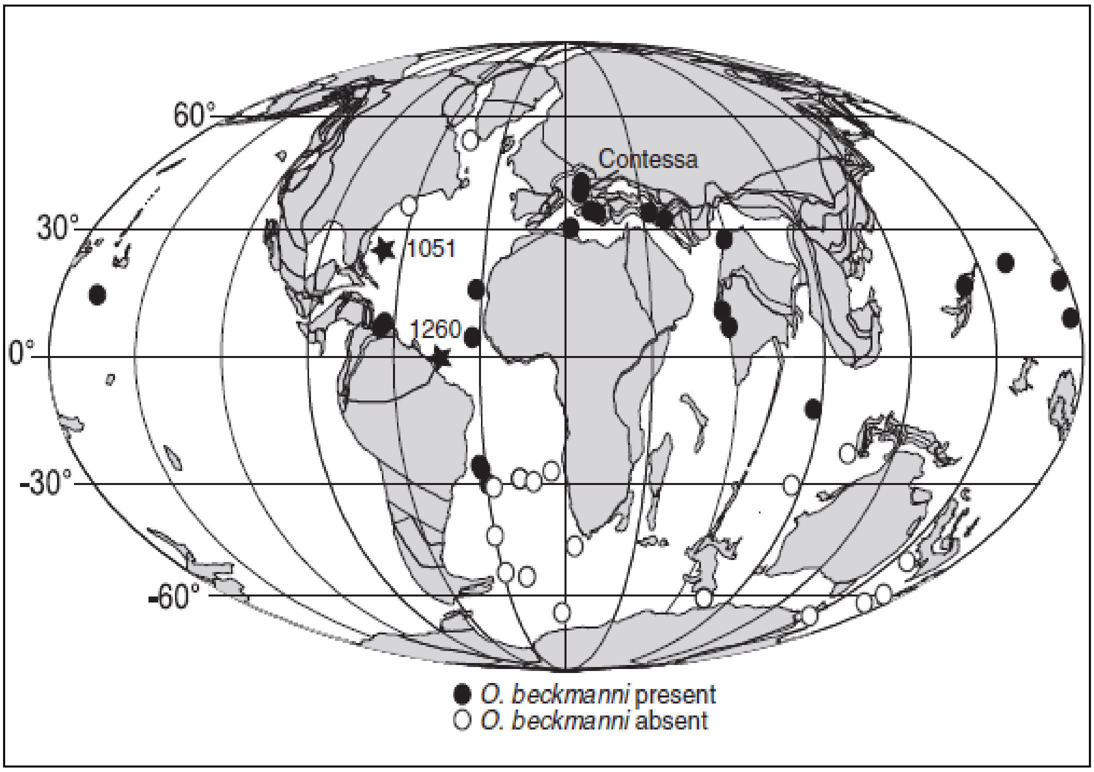

Figure 66. Palaeogeographic reconstruction of the Eocene illustrating the presence and absence of *Orbulinoides beckmanni* (Edgar *et al*., 2010).

turborotalids and hantkeninids are subsurface intermediate dwellers and subbotinids are deep dwellers indicating the cooler waters (Luciani *et al*., 2010) (Figure 62). Therefore, higher abundance and diversification of the morozovellids and the acarininids in the Karaburun Section, which is located in the most western part of the study area, indicates the warmer conditions in this location during the Middle Eocene. On the other hand, located in the east, the İstafan and the Sinay-Karasu sections reflect the cooler and more eutrophic conditions indicated by the recognized assemblage. It shows a regional difference between east and west during the Middle Eocene.

Another important data recognized in this study is the record of the endemic Crimean-Caucasus fauna, such as *Globigerina turkmenica* and *Globigerina azerbaidjanica* at the uppermost part of the Middle Eocene.

Consequently, all these data suggest that there was no connection between the Mediterranean region and the Crimean-Caucasus realms until the latest Middle Eocene, although the Black Sea realm was located between them. On the other hand, the existence of the endemic species (*Globigerina turkmenica* and *Globigerina azerbaidjanica*) of the Crimean-Caucasus region in the studied sequence indicates that there was a possible connection between the Black Sea and the Crimean-Caucasus realm at least during the latest Middle Eocene time.

6.3. Conclusions

Nine stratigraphical sections have been measured in the Western and Central Black Sea Region. A total of 327 samples have been gathered from 2 sections around the Akçakoca, Düzce region and 7 sections around the Sinop region.

As a result of detailed taxonomical studies, a total of 18 genera and 87 planktonic foraminifera species have been identified. A total of 3 orders, 19 superfamilies, 30 families, 38 genera and 14 species of benthic foraminifera have also been recorded in the Erfelek 1 Section.

Thirteen planktonic foraminiferal biozones and four subzones have been defined in this study for the Paleocene-Eocene interval in the ascending oreder: **(1)** *Parvularugoglobigerina eugubina-Praemurica uncinata* Interval Zone (with *Subbotina triloculinoides-Praemurica inconstans* Interval Subzone and *Praemurica inconstans-Praemurica uncinata* Interval Subzone) and **(2)** *Praemurica uncinata-Morozovella angulata* Interval Zone for the Early Paleocene; **(3)** *Morozovella angulata-Acarinina nitida* Interval Zone and **(4)** *Acarinina nitida-Globanomalina pseudomenardii* Concurrent Range Zone for the Late Paleocene; **(5)** *Morozovella velascoensis* Partial-range Zone for the Late Paleocene-Early Eocene; **(6)** *Morozovella subbotinae* Partial-range Zone (with *Morozovella edgari* Partial-range Subzone and *Morozovella* formosa/Morozovella *lensiformis-Morozovella aragonensis* Interval Subzone), **(7)** *Morozovella aragonensis-Morozovella formosa* Concurrent-range Zone, **(8)** *Acarinina pentacamerata* Partial-range Zone and **(9)** *Acarinina cuneicamerata-Hantkenina* spp. Interval Zone for the Early Eocene and **(10)** *Hantkenina* spp.-*Acarinina boudreauxi* Concurrent-range Zone, **(11)** *Globigerina eoceanica* Partial-range Zone and **(12)** *Globigerina turkmenica-Globigerina azerbaidjanica* Concurrent-range Zone for the Middle Eocene and **(13)** *Globigerina azerbaidjanica-Acarinina medizzai* Interval Zone for the Late Eocene.

Paleocene-Eocene boundary has been determined within the *Morozovella velascoensis* Partial Range Zone. The first occurrences of *Acarinina wilcoxensis* and *Acarinina pseudotopilensis* have been used to define the base of the Eocene.

Decrease in the species abundance and diversity for both planktonic and benthic foraminifera and decrease in the calcite content and increase in the quartz and kaolinite content have been recorded across the Paleocene-Eocene boundary.

During the Middle Eocene, the discrepancies in the assemblages of planktonic foraminifera have been recorded from the Black Sea realm with respect to the Mediterranean and Crimean-Caucasus realms.

6.4. Further studies

In order to improve the paleogeographic reconstruction of the Black Sea region, additional stratigraphical sections should be measured. As there are different views on the position of the Paleocene-Eocene boundary in terms of the formations, such as at the boundary between the Akveren-Atbaşı formations, within the Atbaşı formation, or at the boundary between the Atbaşı-Kusuri formations, lithostratigraphical revisions might be made to determine if there is diachronism in the age of the these formations from the Western to the Central Black Sea regions.

Further studies should also be carried out for the Paleocene-Eocene boundary interval in order to get the more precise position of the boundary. In this manner, the sampling intervals should be narrowed in the Erfelek Section. $\delta^{13}C$ isotope studies, which will point out the CIE interval, should also be carried out for the boundary sections to define the precise position of the PETM interval.

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APPENDIX A

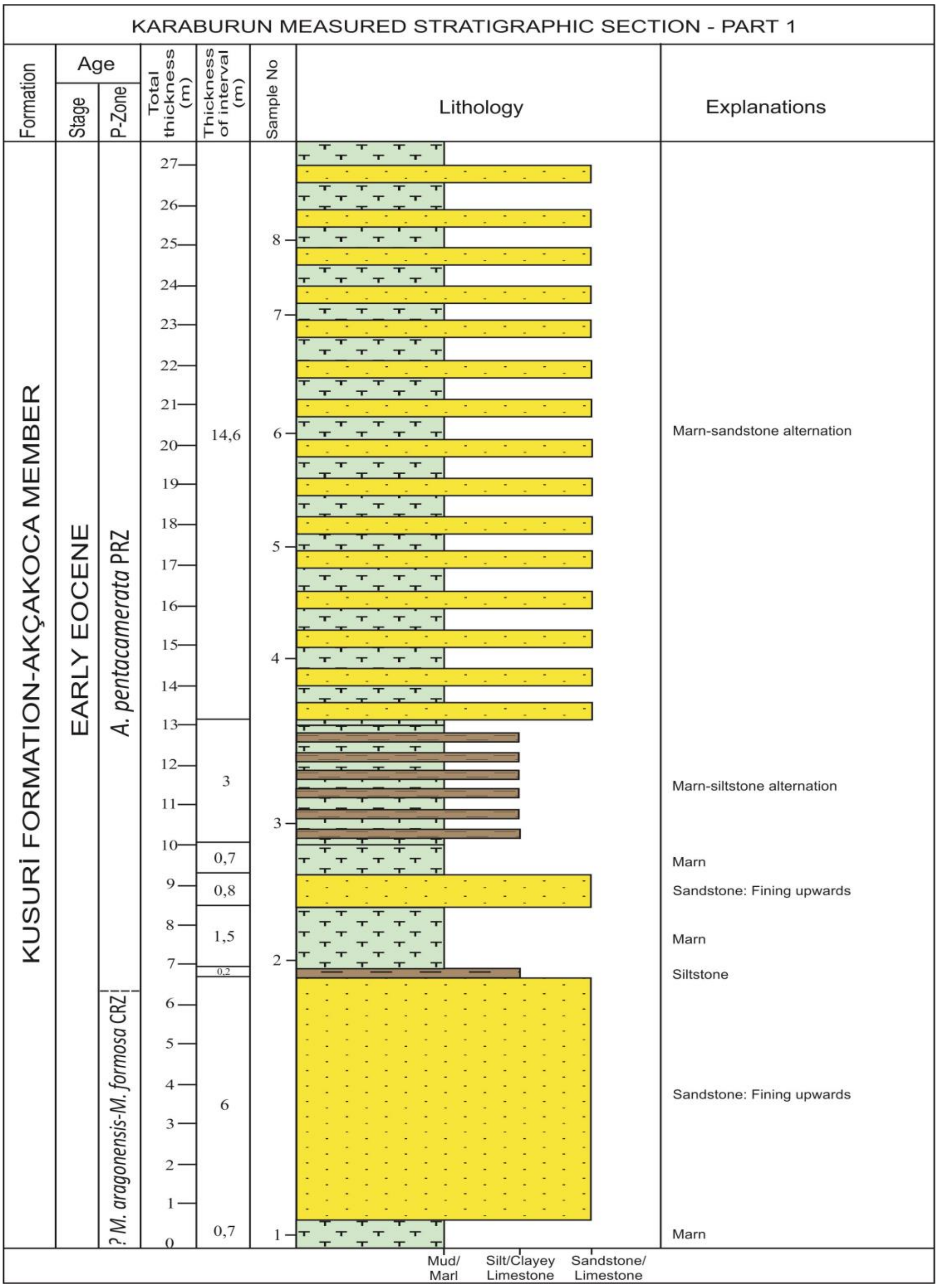


Figure 67. Karaburun Measured Stratigraphic Section.

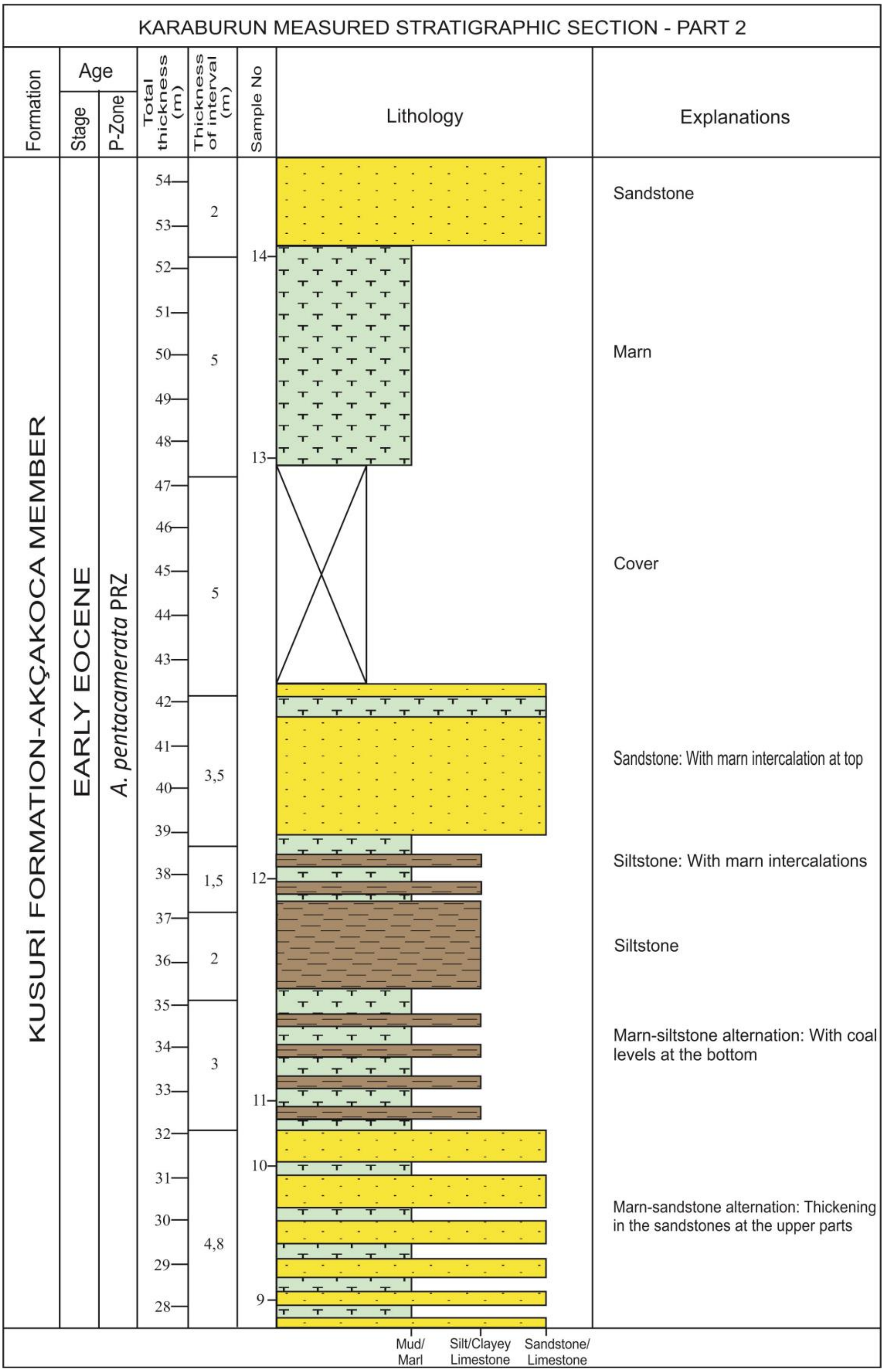
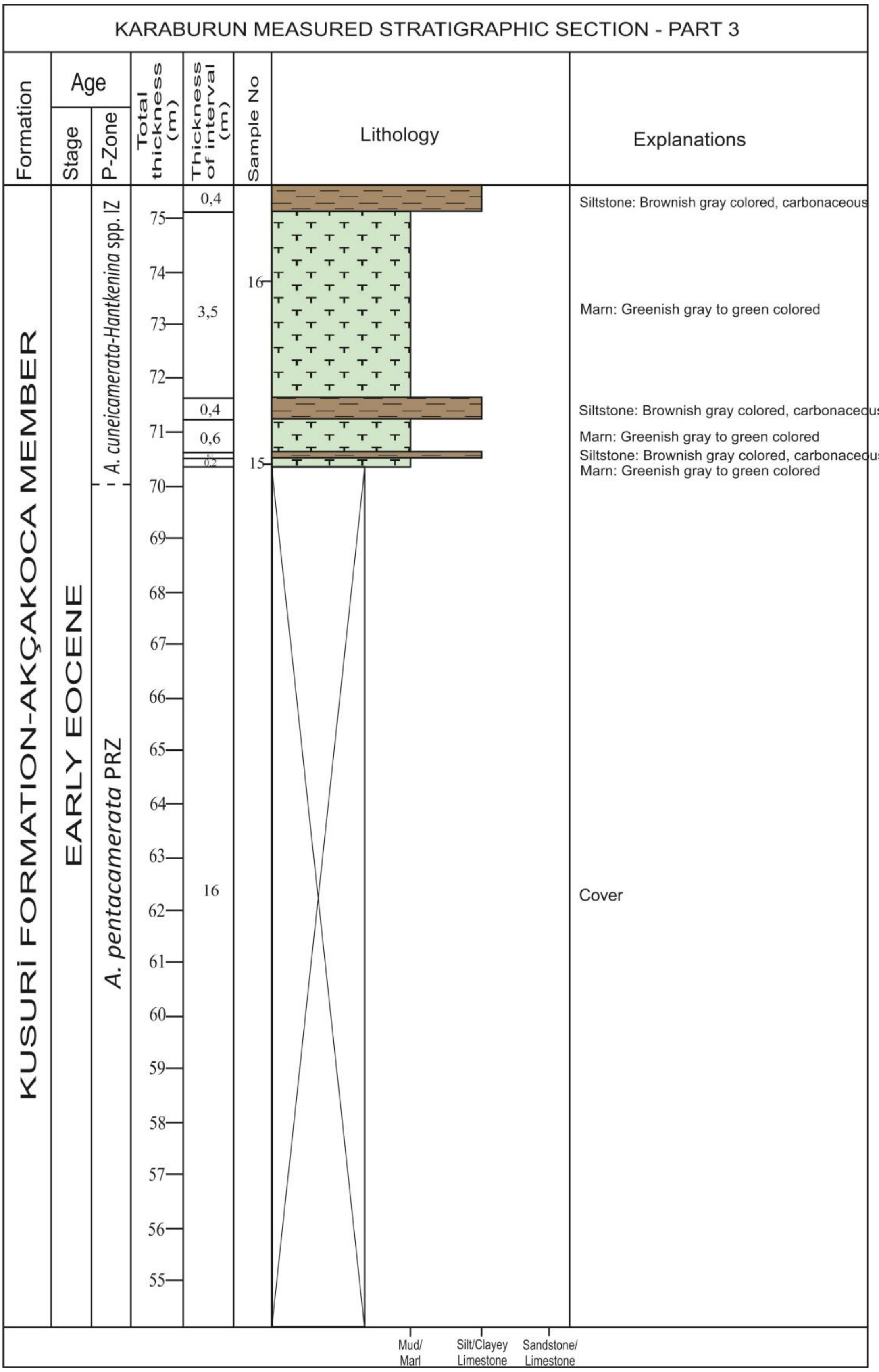


Figure 68. (Cont.)



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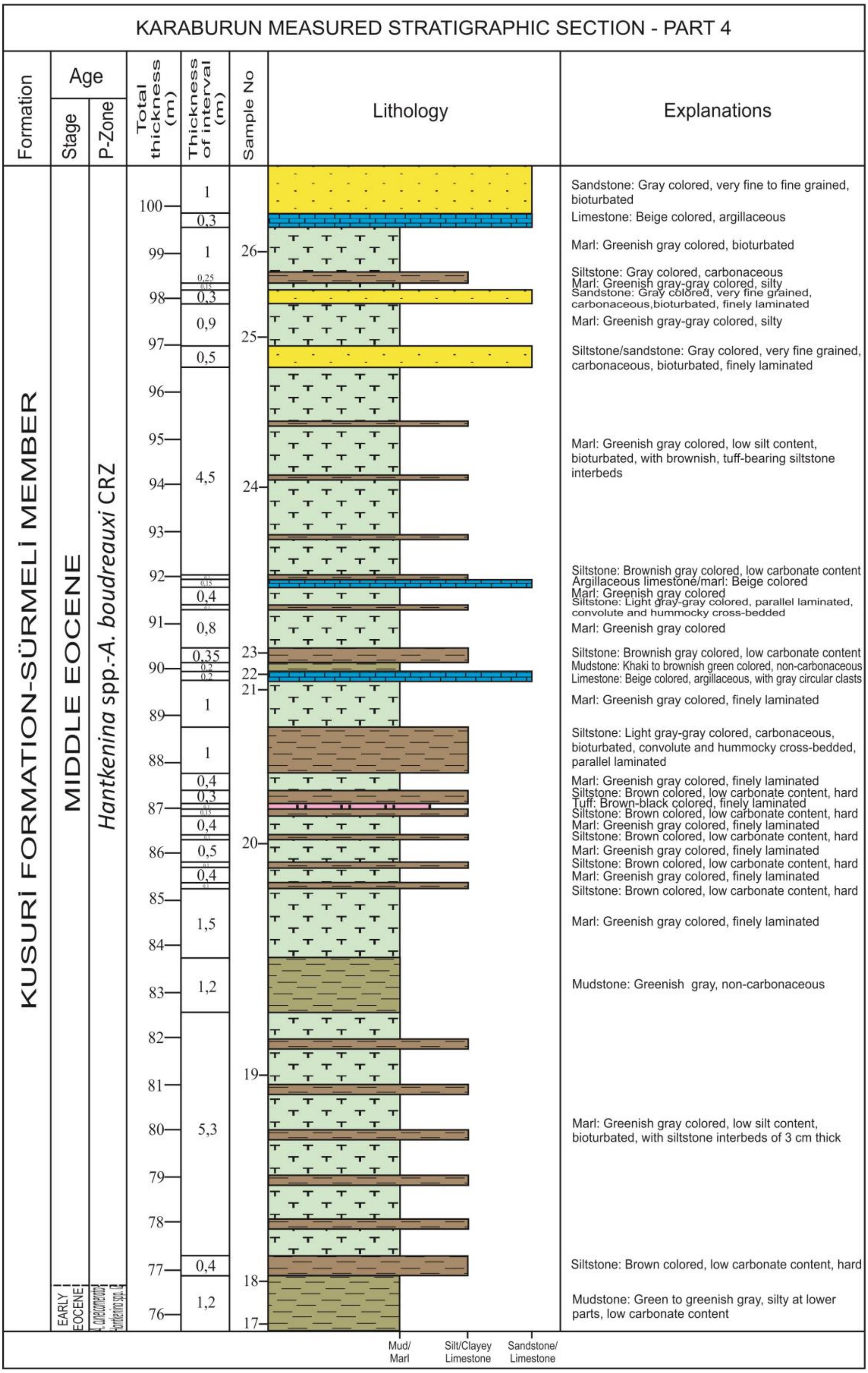

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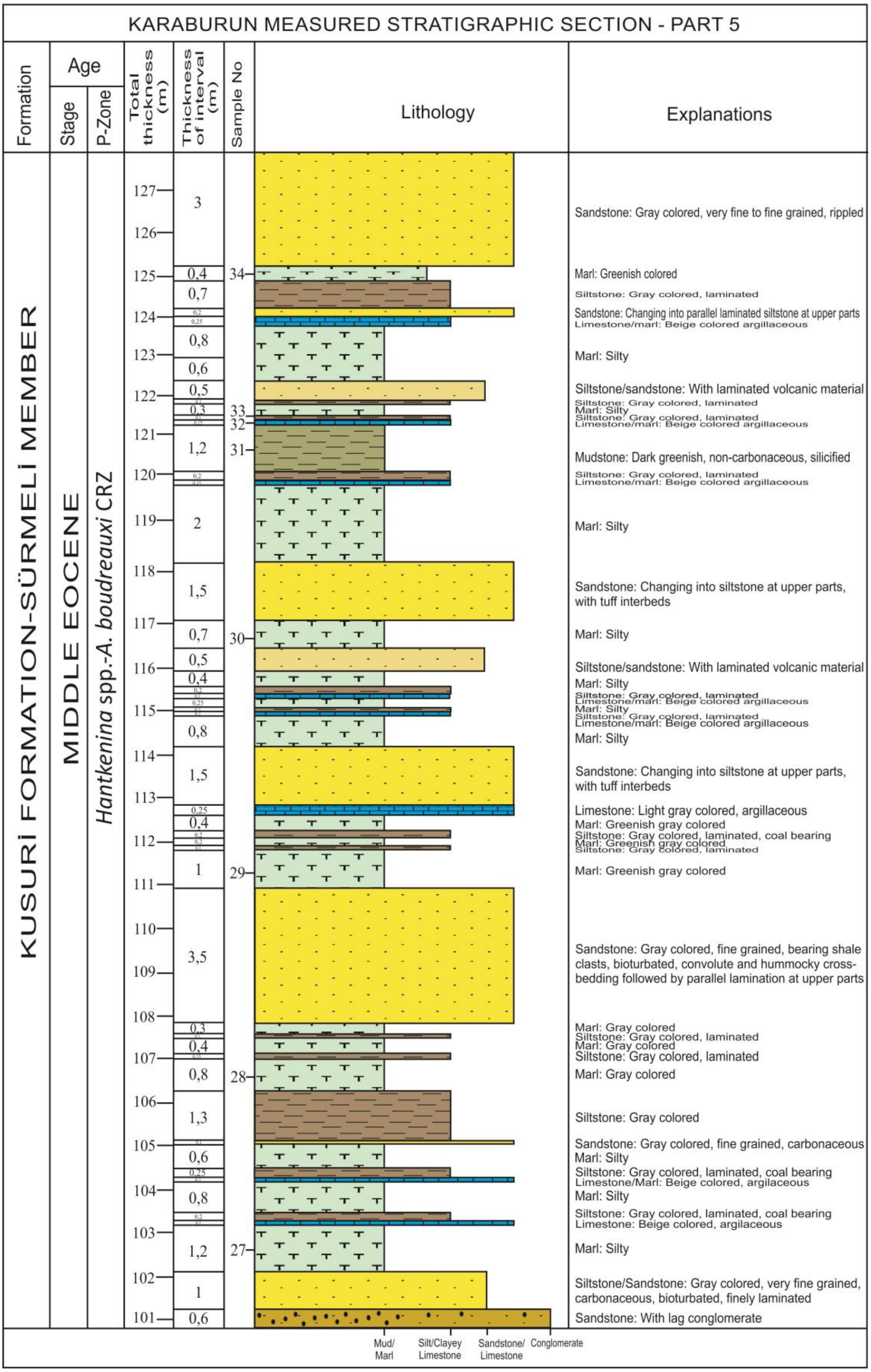


Figure 68. (Cont.)

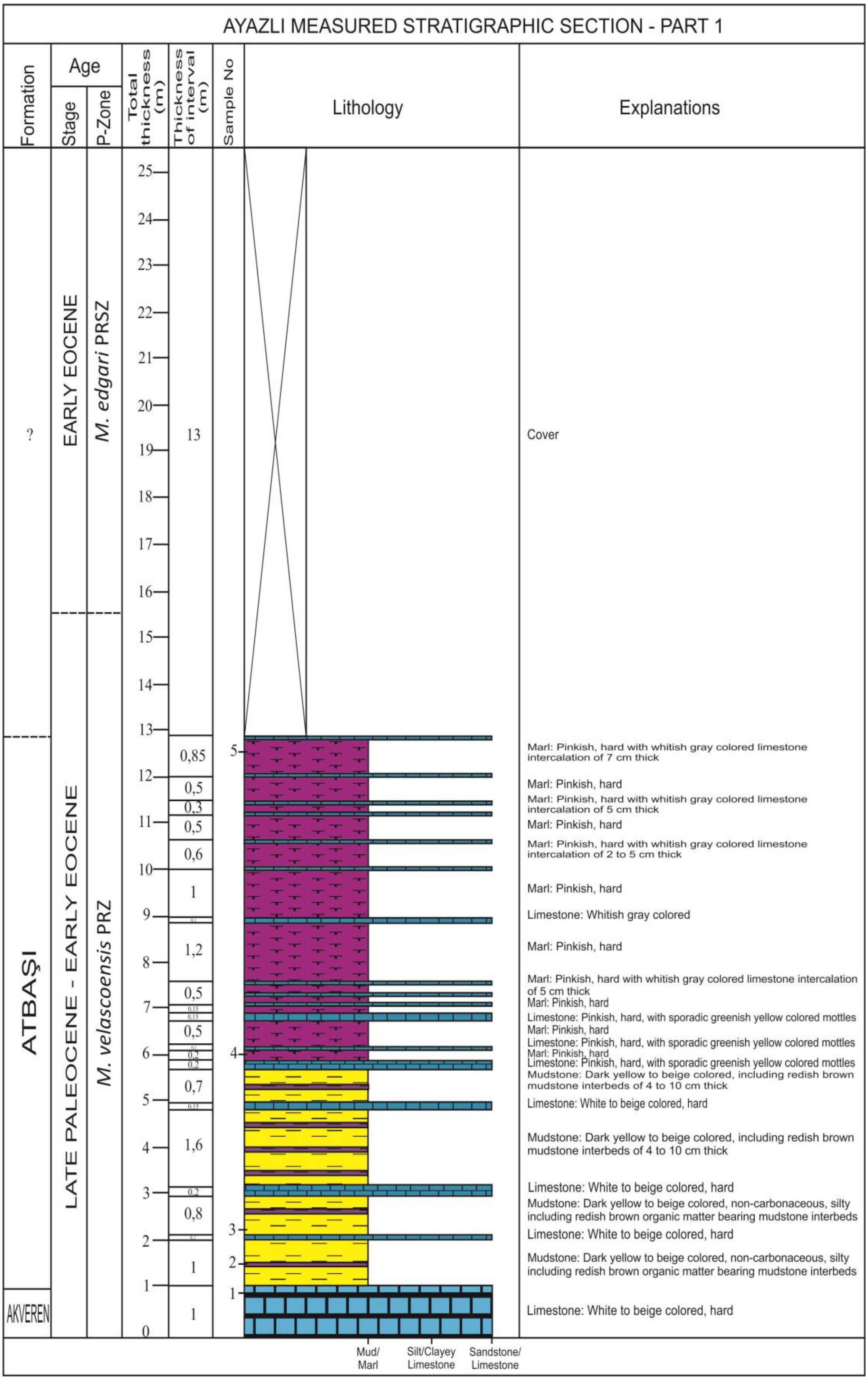


Figure 68. Ayazlı Measured Stratigraphic Section.

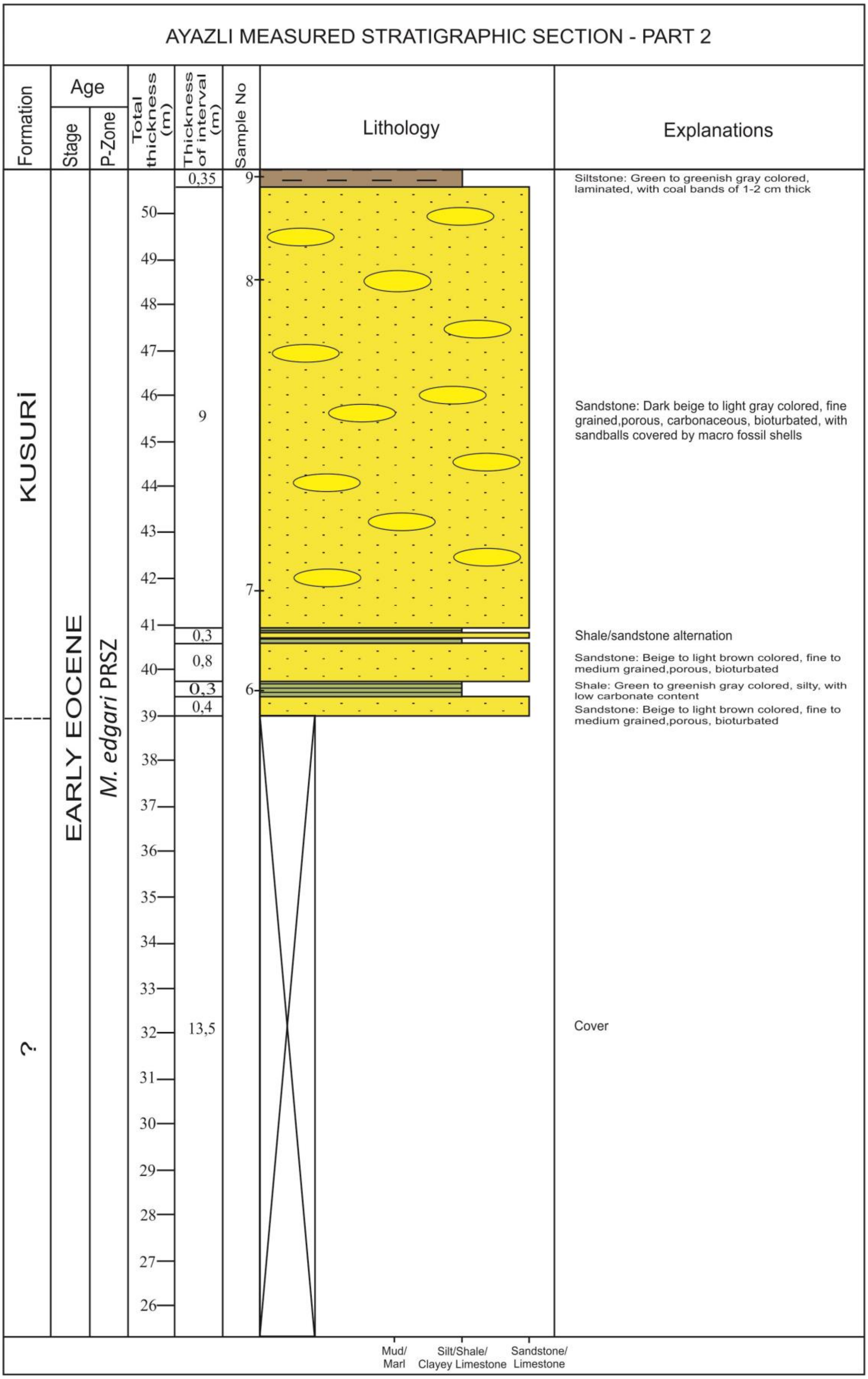
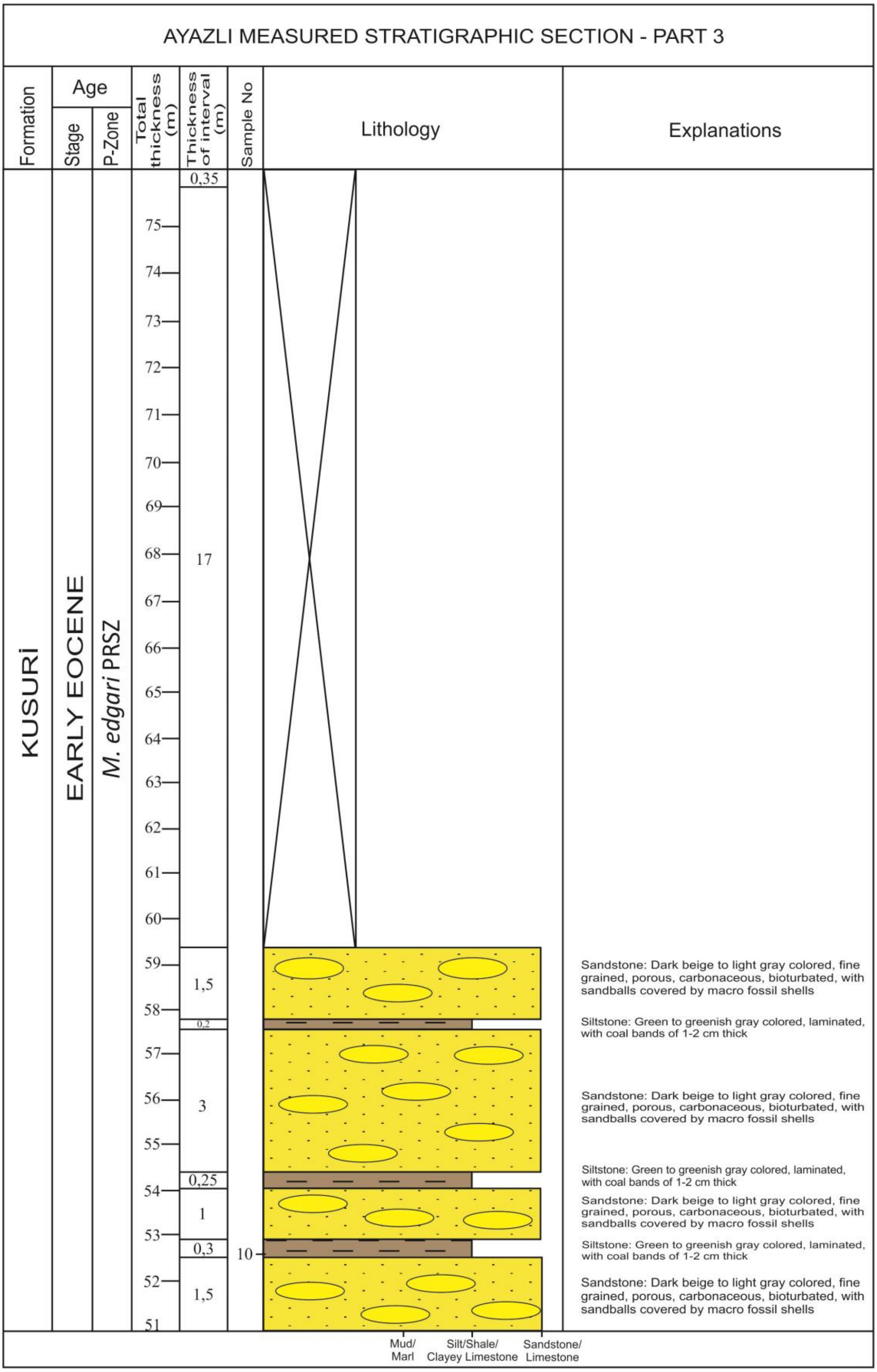


Figure 69. (Cont.)



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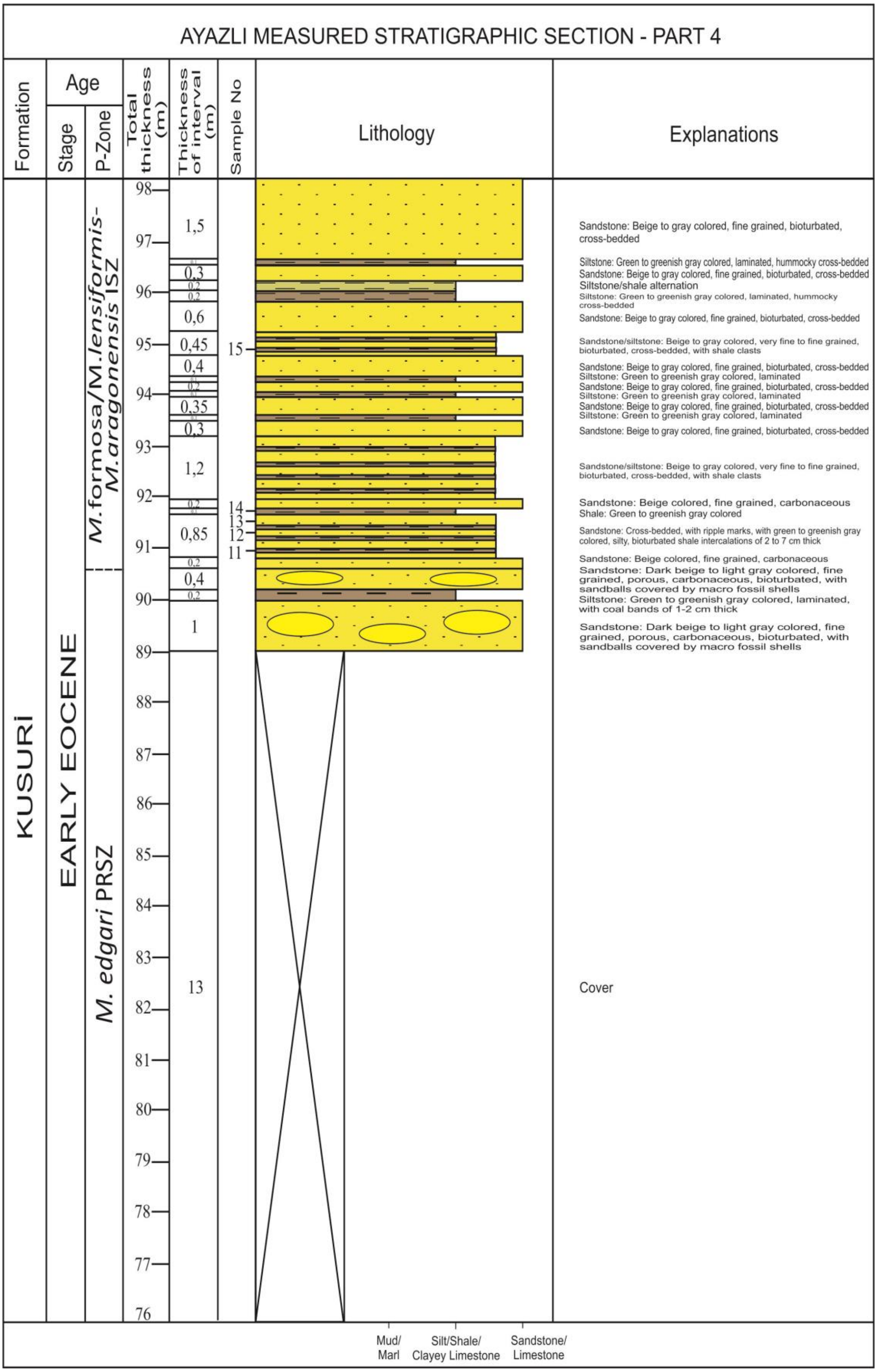

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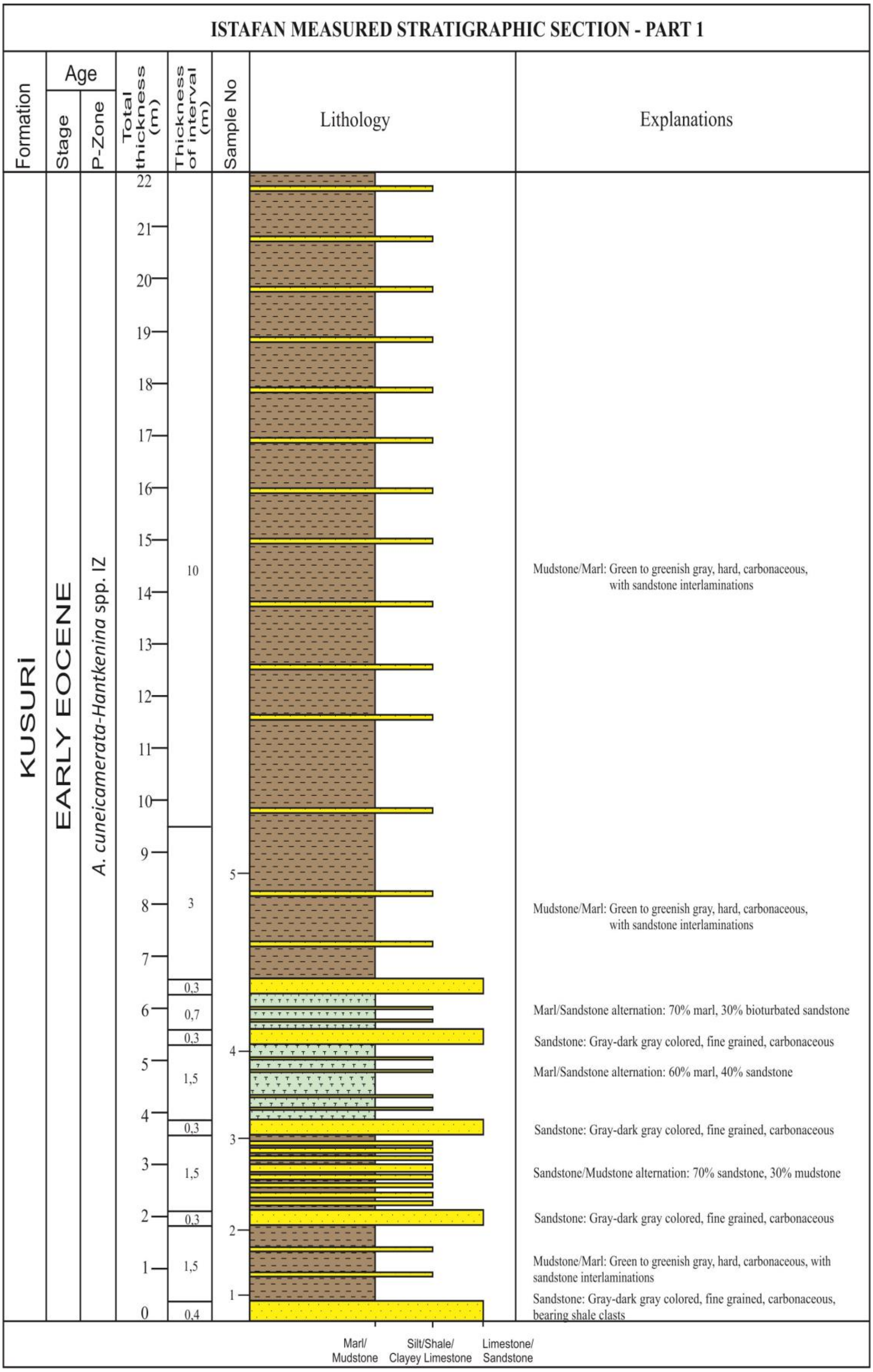


Figure 69. İstafan Measured Stratigraphic Section.

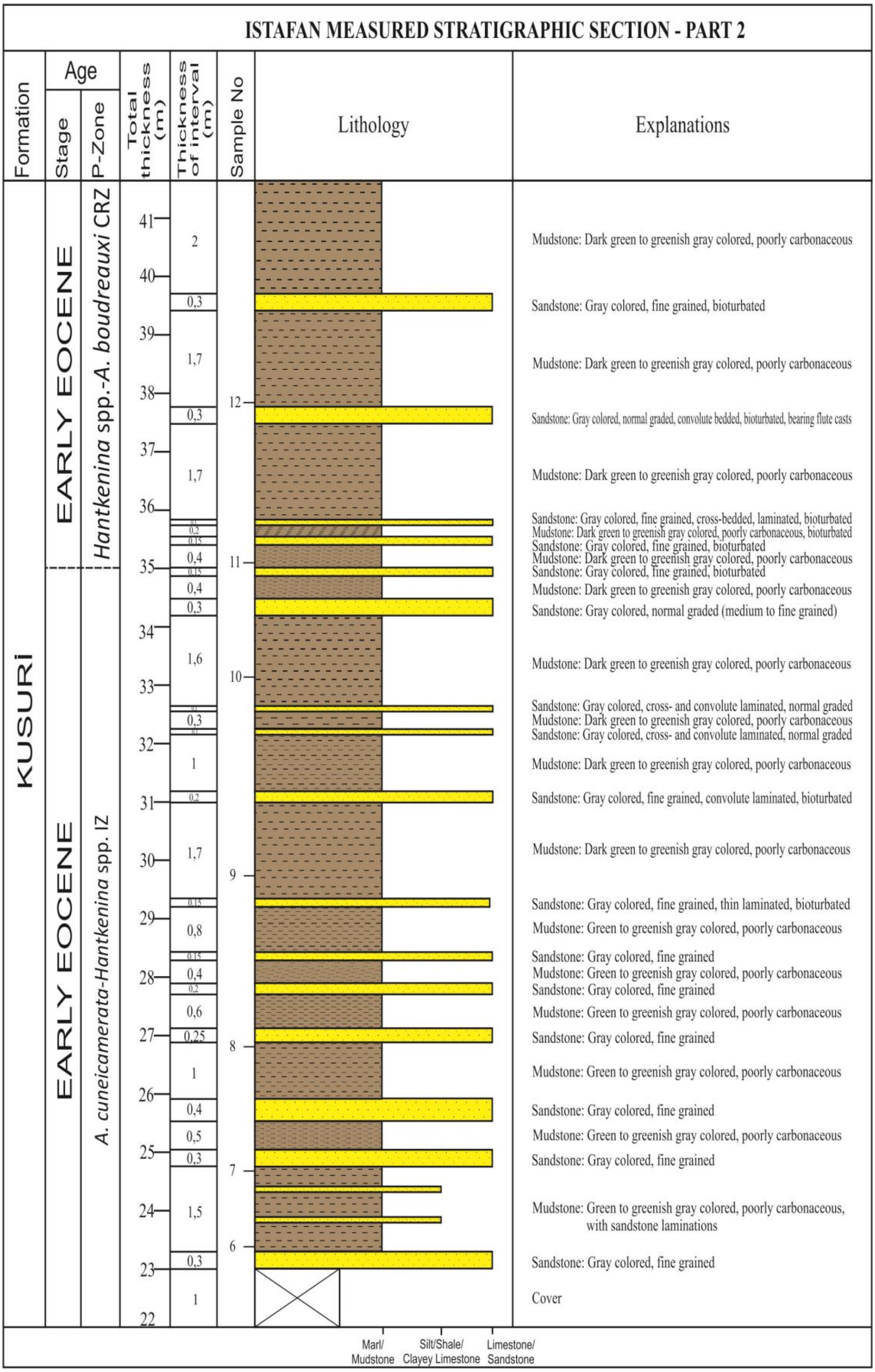
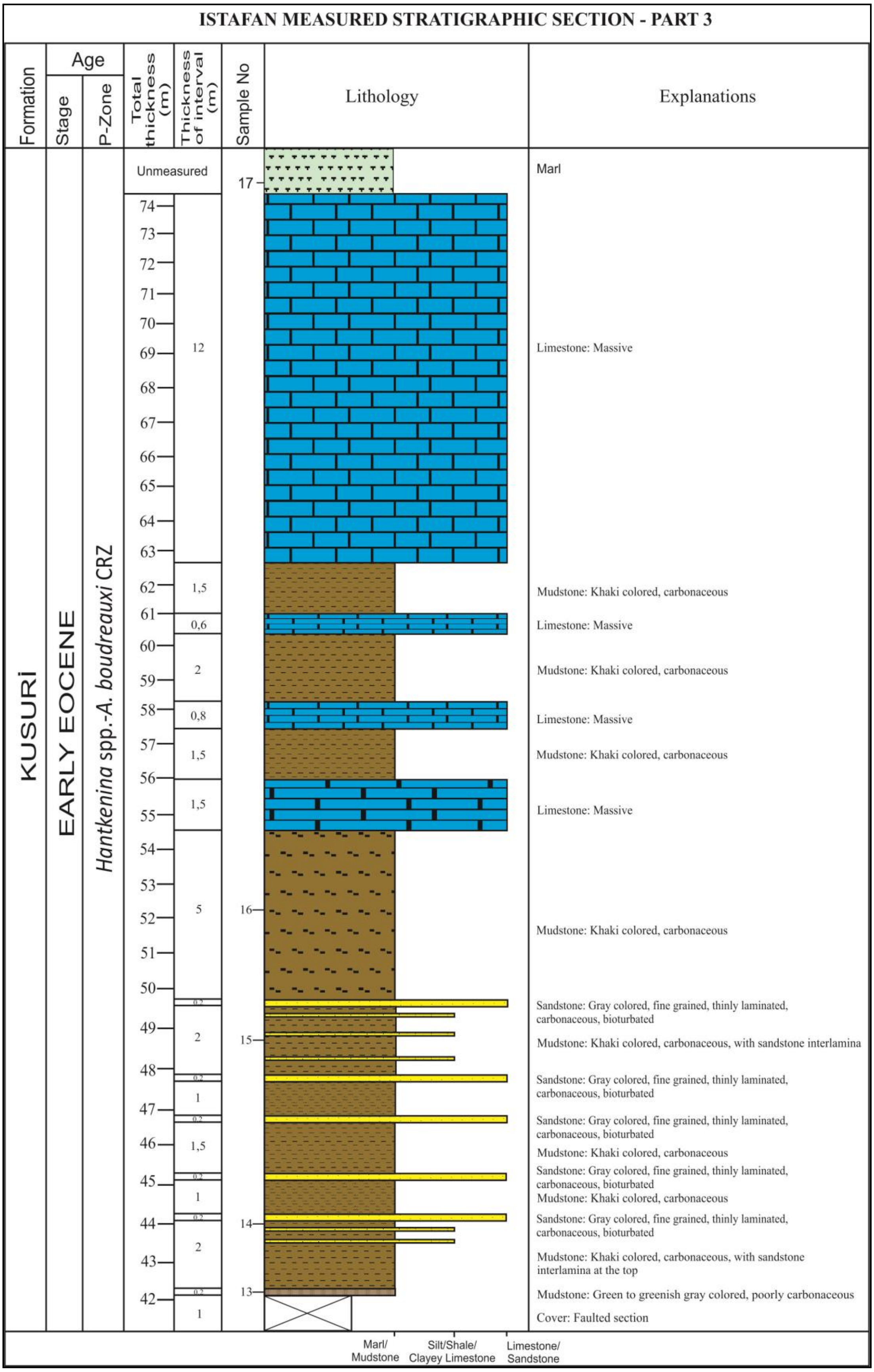


Figure 70. (Cont.)



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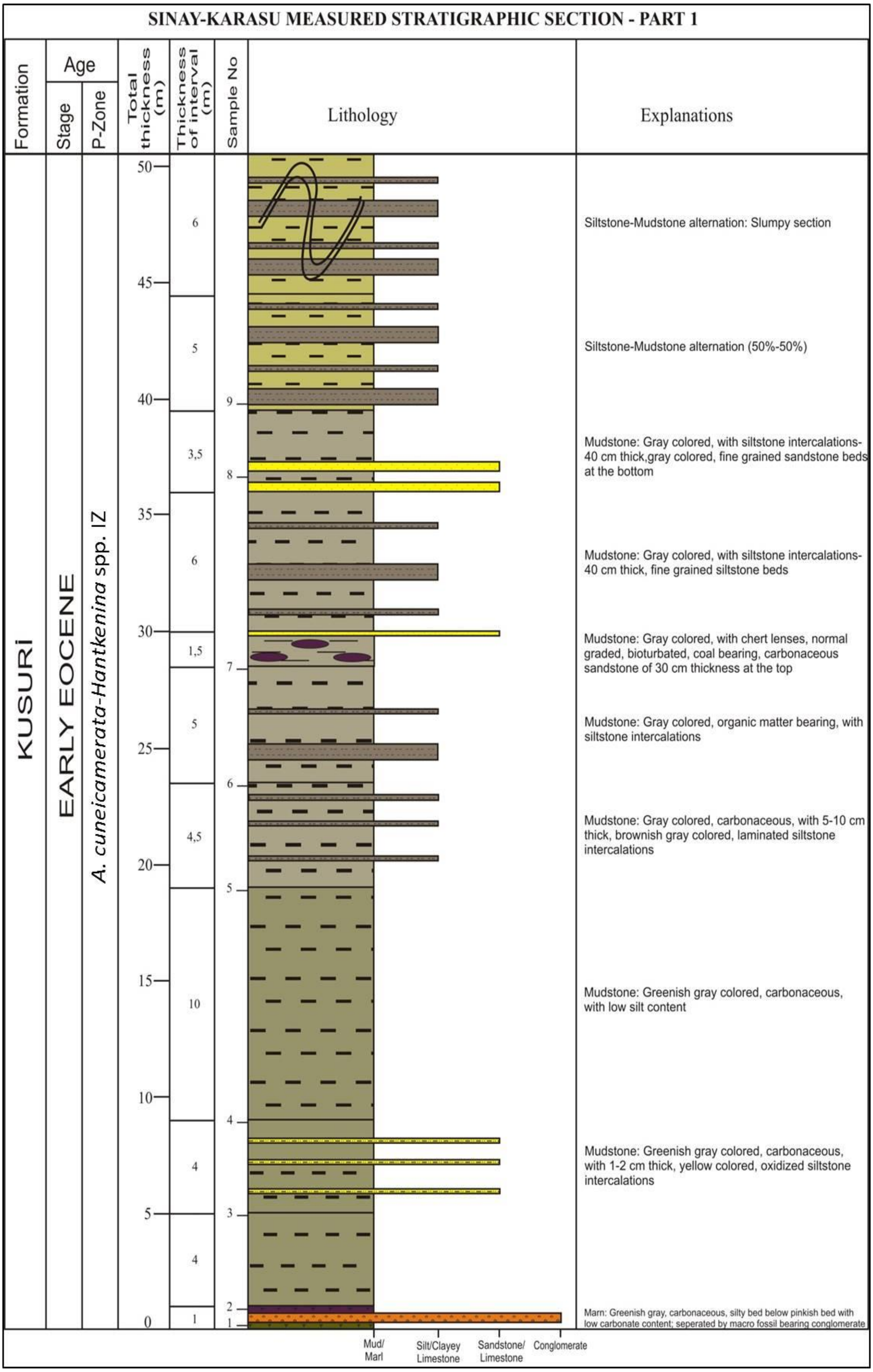


Figure 70. Sinay-Karasu Measured Stratigraphic Section.

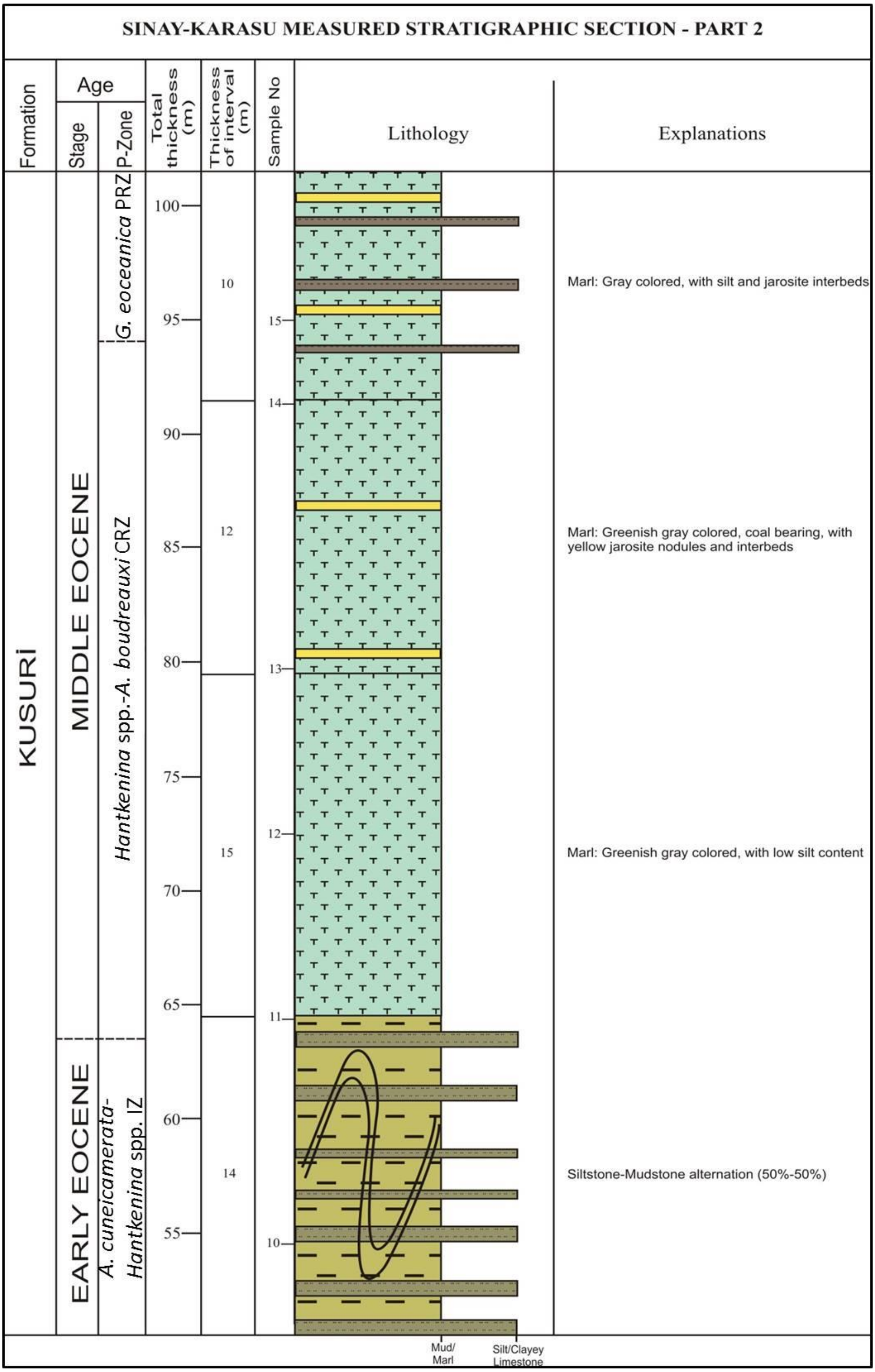


Figure 71. (Cont.)

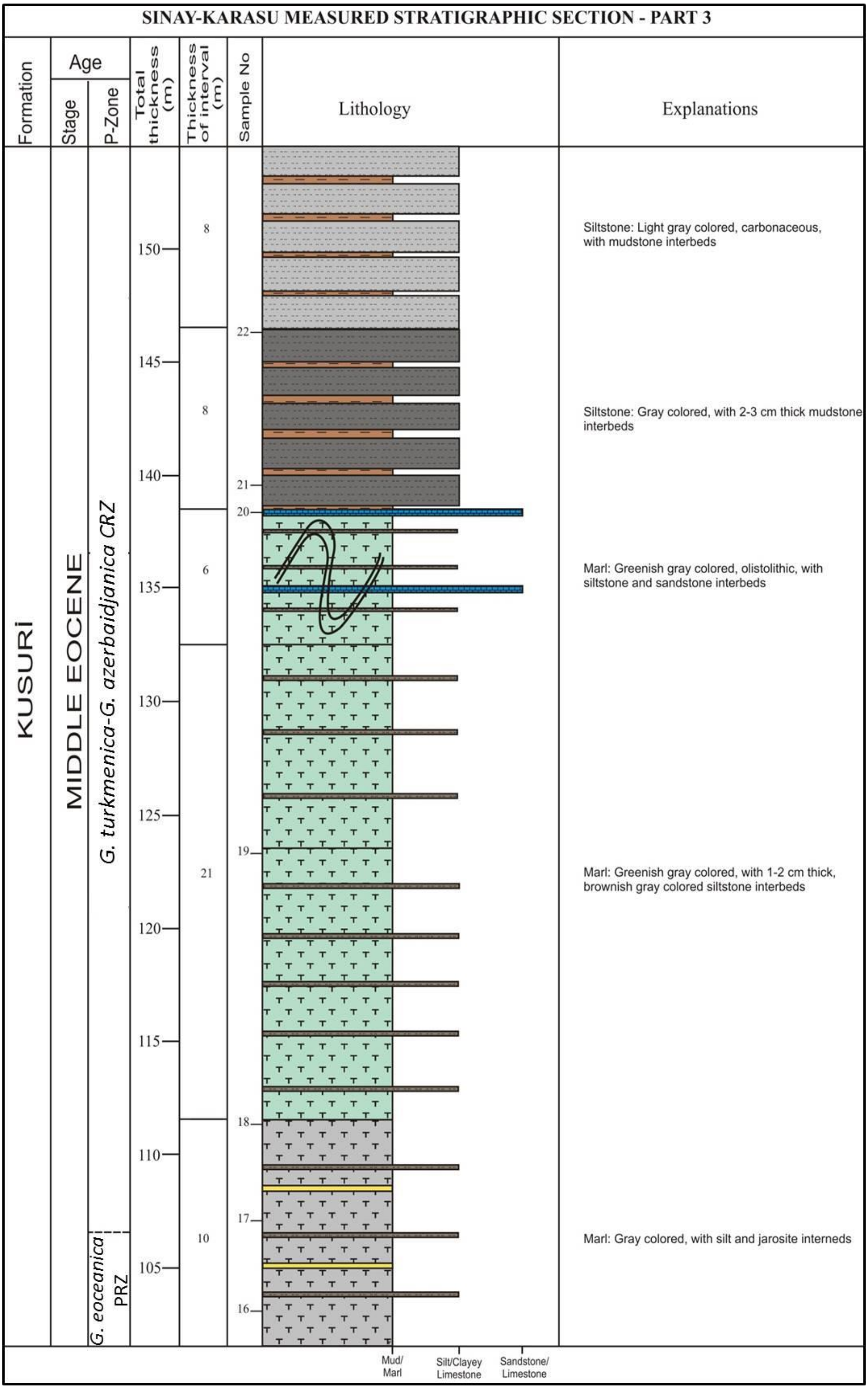
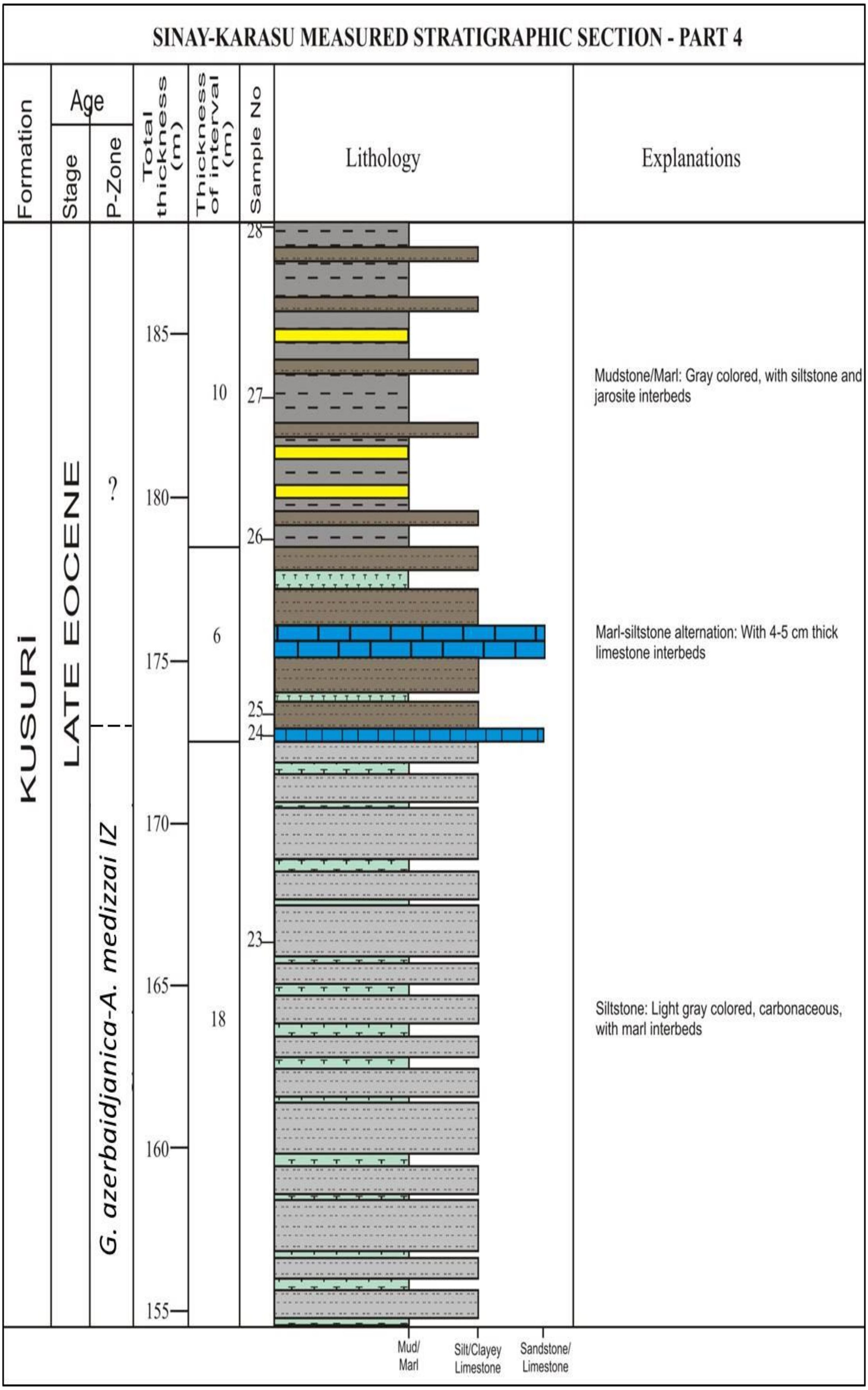


Figure 71. (Cont.)



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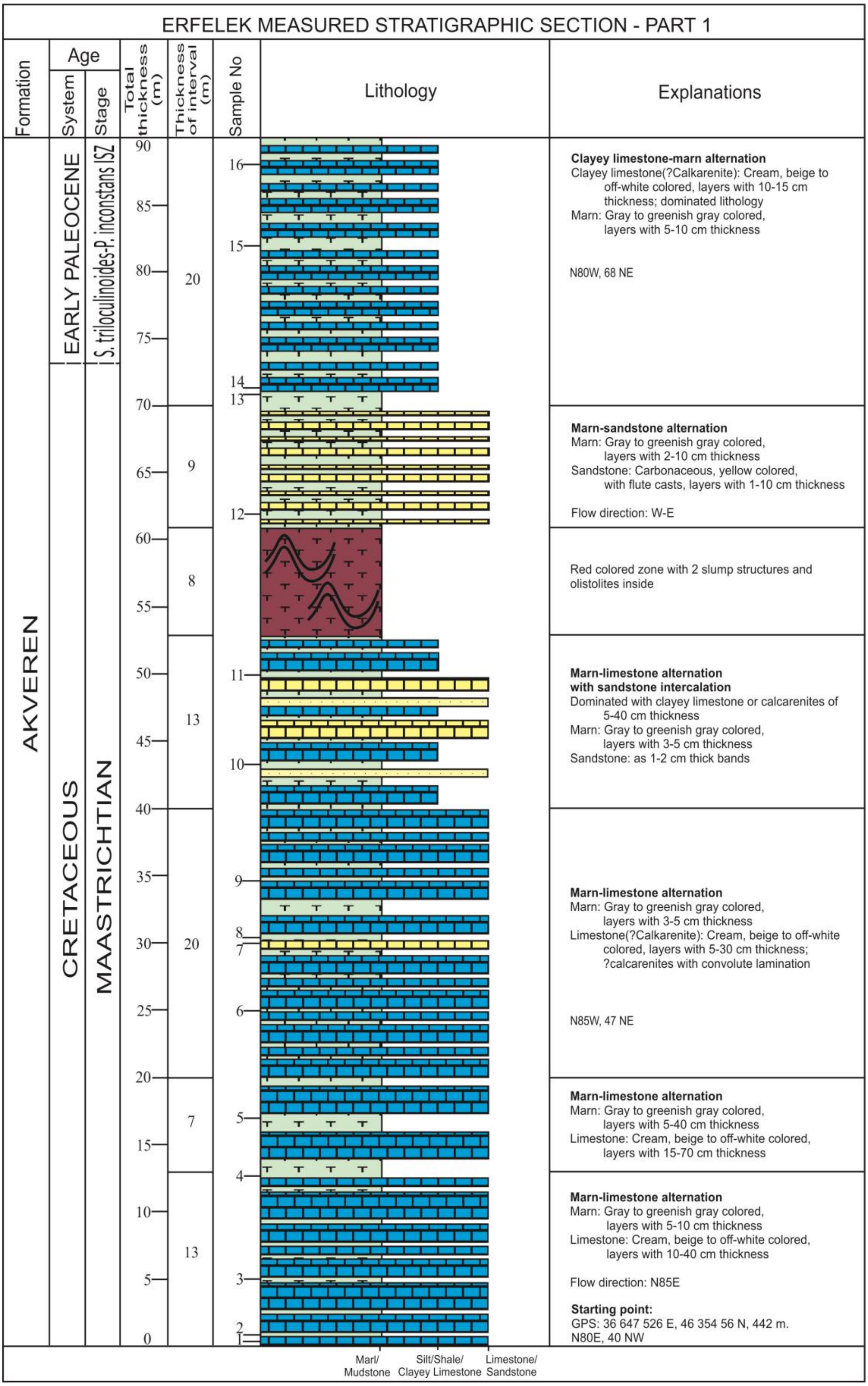
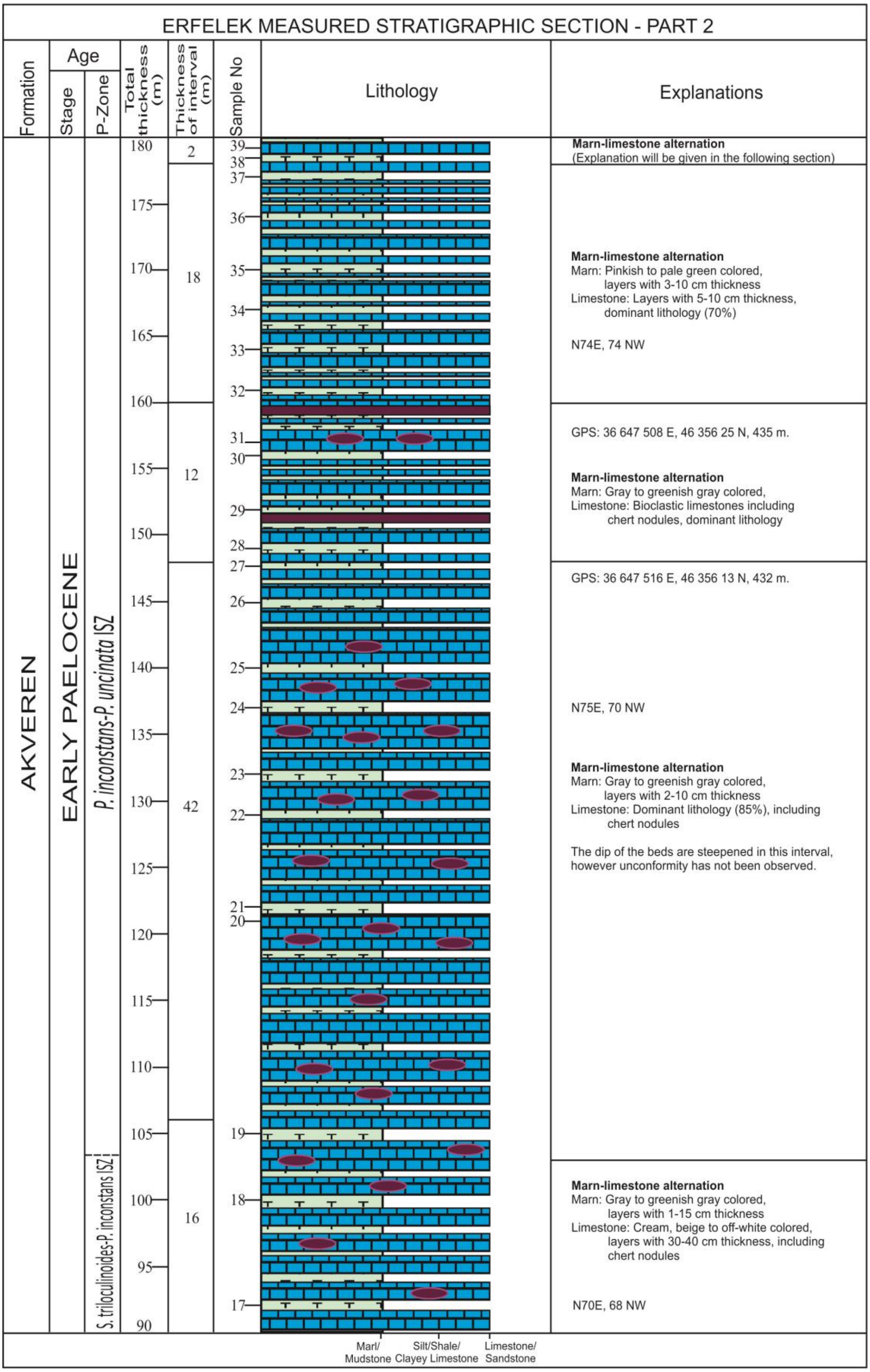


Figure 71. Erfelek Measured Stratigraphic Section.



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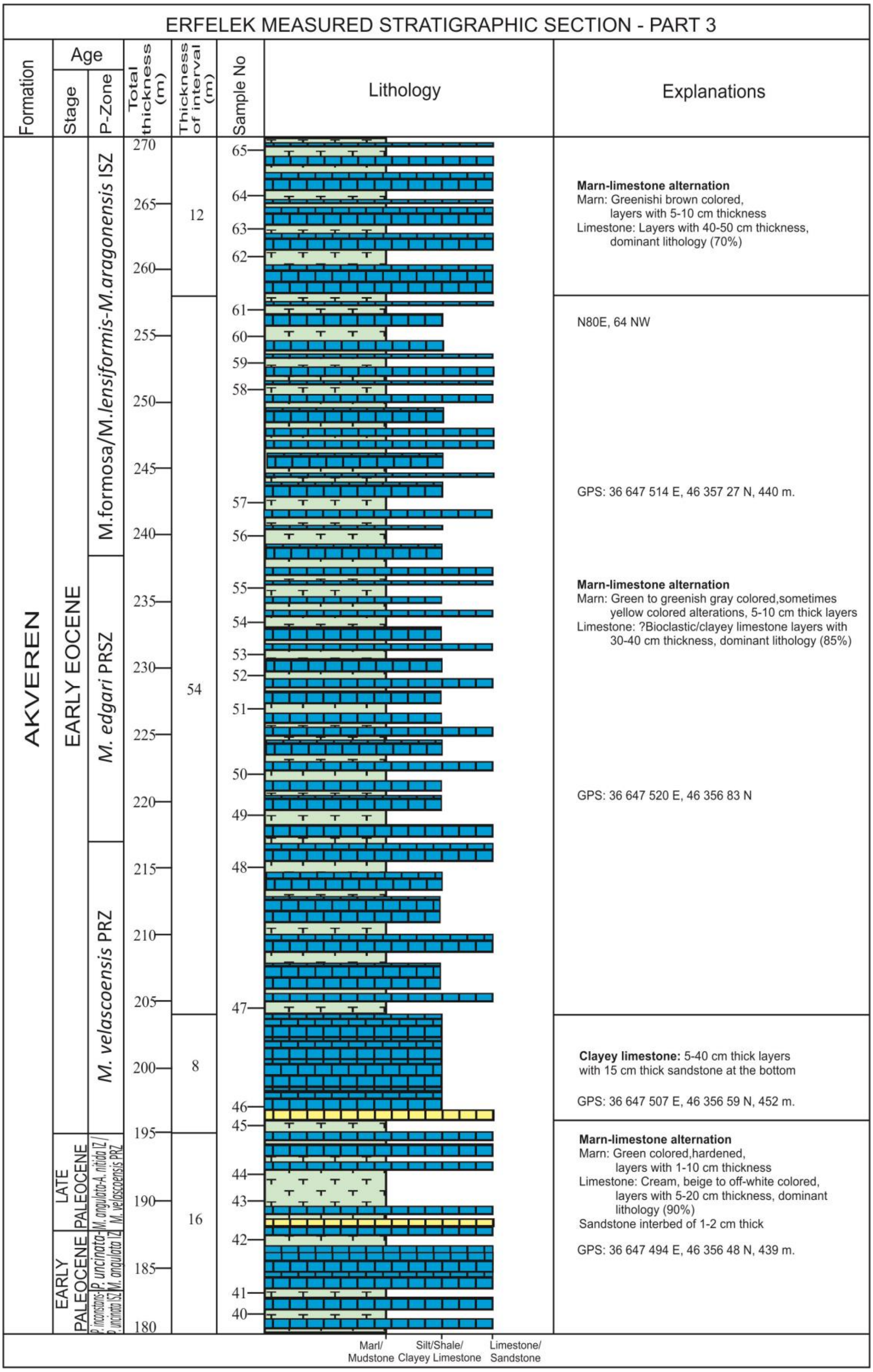
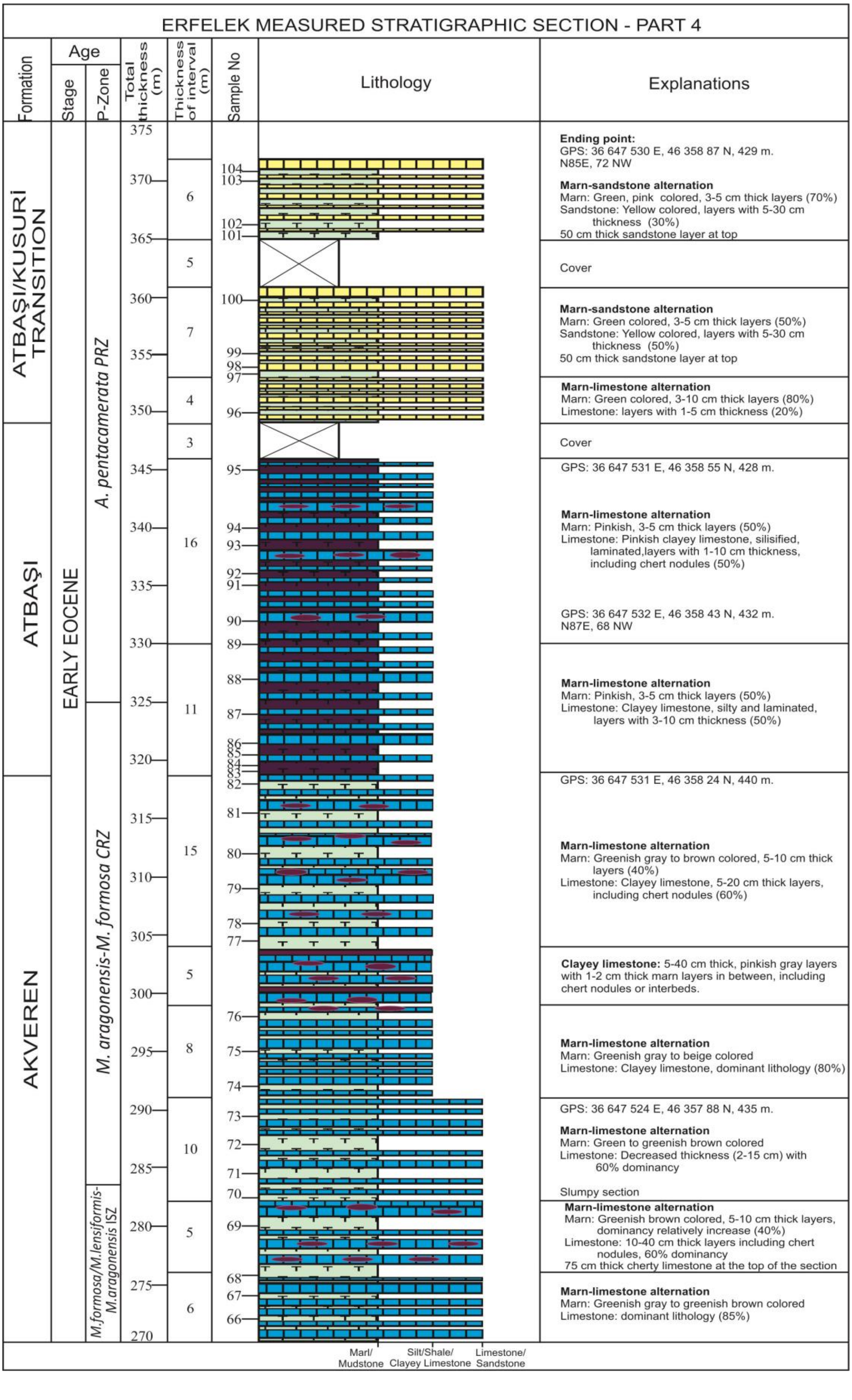


Figure 72. (Cont.)



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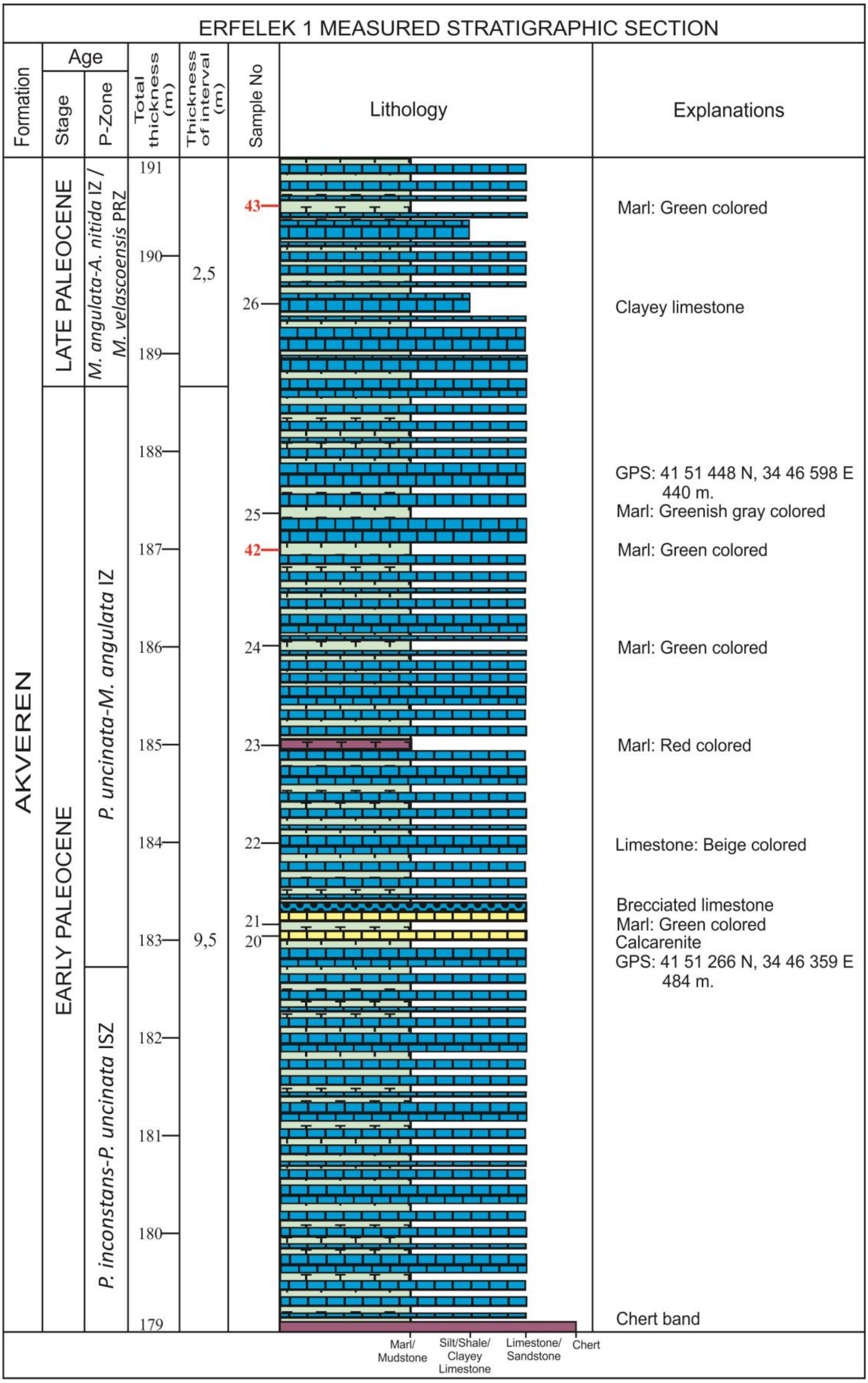


Figure 72. Erfelek 1 Measured Stratigraphic Section.

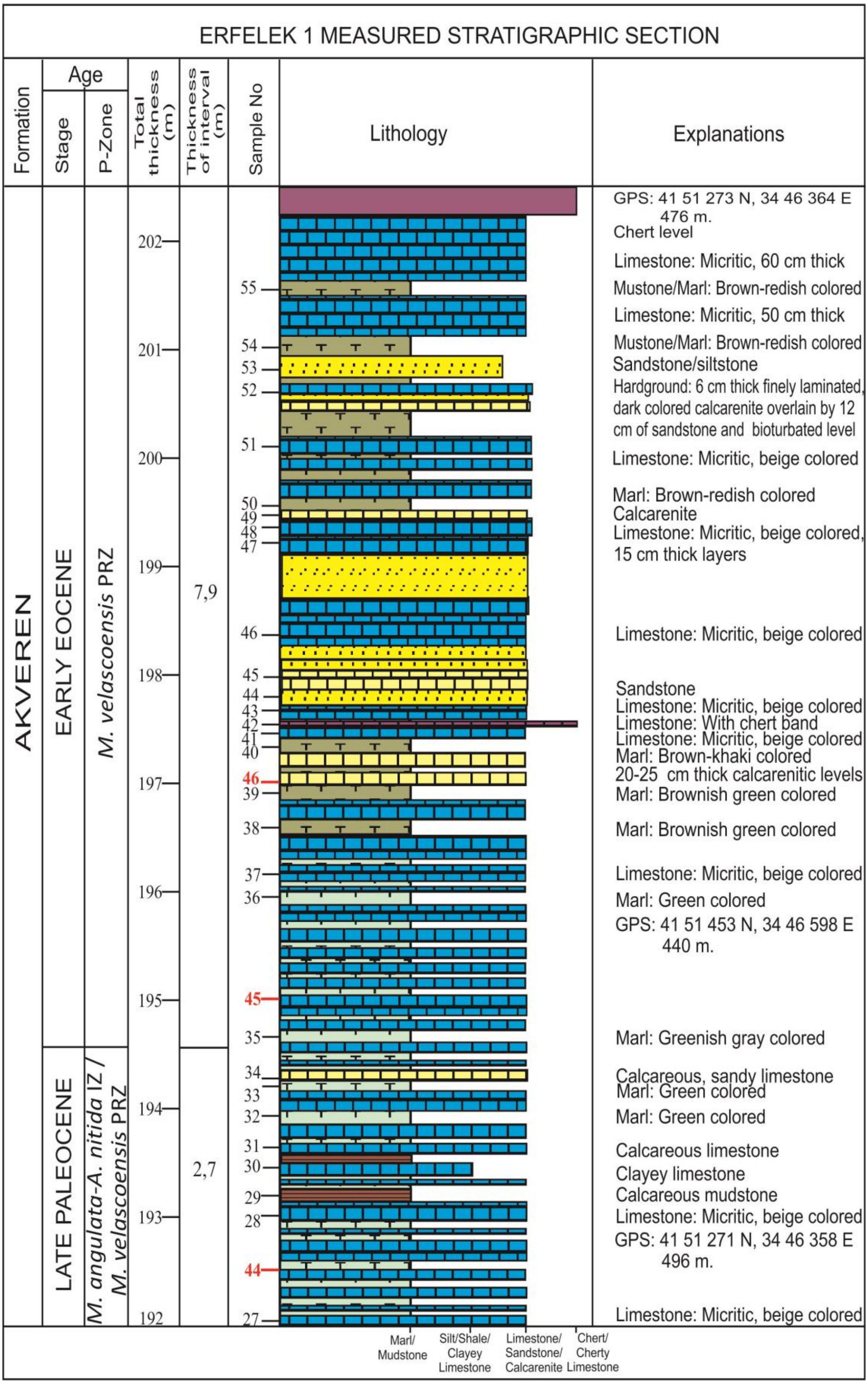


Figure 73. (Cont.)

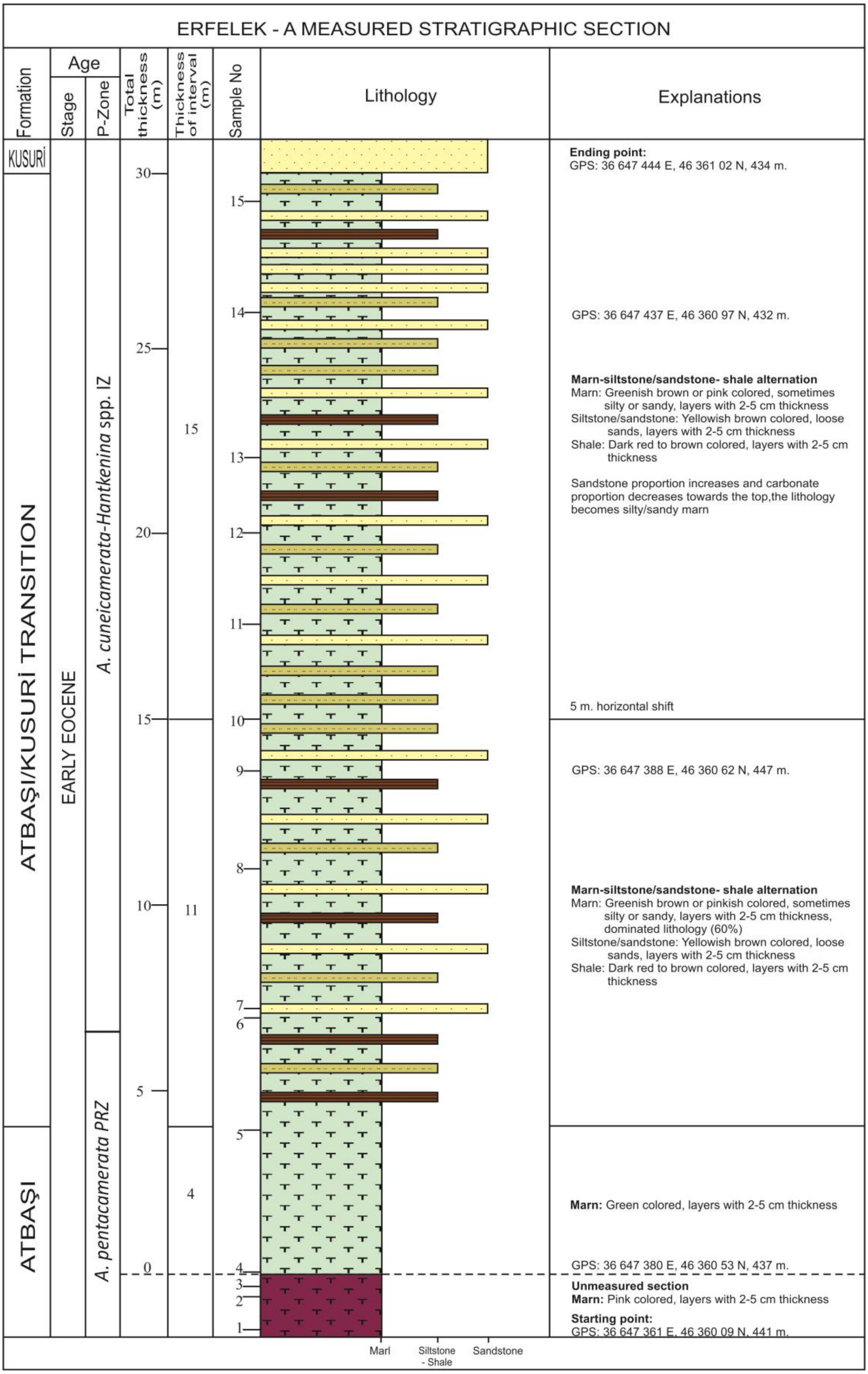


Figure 73. Erfelek-A Measured Stratigraphic Section.

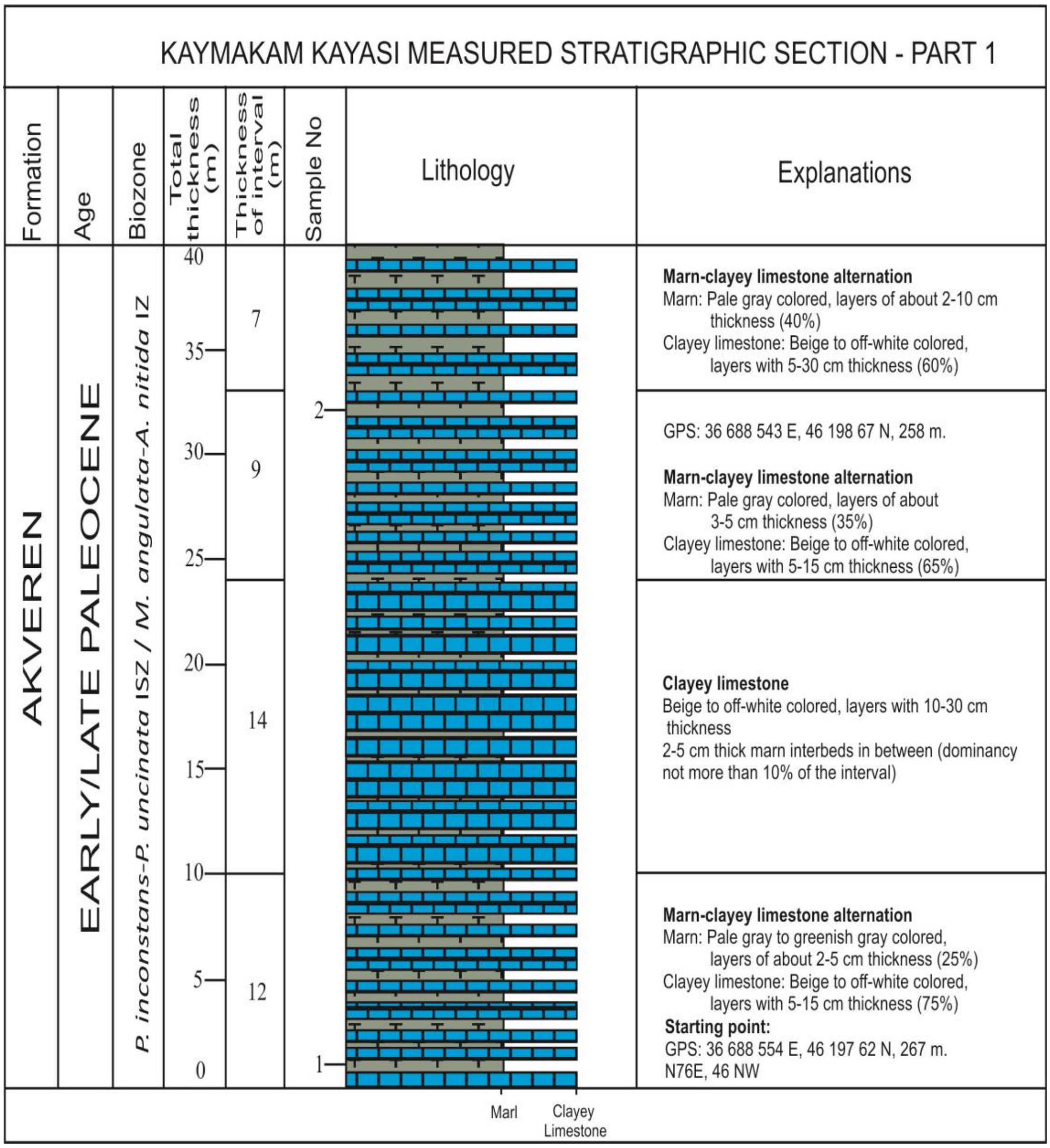
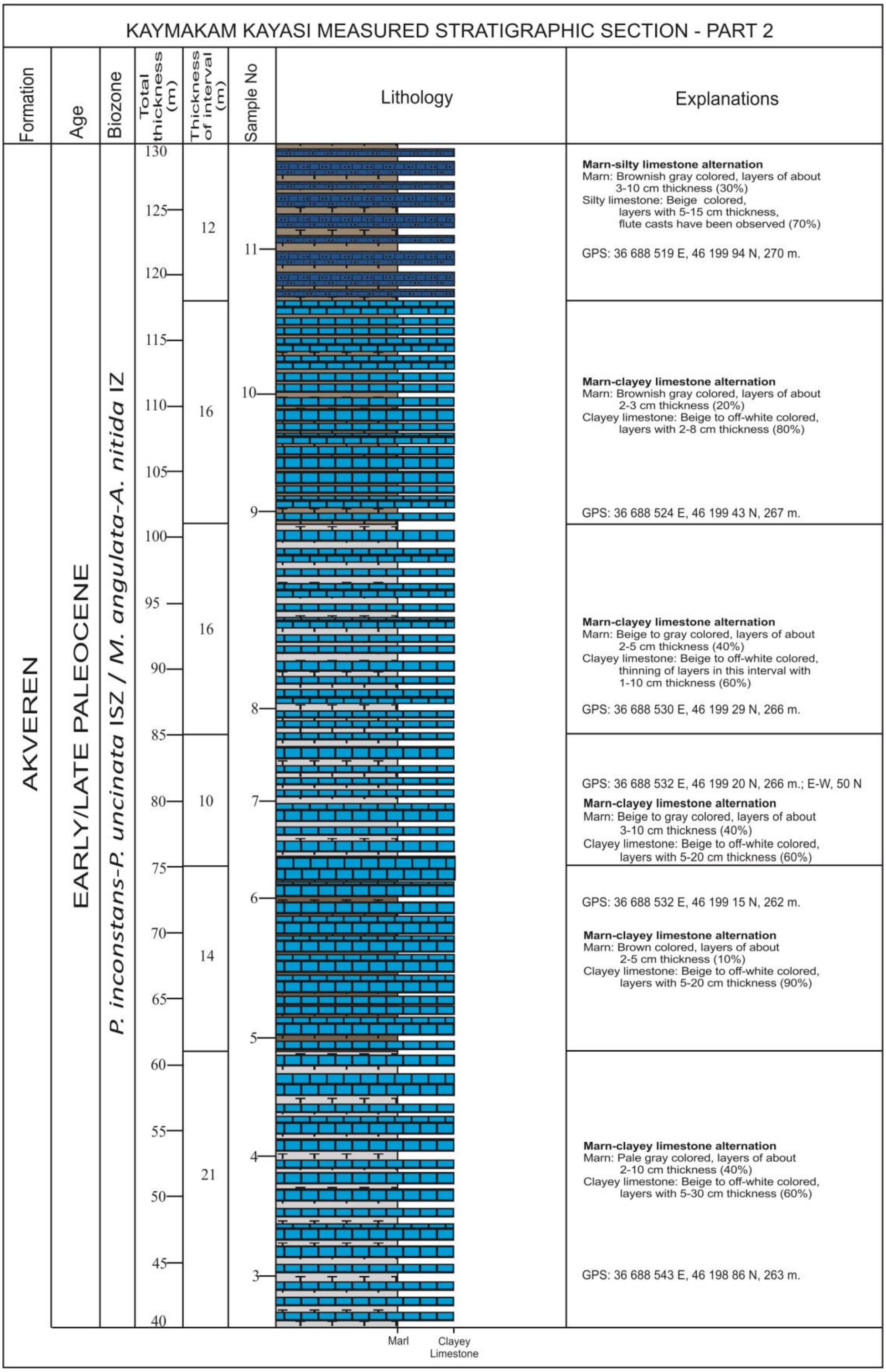


Figure 74. Kaymakam Kayası Measured Stratigraphic Section.



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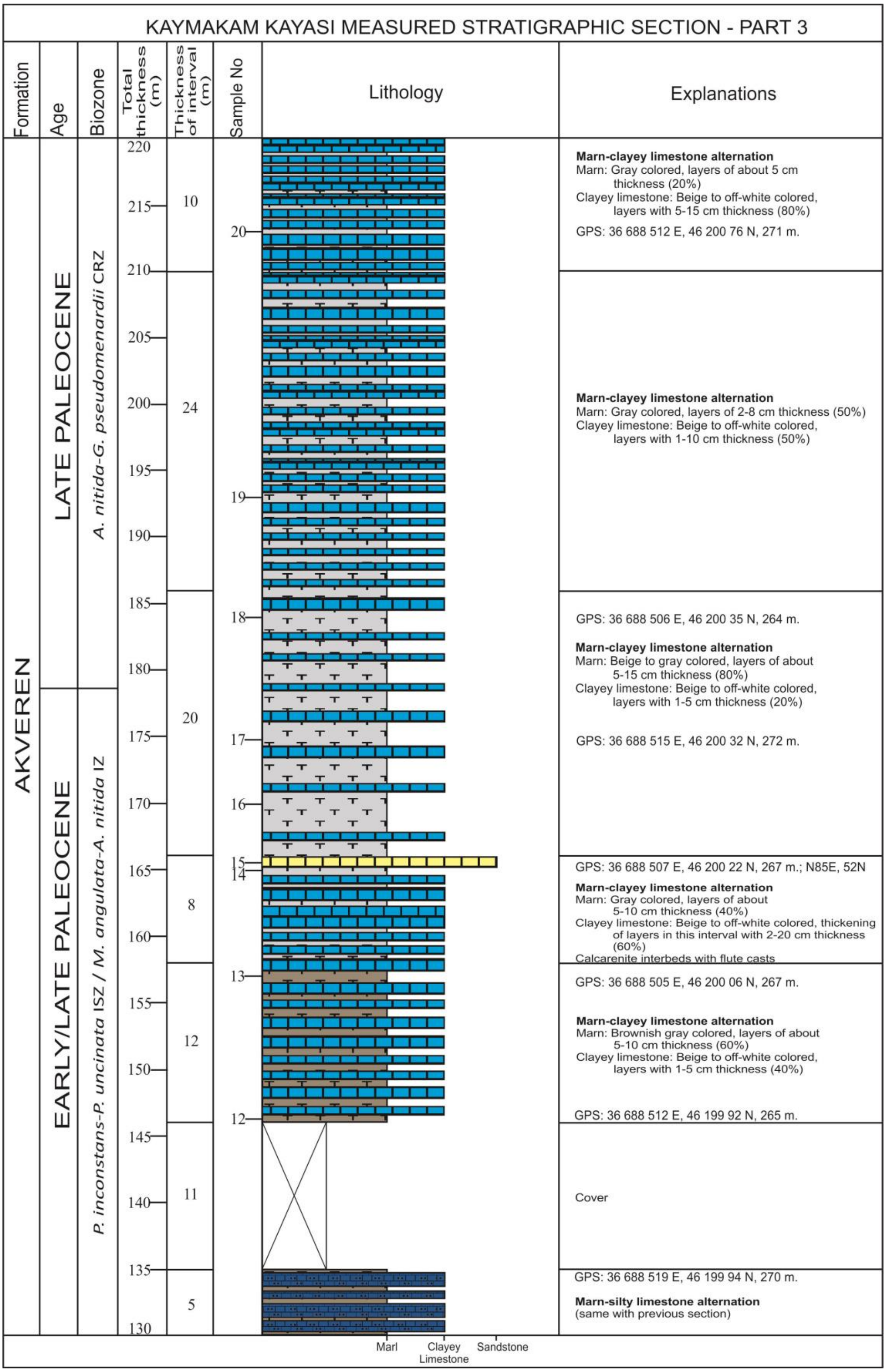

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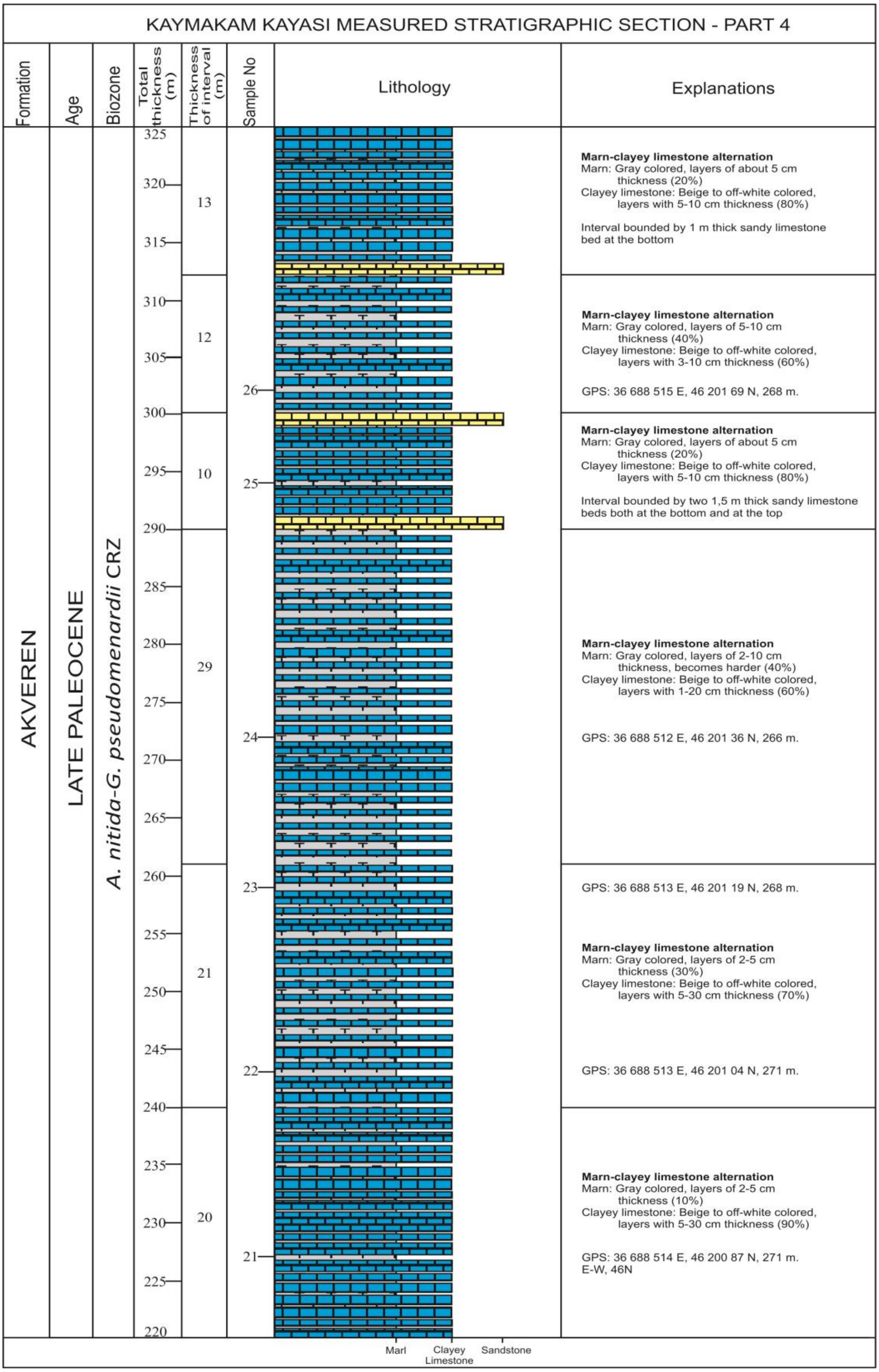

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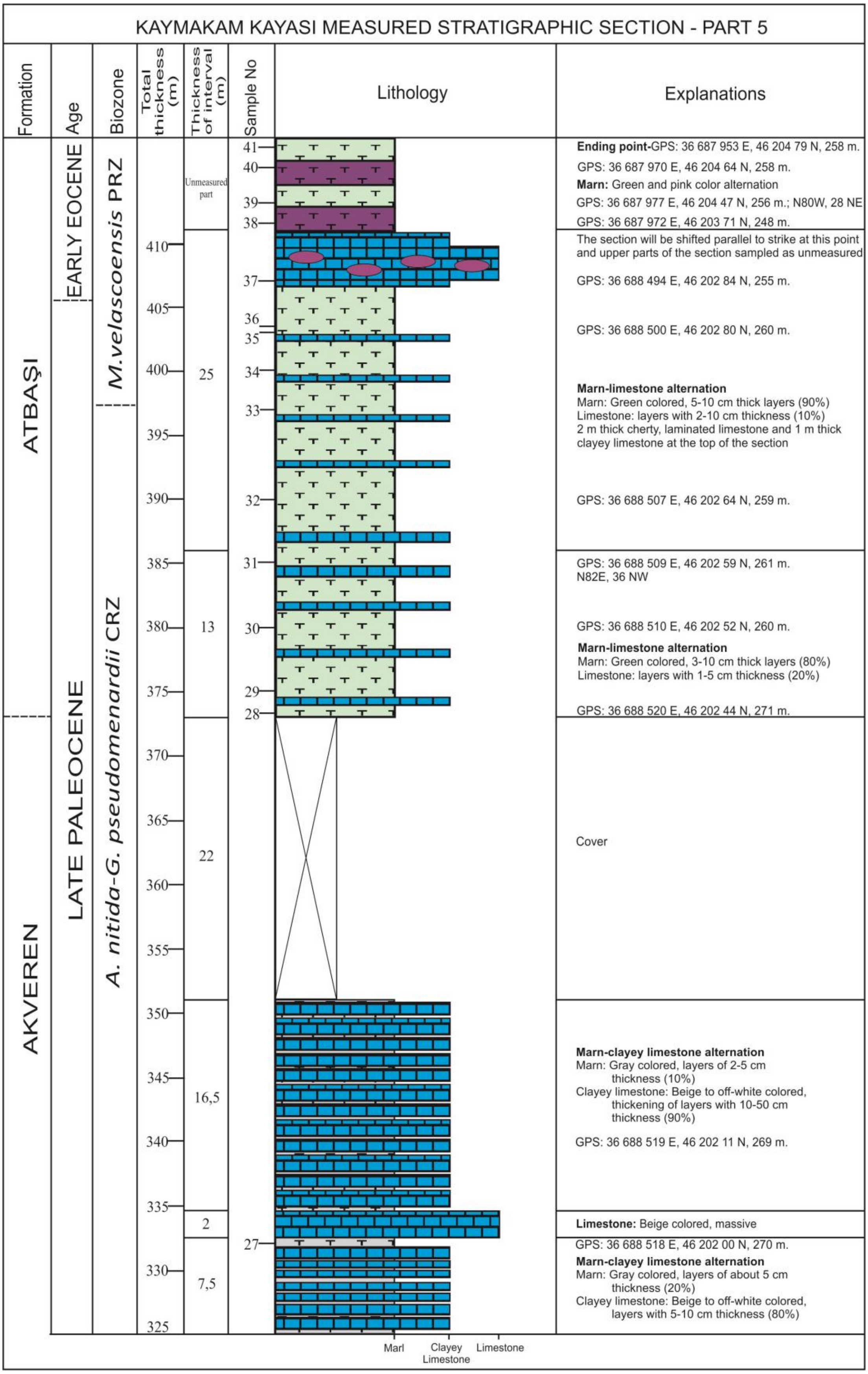

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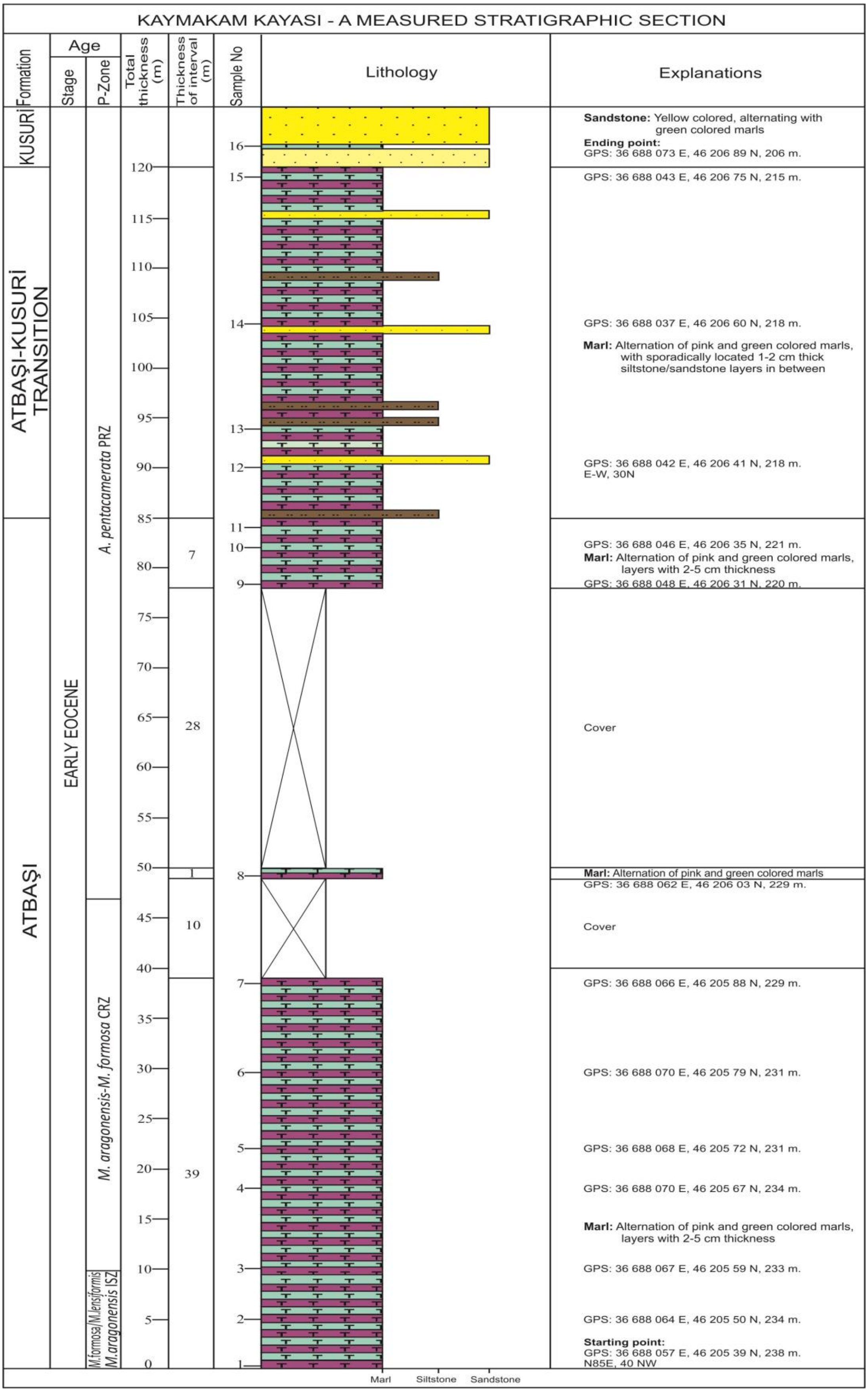


Figure 75. Kaymakam Kayası-A Measured Stratigraphic Section.

APPENDIX B

LIST OF PLANKTONIC FORAMINIFERA

Species Name	Page No.	Plate No.	Figure No.
Acarinina alticonica	158	3	18-21
Acarinina boudreauxi	161	4	1
Acarinina bullbrooki	161	4	2-3
Acarinina coalingensis	162	4	4
Acarinina collactea	163		
Acarinina cuneicamerata	163	4	5
Acarinina esnaensis	164	4	6
Acarinina esnehensis	165		
Acarinina interposita	165	4	7
Acarinina medizzai	165		
Acarinina nitida	165		
Acarinina pentacamerata	166	4	8-10
Acarinina cf. *praetopilensis*	167		
Acarinina primitiva	168	4	11-16
Acarinina pseudotopilensis	168	4	17
Acarinina punctocarinata	169		
Acarinina quetra	169	4	18-19
Acarinina soldadoensis	170	4	20
Acarinina wilcoxensis	171	5	1
Eoglobigerina spirialis	119		
Globanomalina australiformis	151	3	11
Globanomalina chapmani	153	3	12
Globanomalina compressa	153	3	13
Globanomalina ehrenbergi	154		
Globanomalina imitata	155	3	14
Globanomalina planoconica	155	3	15
Globanomalina pseudomenardii	155		
Globigerina azerbaidjanica	121	1	1-3
Globigerina eocaenica	121	1	4
Globigerina incretacea	123		

LIST OF BENTHIC FORAMINIFERA

Nuttallites sp.	198	8	1
Oridorsalis sp.	200	8	8-9
Osangularia sp.	200	8	10
Placentammina placenta	208	11, 14	11-13, 5
Planulina sp.	204	10	5-6
Psammosiphonella sp.	207	11	9
Pullenia coryelli	203	9	19
Rhabdamminidae	208	11	10
Rzehakina sp.	210	12	13
Saracenaria sp.	202	9	16-17
Spiroplectammina sp.	210	12, 14	14-15, 3
Trochammina sp.	211	12	19
Undetermined foraminifera	212	13	1-5

EXPLANATION OF PLATES

PLATE 1

(SEM microphotographs, Scale bars = 100µm)

1. *Globigerina azerbaidjanica*, spiral view, Sinay-Karasu Section, sample no. 18
2. *Globigerina azerbaidjanica*, umbilical view, Sinay-Karasu Section, sample no. 18
3. *Globigerina azerbaidjanica*, umbilical view, Sinay-Karasu Section, sample no. 19
4. *Globigerina eoceanica,* umbilical view, Karaburun Section, sample no. 15
5. *Globigerina subcorpulenta*, umbilical view, Sinay-Karasu Section, sample no. 17
6. *Globigerina turkmenica*, spiral view, Sinay-Karasu Section, sample no. 19
7. *Globigerina turkmenica*, umbilical view, Sinay-Karasu Section, sample no. 19
8. *Globigerinatheka subconglobata*, umbilical view, Sinay-Karasu Section, sample no. 19
9. *Globigerinatheka subconglobata*, umbilical view, Sinay-Karasu Section, sample no. 14
10. *Globoturborotalita bassriveriensis,* spiral view, Karaburun Section, sample no. 4
11. *Globoturborotalita bassriveriensis*, umbilical view, Erfelek 1 Section, sample no. 36
12. *Parasubbotina inaequispira*, umbilical view, Karaburun Section, sample no. 6
13. *Parasubbotina pseudobulloides,* spiral view, Erfelek Section, sample no. 19
14. *Parasubbotina pseudobulloides,* spiral view, Erfelek Section, sample no. 19
15. *Parasubbotina pseudobulloides,* umbilical view, Erfelek Section, sample no. 40
16. *Parasubbotina varianta,* Erfelek Section, spiral view, sample no. 38
17. *Pseudohastigerina micra*, Karaburun Section, sample no. 15
18. *Pseudohastigerina wilcoxensis*, Karaburun Section, sample no. 14
19. *Pseudohastigerina wilcoxensis*, Karaburun Section, sample no. 15
20. *Pseudohastigerina wilcoxensis*, Karaburun Section, sample no. 3
21. *Subbotina eoceana,* spiral view, Karaburun Section, sample no. 15
22. *Subbotina eoceana,* umbilical view, Karaburun Section, sample no. 6

PLATE 1

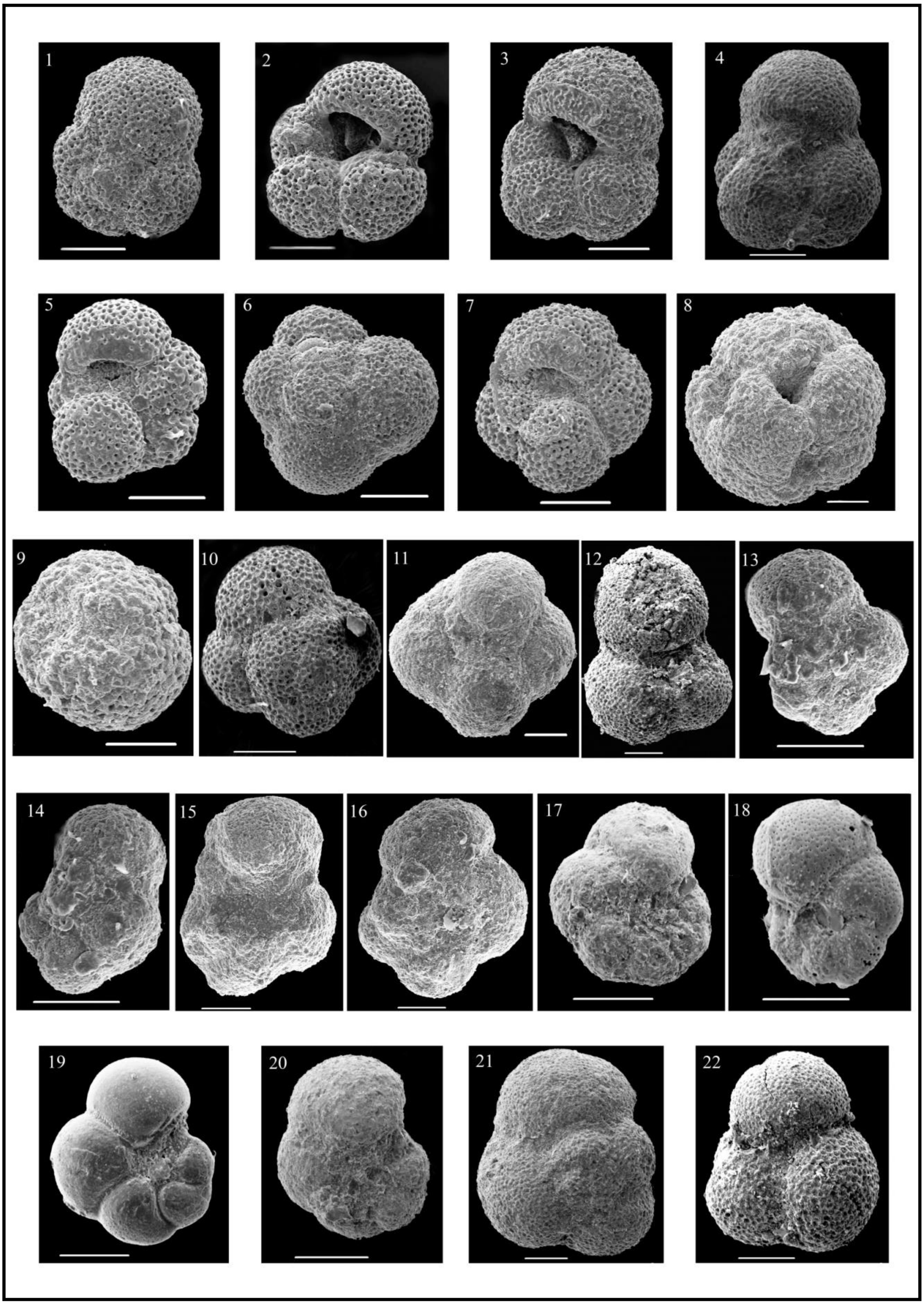


PLATE 2

(SEM microphotographs, Scale bars = 100µm)

1. *Subbotina eoceana*, umbilical view, Karaburun Section, sample no. 15
2. *Subbotina eoceana*, side view, Karaburun Section, sample no. 10
3. *Subbotina hagni*, spiral view, Karaburun Section, sample no. 15
4. *Subbotina hagni*, umbilical view, Karaburun Section, sample no. 15
5. *Subbotina linaperta*, spiral view, Karaburun Section, sample no. 5
6. *Subbotina linaperta*, spiral view, Karaburun Section, sample no. 6
7. *Subbotina linaperta*, umbilical view, Karaburun Section, sample no. 3
8. *Subbotina linaperta*, umbilical view, Karaburun Section, sample no. 3
9. *Subbotina linaperta*, side view, Karaburun Section, sample no. 3
10. *Subbotina linaperta*, side view, Karaburun Section, sample no. 9
11. *Subbotina patagonica*, umbilical view, Karaburun Section, sample no. 4
12. *Subbotina patagonica*, umbilical view, Karaburun Section, sample no. 7
13. *Subbotina patagonica*, side view, Karaburun Section, sample no. 4
14. *Subbotina roesnaensis*, spiral view, Karaburun Section, sample no. 4
15. *Subbotina roesnaensis*, umbilical view, Karaburun Section, sample no. 4
16. *Subbotina roesnaensis*, umbilical view, Karaburun Section, sample no. 4
17. *Subbotina triangularis*, Erfelek Section, sample no. 38
18. *Subbotina triloculinoides*, Erfelek Section, sample no. 43
19. *Subbotina yeguaensis*, umbilical view, Sinay-Karasu Section, sample no. 14
20. *Turborotalia cocoaensis*, side view, Sinay-Karasu Section, sample no. 17
21. *Turborotalia frontosa*, side view, Sinay-Karasu Section, sample no. 11
22. *Hantkenina* cf. *dumblei*, İstafan Section, sample no. 12

PLATE 2

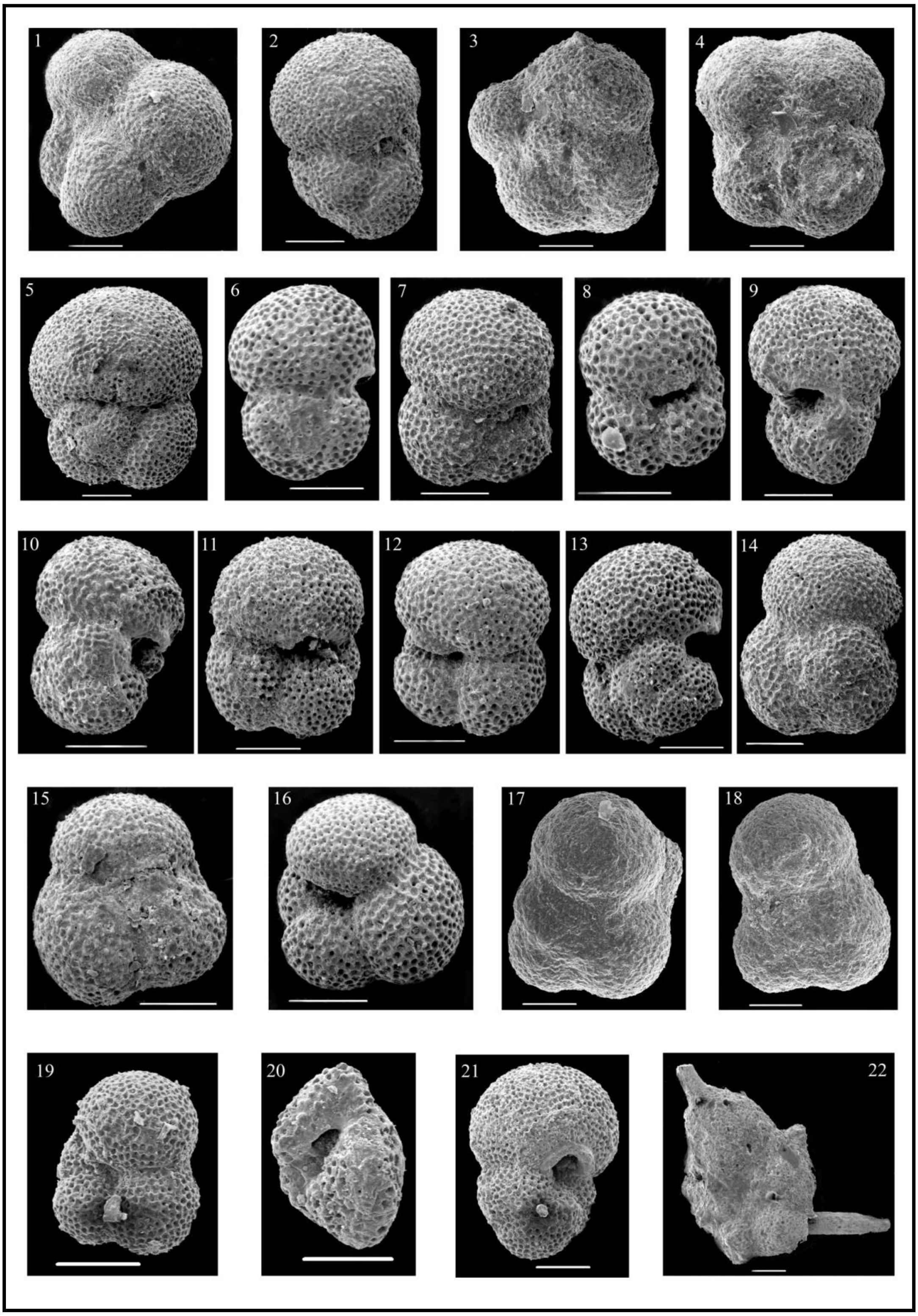


PLATE 3

(SEM microphotographs, Scale bars = 100µm)

1. *Hantkenina* cf. *dumblei,* İstafan Section, sample no. 12
2. *Hantkenina* cf. *dumblei,* İstafan Section, sample no. 13
3. *Hantkenina* cf. *dumblei,* İstafan Section, sample no. 16
4. *Hantkenina* cf. *leibusi,* İstafan Section, sample no. 16
5. *Hantkenina* cf. *leibusi,* İstafan Section, sample no. 16
6. *Hantkenina* cf. *leibusi,* İstafan Section, sample no. 16
7. *Hantkenina* cf. *leibusi,* İstafan Section, sample no. 16
8. *Hantkenina* cf. *leibusi,* İstafan Section, sample no. 12
9. *Hantkenina* cf. *leibusi,* İstafan Section, sample no. 13
10. *Hantkenina mexicana,* İstafan Section, sample no. 12
11. *Globanomalina australiformis,* spiral view, Erfelek Section, sample no. 41
12. *Globanomalina chapmani*, umbilical view, Erfelek Section, sample no. 45
13. *Globanomalina compressa*, umbilical view, Erfelek Section, sample no. 43
14. *Globanomalina imitata*, umbilical view, Erfelek Section, sample no. 37
15. *Globanomalina planoconica*, umbilical view, Erfelek Section, sample no. 47
16. *Planoglobanomalina pseudoalgeriana,* Karaburun Section, sample no. 15
17. *Planoglobanomalina pseudoalgeriana,* Karaburun Section, sample no. 19
18. *Acarinina alticonica,* spiral view, Karaburun Section, sample no. 3
19. *Acarinina alticonica,* spiral view, Karaburun Section, sample no. 3
20. *Acarinina alticonica,* umbilical view, Karaburun Section, sample no. 3
21. *Acarinina alticonica,* side view, Karaburun Section, sample no. 4

PLATE 3

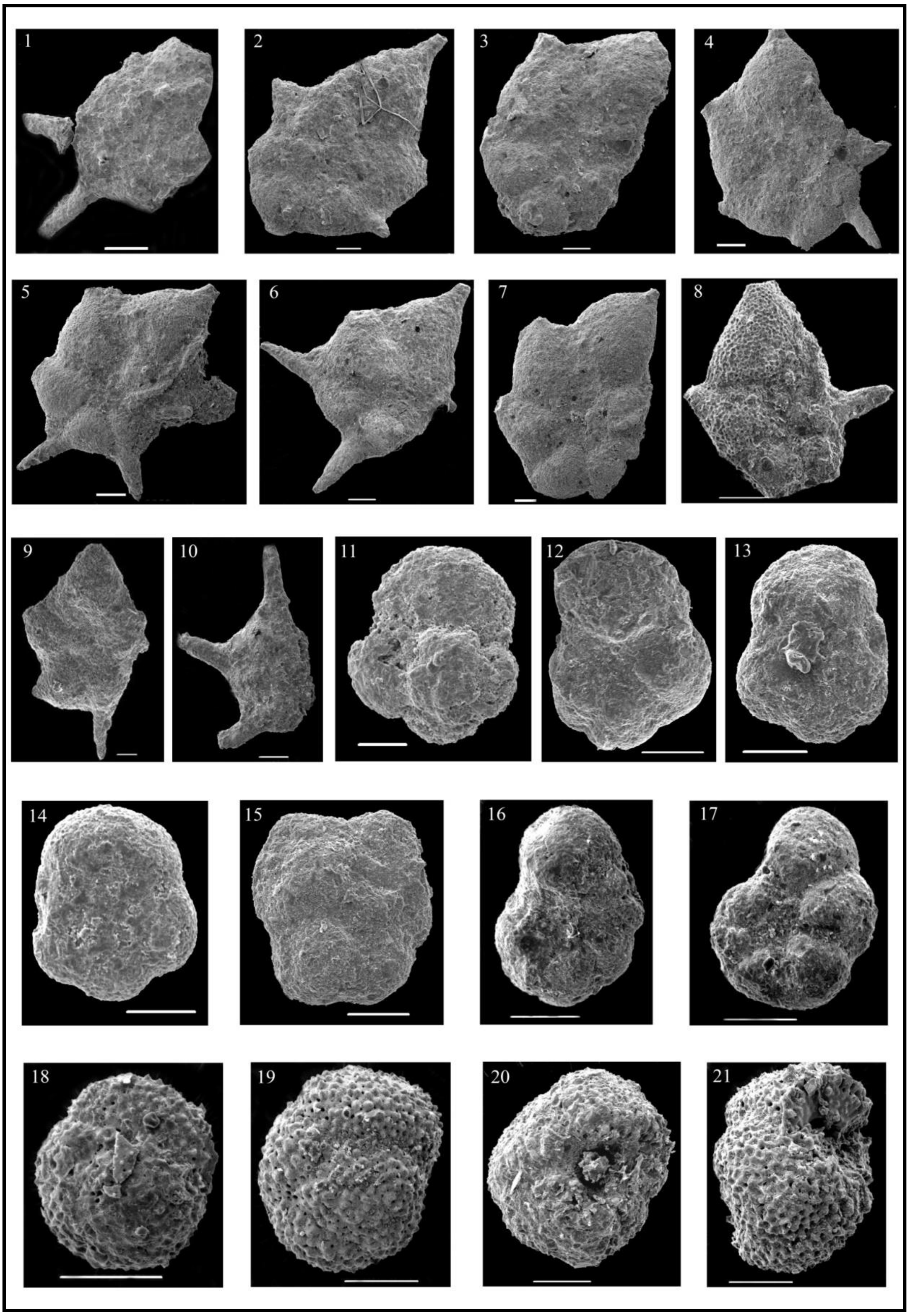


PLATE 4

(SEM microphotographs, Scale bars = 100µm)

1. *Acarinina boudreauxi*, umbilical view, Erfelek A Section, sample no. 11
2. *Acarinina bullbrooki*, spiral view, İstafan Section, sample no. 1
3. *Acarinina bullbrooki*, umbilical view, İstafan Section, sample no. 1
4. *Acarinina coalingensis,* umbilical view, Karaburun Section, sample no. 4
5. *Acarinina cuneicamerata*, spiral view, Erfelek A Section, sample no. 6
6. *Acarinina esnaensis*, umbilical view, Erfelek Section, sample no. 50
7. *Acarinina* cf. *interposita,* umbilical view, Karaburun Section, sample no. 4
8. *Acarinina pentacamerata,* spiral view, Karaburun Section, sample no. 4
9. *Acarinina* cf. *pentacamerata,* spiral view, Karaburun Section, sample no. 11
10. *Acarinina pentacamerata*, umbilical view, Karaburun Section, sample no. 10
11. *Acarinina primitiva,* spiral view, Karaburun Section, sample no. 4
12. *Acarinina primitiva,* umbilical view, Karaburun Section, sample no. 4
13. *Acarinina primitiva*, umbilical view, Karaburun Section, sample no. 4
14. *Acarinina primitiva*, side view, Karaburun Section, sample no. 6
15. *Acarinina primitiva,* side view, Karaburun Section, sample no. 3
16. *Acarinina* cf. *primitiva*, umbilical view, Karaburun Section, sample no. 4
17. *Acarinina pseudotopilensis*, umbilical view, Erfelek A Section, sample no. 13
18. *Acarinina quetra*, spiral view, Erfelek A Section, sample no. 3
19. *Acarinina quetra*, side view, Erfelek A Section, sample no. 11
20. *Acarinina soldadoensis,* umbilical view, Erfelek A Section, sample no. 11

PLATE 4

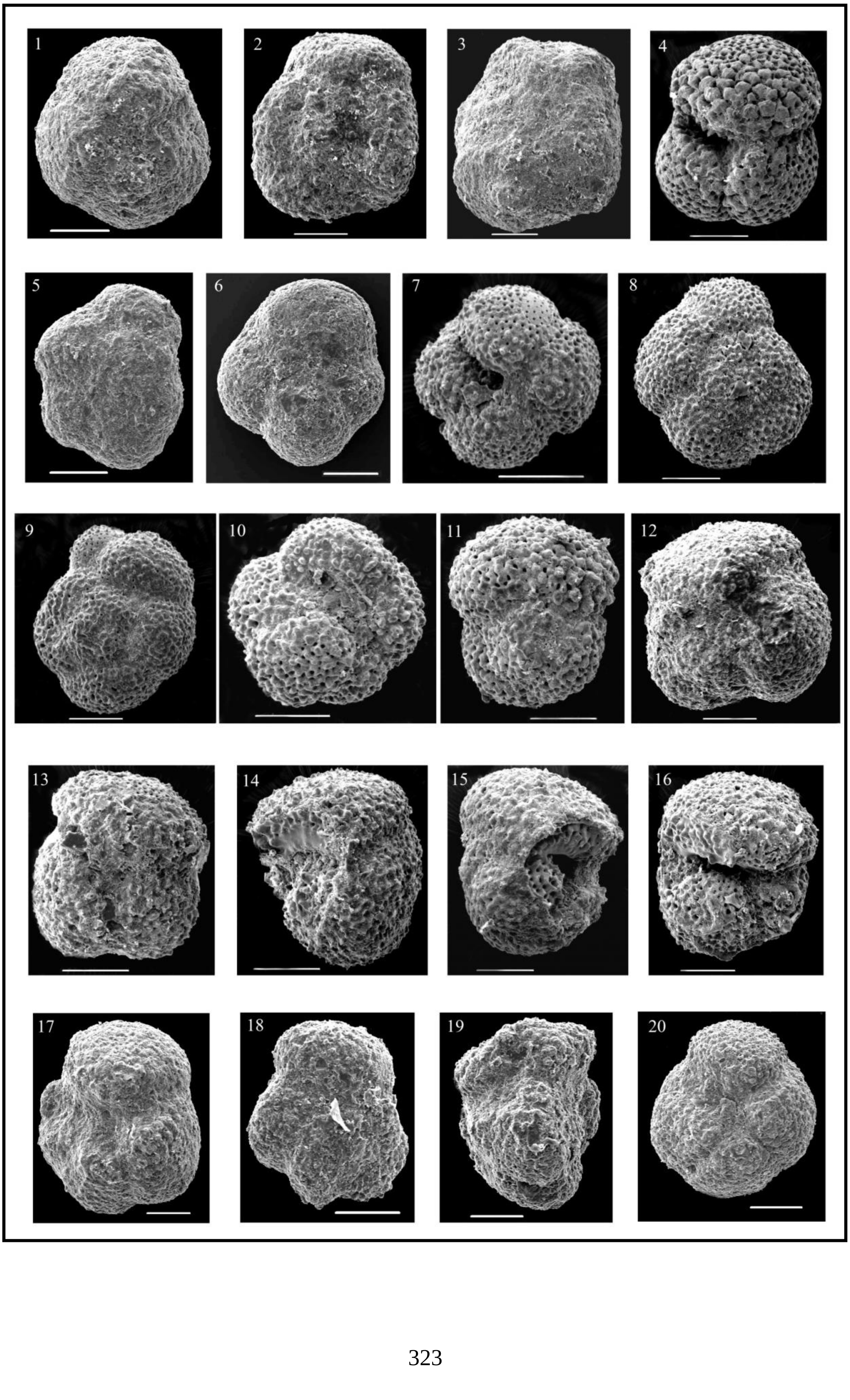


PLATE 5

(SEM microphotographs, Scale bars = 100μm)

1. *Acarinina wilcoxensis,* umbilical view, Karaburun Section, sample no. 10
2. *Igorina broadermanni,* spiral view, Karaburun Section, sample no. 3
3. *Igorina broadermanni*, spiral view, Karaburun Section, sample no. 4
4. *Igorina broadermanni,* spiral view, Karaburun Section, sample no. 10
5. *Igorina broadermanni*, spiral view, Erfelek Section, sample no. 45
6. *Igorina broadermanni,* umbilical view, Karaburun Section, sample no. 9
7. *Igorina broadermanni,* side view, Karaburun Section, sample no. 9
8. *Igorina ladoensis,* spiral view, Karaburun Section, sample no. 10
9. *Igorina ladoensis,* spiral view, Karaburun Section, sample no. 3
10. *Igorina ladoensis,* spiral view, Karaburun Section, sample no. 3
11. *Igorina ladoensis,* umbilical view, Karaburun Section, sample no. 10
12. *Morozovella acuta*, umbilical view, Erfelek Section, sample no. 43
13. *Morozovella aequa,* spiral view, Karaburun Section, sample no. 12
14. *Morozovella aequa,* umbilical view, Karaburun Section, sample no. 4
15. *Morozovella aequa,* umbilical view, Karaburun Section, sample no. 5
16. *Morozovella angulata*, umbilical view, Erfelek 1 Section, sample no. 26
17. *Morozovella angulata,* side view, Erfelek Section, sample no. 43
18. *Morozovella aragonensis,* spiral view, Karaburun Section, sample no. 9
19. *Morozovella aragonensis,* spiral view, Karaburun Section, sample no. 22
20. *Morozovella aragonensis,* umbilical view, Karaburun Section, sample no. 15

PLATE 5

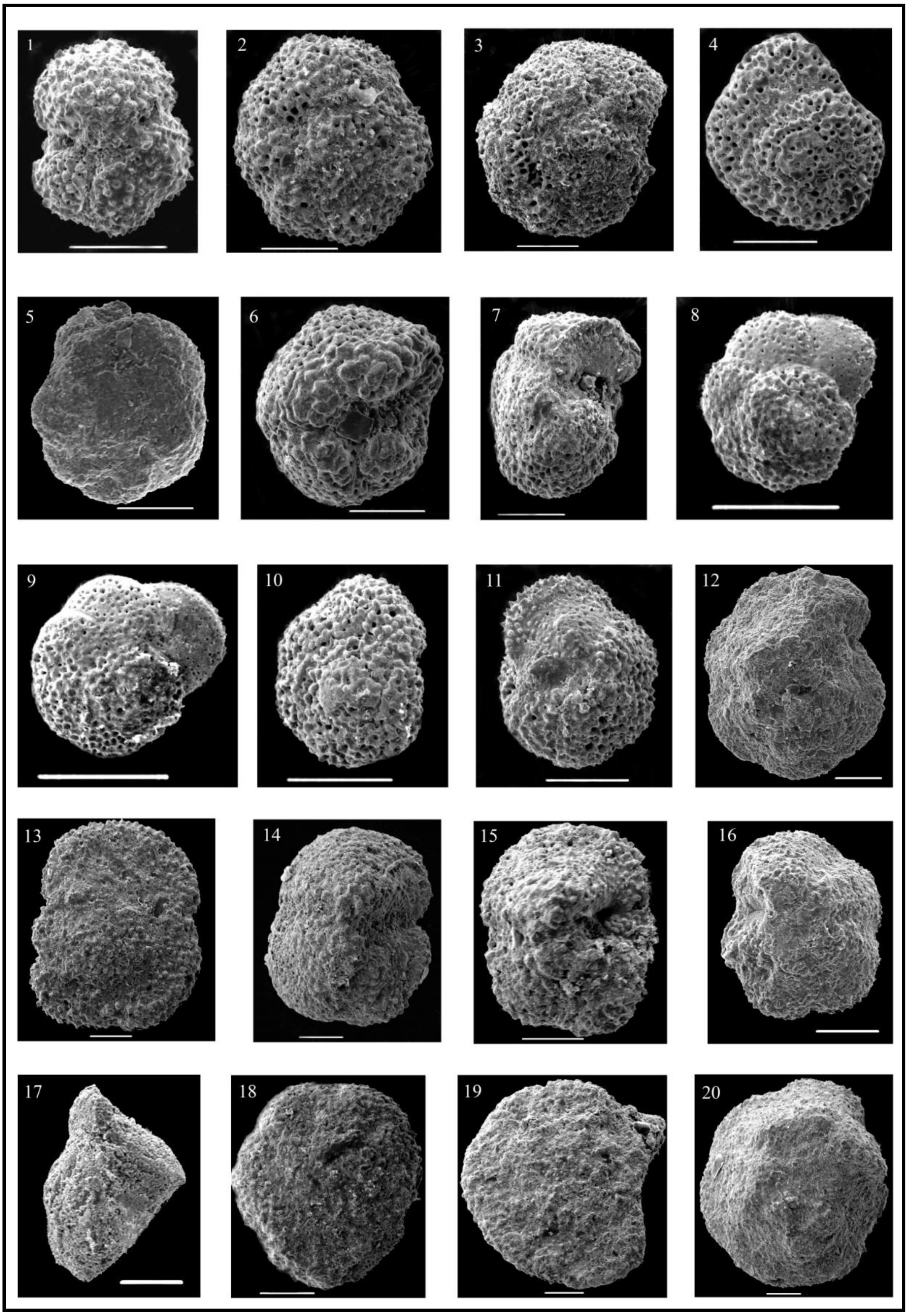


PLATE 6

(SEM microphotographs, Scale bars = 100µm)

1. *Morozovella aragonensis*, side view, Karaburun Section, sample no. 22
2. *Morozovella conicotruncata*, umbilical view, Erfelek 1 Section, sample no. 26
3. *Morozovella conicotruncata*, side view, Erfelek Section, sample no. 43
4. *Morozovella crater*, spiral view, Karaburun Section, sample no. 15
5. *Morozovella crater*, umbilical view, Erfelek A Section, sample no. 6
6. *Morozovella crater*, side view, Karaburun Section, sample no. 15
7. *Morozovella edgari*, spiral view, Erfelek Section, sample no. 45
8. *Morozovella edgari*, umbilical view, Erfelek Section, sample no. 47
9. *Morozovella edgari*, side view, Erfelek Section, sample no. 47
10. *Morozovella edgari*, side view, Erfelek 1 Section, sample no. 38
11. *Morozovella formosa*, spiral view, Erfelek Section, sample no. 56
12. *Morozovella gracilis*, umbilical view, Erfelek Section, sample no. 47
13. *Morozovella lensiformis*, spiral view, Karaburun Section, sample no. 4
14. *Morozovella lensiformis*, spiral view, Karaburun Section, sample no. 9
15. *Morozovella lensiformis*, spiral view, Kaymakam Kayası A Section, sample no. 4
16. *Morozovella lensiformis*, spiral view, Kaymakam Kayası A Section, sample no. 4
17. *Morozovella lensiformis*, umbilical view, Karaburun Section, sample no. 4
18. *Morozovella lensiformis*, umbilical view, Karaburun Section, sample no. 3

PLATE 6

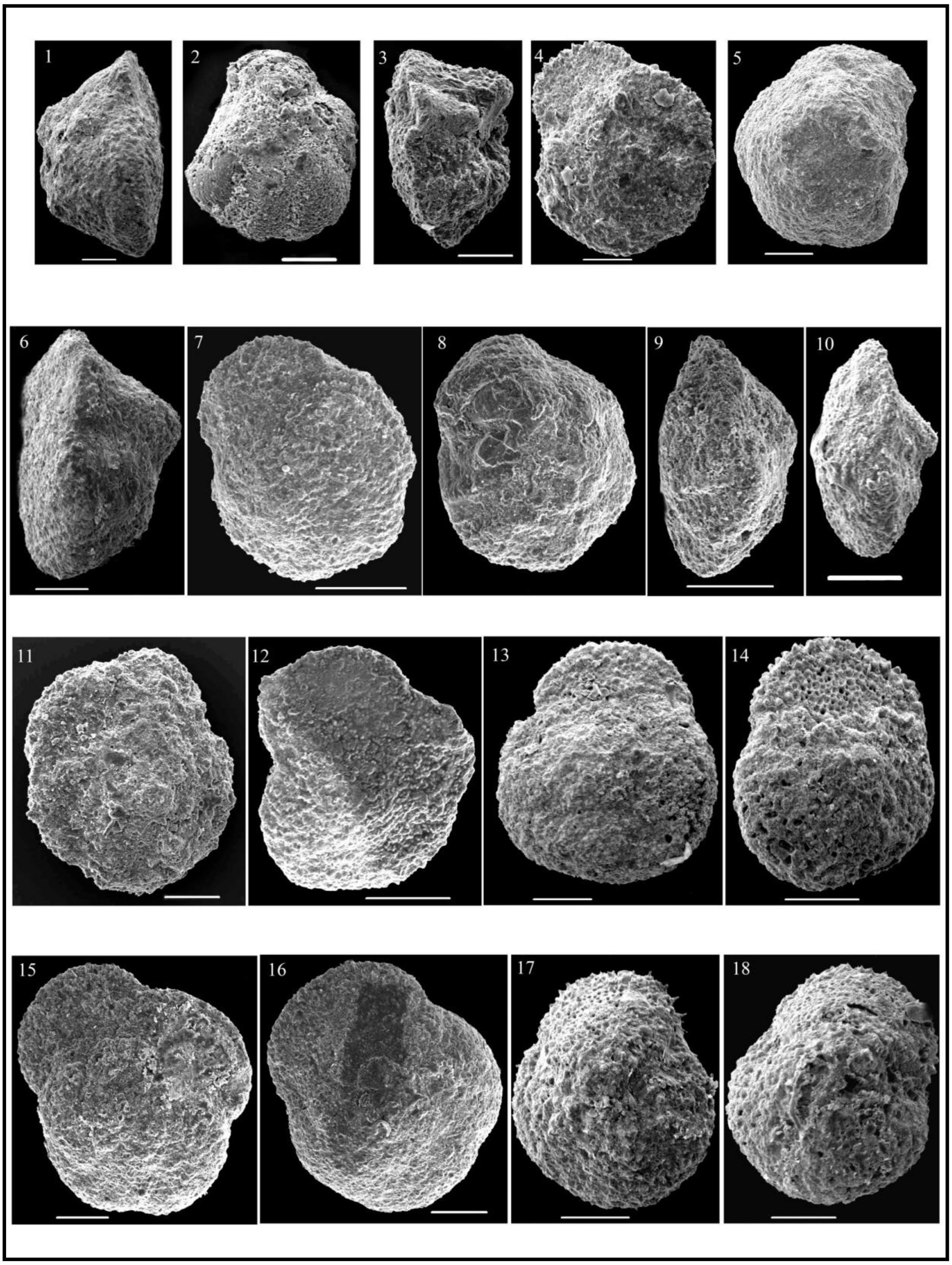


PLATE 7

(SEM microphotographs, Scale bars = 100μm)

1. *Morozovella lensiformis,* Kaymakam Kayası-A Section, sample no. 4
2. *Morozovella lensiformis*, umbilical view, Karaburun Section, sample no. 4
3. *Morozovella lensiformis*, side view, Karaburun Section, sample no. 7
4. *Morozovella lensiformis*, side view, Karaburun Section, sample no. 10
5. *Morozovella lensiformis,* side view, Karaburun Section, sample no. 3
6. *Morozovella occlusa*, spiral view, Ayazlı Section, sample no. 4
7. *Morozovella praeangulata,* spiral view, Kaymakam Kayası Section, sample no. 31
8. *Morozovella subbotinae*, spiral view, Erfelek Section, sample no. 45
9. *Morozovella subbotinae*, spiral view, Karaburun Section, sample no. 4
10. *Morozovella subbotinae*, umbilical view, Erfelek Section, sample no. 47
11. *Morozovella subbotinae*, side view, Karaburun Section, sample no. 6
12. *Morozovella velascoensis*, spiral view, Erfelek Section, sample no. 48
13. *Morozovella velascoensis*, umbilical view, Erfelek Section, sample no. 48
14. *Morozovella velascoensis*, side view, Ayazlı Section, sample no. 4
15. *Planorotalites capdevilensis*, umbilical view, Sinay-Karasu Section, sample no. 6
16. *Planorotalites pseudoscitula,* spiral view, Karaburun Section, sample no. 15
17. *Praemurica inconstans,* spiral view, Erfelek Section, sample no. 38
18. *Praemurica inconstans,* umbilical view, Erfelek Section, sample no. 40

PLATE 7

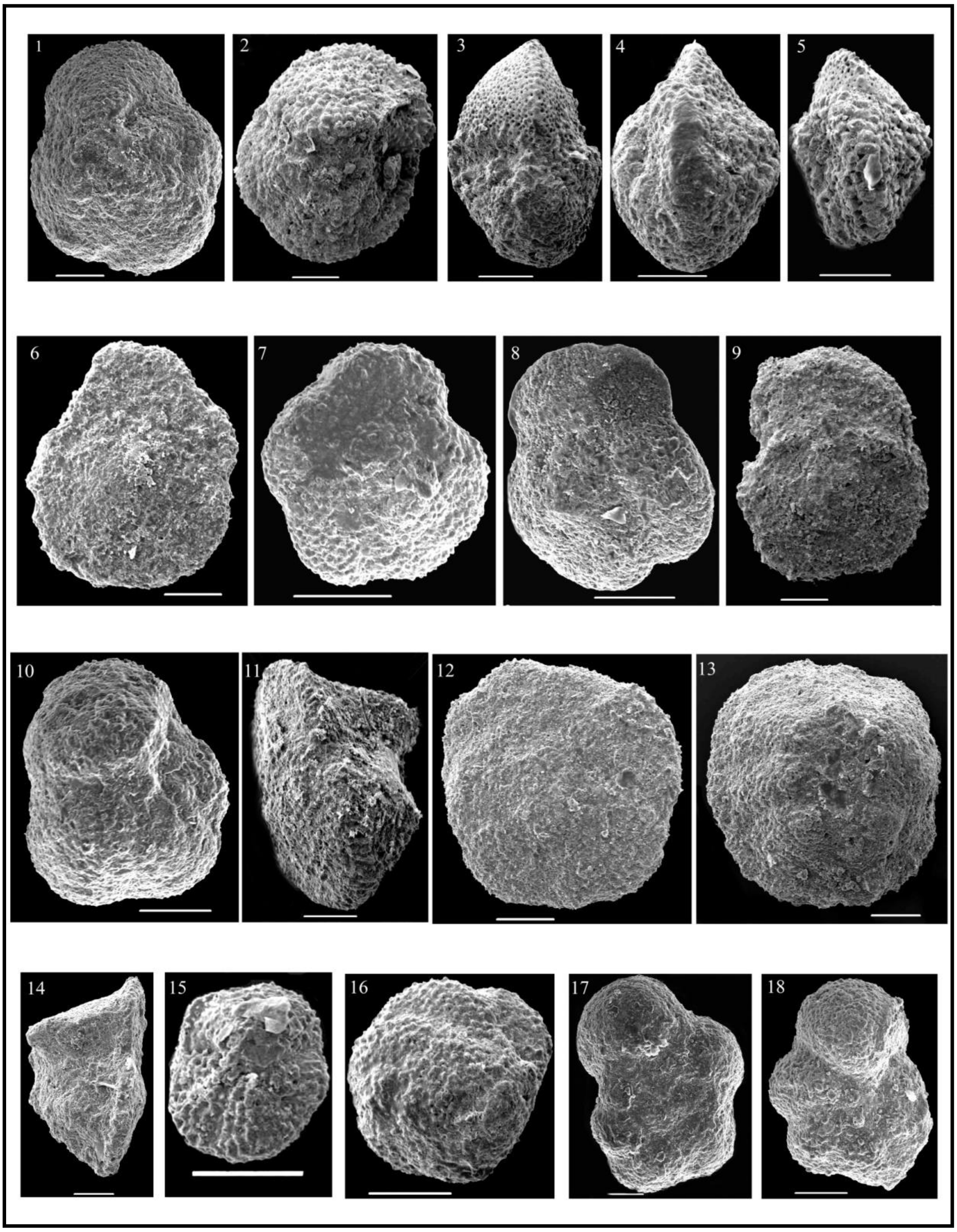


PLATE 8

(SEM microphotographs, Scale bars = 100 µm)

2. *Nuttallides* sp., umbilical view, Erfelek 1 Section, sample no. 31

3. *Bulimina* sp., longitudinal view, Erfelek 1 Section, sample no. 26

4. *Bulimina* sp., longitudinal view, Erfelek 1 Section, sample no. 33

5. *Globocassidulina* sp., umbilical view, Erfelek 1 Section, sample no. 39

6. *Gyroidinoides* sp., umbilical view, Erfelek 1 Section, sample no. 38

7. *Anomalinoides* sp., spiral view, Erfelek 1 Section, sample no. 33

8. *Anomalinoides* sp., side view, Erfelek 1 Section, sample no. 26

9. *Oridorsalis* sp., spiral view, Erfelek 1 Section, sample no. 32

10. *Oridorsalis* sp., side view, Erfelek 1 Section, sample no. 32

11. *Osangularia* sp., spiral view, Erfelek 1 Section, sample no. 32

12. *Aragonia* sp., longitudinal view, Erfelek 1 Section, sample no. 31

13. *Aragonia* sp., longitudinal view, Erfelek 1 Section, sample no. 38

14. *Fissurina* sp., longitudinal view, Erfelek 1 Section, sample no. 23

15. *Fissurina* sp., longitudinal view, Erfelek 1 Section, sample no. 25

16. *Fissurina* sp., longitudinal view, Erfelek 1 Section, sample no. 33

17. *Fissurina* sp., longitudinal view, Erfelek 1 Section, sample no. 39

PLATE 8

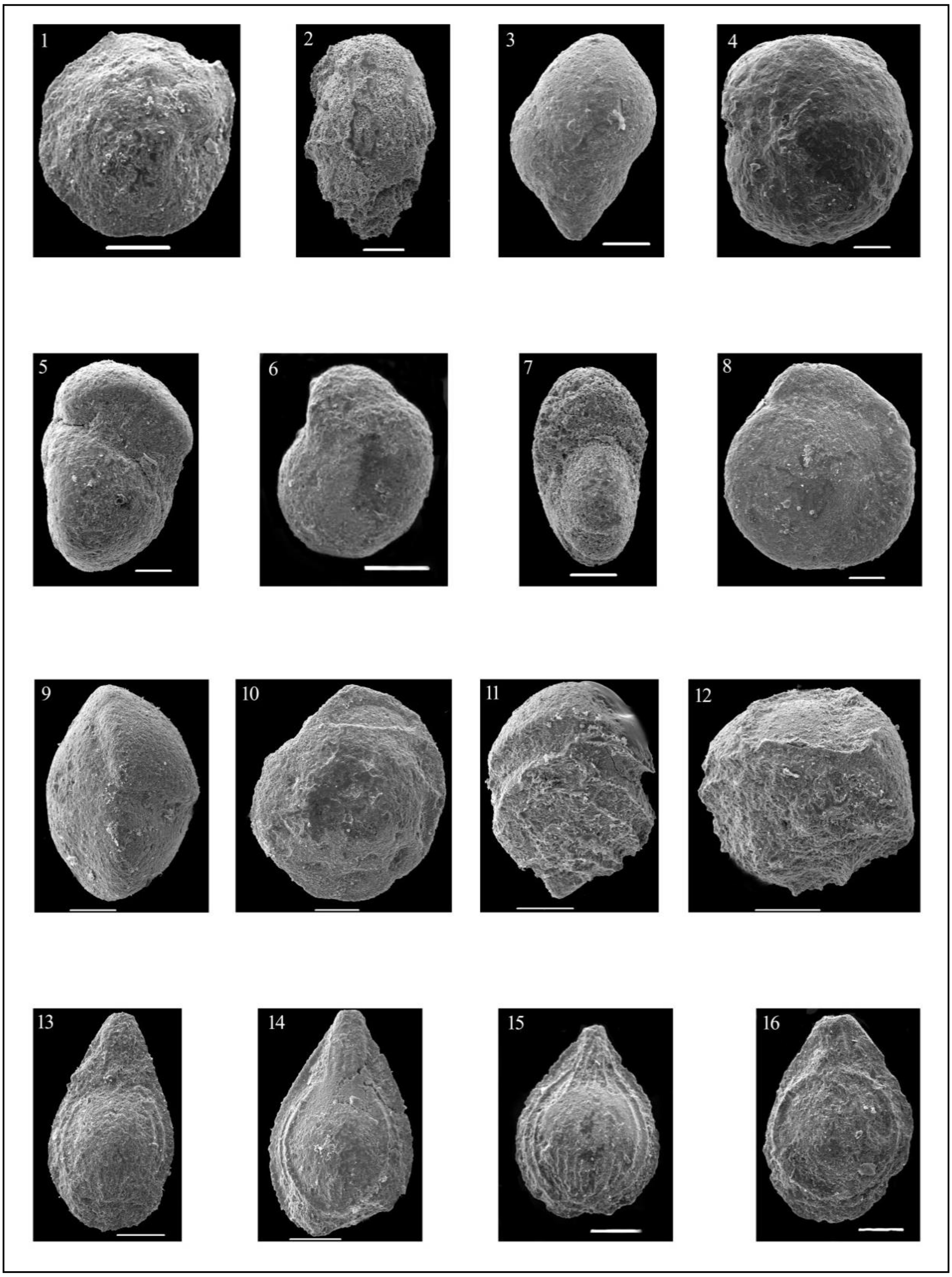


PLATE 9

(SEM microphotographs, Scale bars = 100 μm)

1. *Lagena* sp., longitudinal view, Erfelek 1 Section, sample no. 32
2. *Lagena* sp., longitudinal view, Erfelek 1 Section, sample no. 33
3. *Lagena* sp., longitudinal view, Erfelek 1 Section, sample no. 33
4. *Lagena* sp., longitudinal view, Erfelek 1 Section, sample no. 38
5. Nodosaridae, longitudinal view, Erfelek 1 Section, sample no. 33
6. Nodosaridae, longitudinal view, Erfelek 1 Section, sample no. 26
7. Nodosaridae, longitudinal view, Erfelek 1 Section, sample no. 26
8. *Dentalina* sp., longitudinal view, Erfelek 1 Section, sample no. 26
9. *Dentalina* sp., longitudinal view, Erfelek 1 Section, sample no. 39
10. *Nodosaria* sp., longitudinal view, Erfelek 1 Section, sample no. 38
11. *Lenticulina* sp., Erfelek 1 Section, sample no. 33
12. *Lenticulina* sp., Erfelek 1 Section, sample no. 48
13. *Lenticulina* sp., Erfelek 1 Section, sample no. 50
14. *Neoflabellina* sp., longitudinal view, Erfelek 1 Section, sample no. 26
15. *Neoflabellina* sp., longitudinal view, Erfelek 1 Section, sample no. 33
16. *Saracenaria* sp., Erfelek 1 Section, sample no. 32
17. *Saracenaria* sp., Erfelek 1 Section, sample no. 40
18. *Nonion* sp., Erfelek 1 Section, sample no. 28
19. *Pullenia* sp., side view, Erfelek 1 Section, sample no. 20

PLATE 9

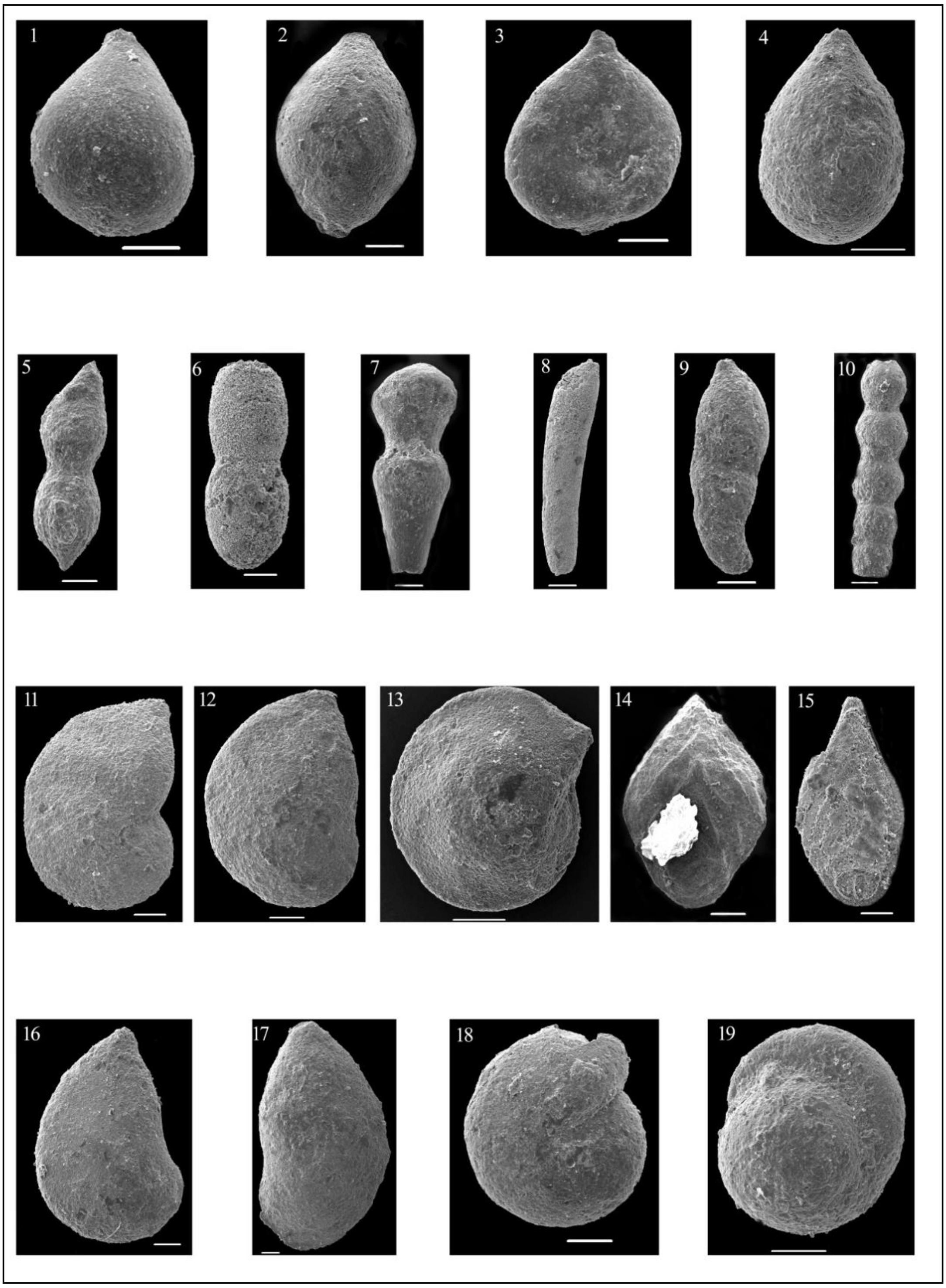


PLATE 10

(SEM microphotographs, Scale bars = 100 µm)

1. *Cibicides* sp., umbilical view, Erfelek 1 Section, sample no. 33
2. *Cibicides* sp., side view, Erfelek 1 Section, sample no. 33
3. *Cibicidoides* sp., spiral view, Erfelek 1 Section, sample no. 26
4. *Cibicidoides* sp., side view, Erfelek 1 Section, sample no. 31
5. *Planulina* sp., spiral view, Erfelek 1 Section, sample no. 40
6. *Planulina* sp., umbilical view, Erfelek 1 Section, sample no. 40
7. *Ellipsoglandulina* sp., longitudinal view, Erfelek 1 Section, sample no. 23
8. *Ellipsoglandulina* sp., longitudinal view, Erfelek 1 Section, sample no. 31
9. *Ammodiscus cretaceous*, Erfelek 1 Section, sample no. 50
10. *Ammodiscus glabratus*, Erfelek 1 Section, sample no. 35
11. *Ammodiscus glabratus*, Erfelek 1 Section, sample no. 50
12. *Ammodiscus peruvianus*, Erfelek 1 Section, sample no. 35
13. *Ammodiscus peruvianus*, Erfelek 1 Section, sample no. 39
14. *Ammodiscus peruvianus*, Erfelek 1 Section, sample no. 39

PLATE 10

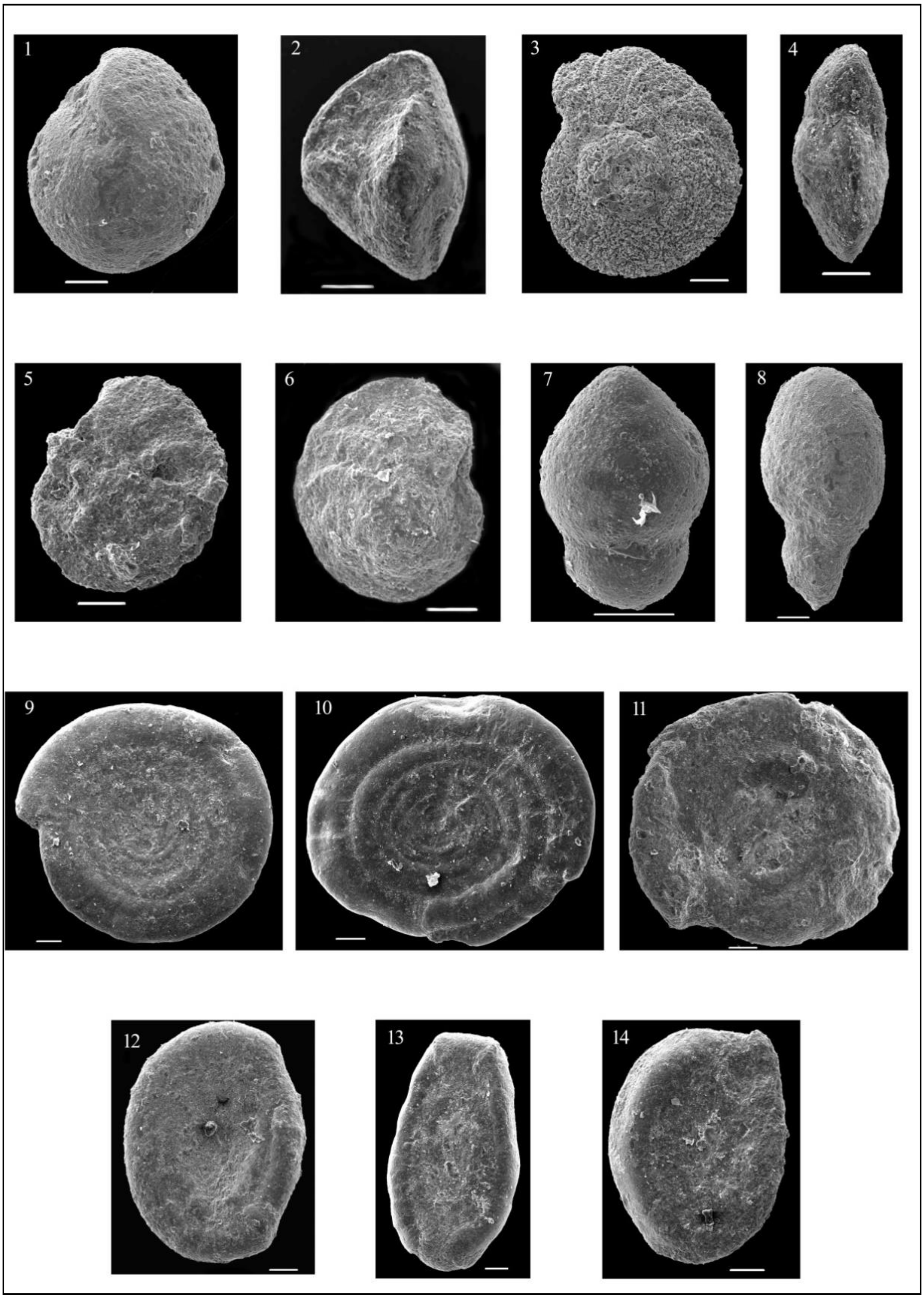


PLATE 11

(SEM microphotographs, Scale bars = 100 μm)

1. *Glomospira charoides*, Erfelek 1 Section, sample no. 28
2. *Glomospira charoides*, Erfelek 1 Section, sample no. 38
3. *Glomospira diffudens*, Erfelek 1 Section, sample no. 26
4. *Glomospira irregularis*, Erfelek 1 Section, sample no. 26
5. *Glomospira irregularis*, Erfelek 1 Section, sample no. 50
6. *Nothia excelsa*, Erfelek 1 Section, sample no. 40
7. *Nothia excelsa*, Erfelek 1 Section, sample no. 23
8. *Nothia excelsa*, Erfelek 1 Section, sample no. 23
9. *Psammosiphonella* sp., Erfelek 1 Section, sample no. 39
10. Rhabdamminidae, Erfelek 1 Section, sample no. 39
11. *Placentammina placenta* , Erfelek 1 Section, sample no. 40
12. *Placentammina placenta* , Erfelek 1 Section, sample no. 41
13. *Placentammina placenta* , Erfelek 1 Section, sample no. 50
14. *Hyperammina dilatata*, Erfelek 1 Section, sample no. 28
15. *Hyperammina dilatata*, Erfelek 1 Section, sample no. 28
16. *Hyperammina dilatata*, Erfelek 1 Section, sample no. 48
17. *Hyperammina dilatata*, Erfelek 1 Section, sample no. 43
18. *Hyperammina dilatata*, Erfelek 1 Section, sample no. 43

PLATE 11

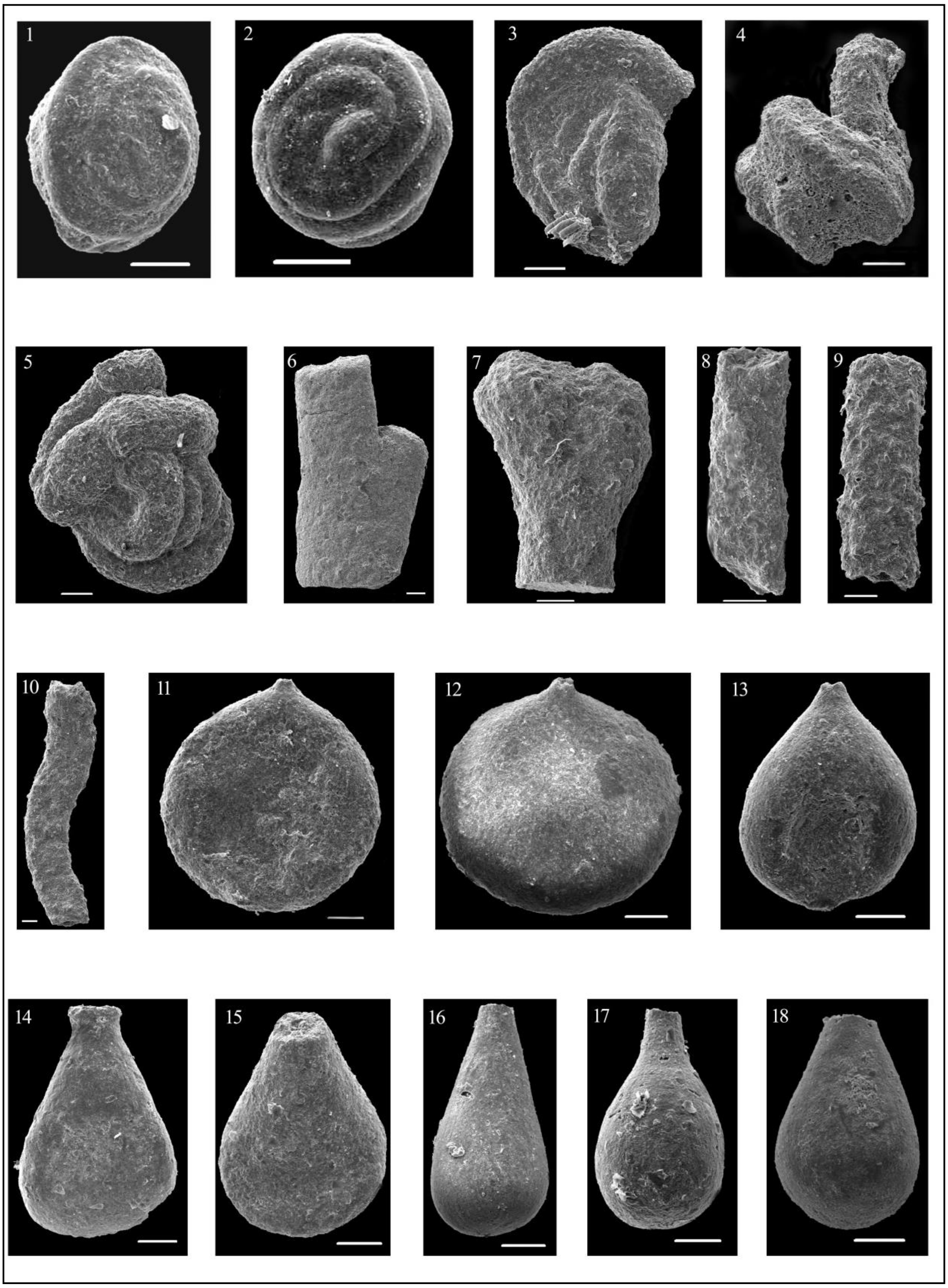


PLATE 12

(SEM microphotographs, Scale bars = 100 µm)

1. Hormosinidae, Erfelek 1 Section, sample no. 33

2. Hormosinidae, Erfelek 1 Section, sample no. 40

3. *Caudammina ovula*, Erfelek 1 Section, sample no. 39

4. *Caudammina ovula*, Erfelek 1 Section, sample no. 39

5. *Caudammina ovula*, Erfelek 1 Section, sample no. 40

6. *Hormosina* sp., Erfelek 1 Section, sample no. 39

7. *Kalamopsis grzybowskii*, Erfelek 1 Section, sample no. 23

8. *Kalamopsis grzybowskii*, Erfelek 1 Section, sample no. 38

9. *Kalamopsis grzybowskii*, Erfelek 1 Section, sample no. 39

10. *Haplophragmoides* sp., Erfelek 1 Section, sample no. 24

11. *Haplophragmoides* sp., Erfelek 1 Section, sample no. 23

12. *Haplophragmoides suborbicularis* , Erfelek 1 Section, sample no. 26

13. *Rzehakina* sp., Erfelek 1 Section, sample no. 48

14. *Spiroplectammina* sp., Erfelek 1 Section, sample no. 33

15. *Spiroplectammina* sp., Erfelek 1 Section, sample no. 33

16. *Dorothia* sp., Erfelek 1 Section, sample no. 20

17. *Dorothia* sp., Erfelek 1 Section, sample no. 24

18. *Clavulinoides* sp., Erfelek 1 Section, sample no. 23

19. *Trochammminoides* sp., Erfelek 1 Section, sample no. 40

PLATE 12

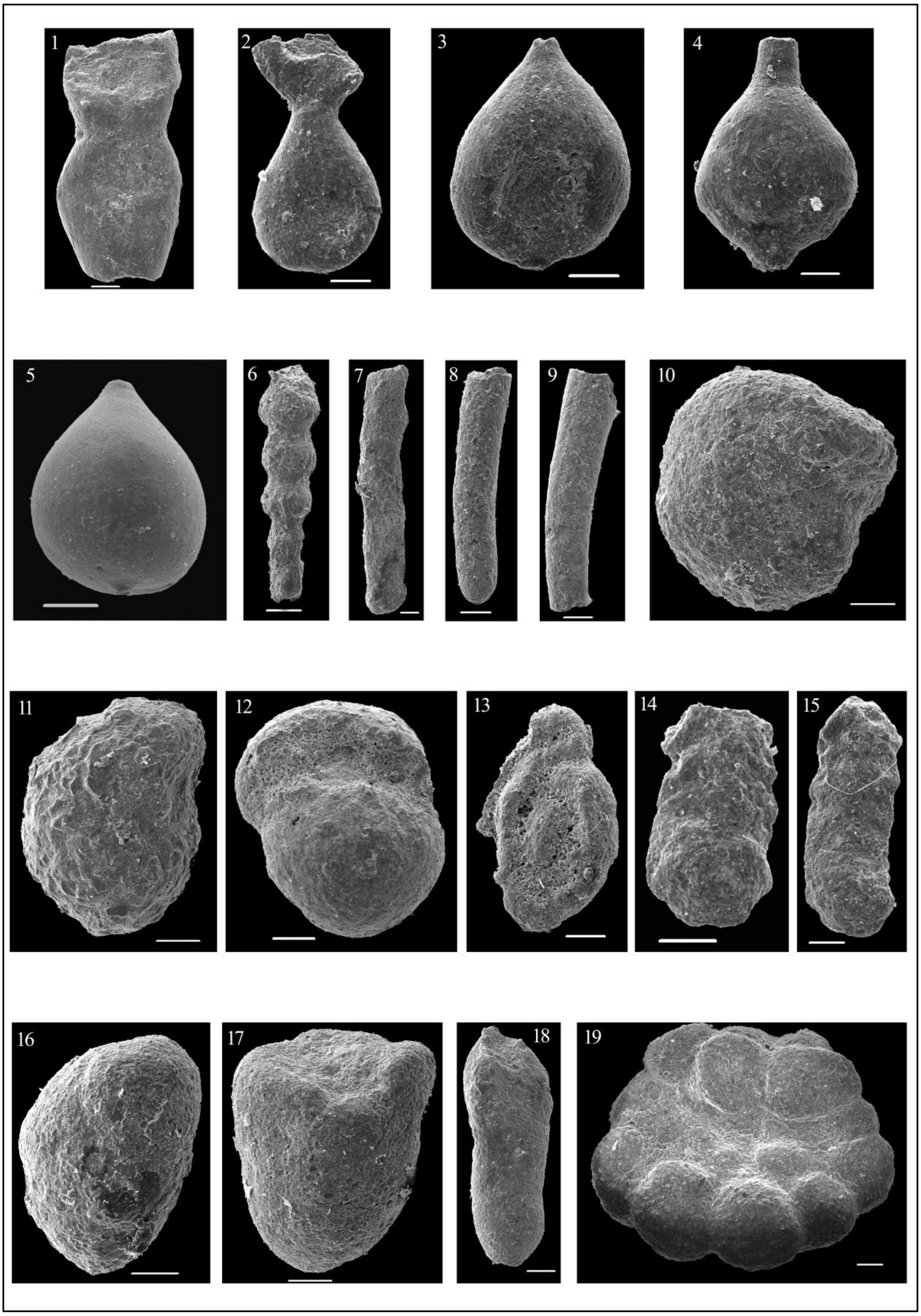


PLATE 13

(Binocular microscope microphotographs, Scale bars = 100 μm)

1. *Ammodiscus glabratus*, Erfelek 1 Section, sample no. 42
2. *Nothia excelsa*, Erfelek 1 Section, sample no. 42
3. *Spiroplectammina* sp., Erfelek 1 Section, sample no. 43
4. *Fissurina* sp., Erfelek 1 Section, sample no. 43
5. *Placentammina placenta* , Erfelek 1 Section, sample no. 47
6. *Neoflabellina* sp., Erfelek 1 Section, sample no. 48
7. *Ammodiscus peruvianus*, Erfelek 1 Section, sample no. 48
8. *Kalamopsis grzybowskii*, Erfelek 1 Section, sample no. 55
9. *Hyperammina dilatata*, Erfelek 1 Section, sample no. 55

PLATE 13

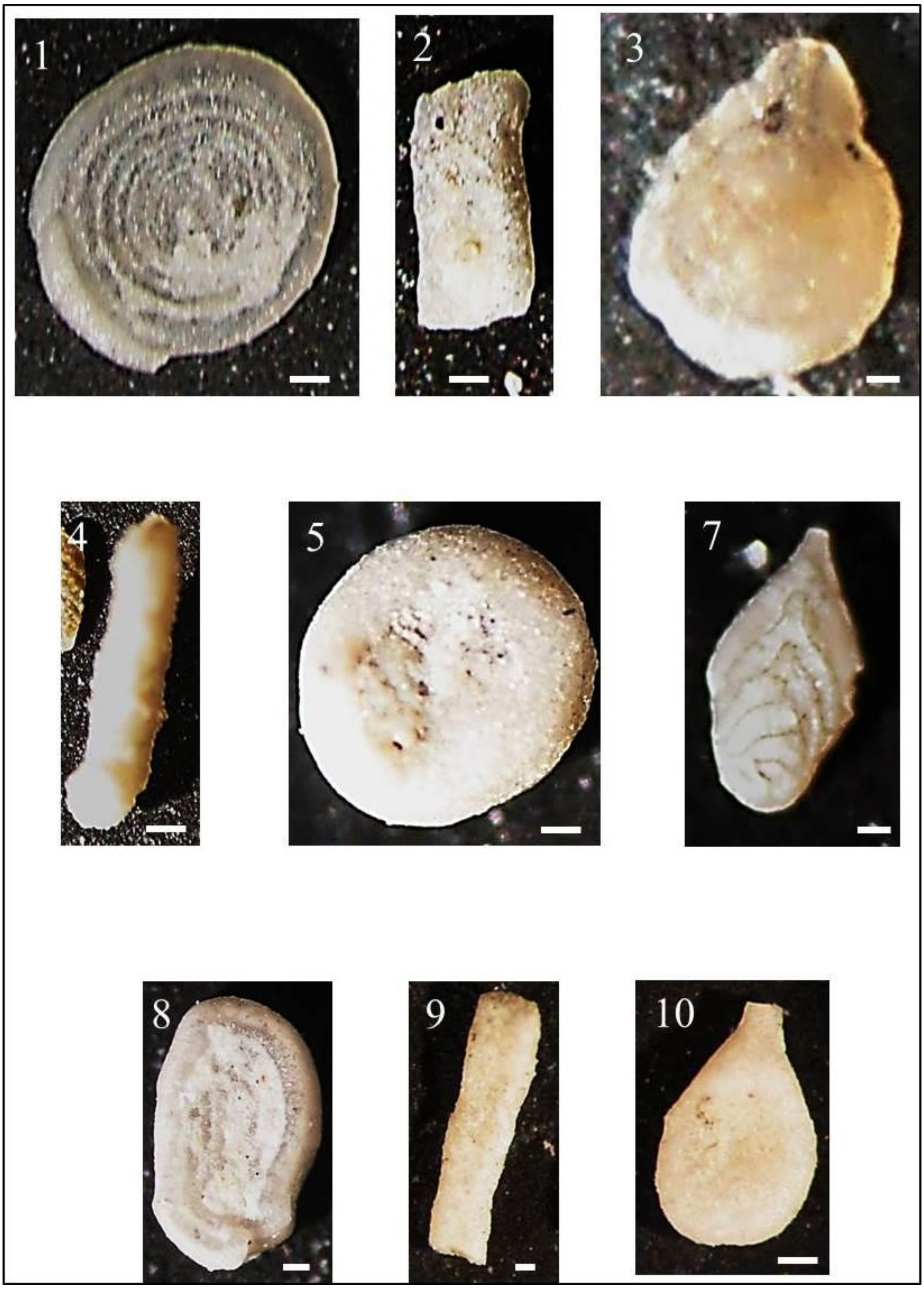


PLATE 14

(Scale bars = 100 μm)

1. Undetermined foraminifera as a cast, umbilical view, Binocular microscope microphotograph, Erfelek 1 Section, sample no. 34

2. Undetermined foraminifera as a cast, umbilical view, Binocular microscope microphotograph, Erfelek 1 Section, sample no. 34

3. Undetermined foraminifera as a cast, spiral view, Binocular microscope microphotograph, Erfelek 1 Section, sample no. 37

4. Undetermined foraminifera as a cast, umbilical view, Binocular microscope microphotograph, Erfelek 1 Section, sample no. 37

5. Undetermined foraminifera as a cast, spiral view, SEM microphotograph, Erfelek 1 Section, sample no. 37

PLATE 14

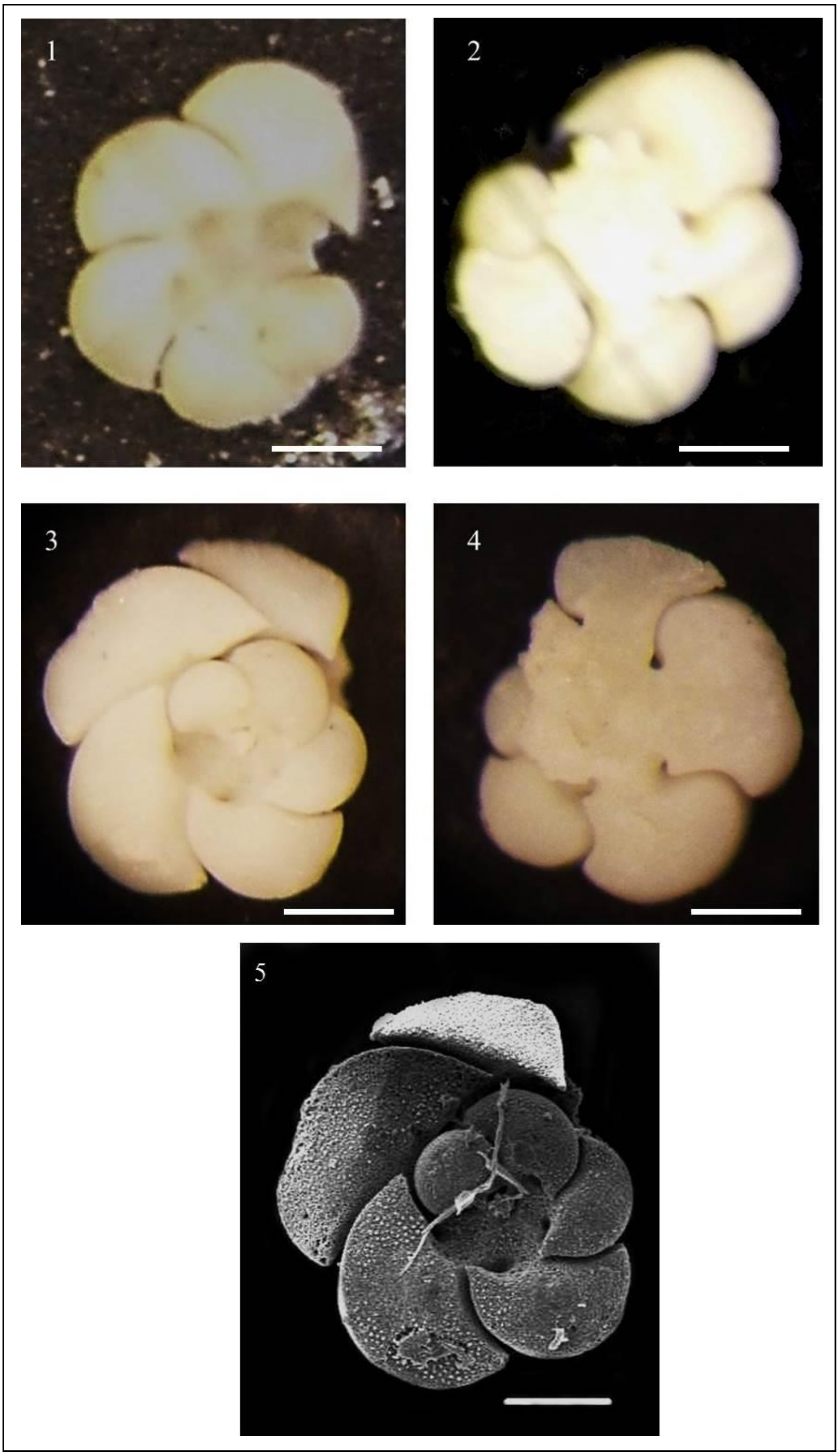
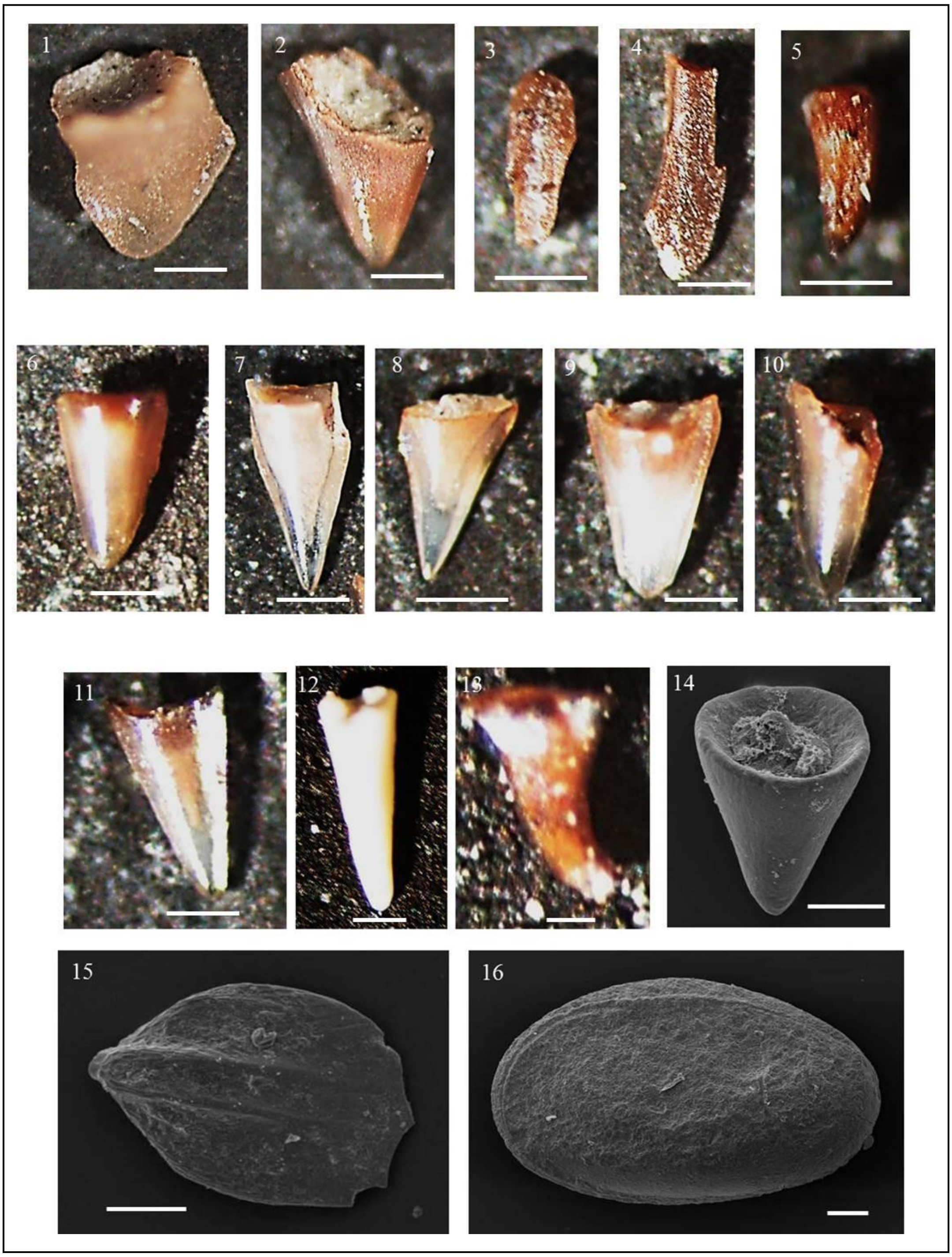


PLATE 15

(Scale bars = 100 μm)

1. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 43
2. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 43
3. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 44
4. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 44
5. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 44
6. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 45
7. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 47
8. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 47
9. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 47
10. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 47
11. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 47
12. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 54
13. Fish tooth, Binocular microscope microphotograph, Erfelek Section, sample no. 56
14. Fish tooth , SEM microphotograph, Erfelek 1 Section, sample no. 34
15. Otolith, SEM microphotograph, Erfelek 1 Section, sample no. 33
16. Ostrakoda, SEM microphotograph, Erfelek 1 Section, sample no. 39

PLATE 15



APPENDIX C

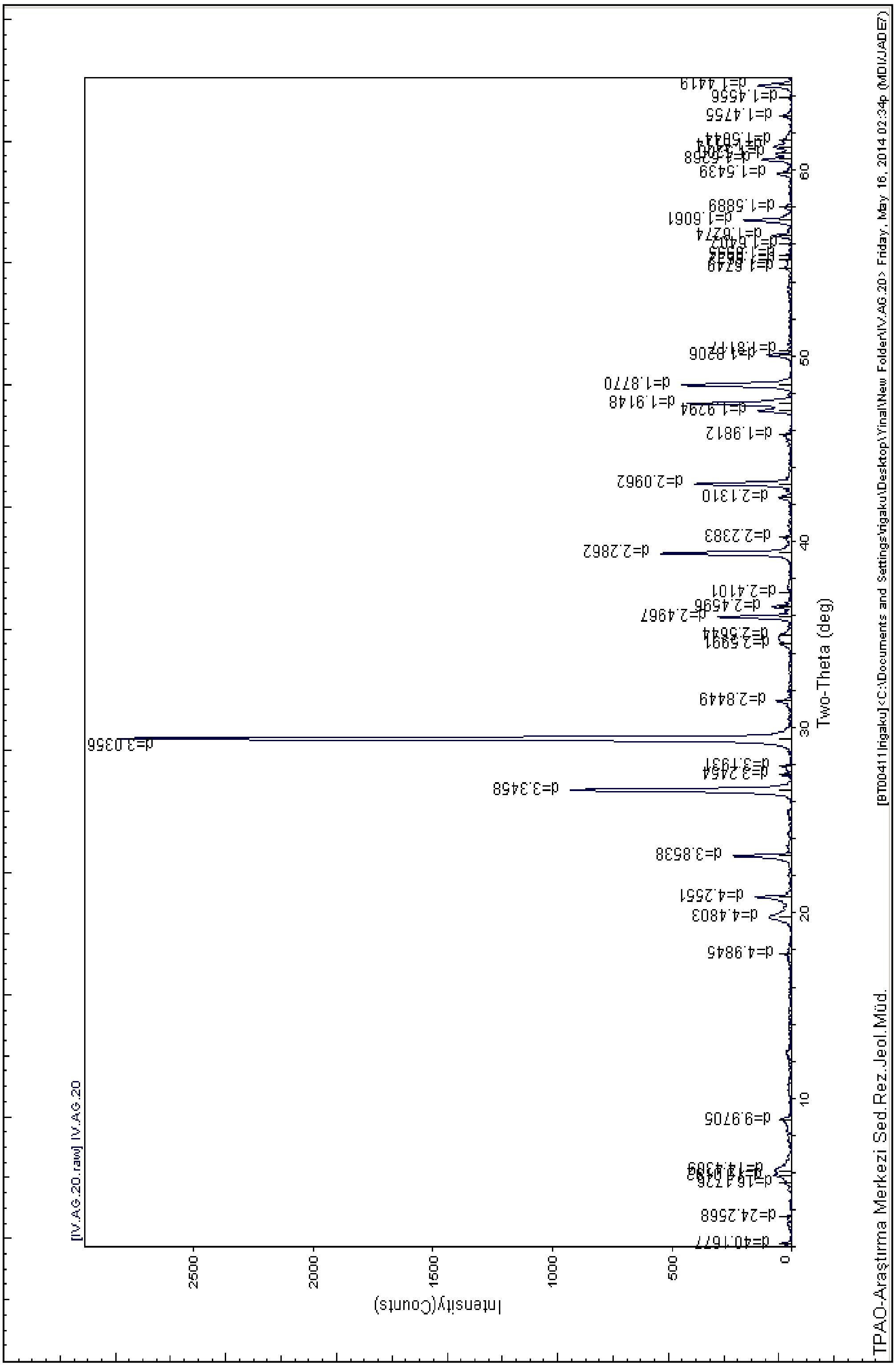


Figure 76. Bulk rock XRD diffractogram for Sample 20 of the Erfelek 1 Section.

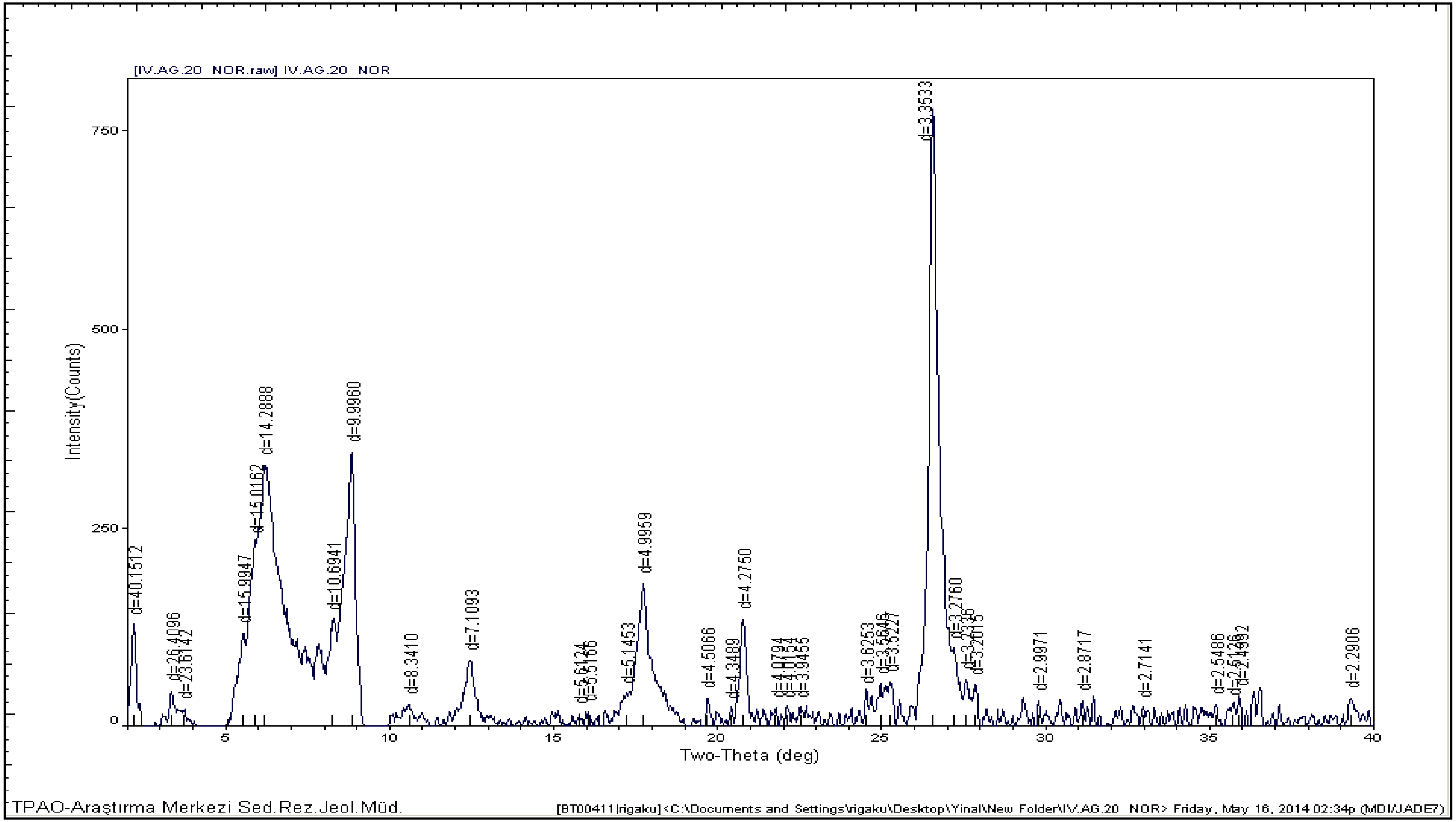


Figure 77. Clay mineral (air dried) XRD diffractogram for Sample 20 of the Erfelek 1 Section.

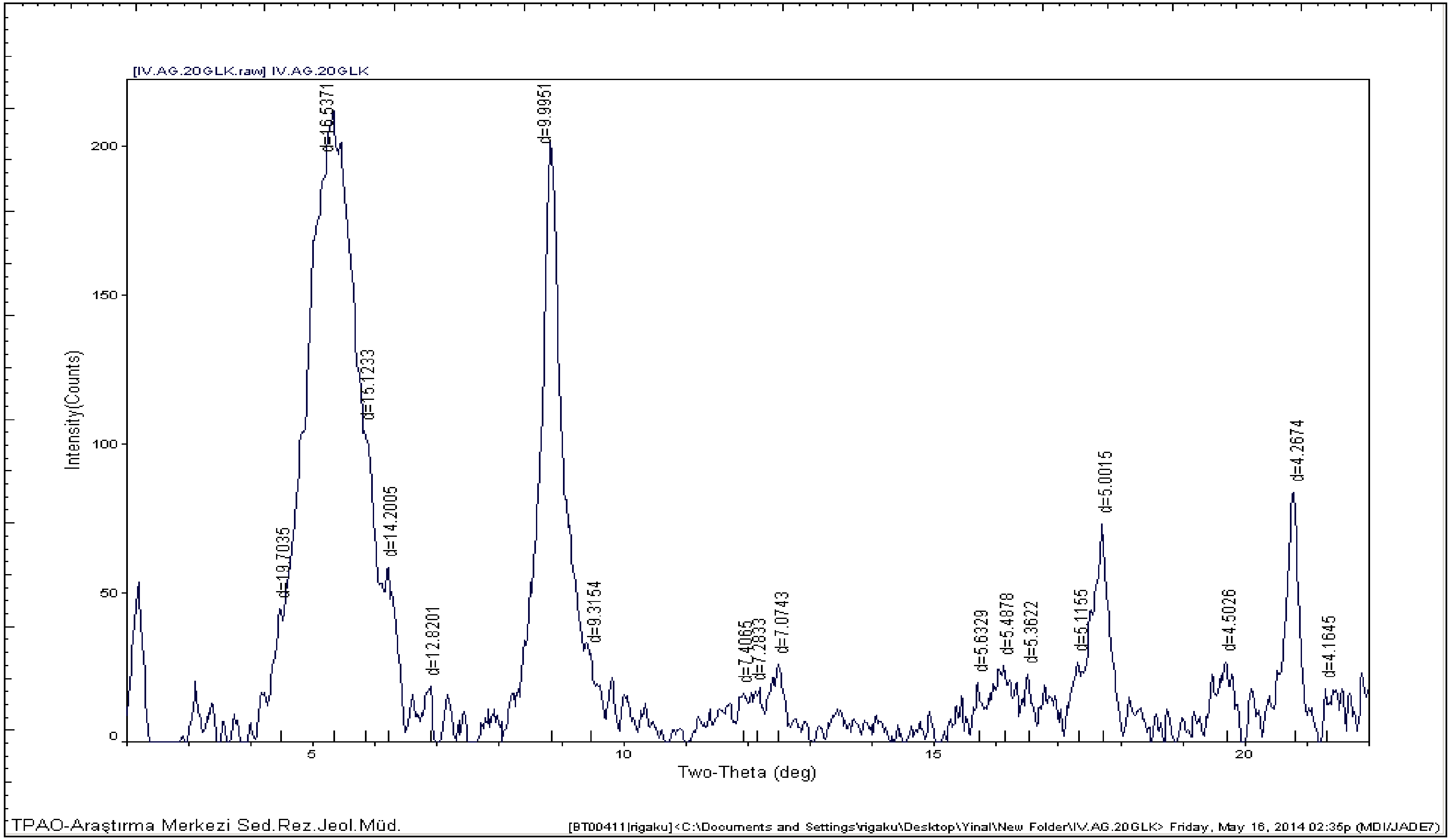


Figure 78. Clay mineral (etylene glycol) XRD diffractogram for Sample 20 of the Erfelek 1 Section.

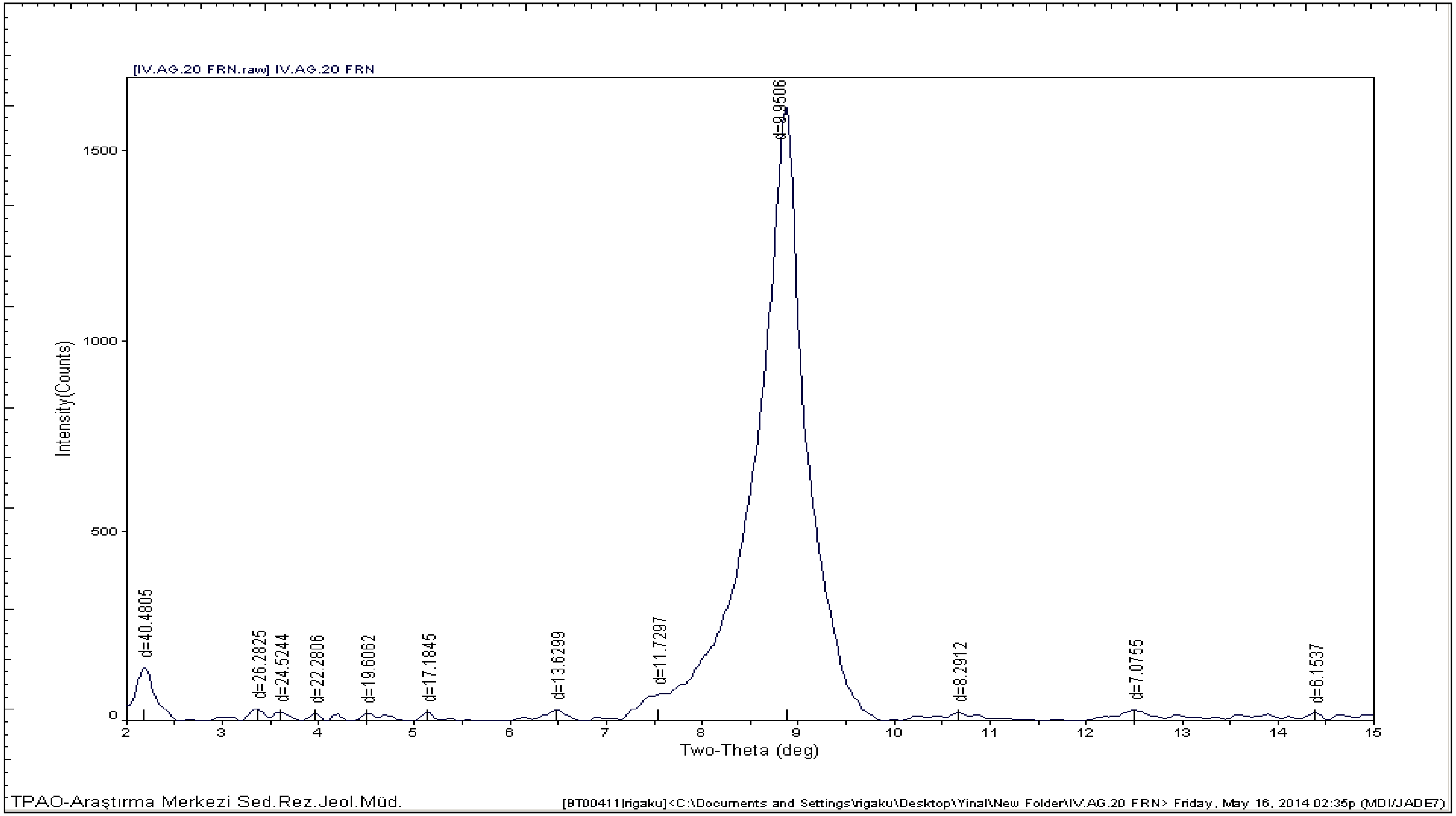


Figure 79. Clay mineral (heated) XRD diffractogram for Sample 20 of the Erfelek 1 Section.

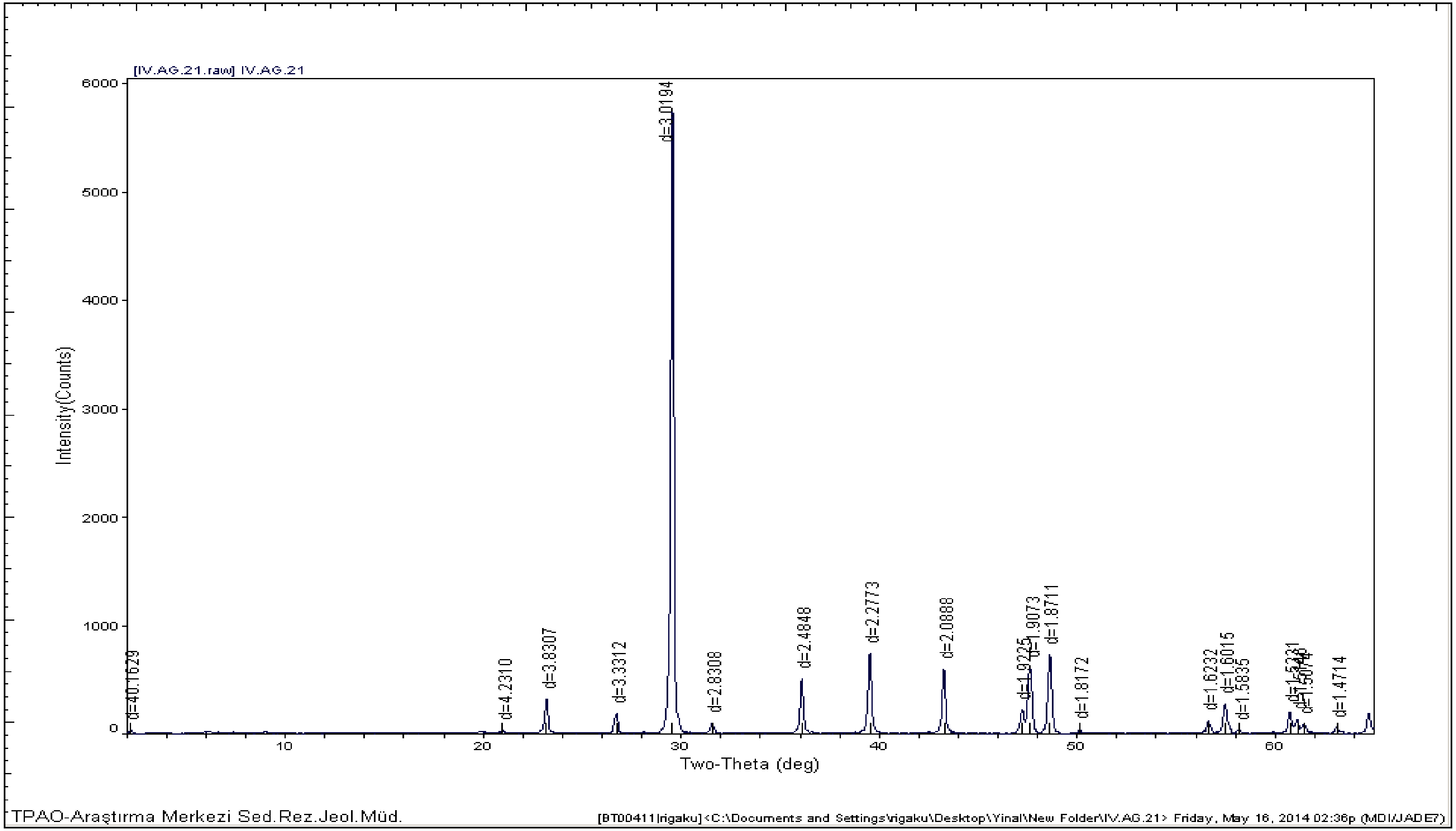


Figure 80. Bulk rock XRD diffractogram for Sample 21of the Erfelek 1 Section.

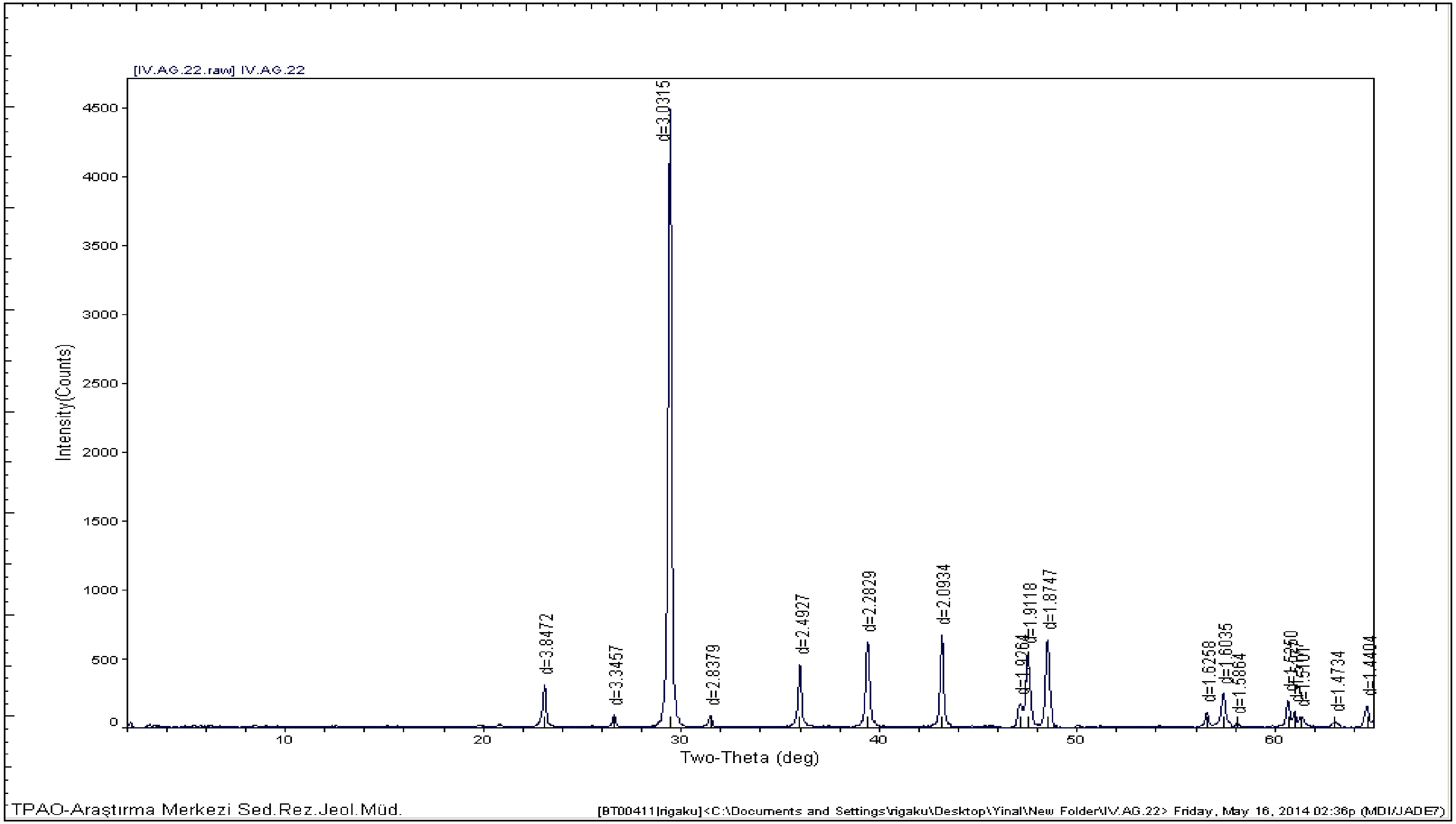


Figure 81. Bulk rock XRD diffractogram for Sample 22 of the Erfelek 1 Section.

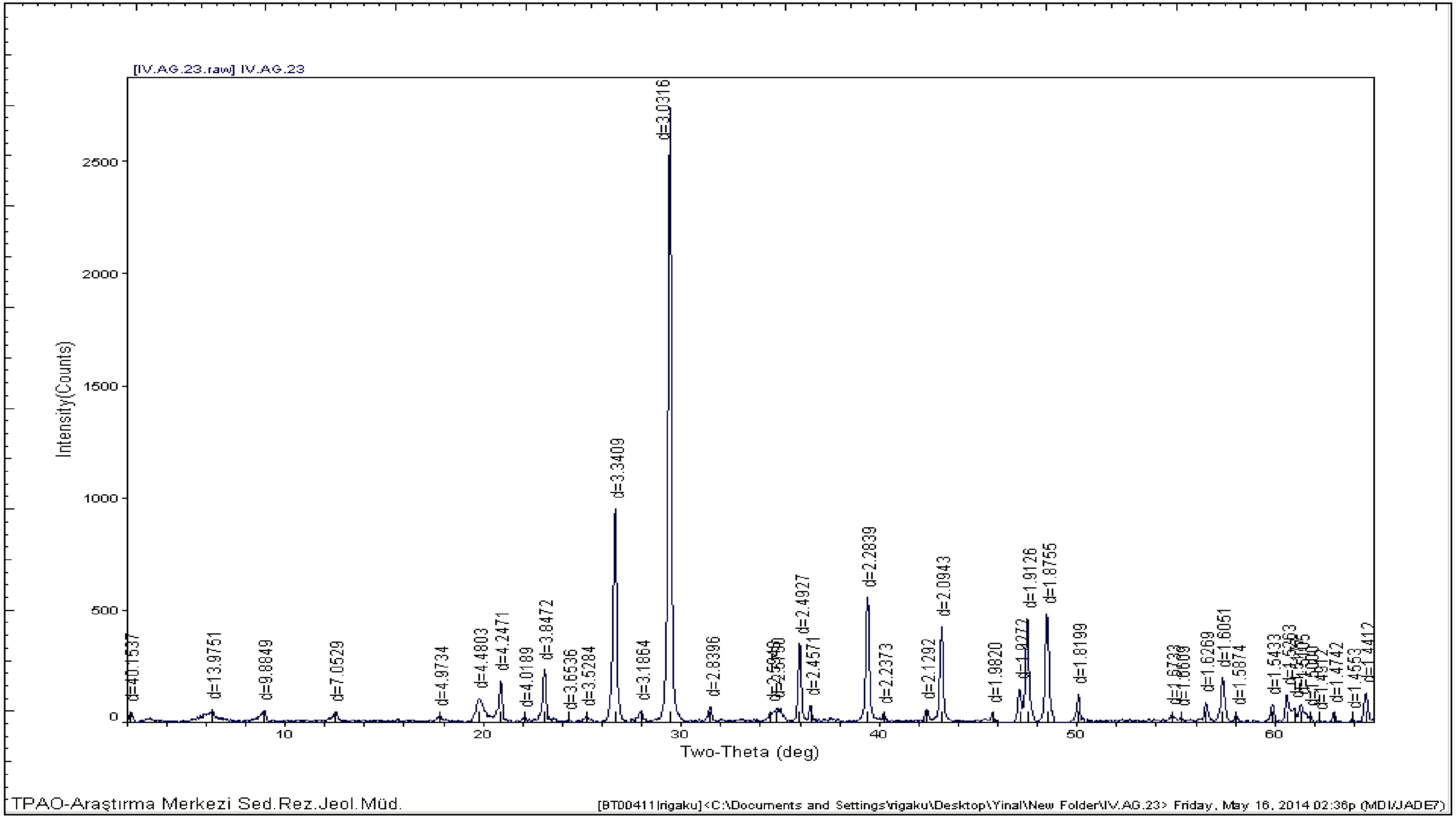


Figure 82. Bulk rock XRD diffractogram for Sample 23 of the Erfelek 1 Section.

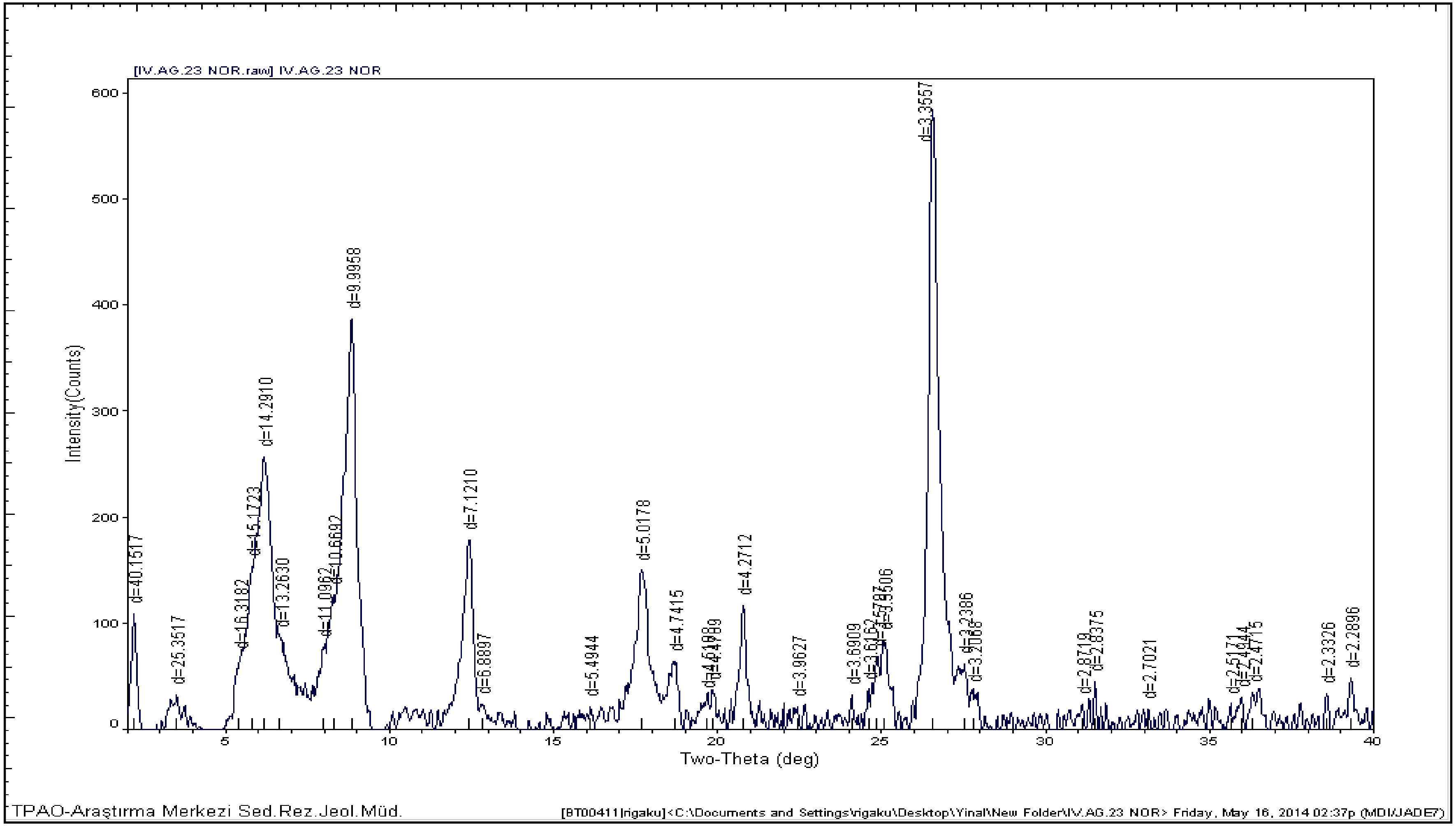


Figure 83. Clay mineral (air dried) XRD diffractogram for Sample 23 of the Erfelek 1 Section.

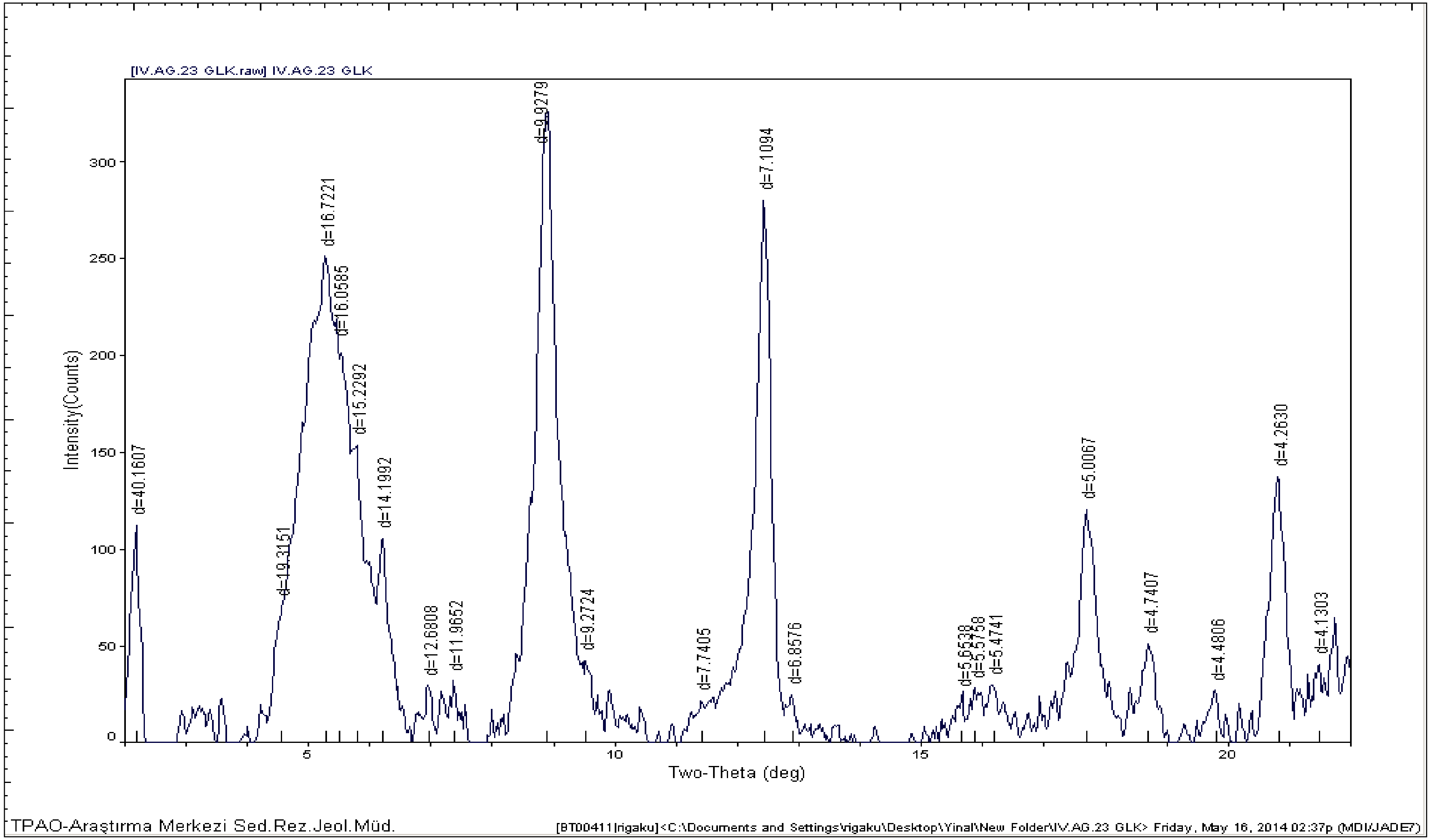


Figure 84. Clay mineral (etylene glycol) XRD diffractogram for Sample 23 of the Erfelek 1 Section.

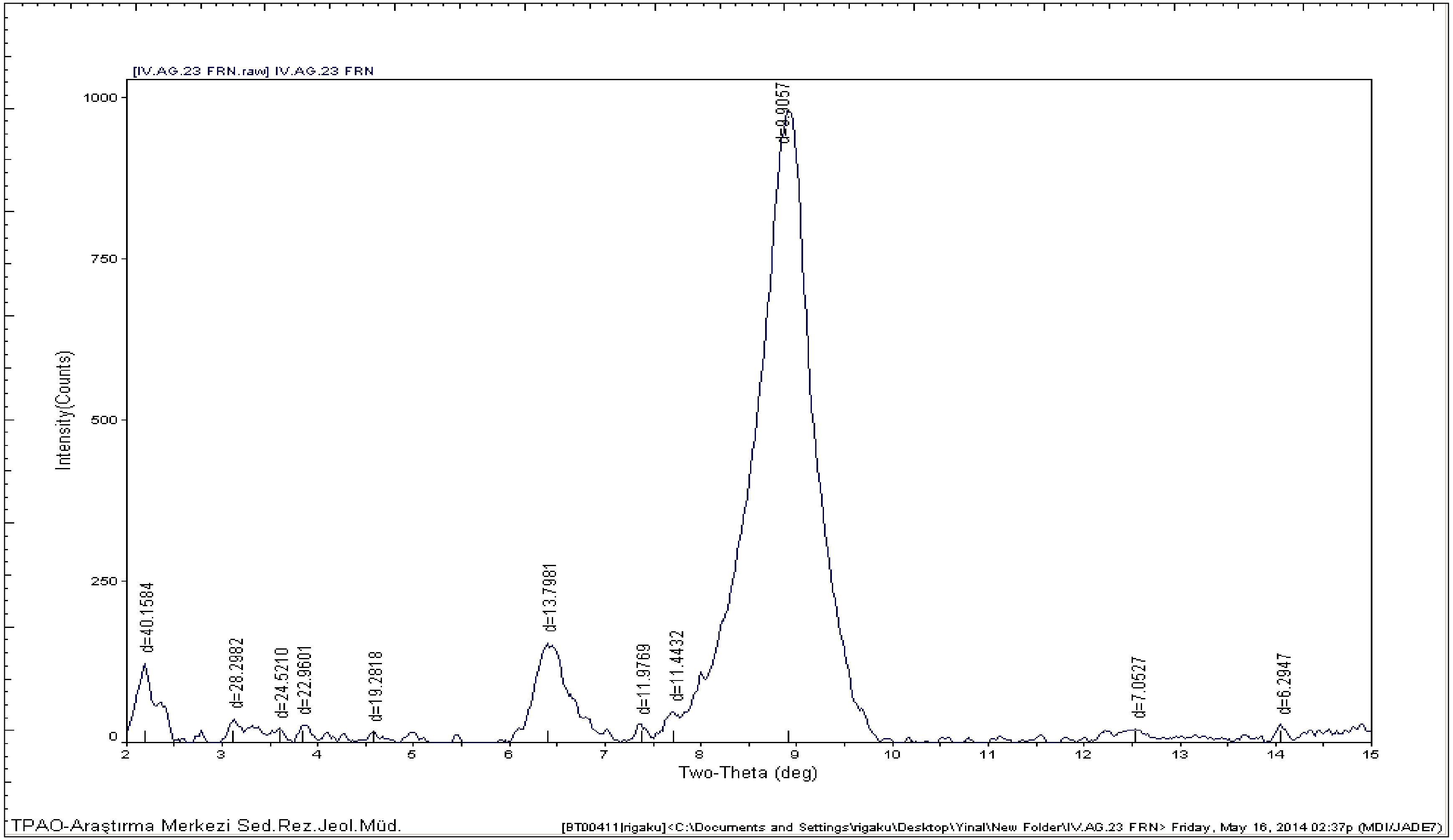


Figure 85. Clay mineral (heated) XRD diffractogram for Sample 23 of the Erfelek 1 Section.

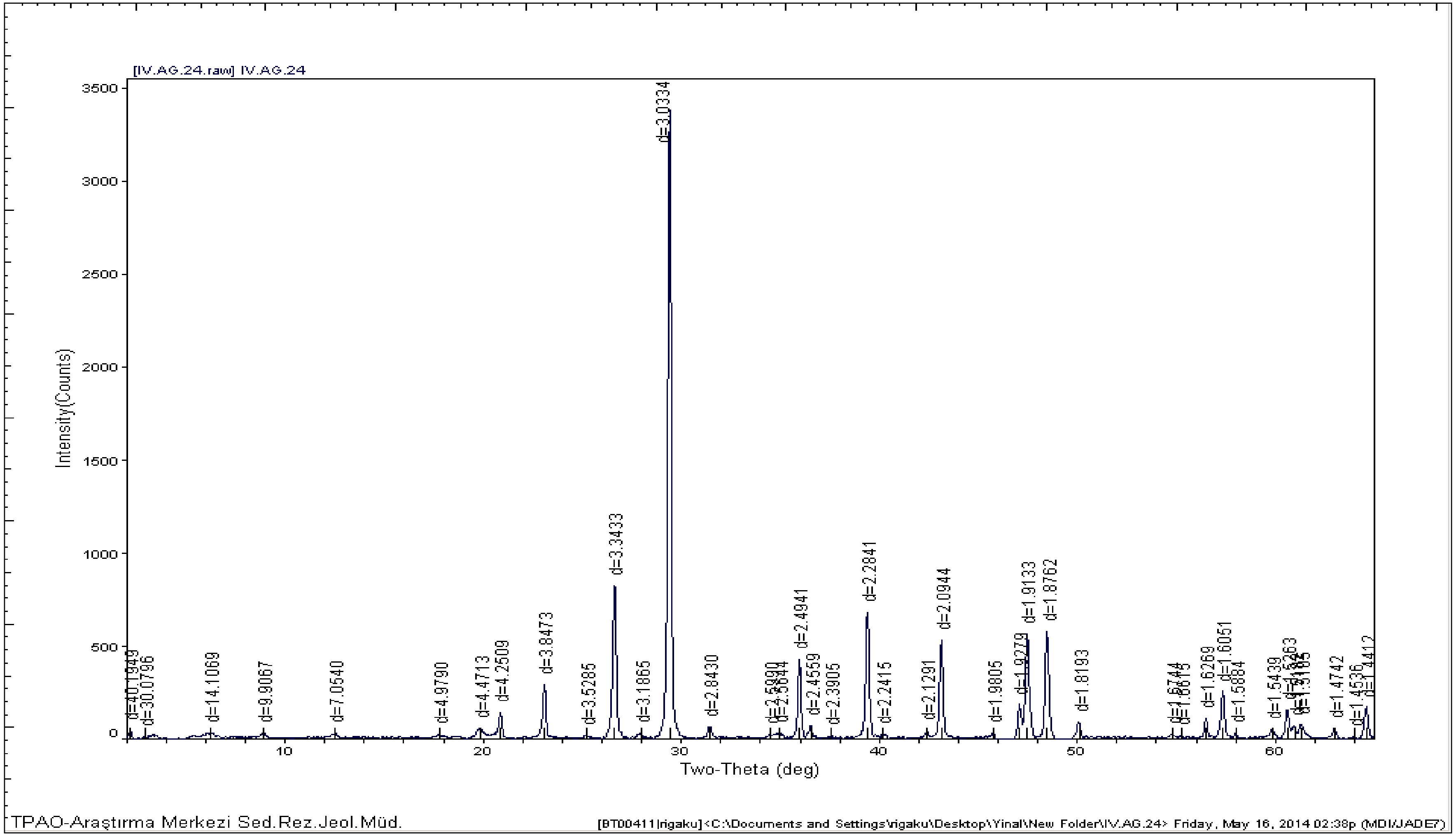


Figure 86. Bulk rock XRD diffractogram for Sample 24 of the Erfelek 1 Section.

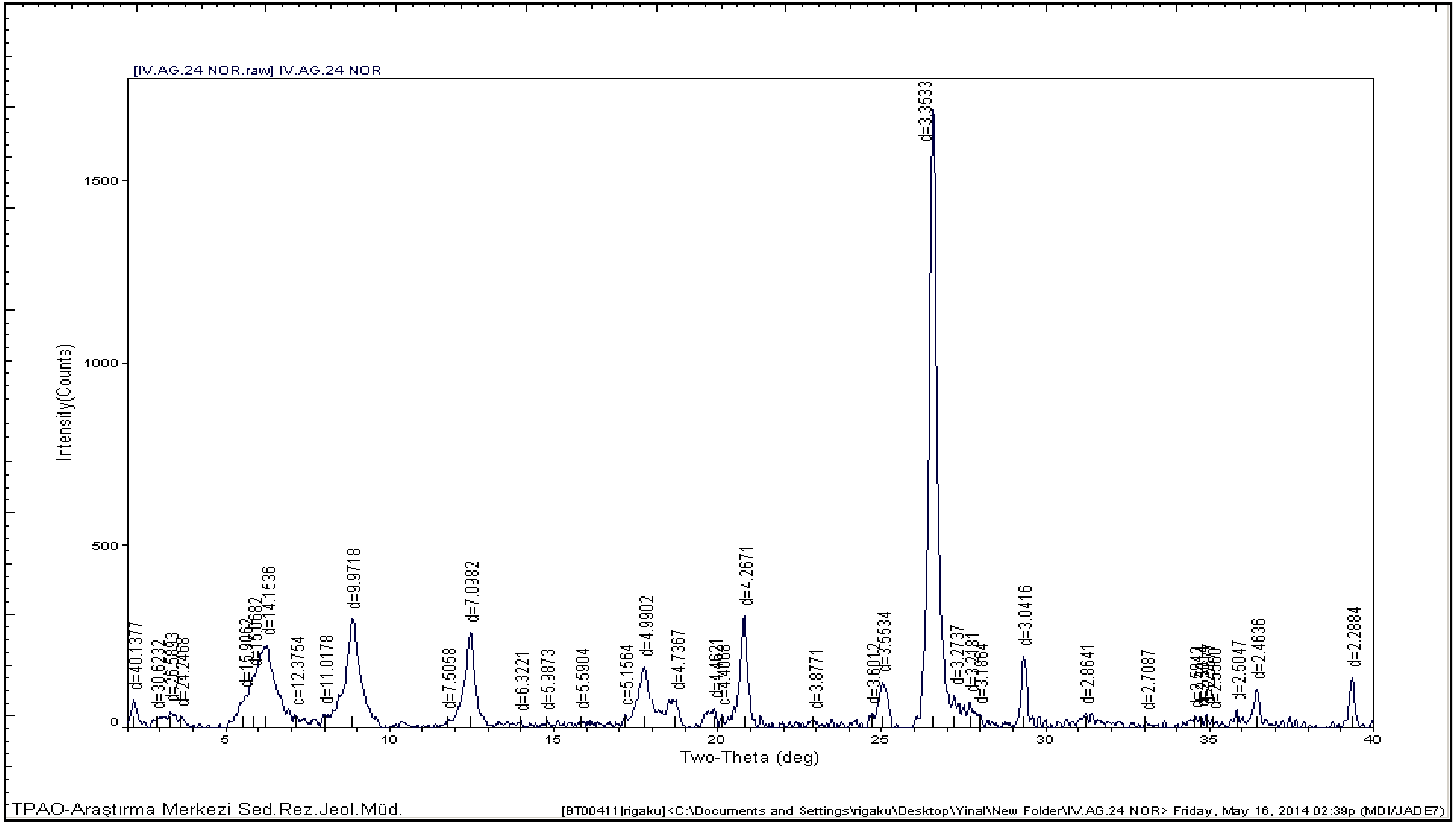


Figure 87. Clay mineral (air dried) XRD diffractogram for Sample 24 of the Erfelek 1 Section.

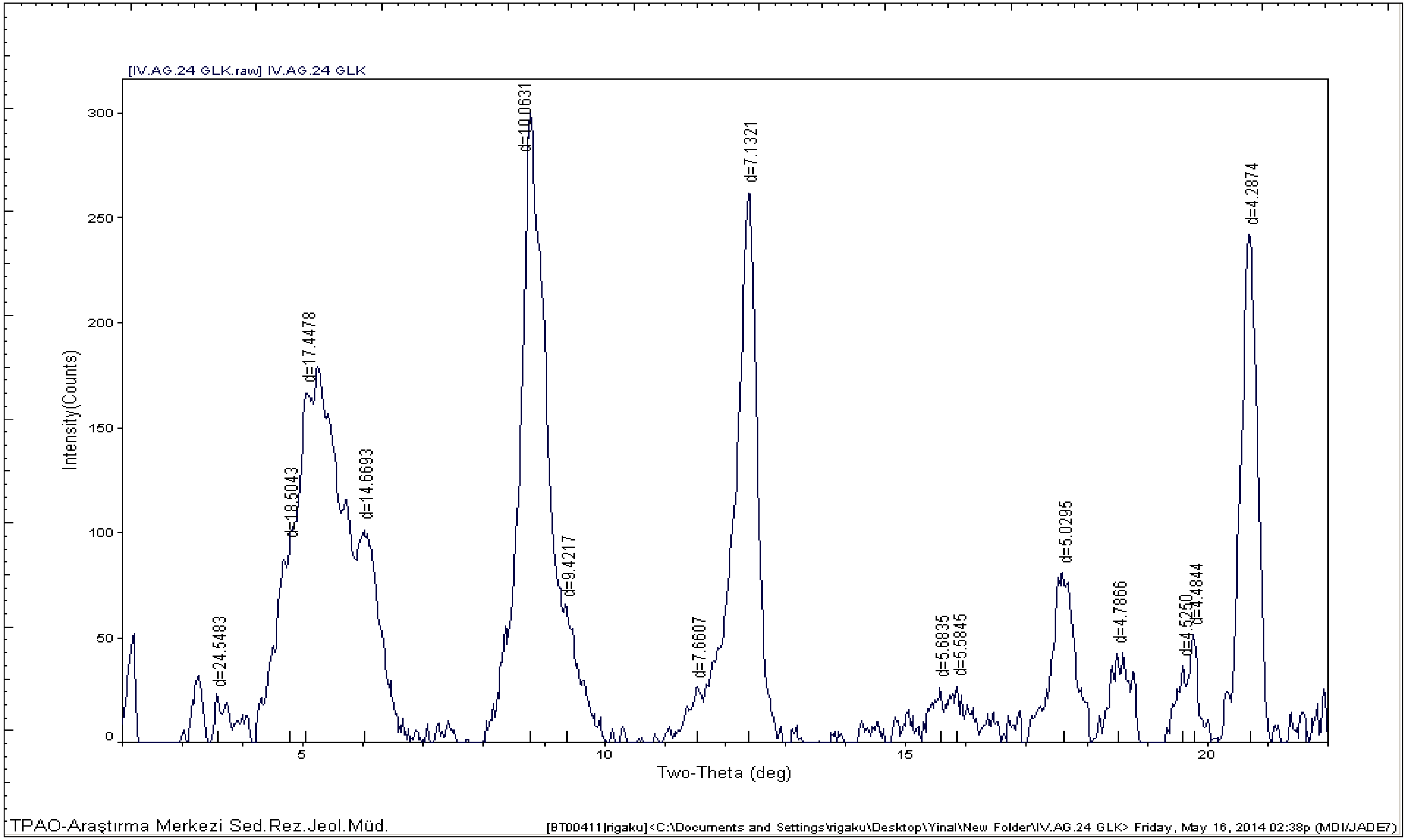


Figure 88. Clay mineral (ethylene glycol) XRD diffractogram for Sample 24 of the Erfelek 1 Section.

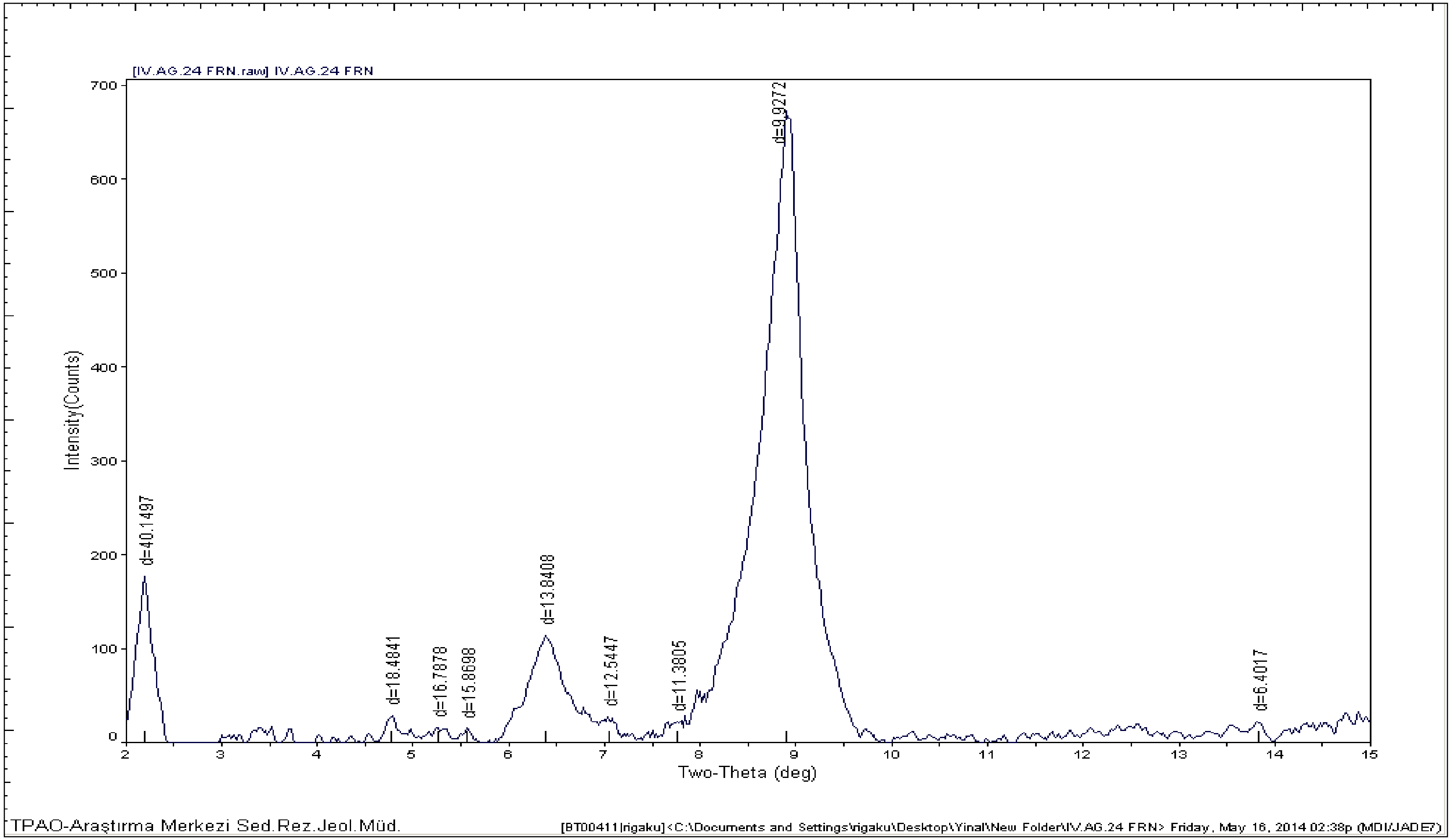


Figure 89. Clay mineral (heated) XRD diffractogram for Sample 24 of the Erfelek 1 Section.

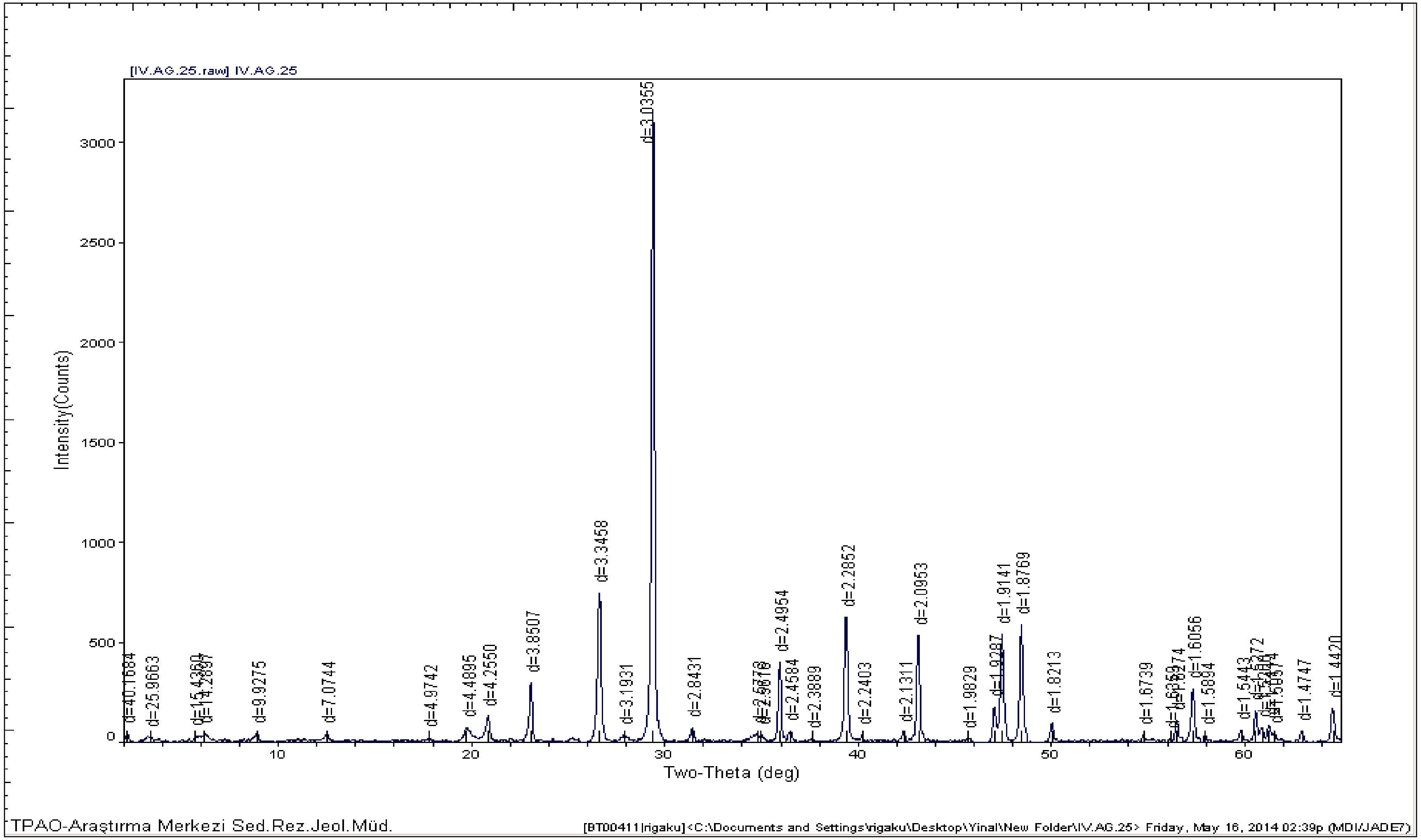


Figure 90. Bulk rock XRD diffractogram for Sample 25 of the Erfelek 1 Section.

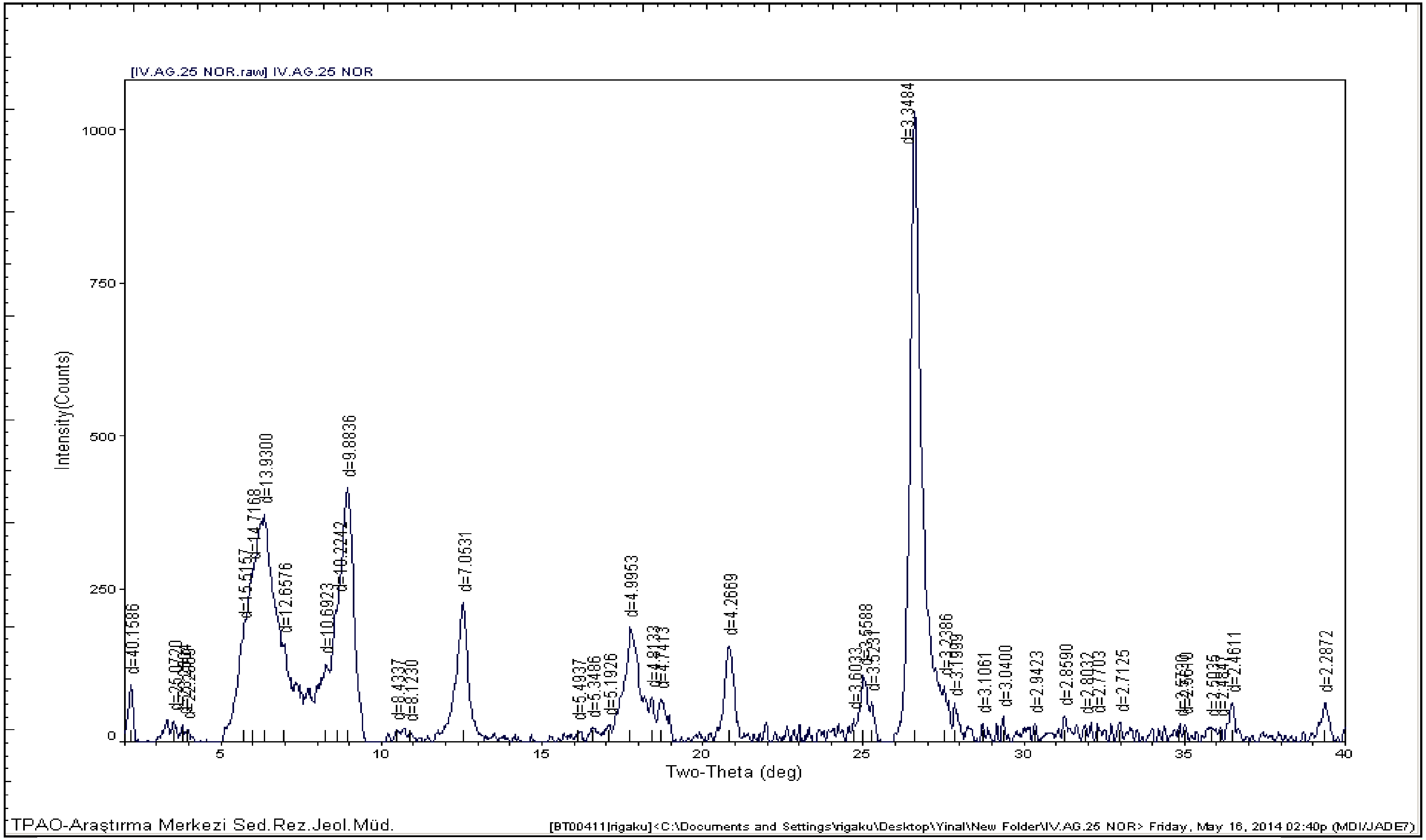


Figure 91. Clay mineral (air dried) XRD diffractogram for Sample 25 of the Erfelek 1 Section.

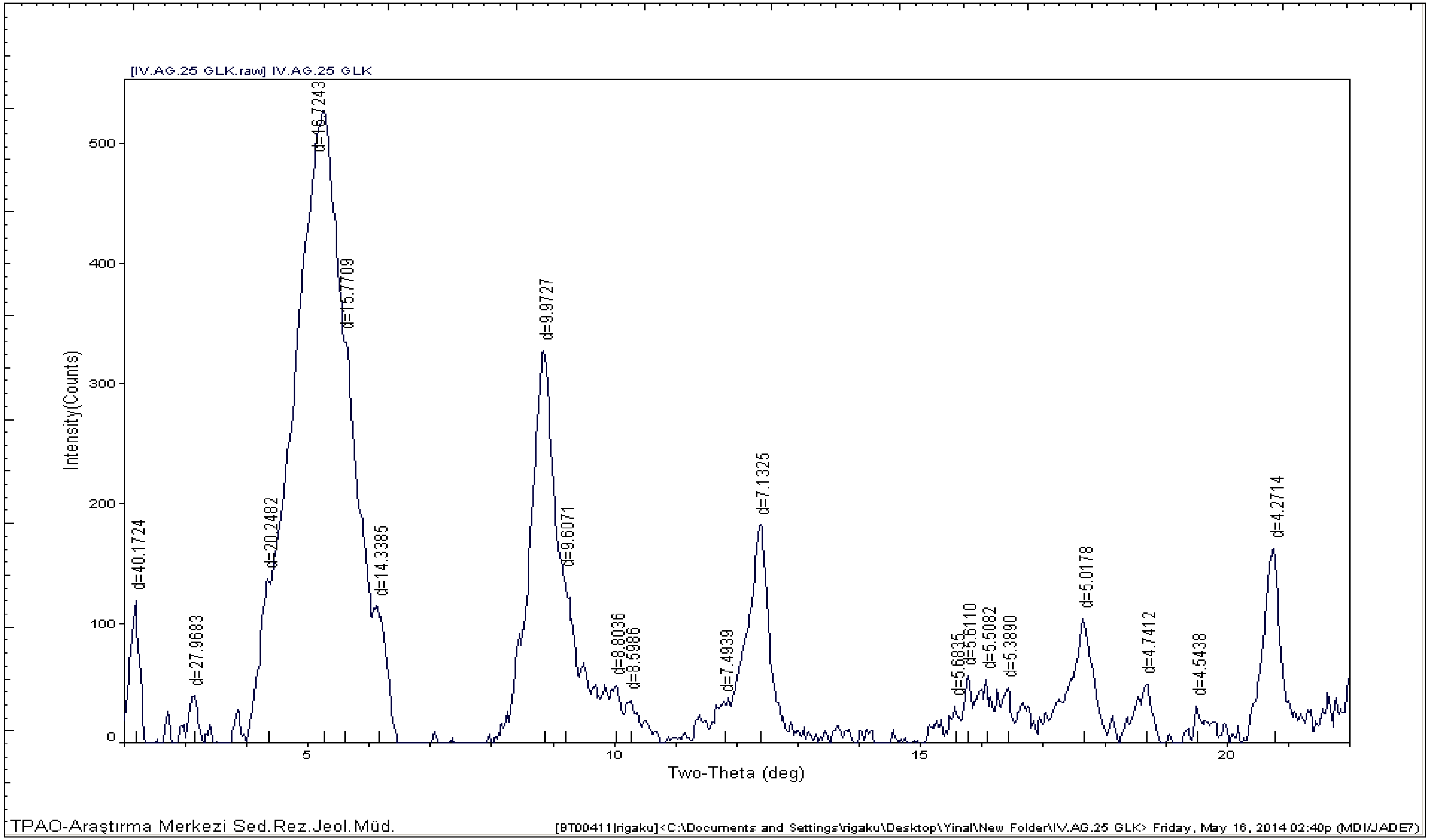


Figure 92. Clay mineral (ethylene glycol) XRD diffractogram for Sample 25 of the Erfelek 1 Section.

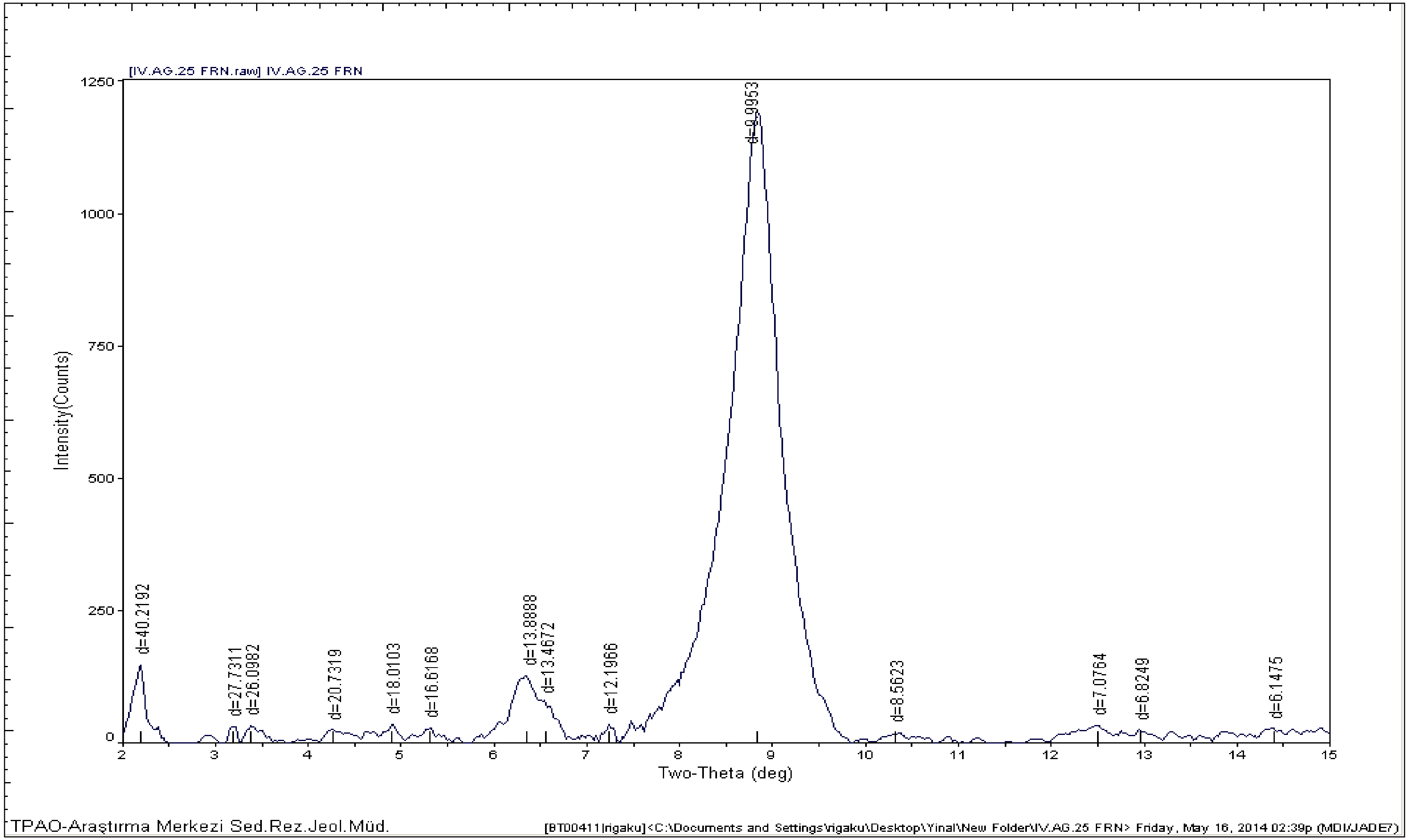


Figure 93. Clay mineral (heated) XRD diffractogram for Sample 25 of the Erfelek 1 Section.

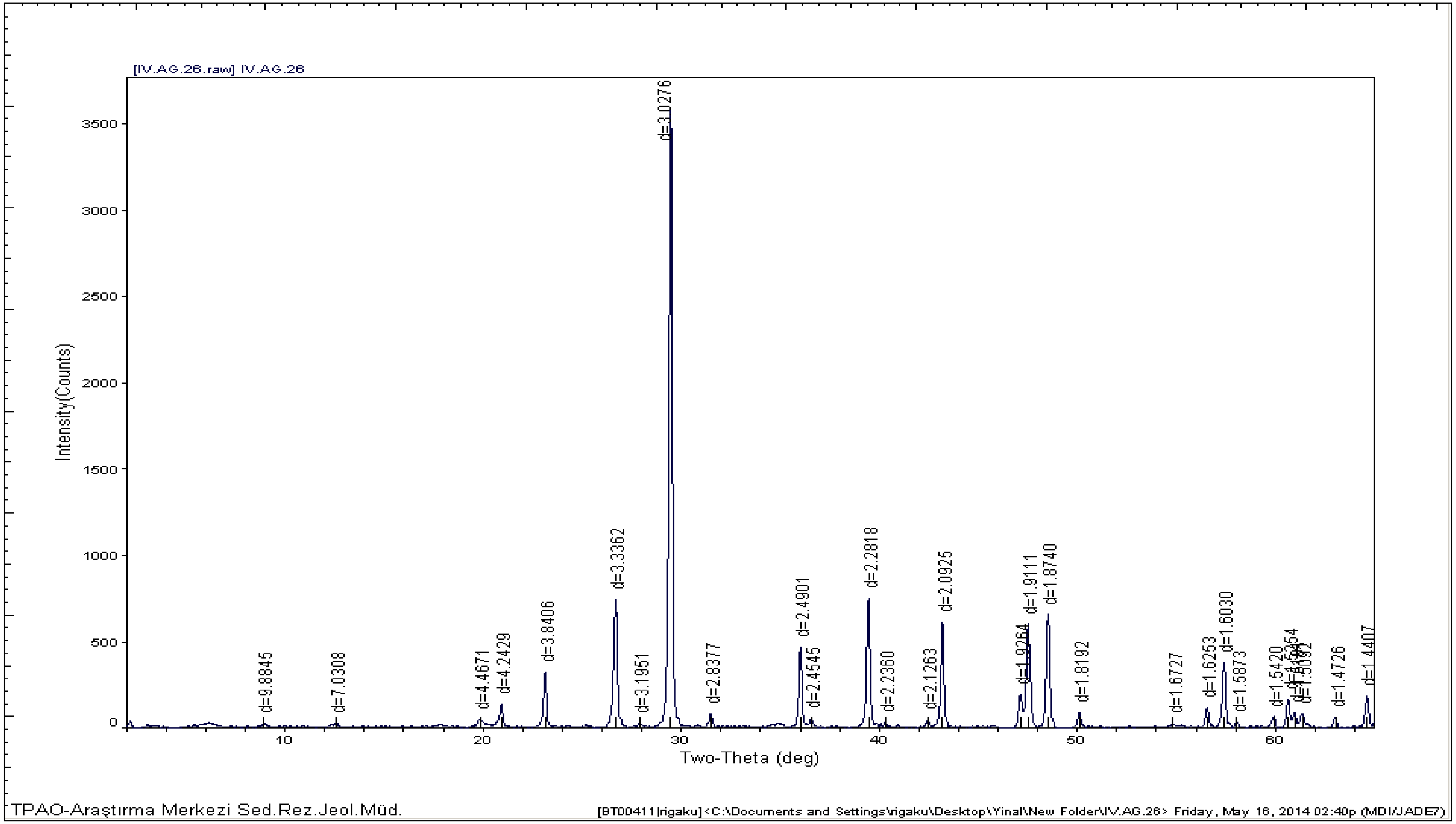


Figure 94. Bulk rock XRD diffractogram for Sample 26 of the Erfelek 1 Section.

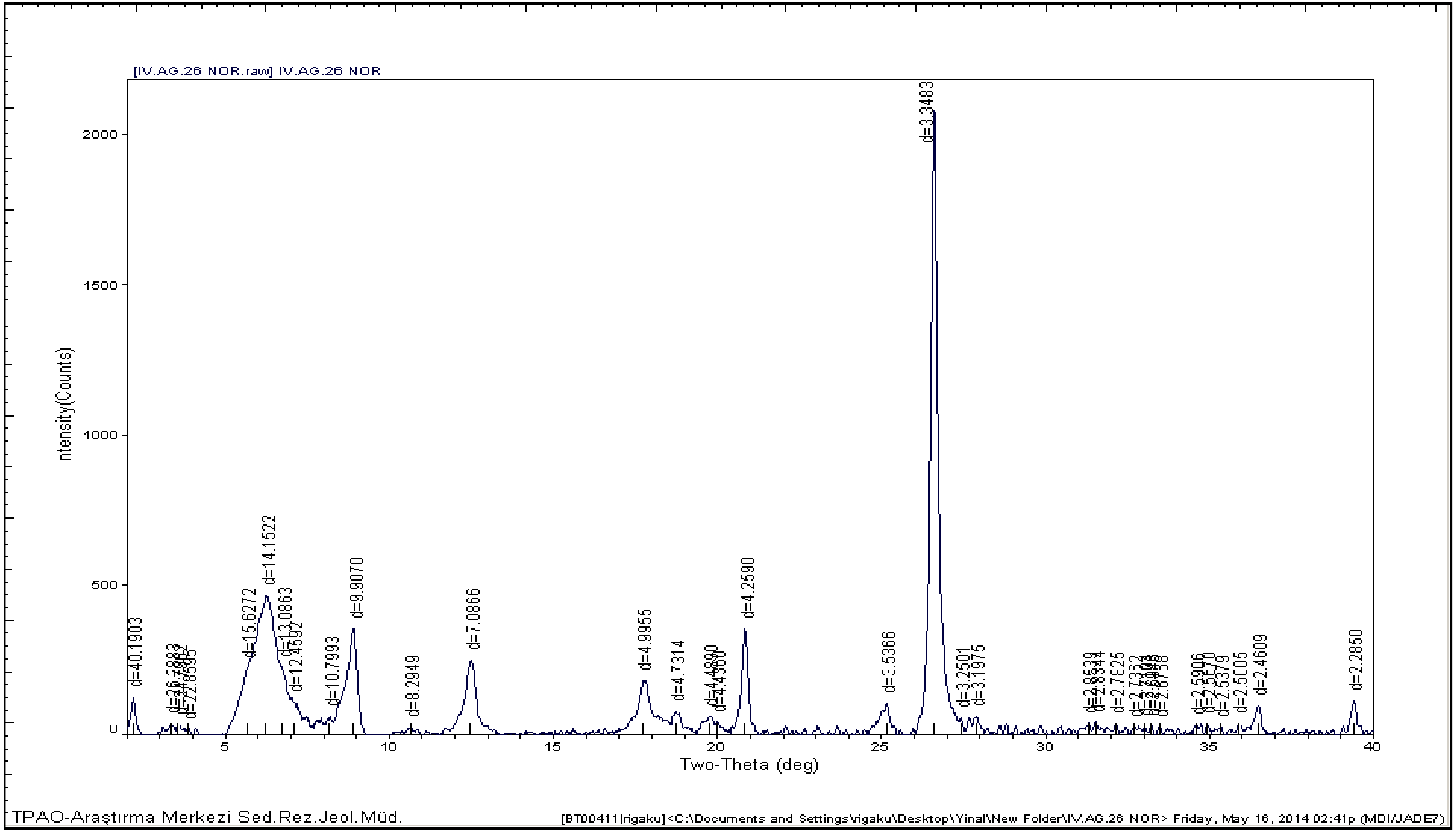


Figure 95. Clay mineral (air dried) XRD diffractogram for Sample 26 of the Erfelek 1 Section.

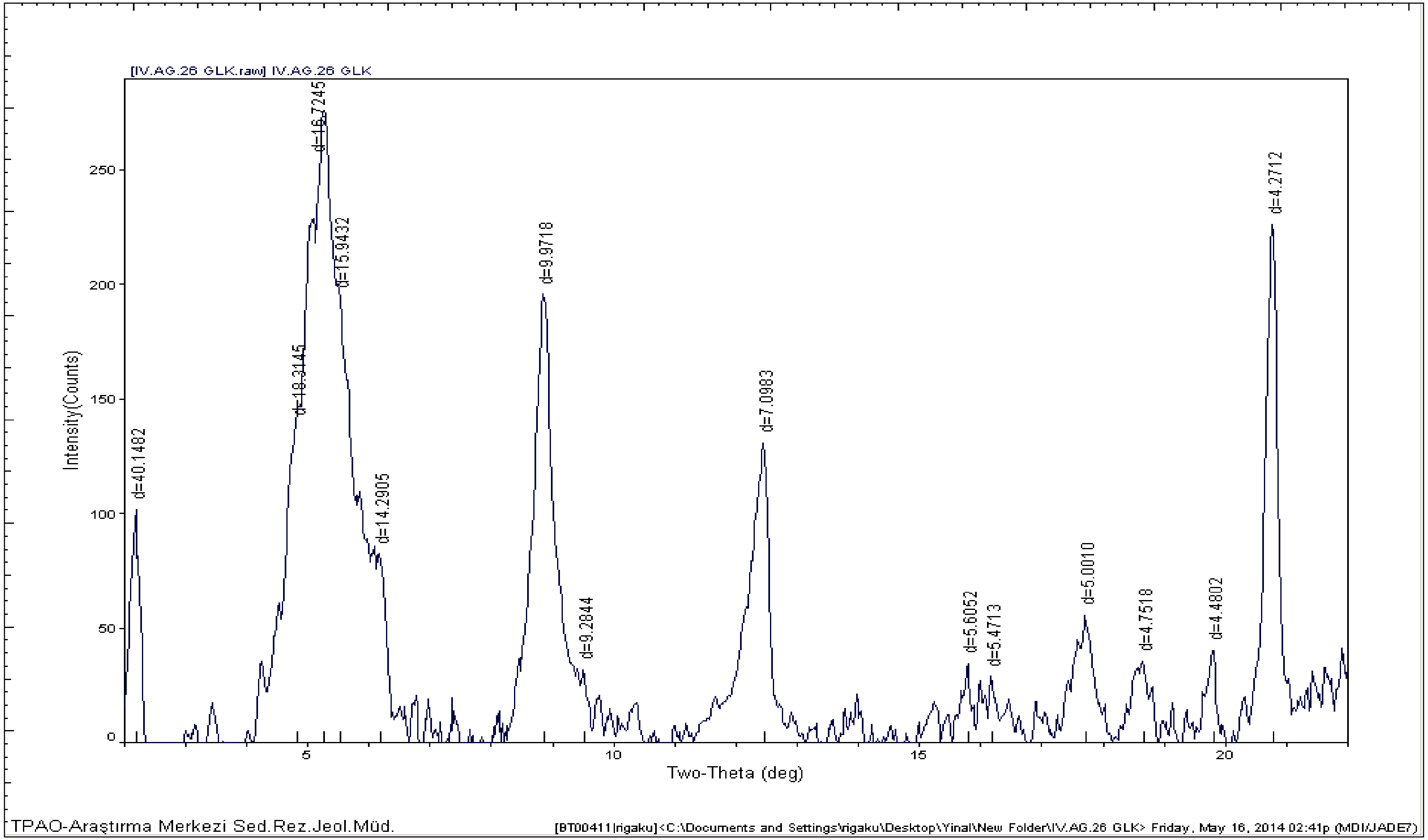


Figure 96. Clay mineral (ethylene glycol) XRD diffractogram for Sample 26 of the Erfelek 1 Section.

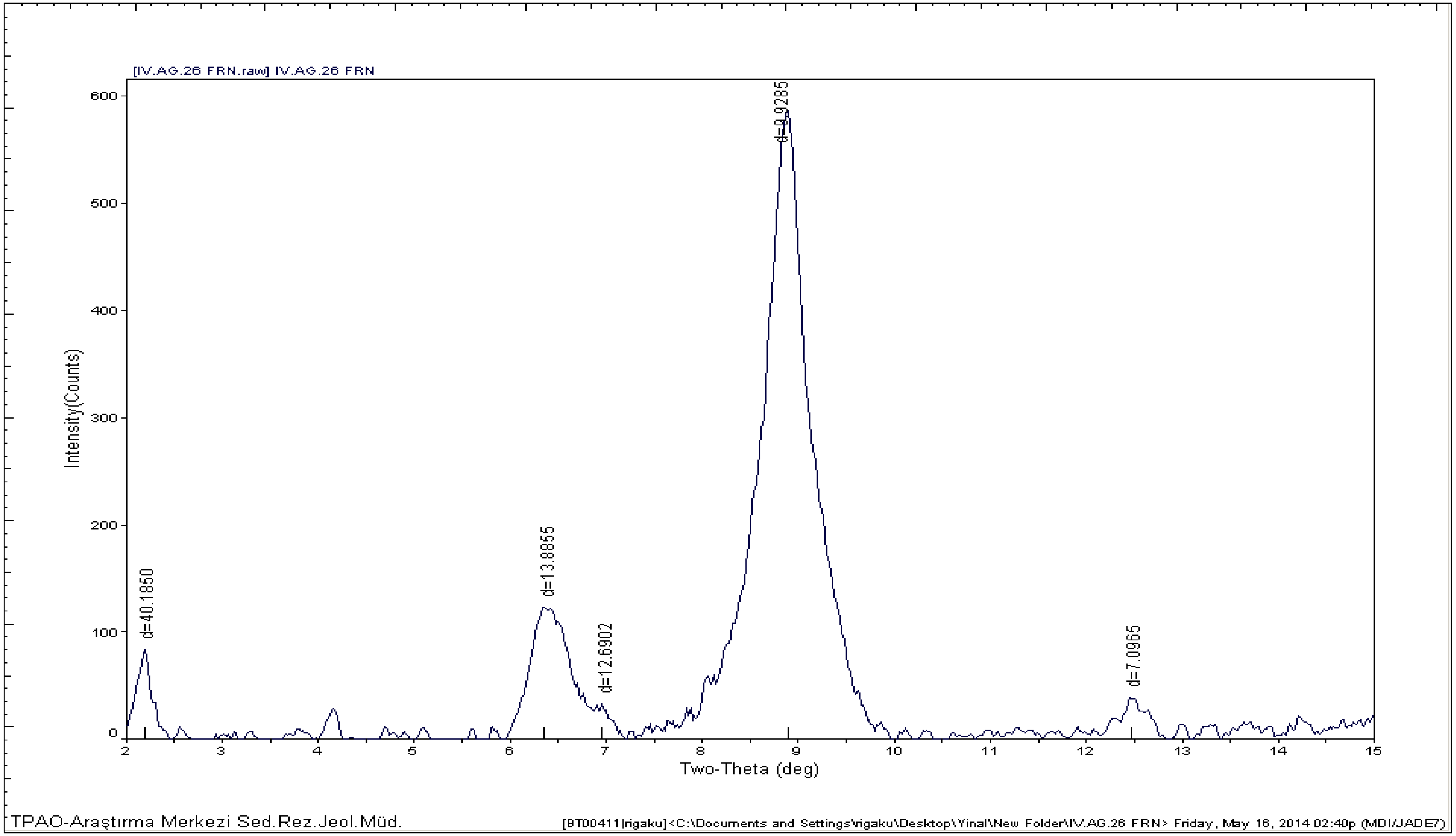


Figure 97. Clay mineral (heated) XRD diffractogram for Sample 26 of the Erfelek 1 Section.

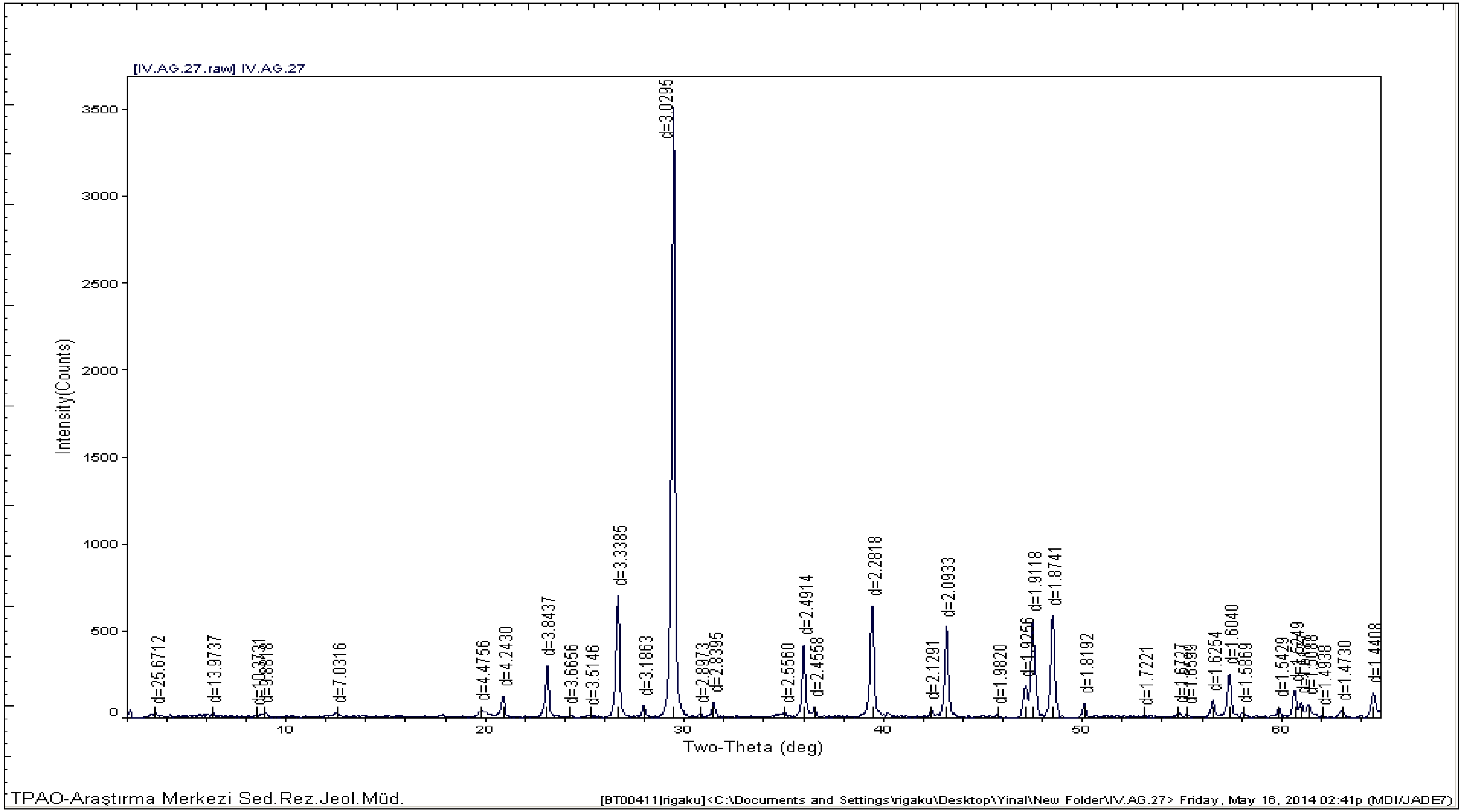


Figure 98. Bulk rock XRD diffractogram for Sample 27 of the Erfelek 1 Section.

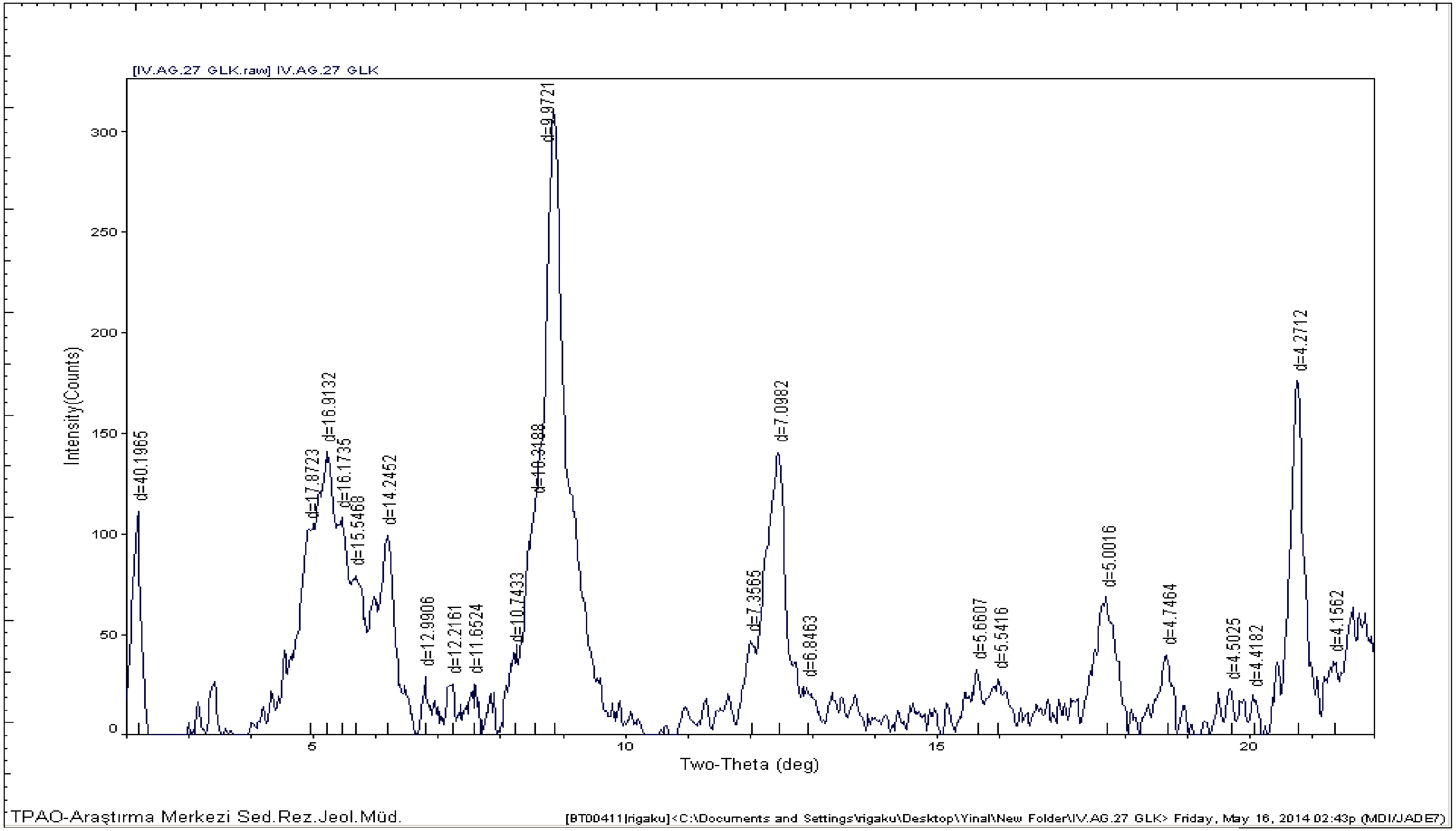


Figure 99. Clay mineral (ethylene glycol) XRD diffractogram for Sample 27 of the Erfelek 1 Section.

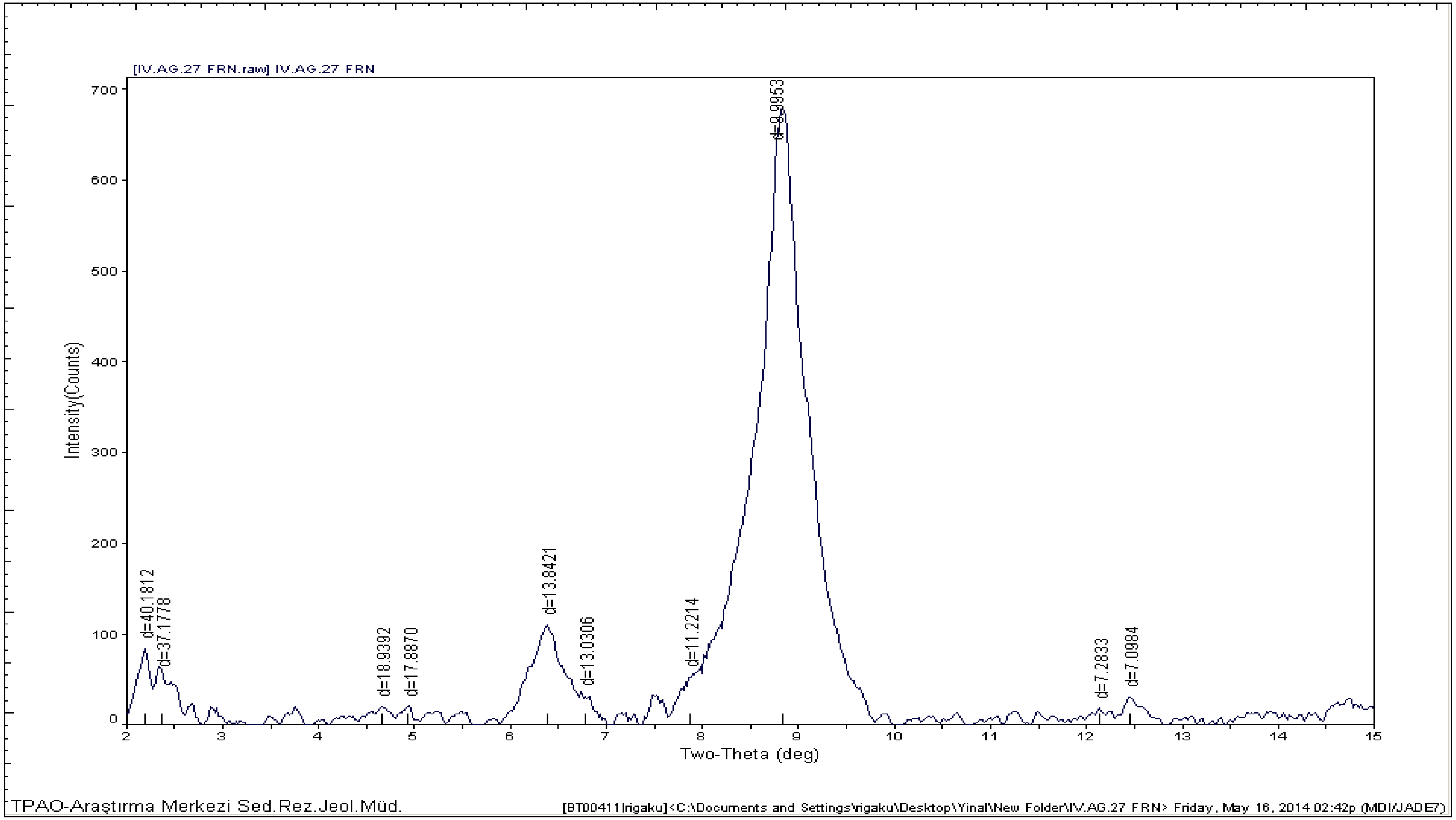


Figure 100. Clay mineral (heated) XRD diffractogram for Sample 27 of the Erfelek 1 Section.

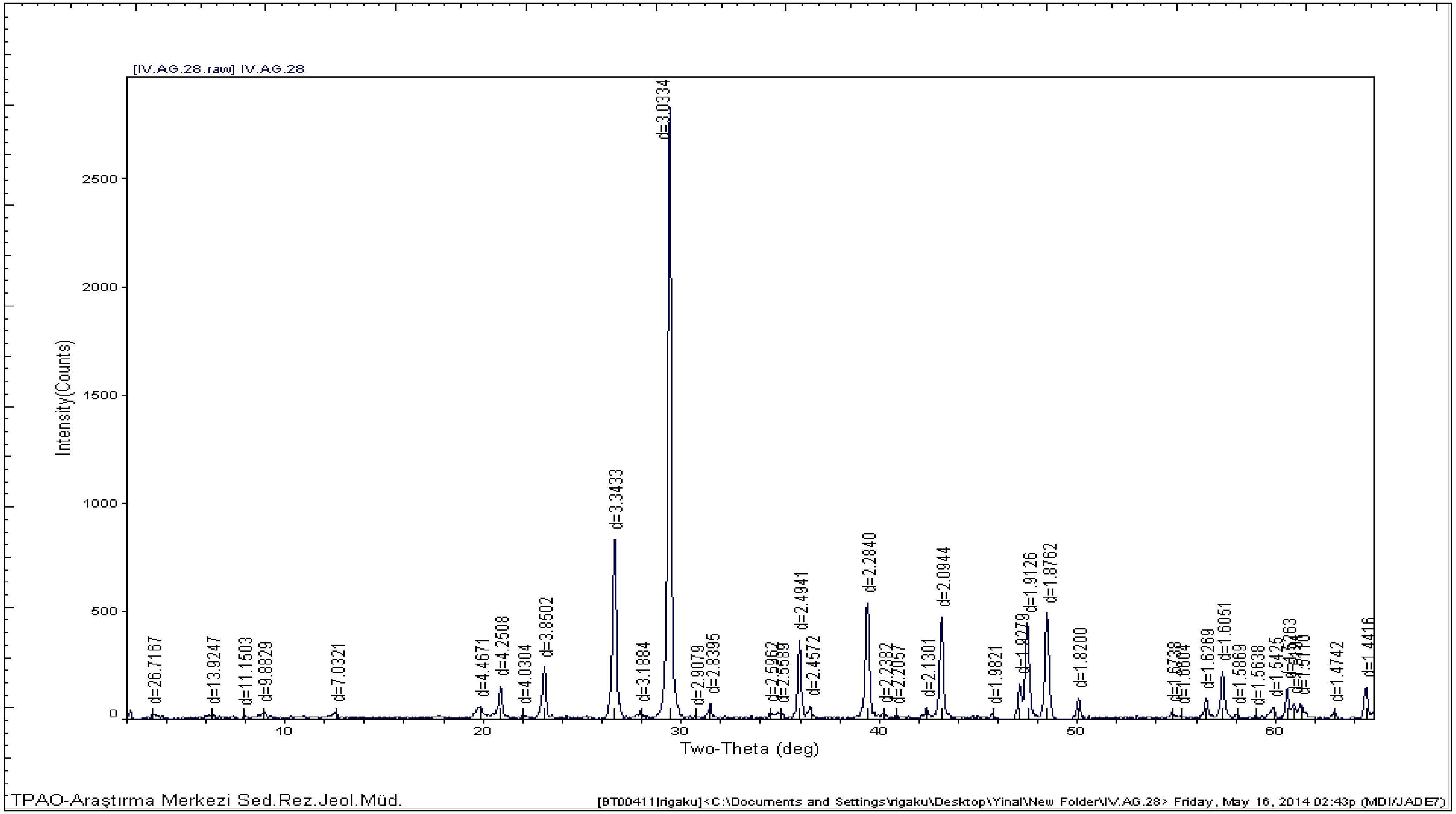


Figure 101. Bulk rock XRD diffractogram for Sample 28 of the Erfelek 1 Section.

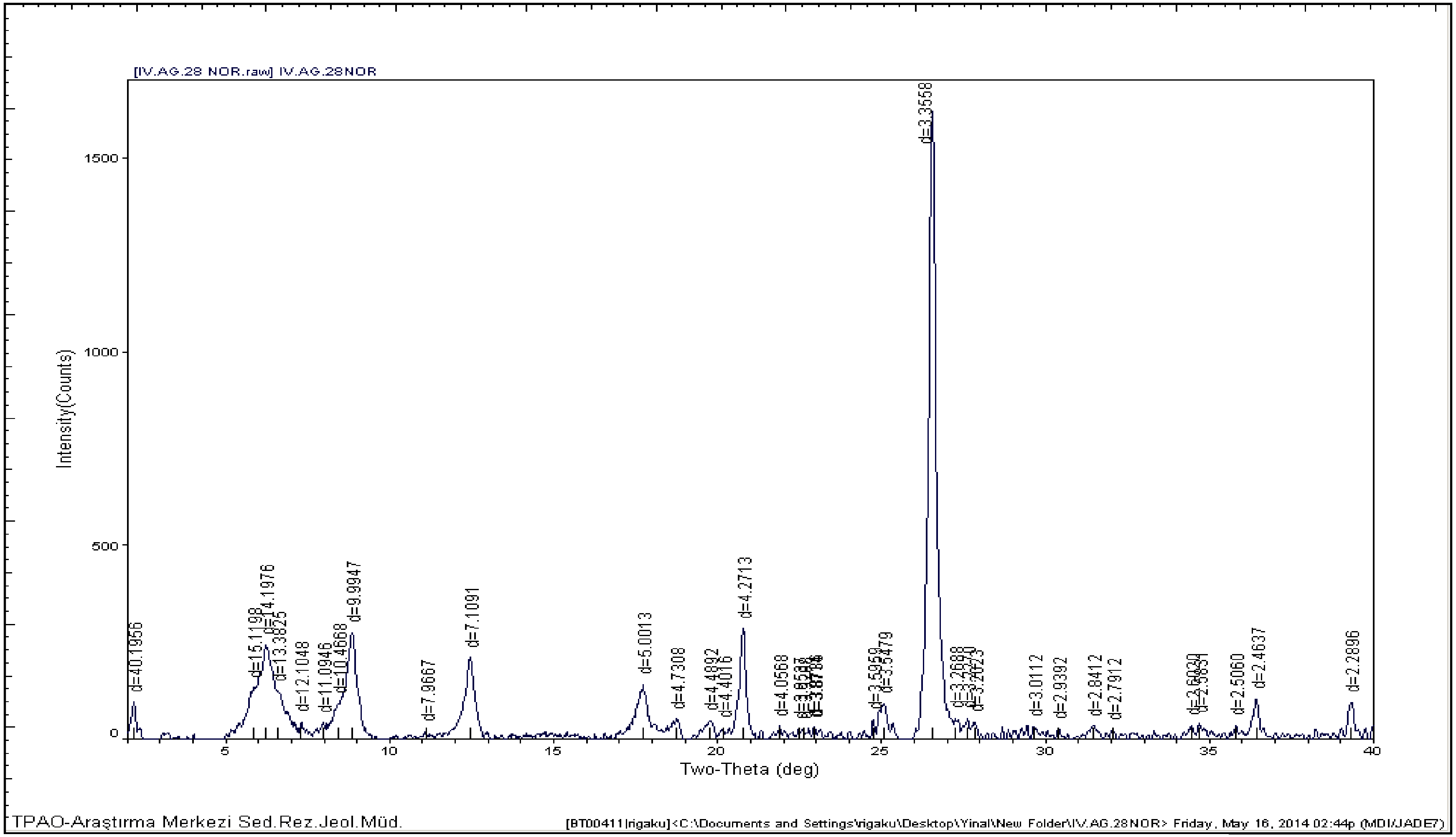


Figure 102. Clay mineral (air dried) XRD diffractogram for Sample 28 of the Erfelek 1 Section.

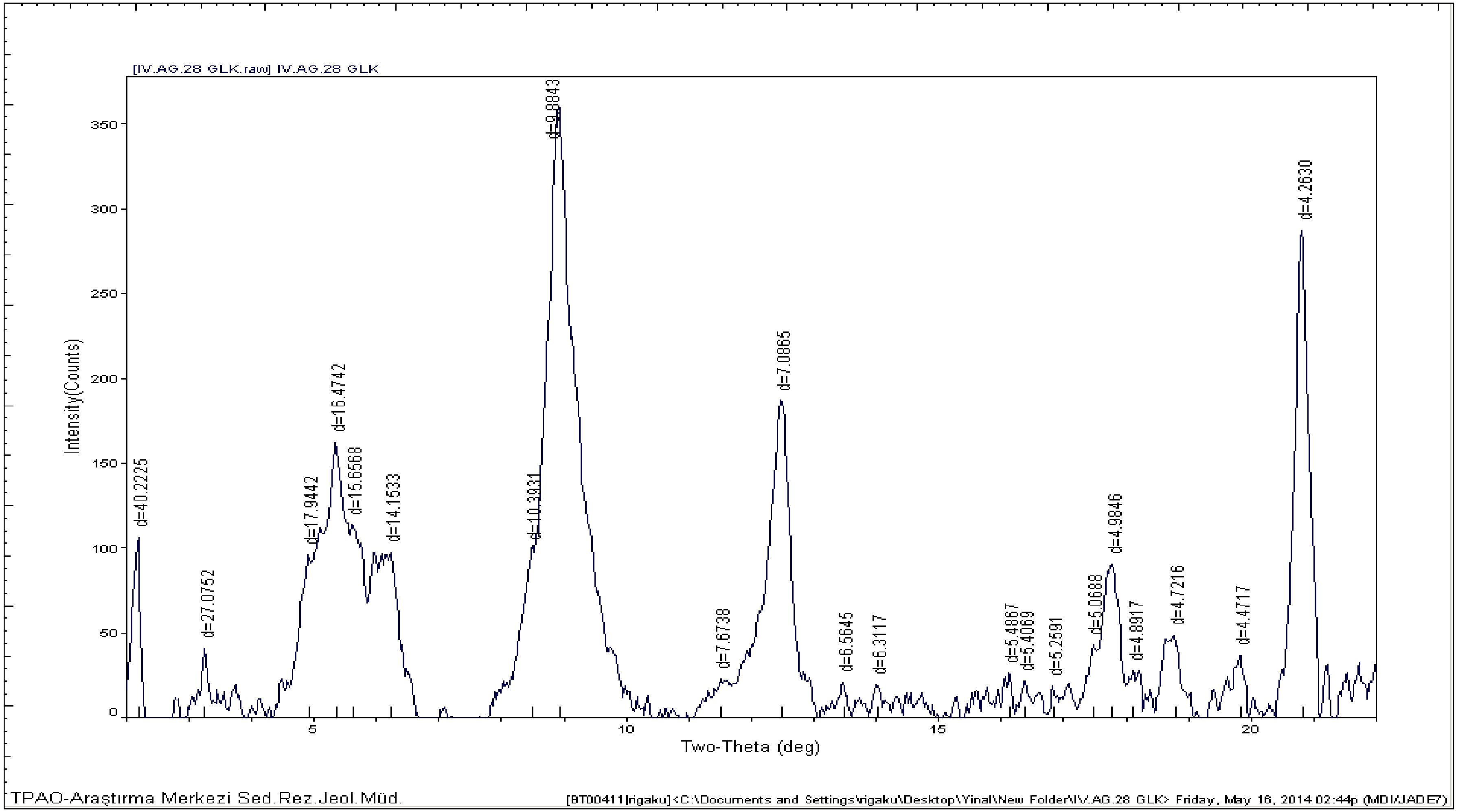


Figure 103. Clay mineral (ethylene glycol) XRD diffractogram for Sample 28 of the Erfelek 1 Section.

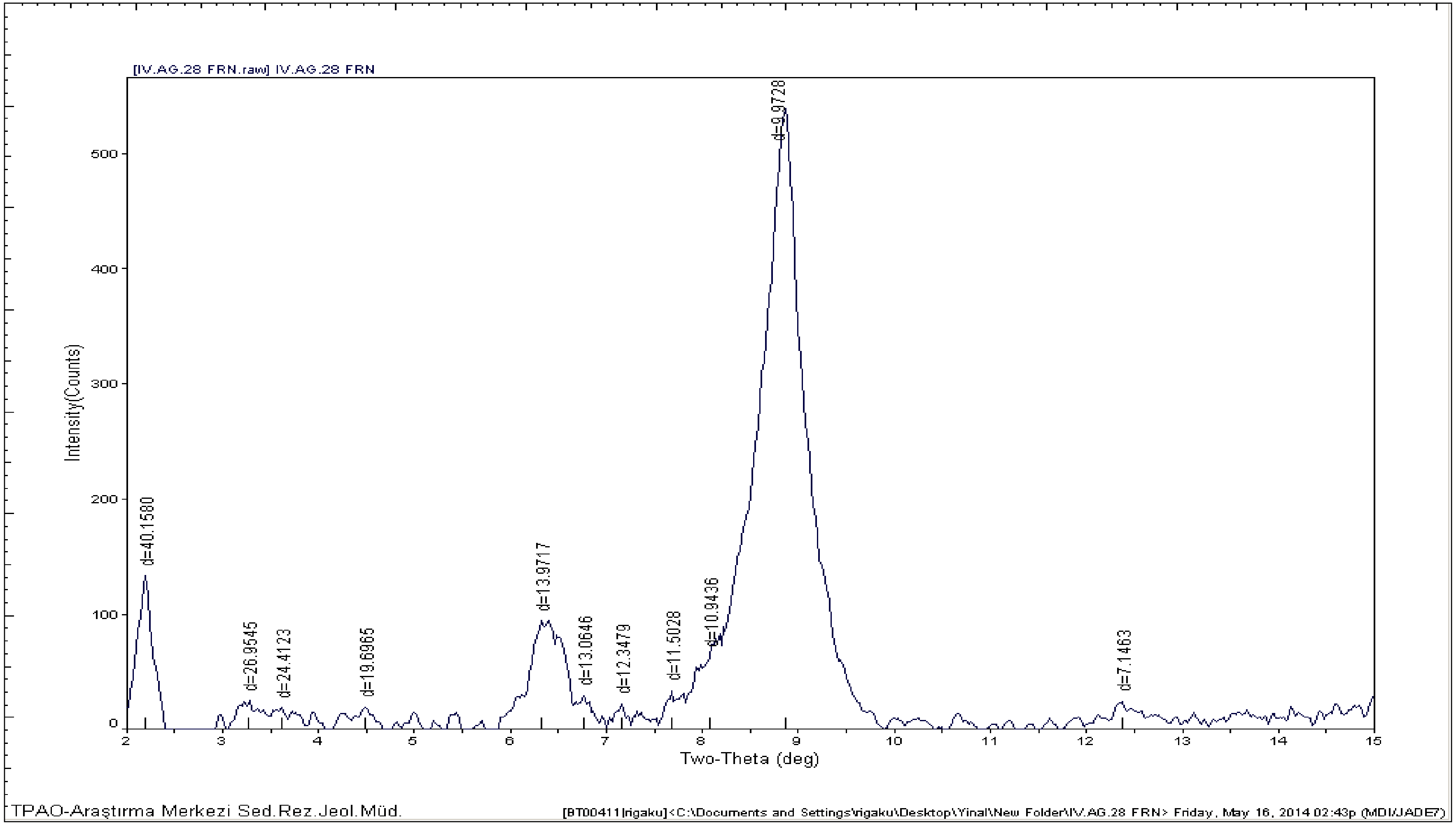


Figure 104. Clay mineral (heated) XRD diffractogram for Sample 28 of the Erfelek 1 Section.

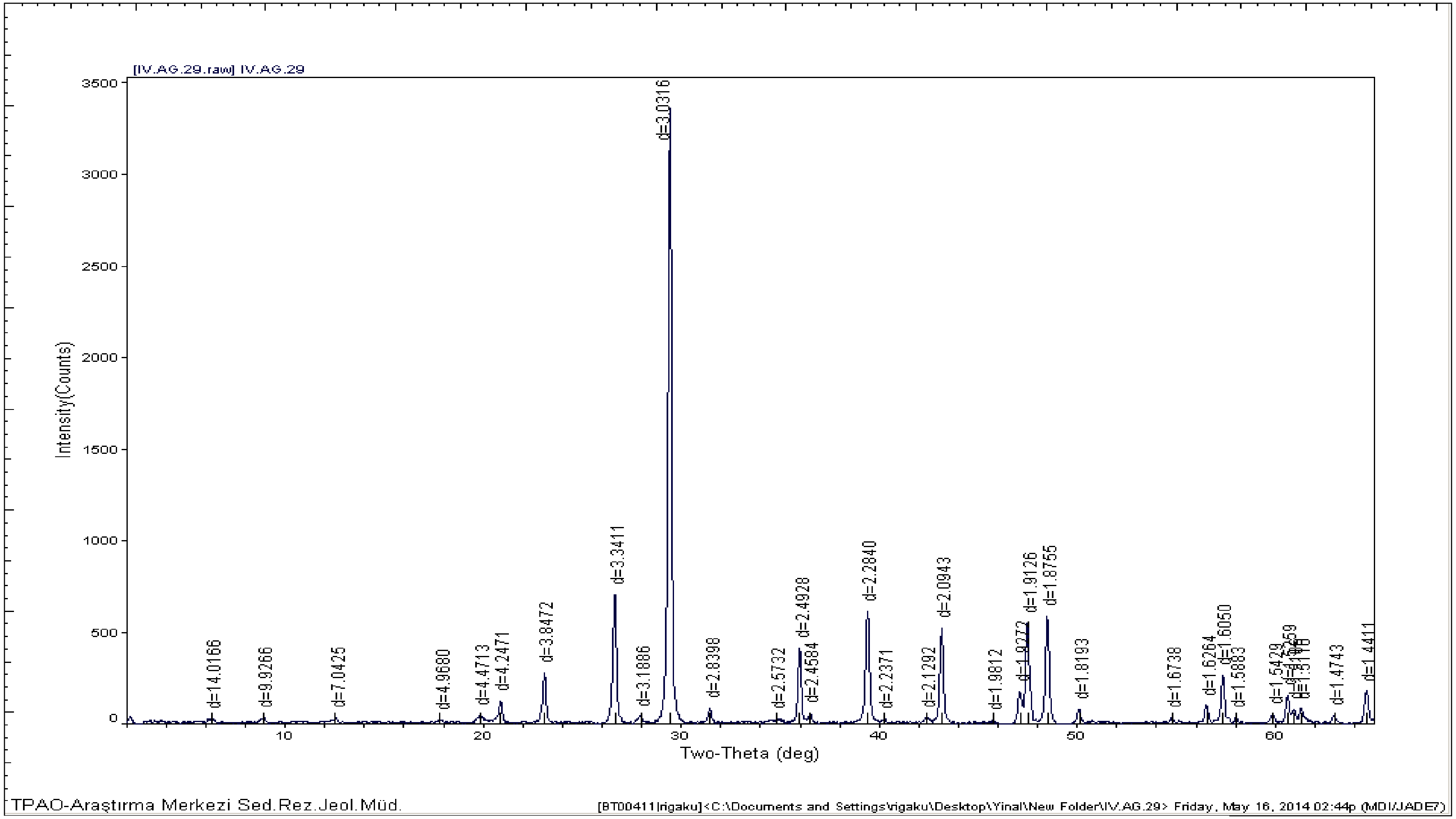


Figure 105. Bulk rock XRD diffractogram for Sample 29 of the Erfelek 1 Section.

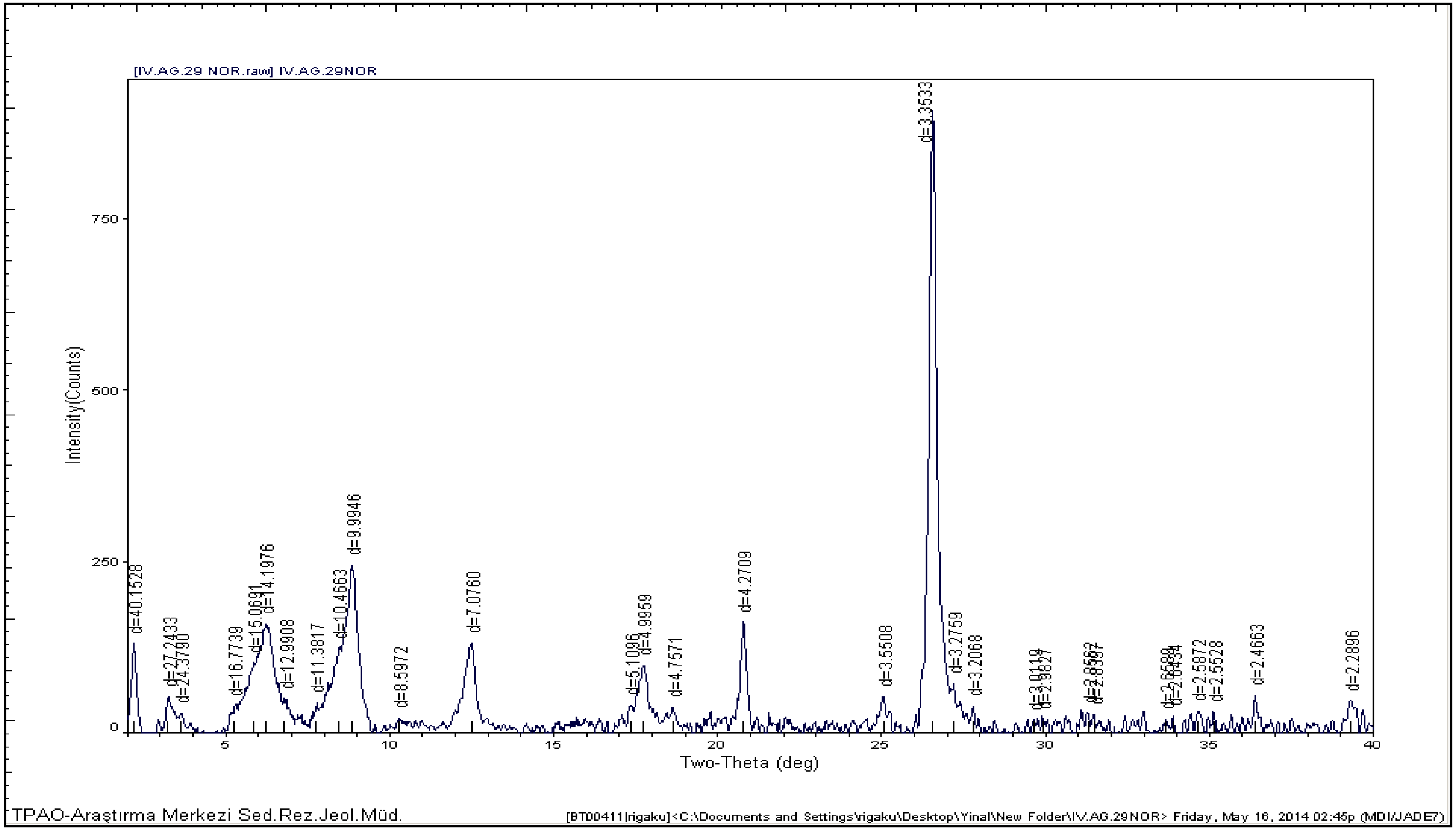


Figure 106. Clay mineral (air dried) XRD diffractogram for Sample 29 of the Erfelek 1 Section.

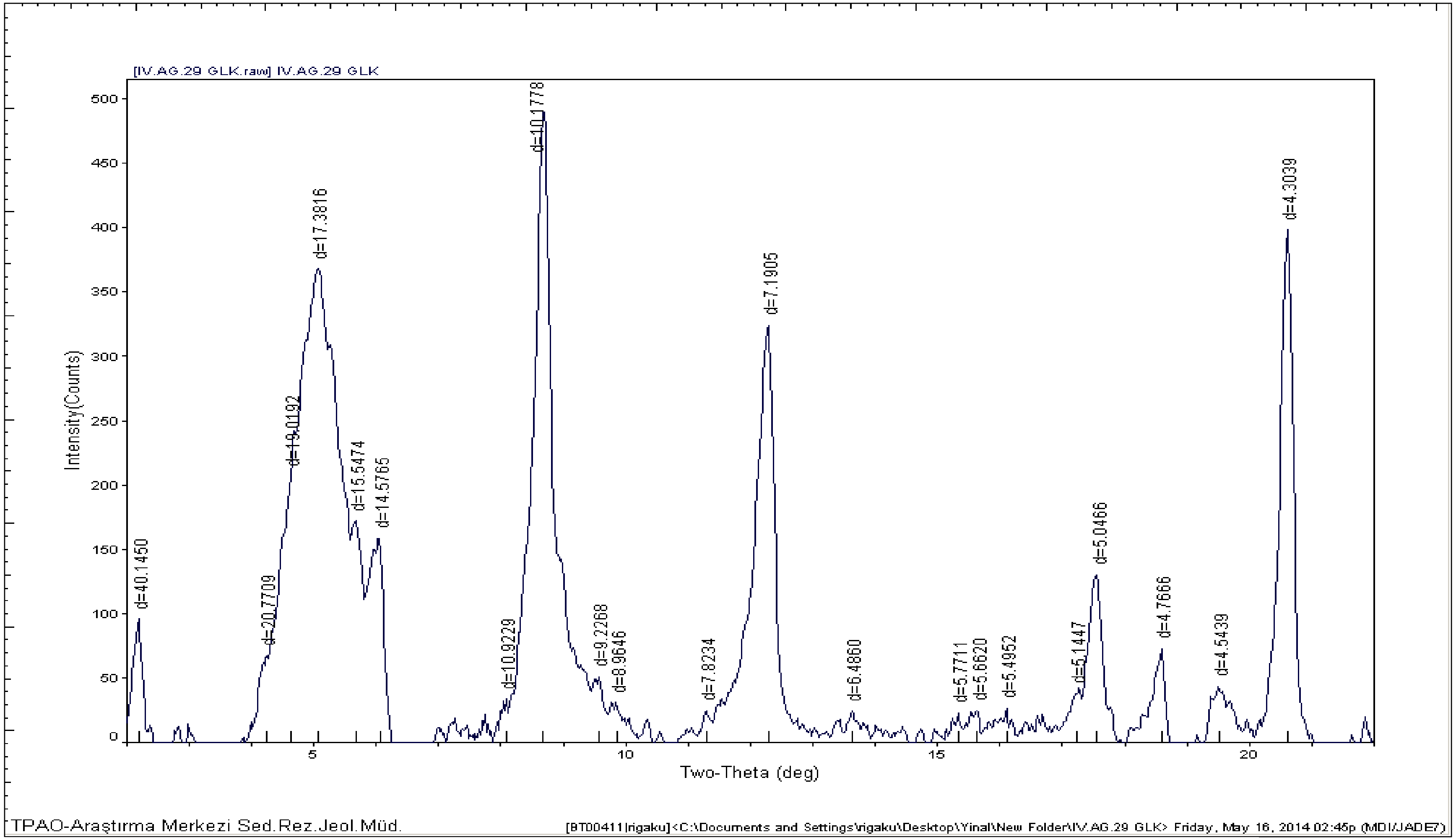


Figure 107. Clay mineral (ethylene glycol) XRD diffractogram for Sample 29 of the Erfelek 1 Section.

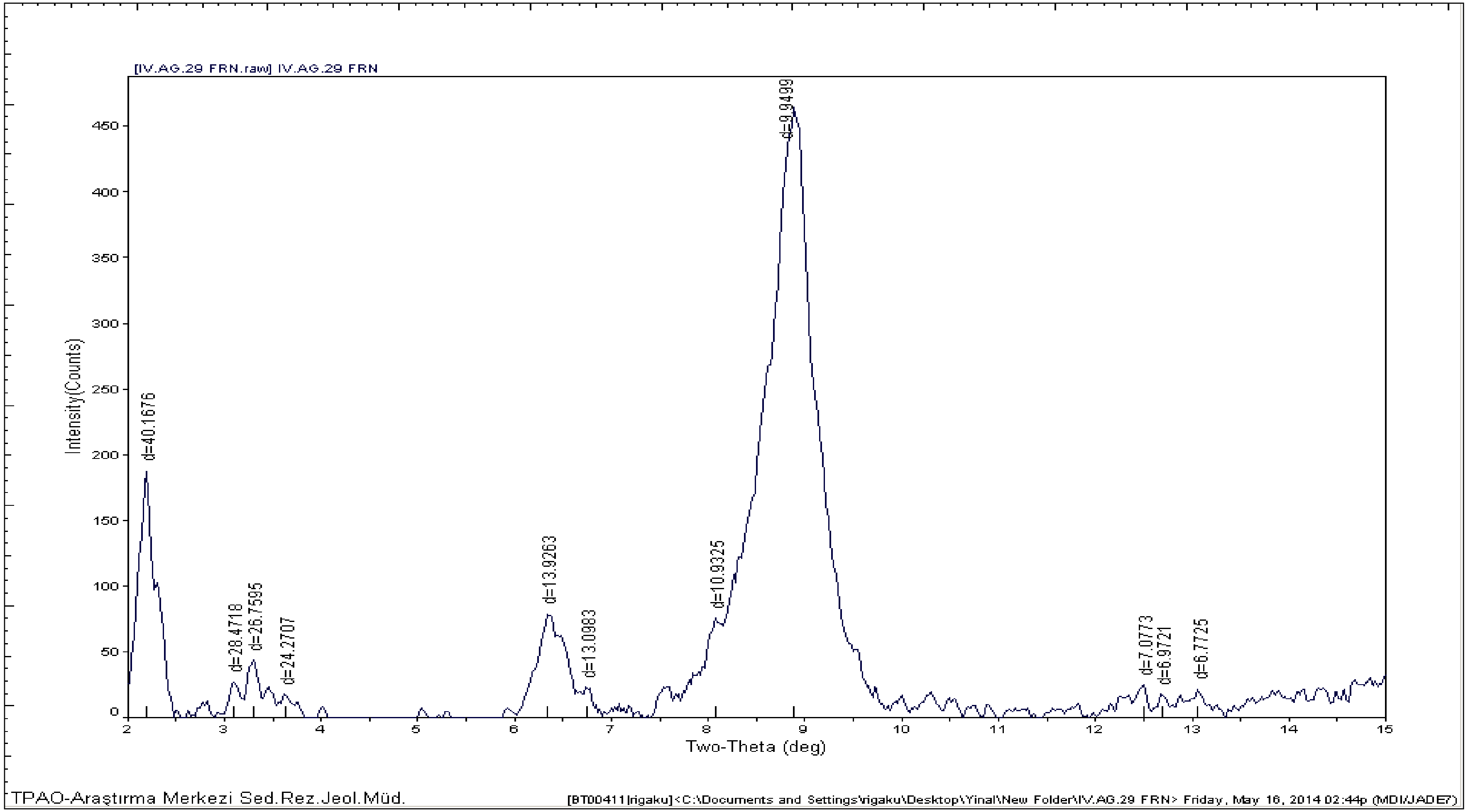


Figure 108. Clay mineral (heated) XRD diffractogram for Sample 29 of the Erfelek 1 Section.

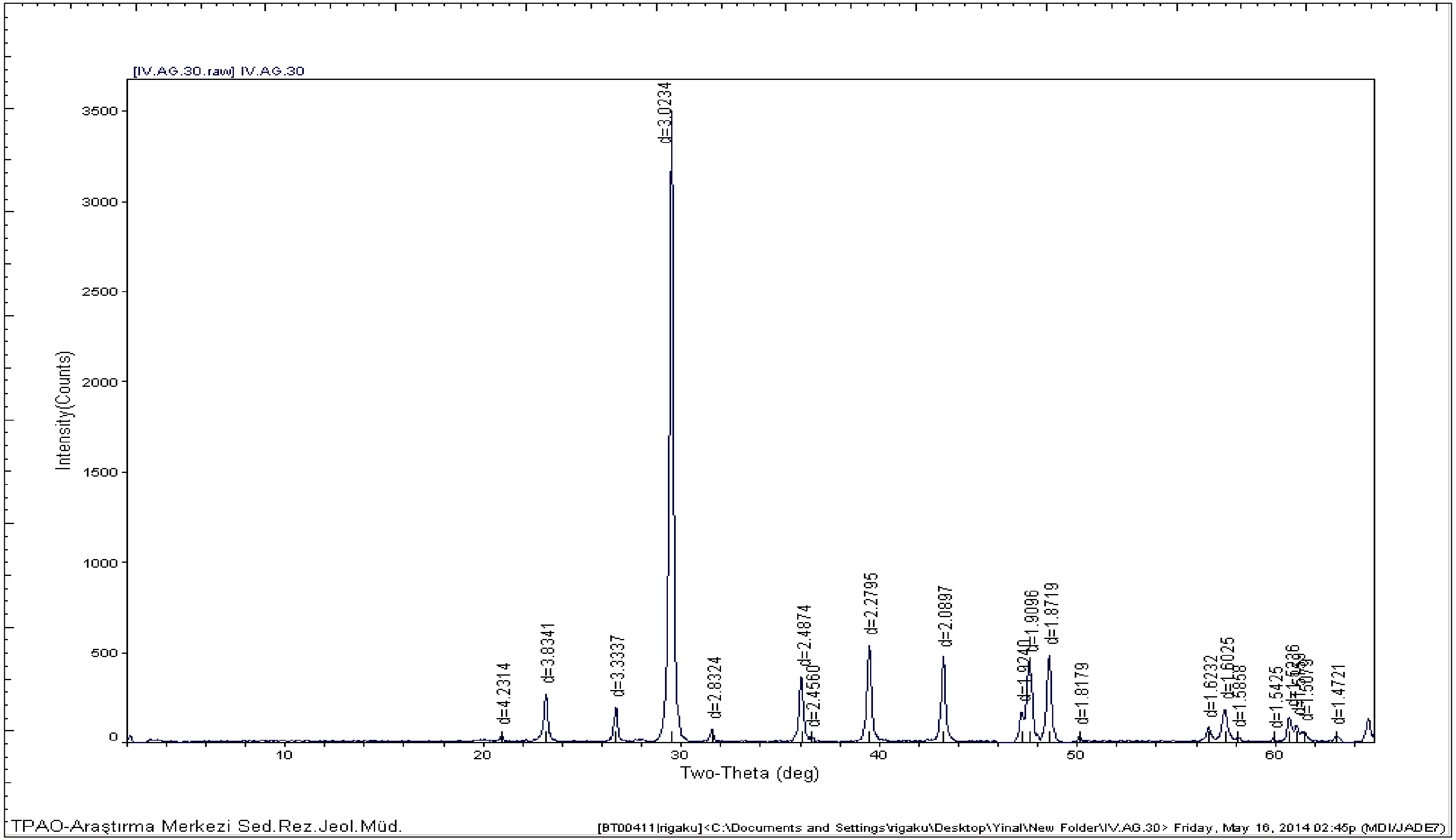


Figure 109. Bulk rock XRD diffractogram for Sample 30 of the Erfelek 1 Section.

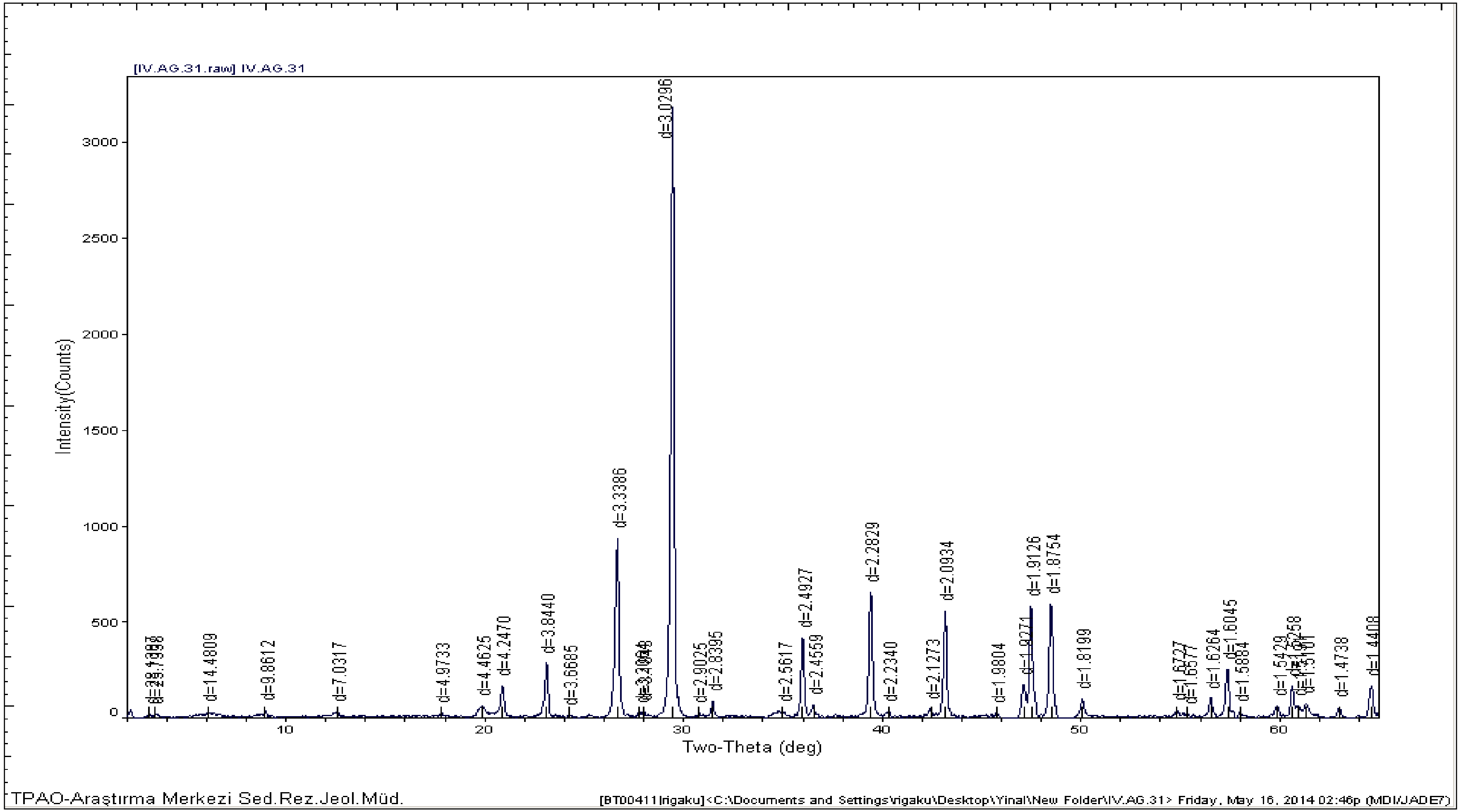


Figure 110. Bulk rock XRD diffractogram for Sample 31 of the Erfelek 1 Section.

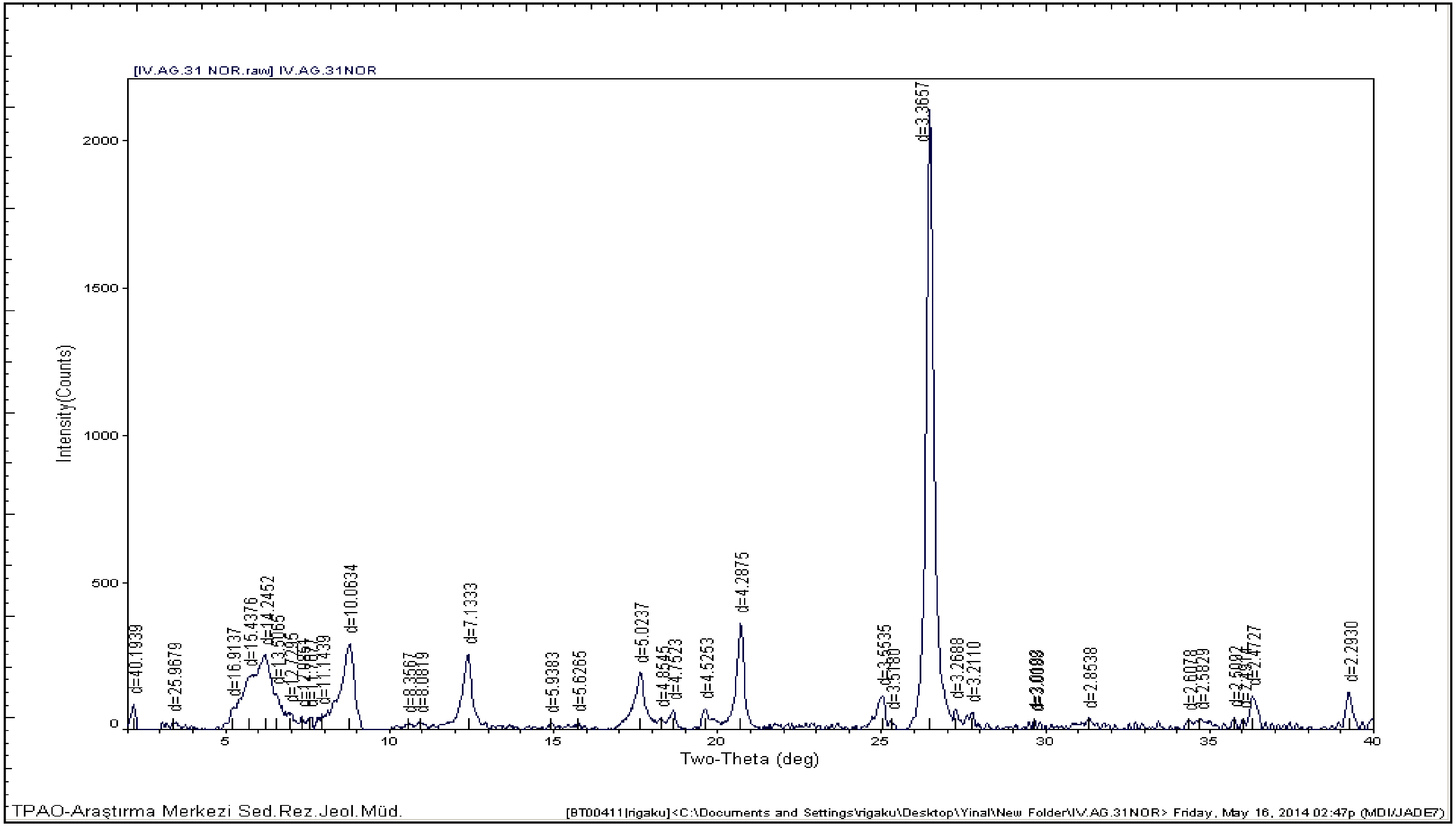


Figure 111. Clay mineral (air dried) XRD diffractogram for Sample 31 of the Erfelek 1 Section.

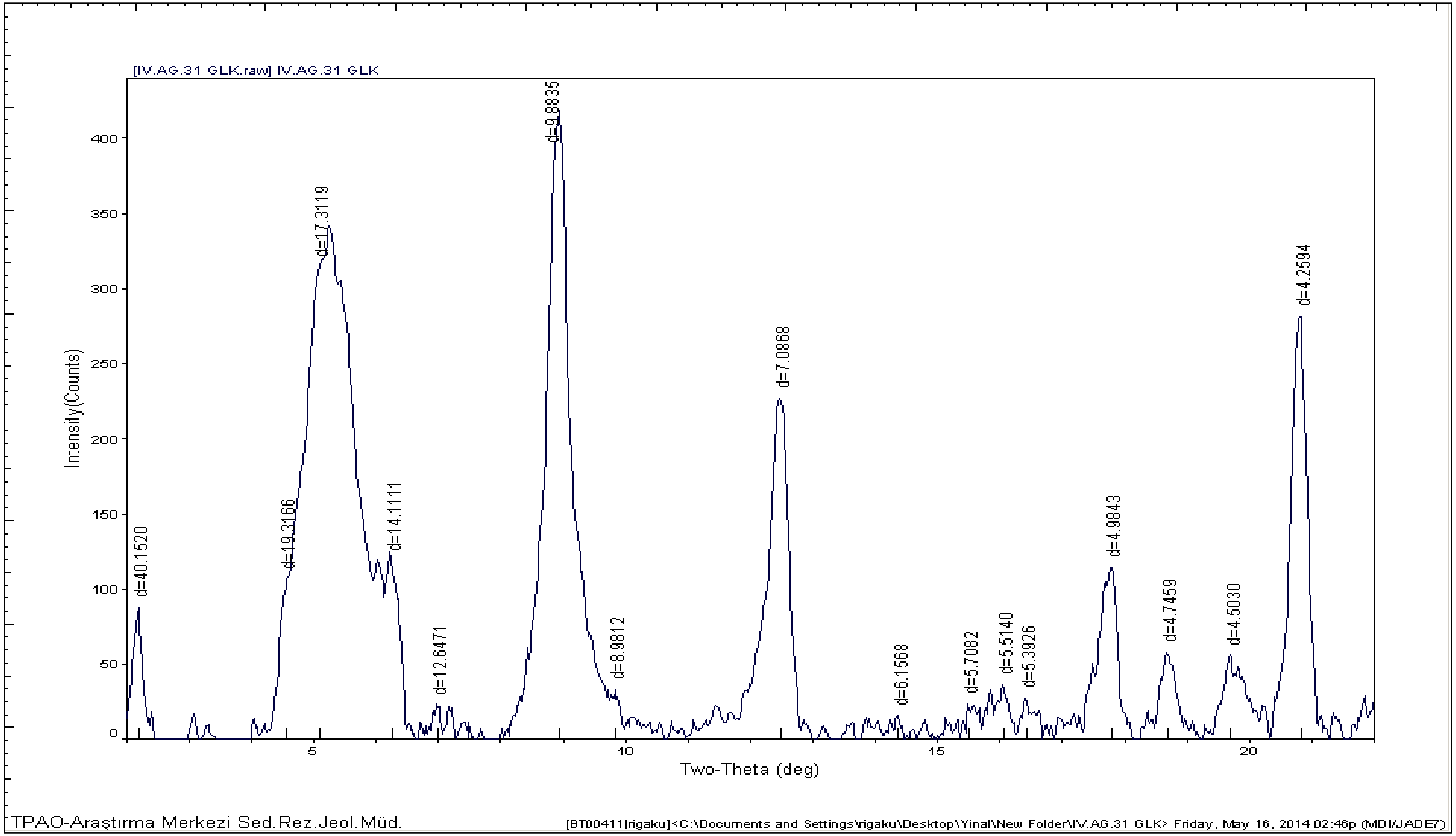


Figure 112. Clay mineral (ethylene glycol) XRD diffractogram for Sample 31 of the Erfelek 1 Section.

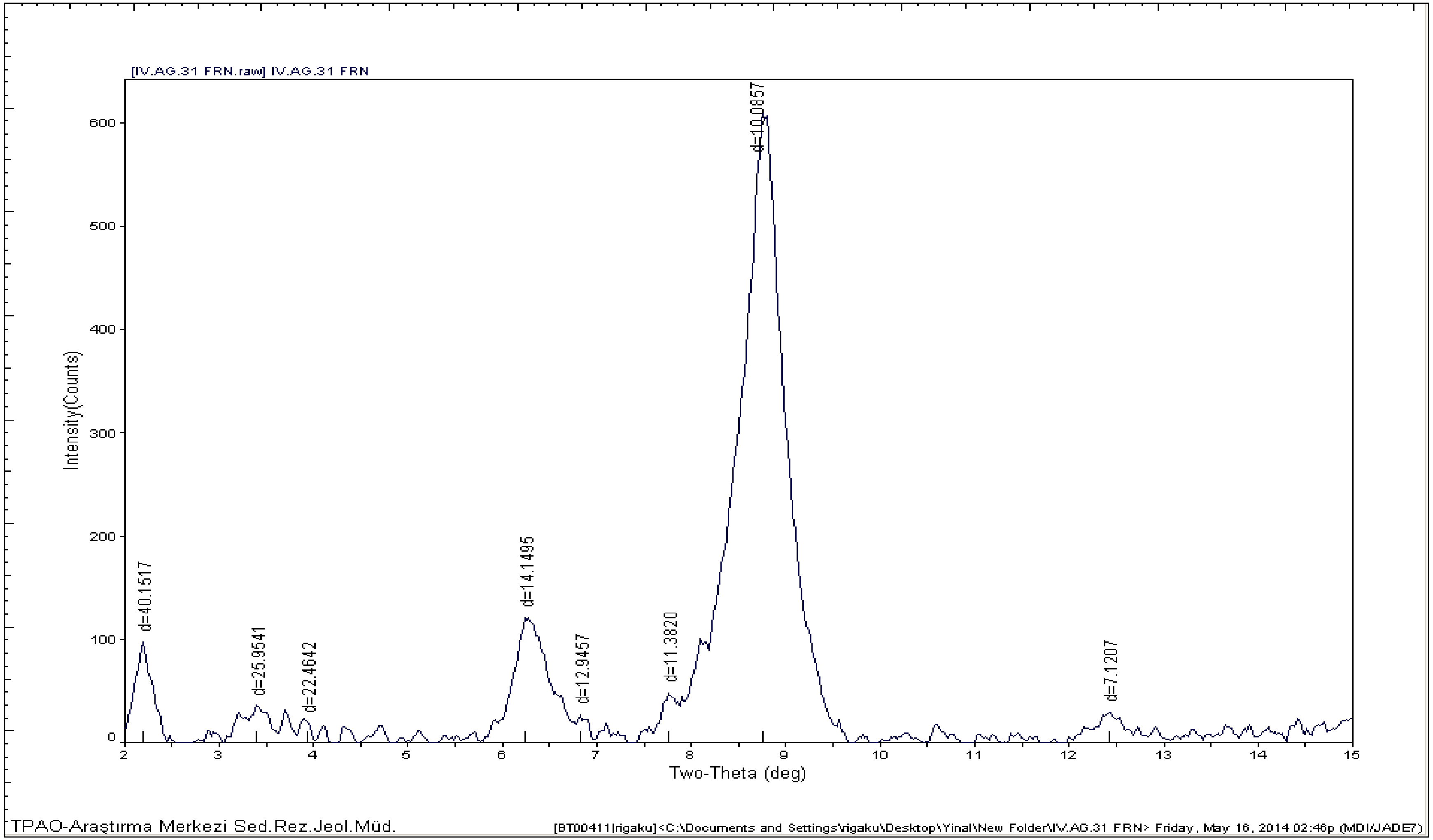


Figure 113. Clay mineral (heated) XRD diffractogram for Sample 31 of the Erfelek 1 Section.

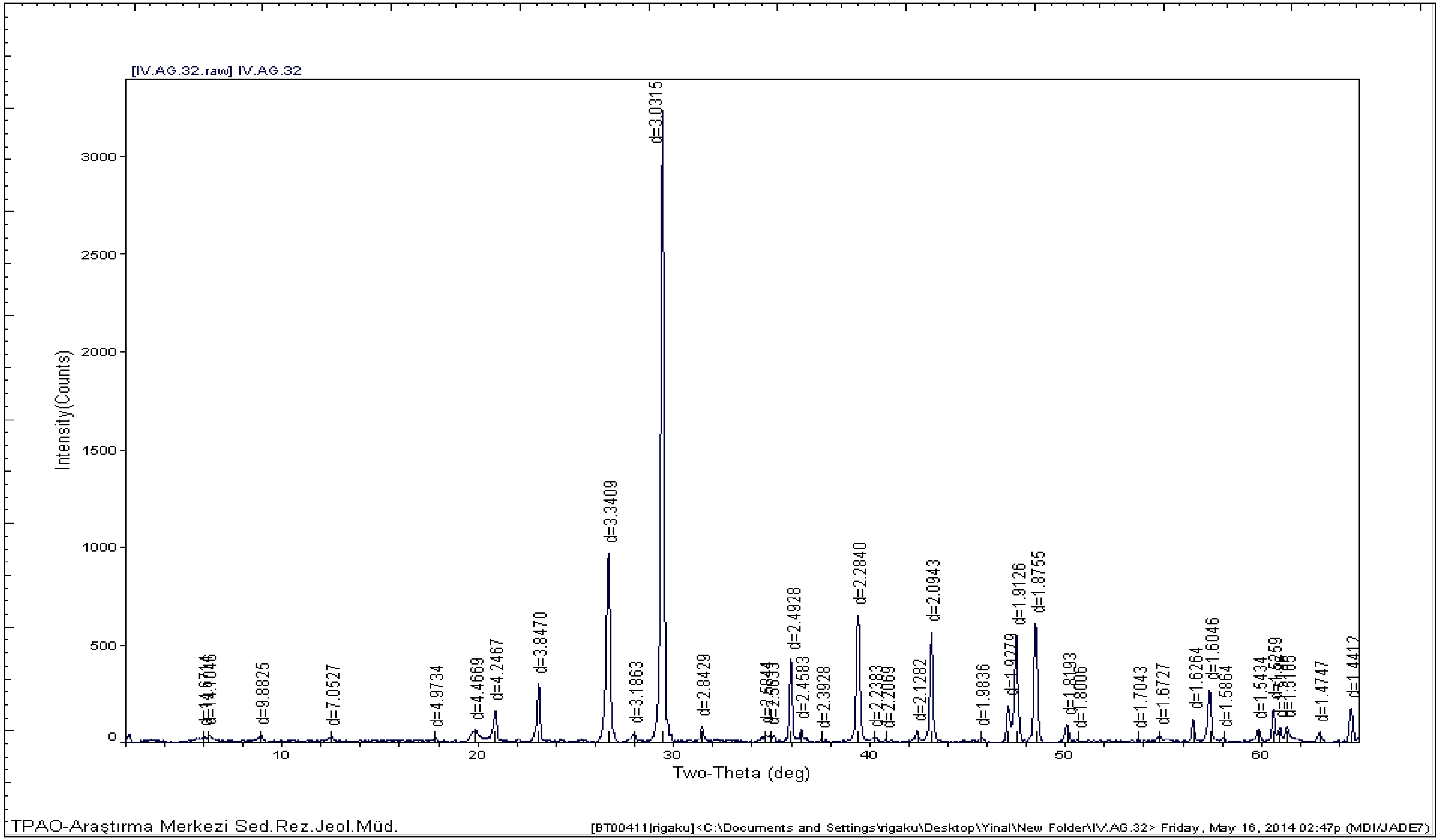


Figure 114. Bulk rock XRD diffractogram for Sample 32 of the Erfelek 1 Section.

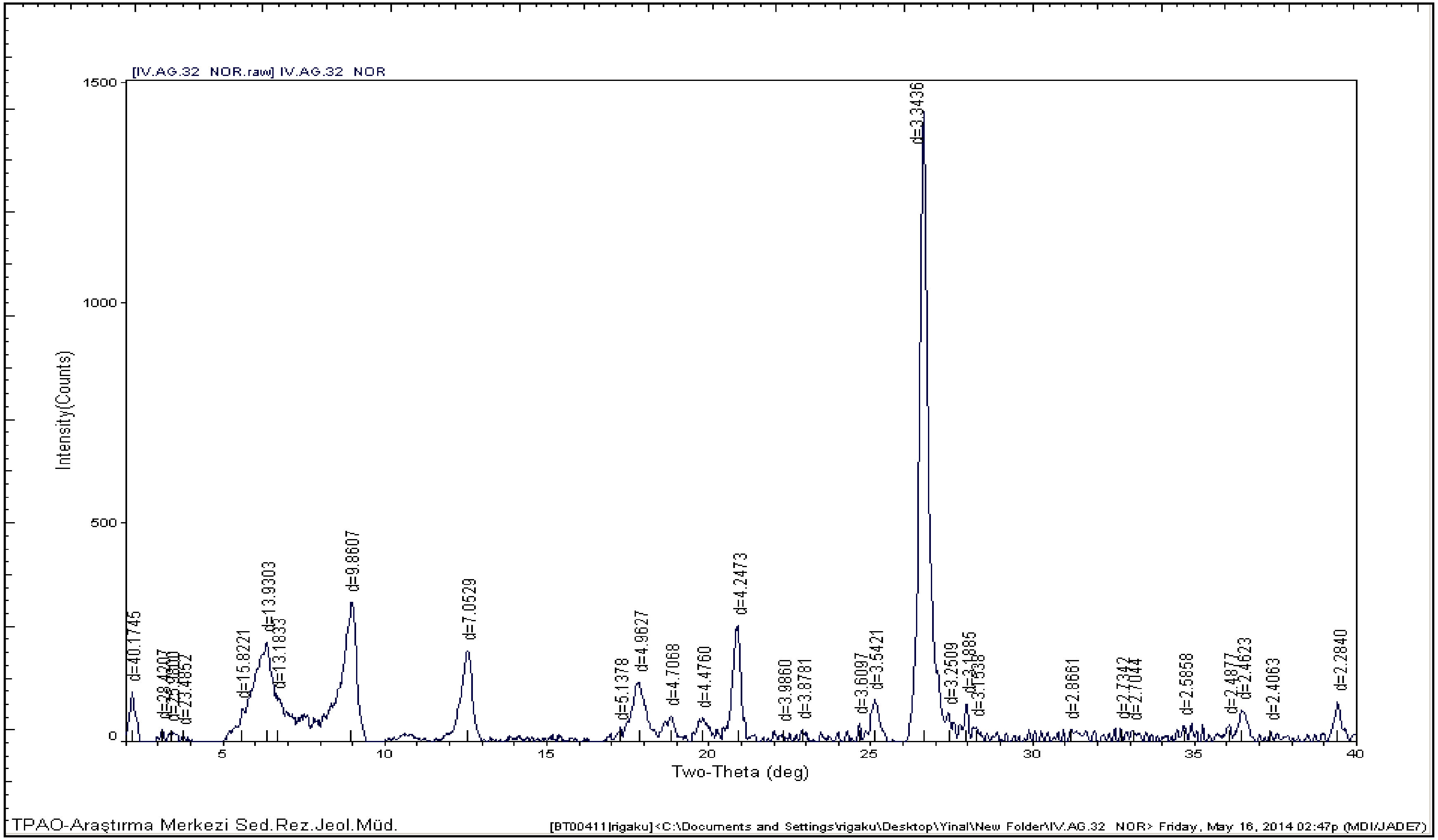


Figure 115. Clay mineral (air dried) XRD diffractogram for Sample 32 of the Erfelek 1 Section.

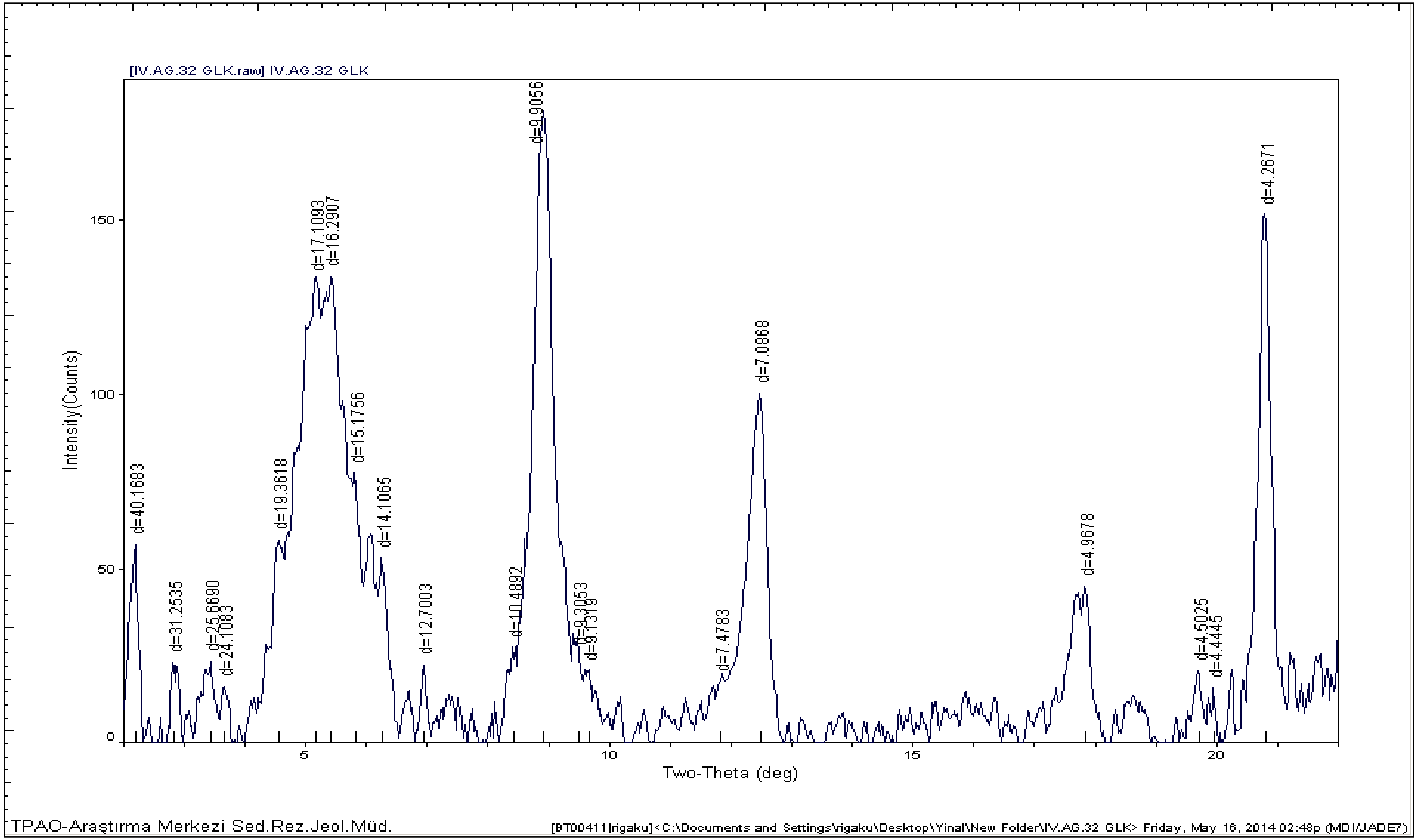


Figure 116. Clay mineral (ethylene glycol) XRD diffractogram for Sample 32 of the Erfelek 1 Section.

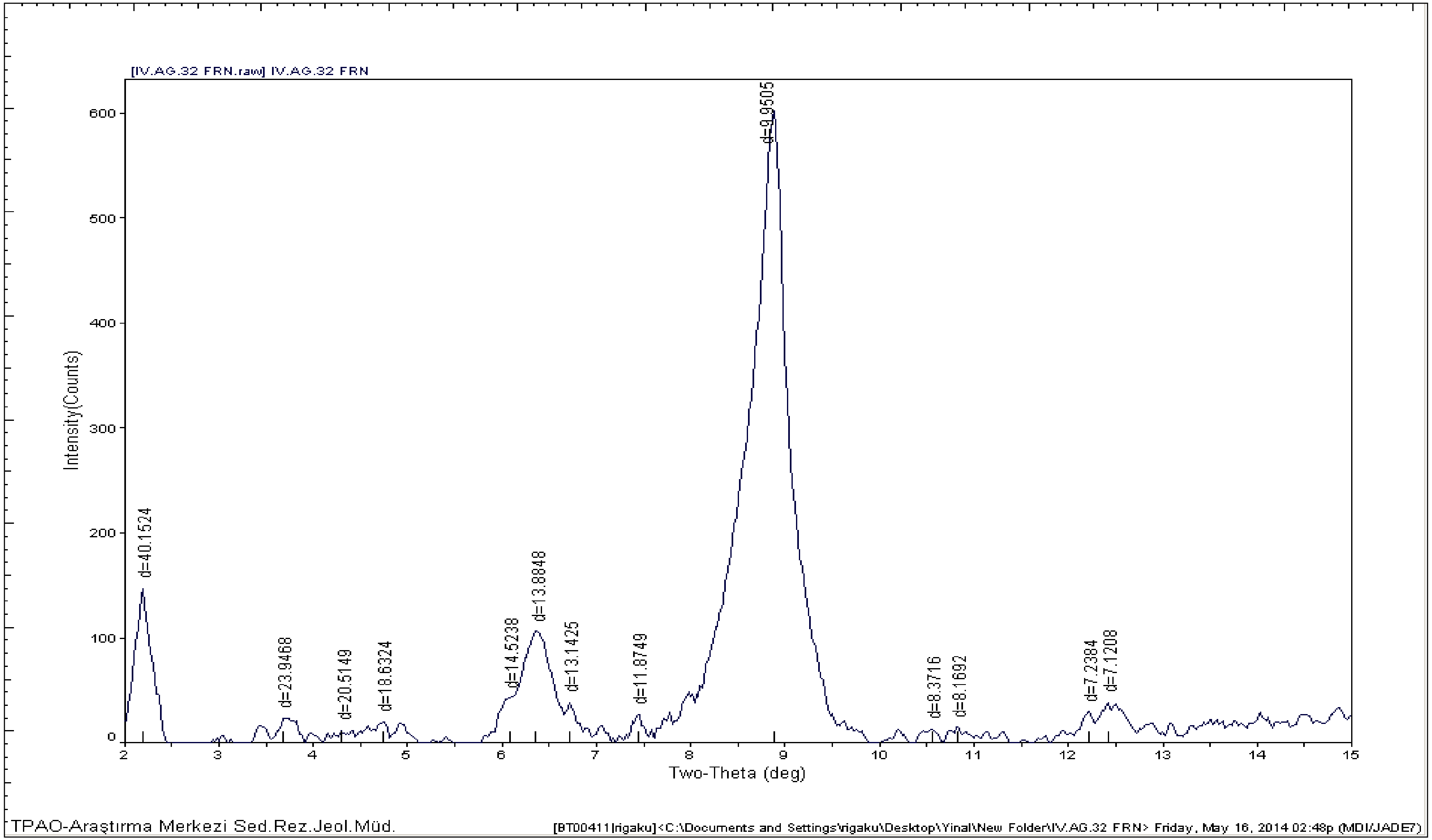


Figure 117. Clay mineral (heated) XRD diffractogram for Sample 32 of the Erfelek 1 Section.

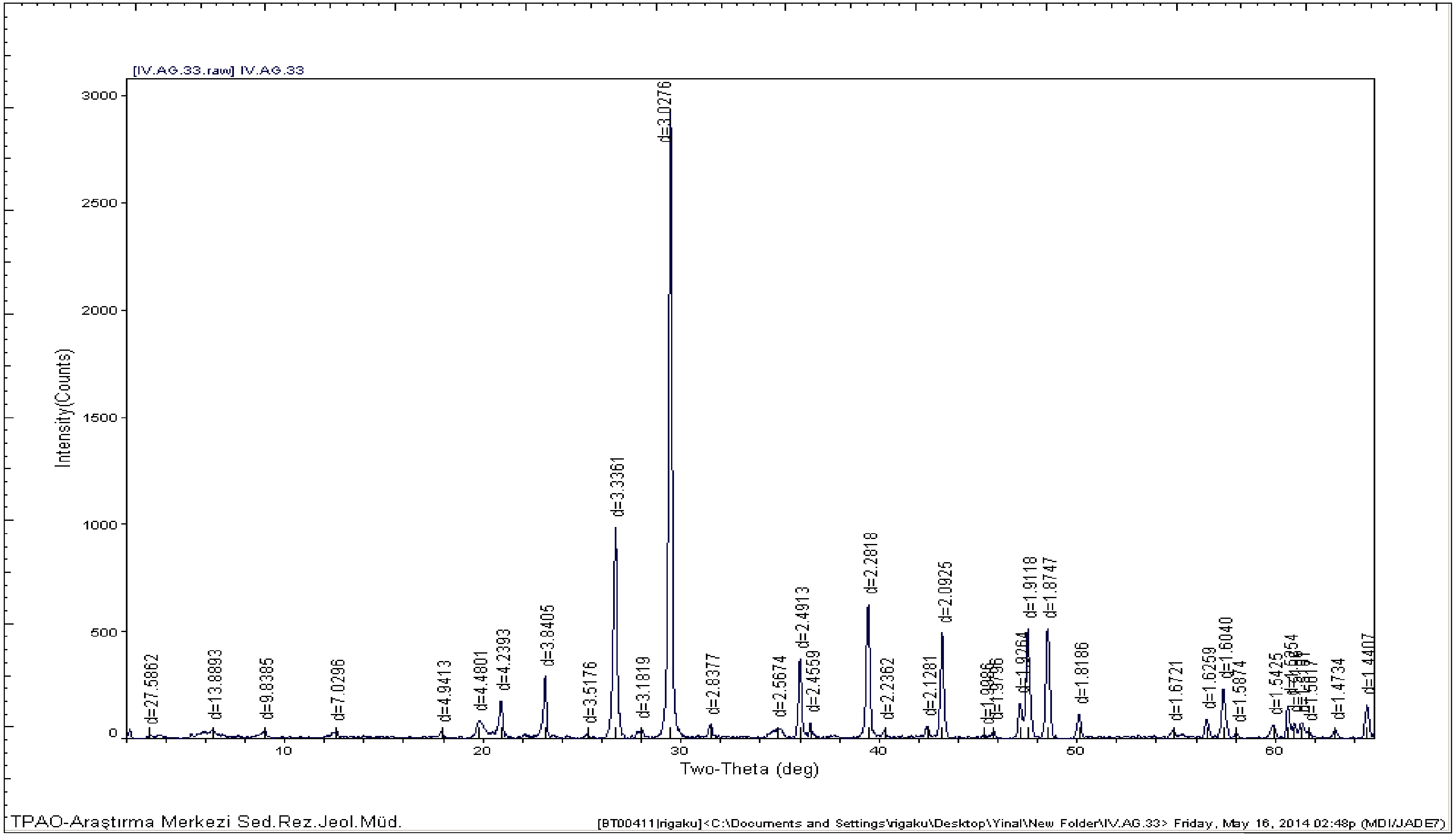


Figure 118. Bulk rock XRD diffractogram for Sample 33 of the Erfelek 1 Section.

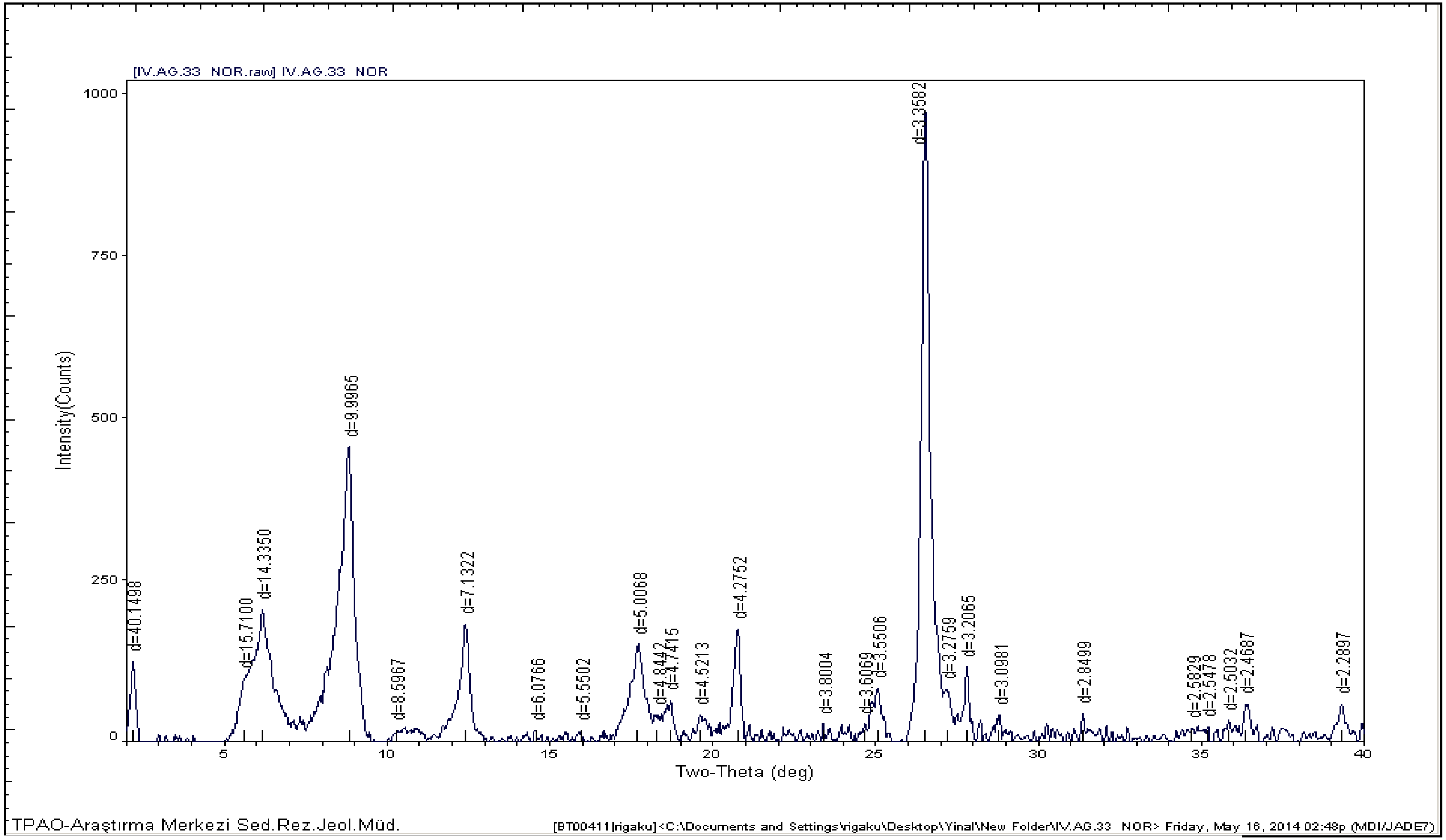


Figure 119. Clay mineral (air dried) XRD diffractogram for Sample 33 of the Erfelek 1 Section.

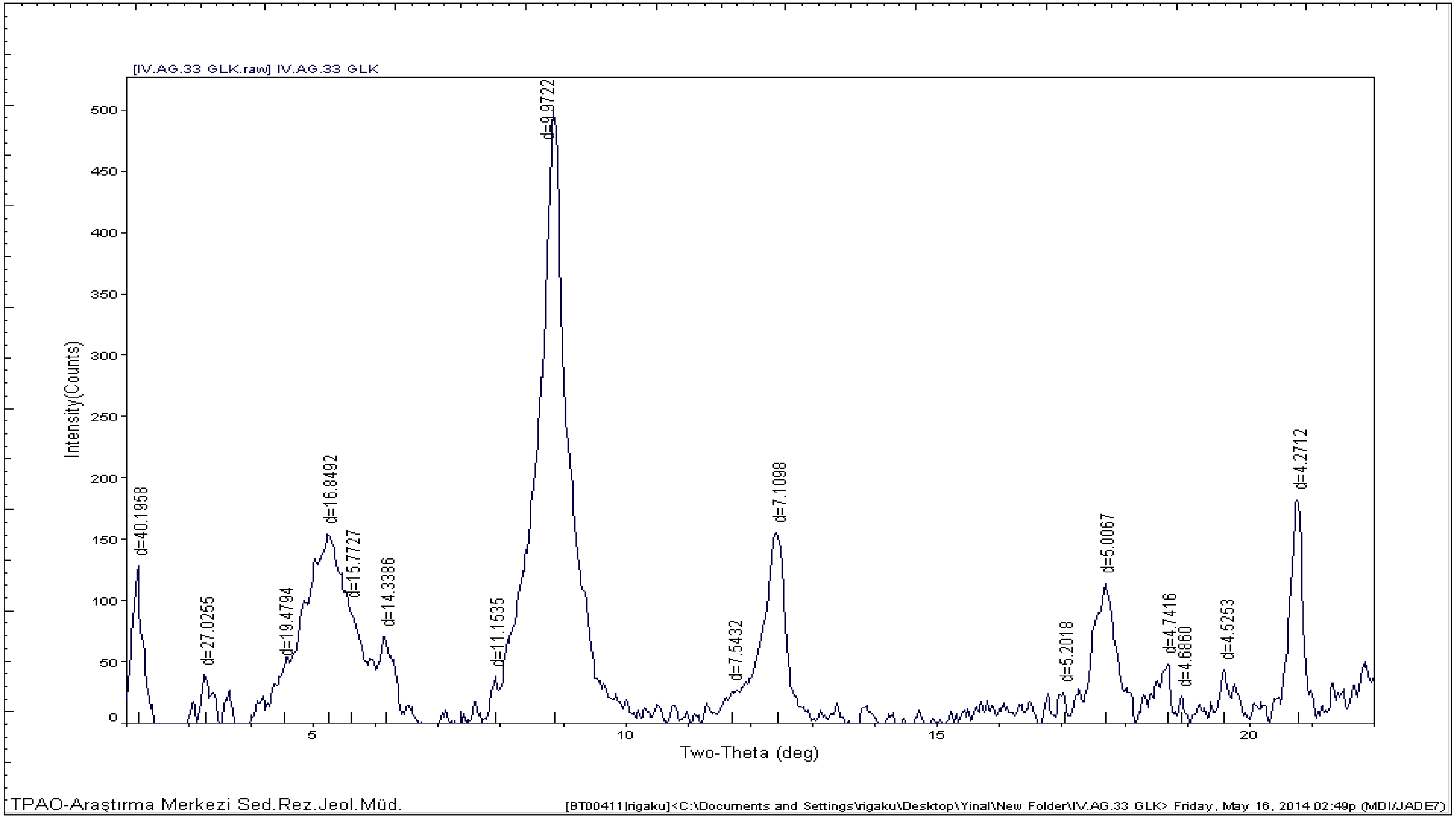


Figure 120. Clay mineral (heated) XRD diffractogram for Sample 33 of the Erfelek 1 Section.

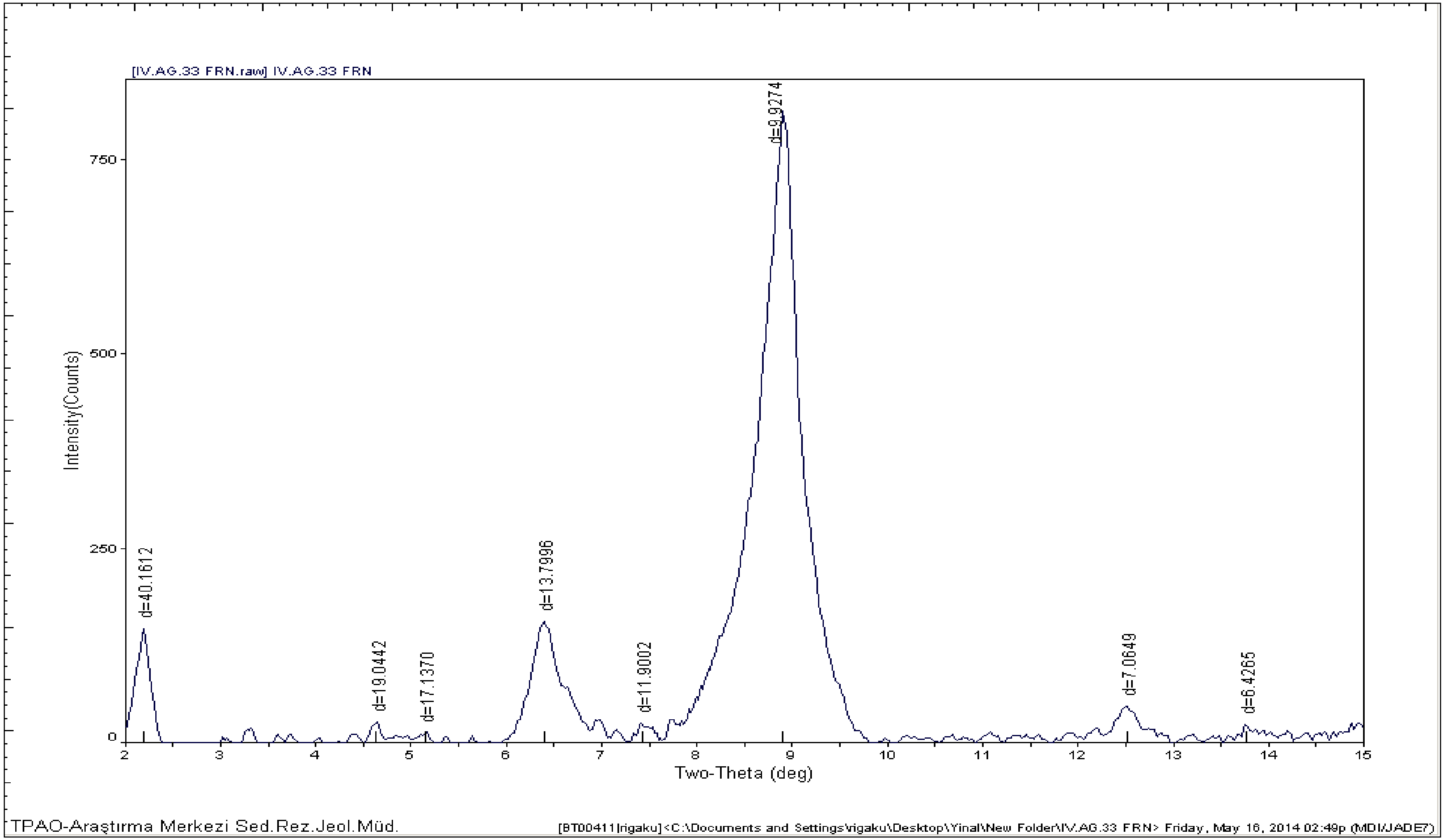


Figure 121. Clay mineral (ethylene glycol) XRD diffractogram for Sample 33 of the Erfelek 1 Section.

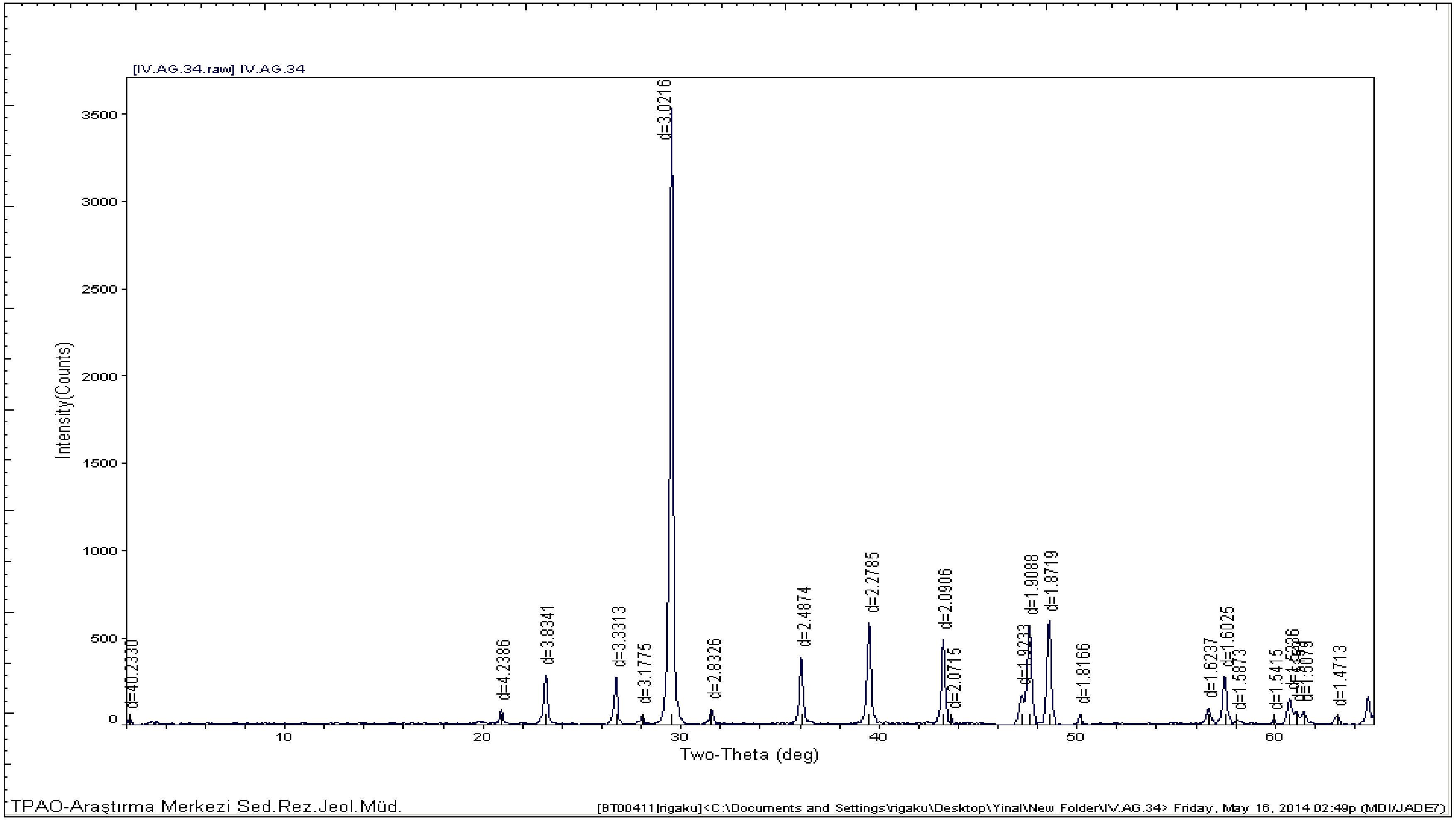


Figure 122. Bulk rock XRD diffractogram for Sample 34 of the Erfelek 1 Section.

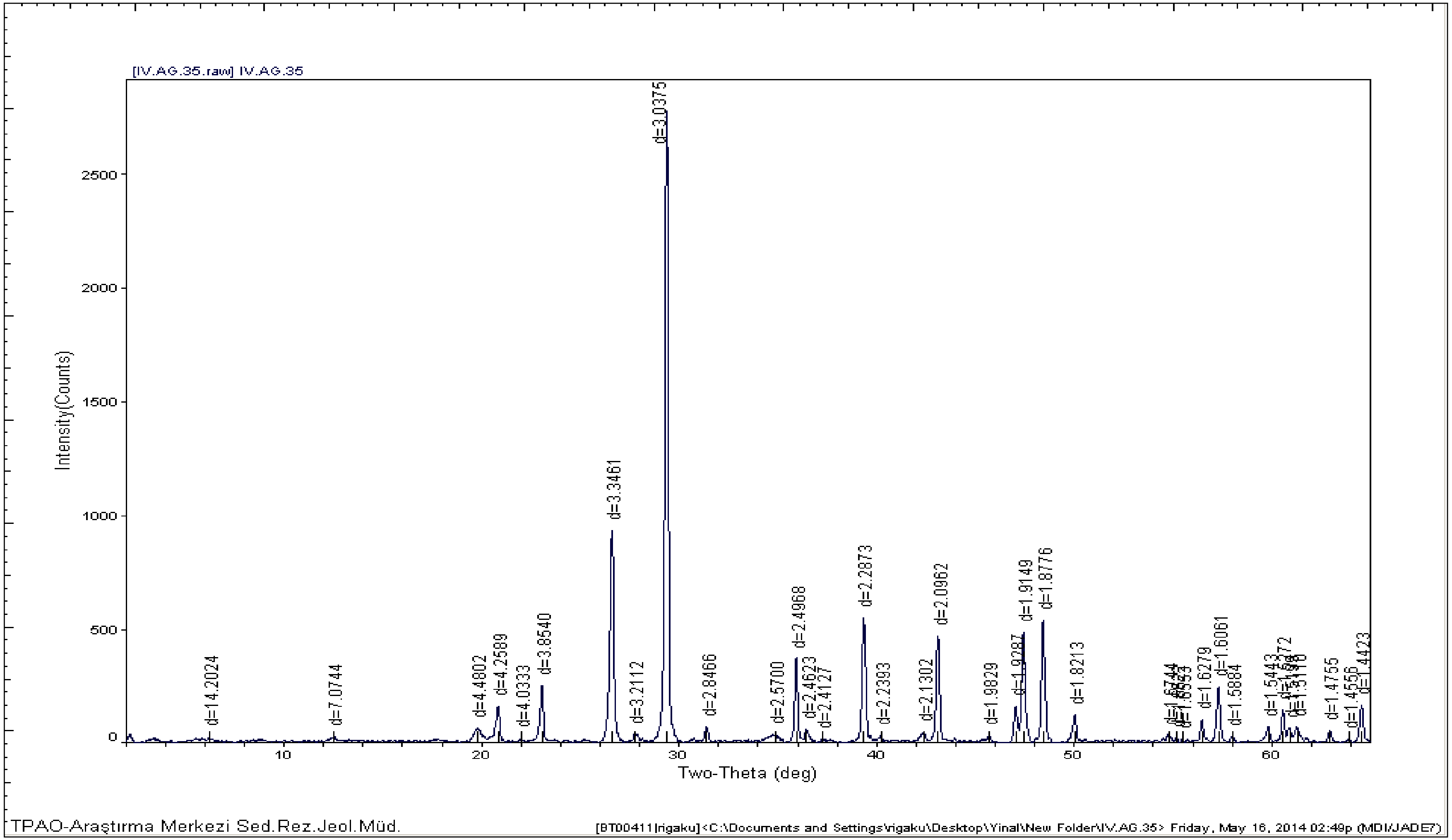


Figure 123. Bulk rock XRD diffractogram for Sample 35 of the Erfelek 1 Section.

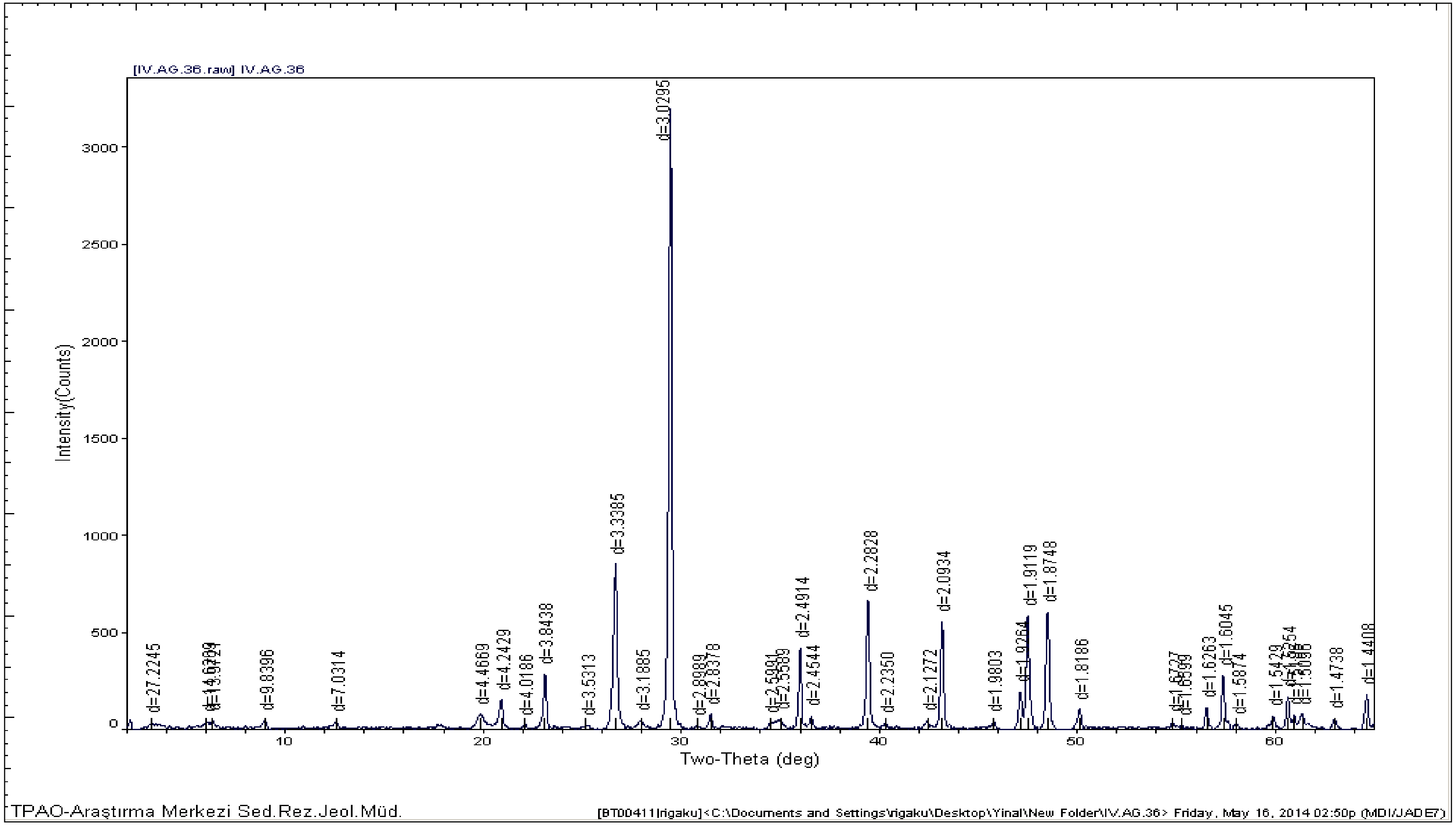


Figure 124. Bulk rock XRD diffractogram for Sample 36 of the Erfelek 1 Section.

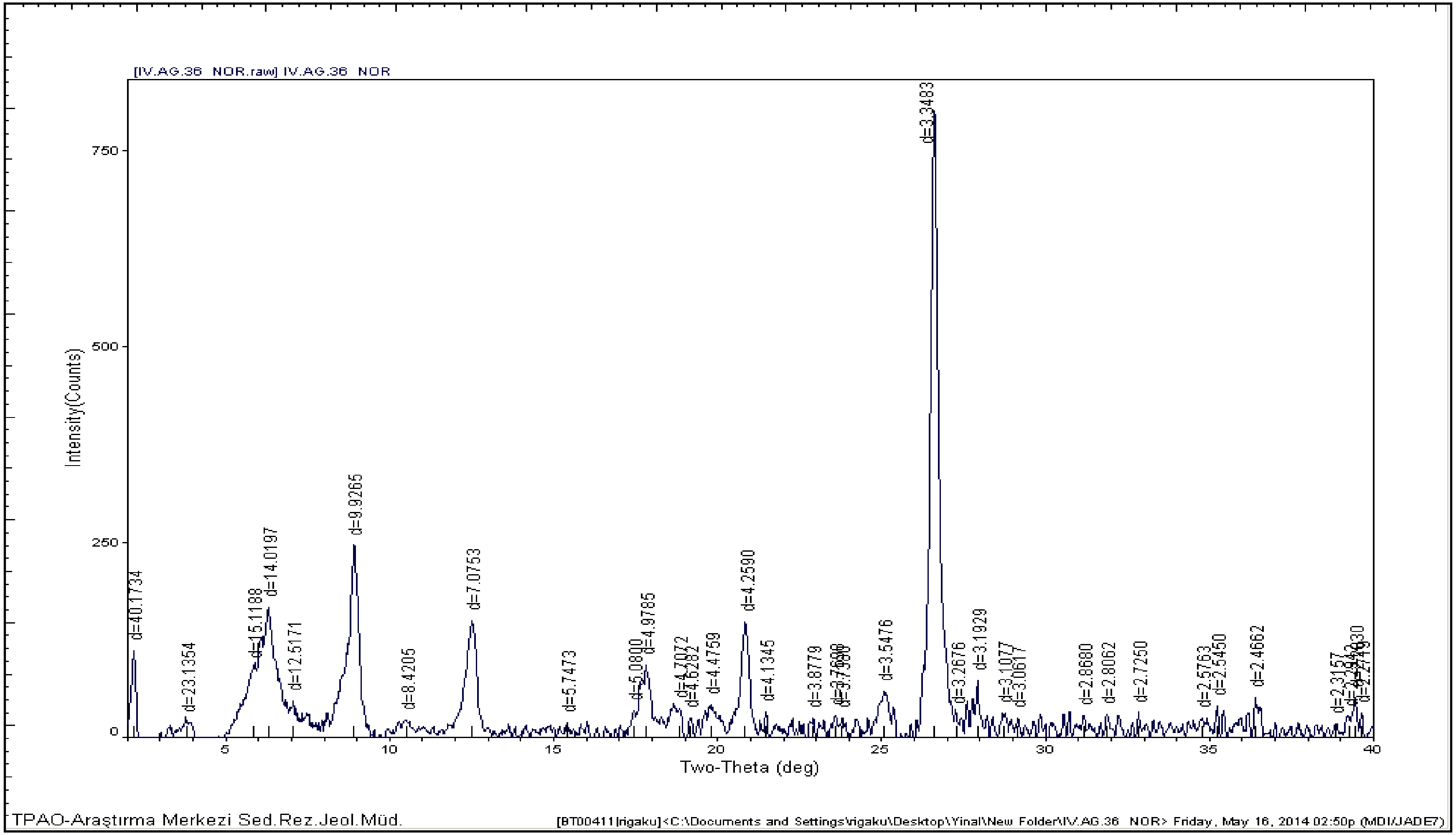


Figure 125. Clay mineral (air dried) XRD diffractogram for Sample 36 of the Erfelek 1 Section.

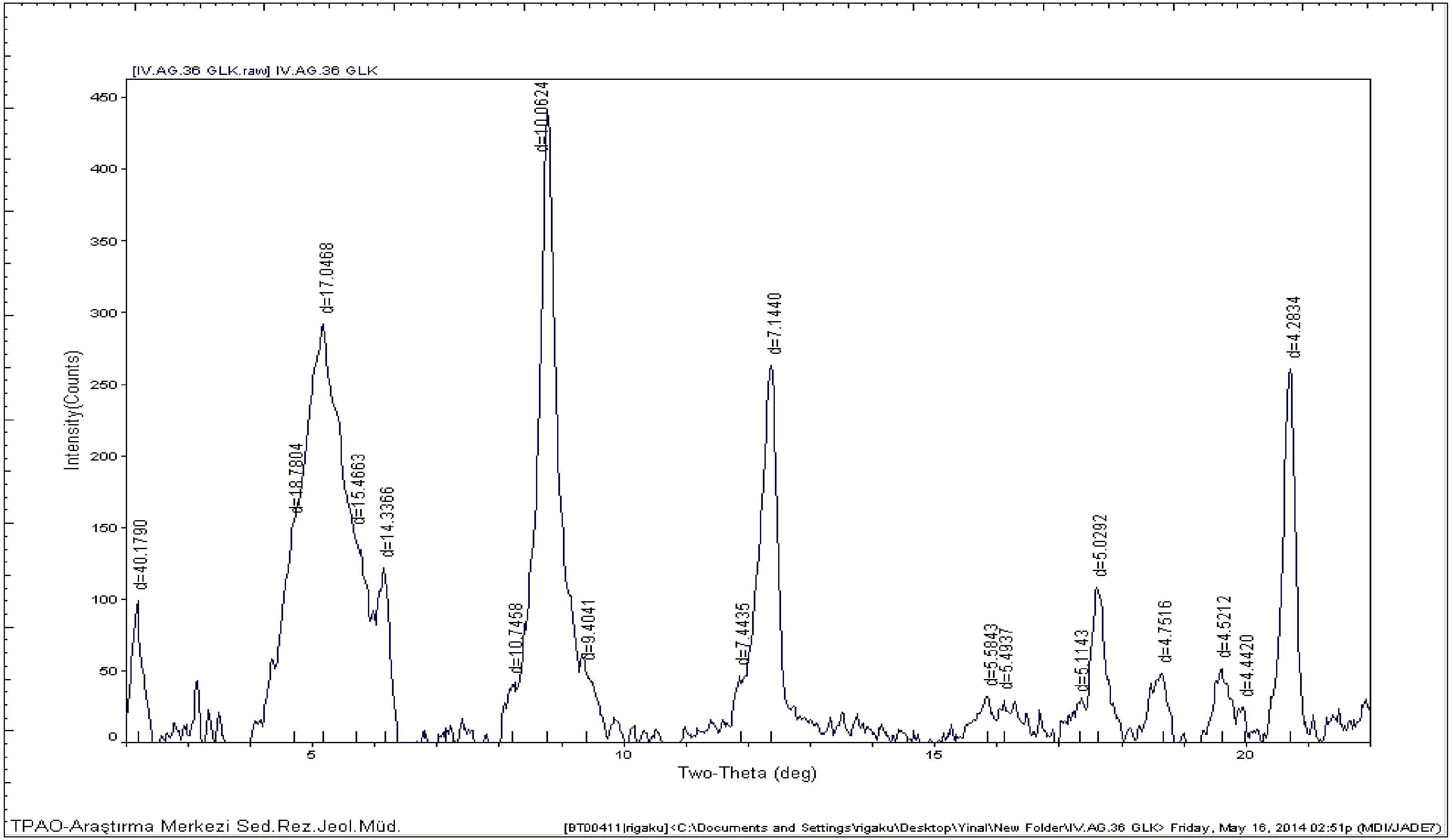


Figure 126. Clay mineral (ethylene glycol) XRD diffractogram for Sample 36 of the Erfelek 1 Section.

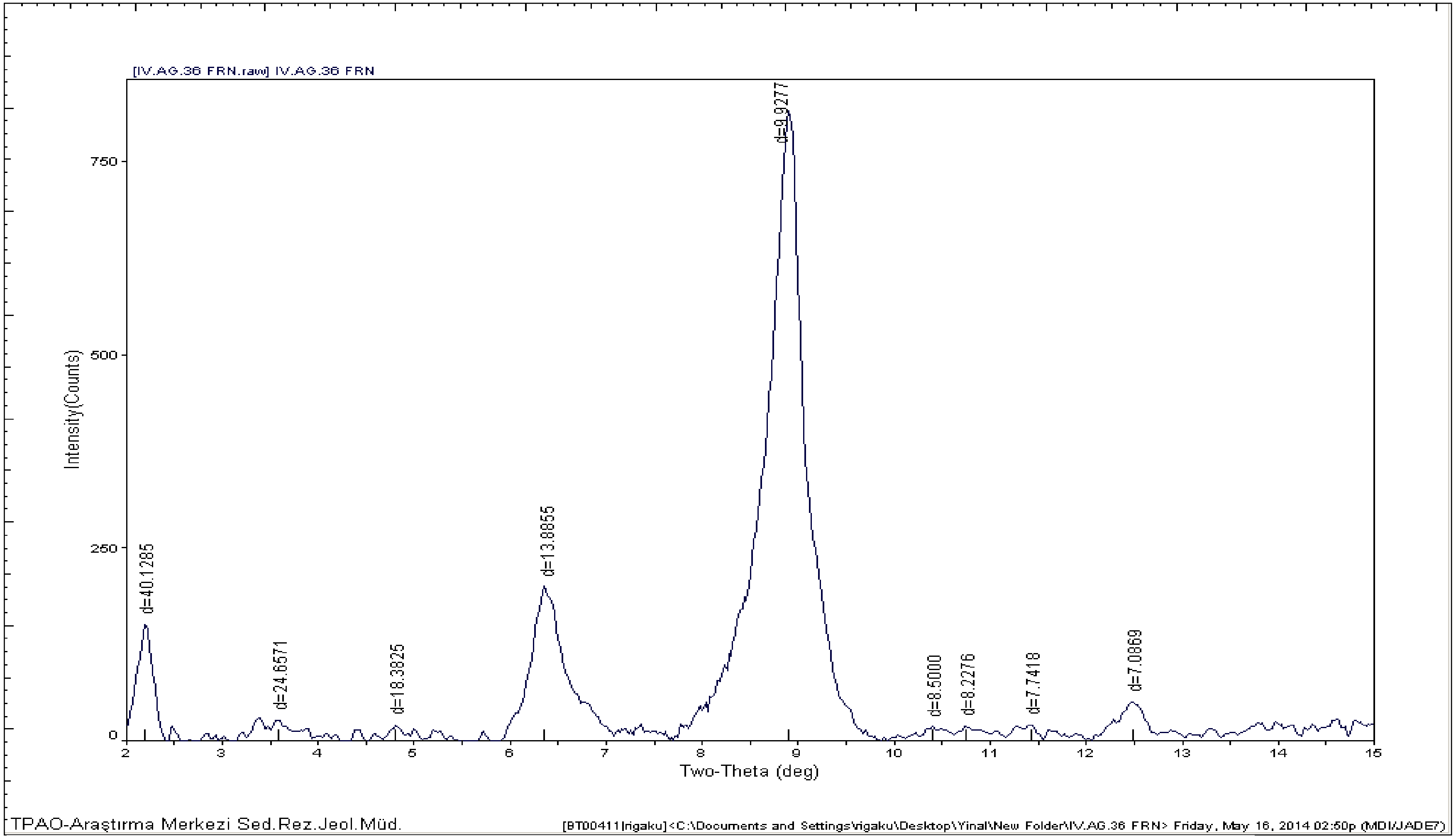


Figure 127. Clay mineral (heated) XRD diffractogram for Sample 36 of the Erfelek 1 Section.

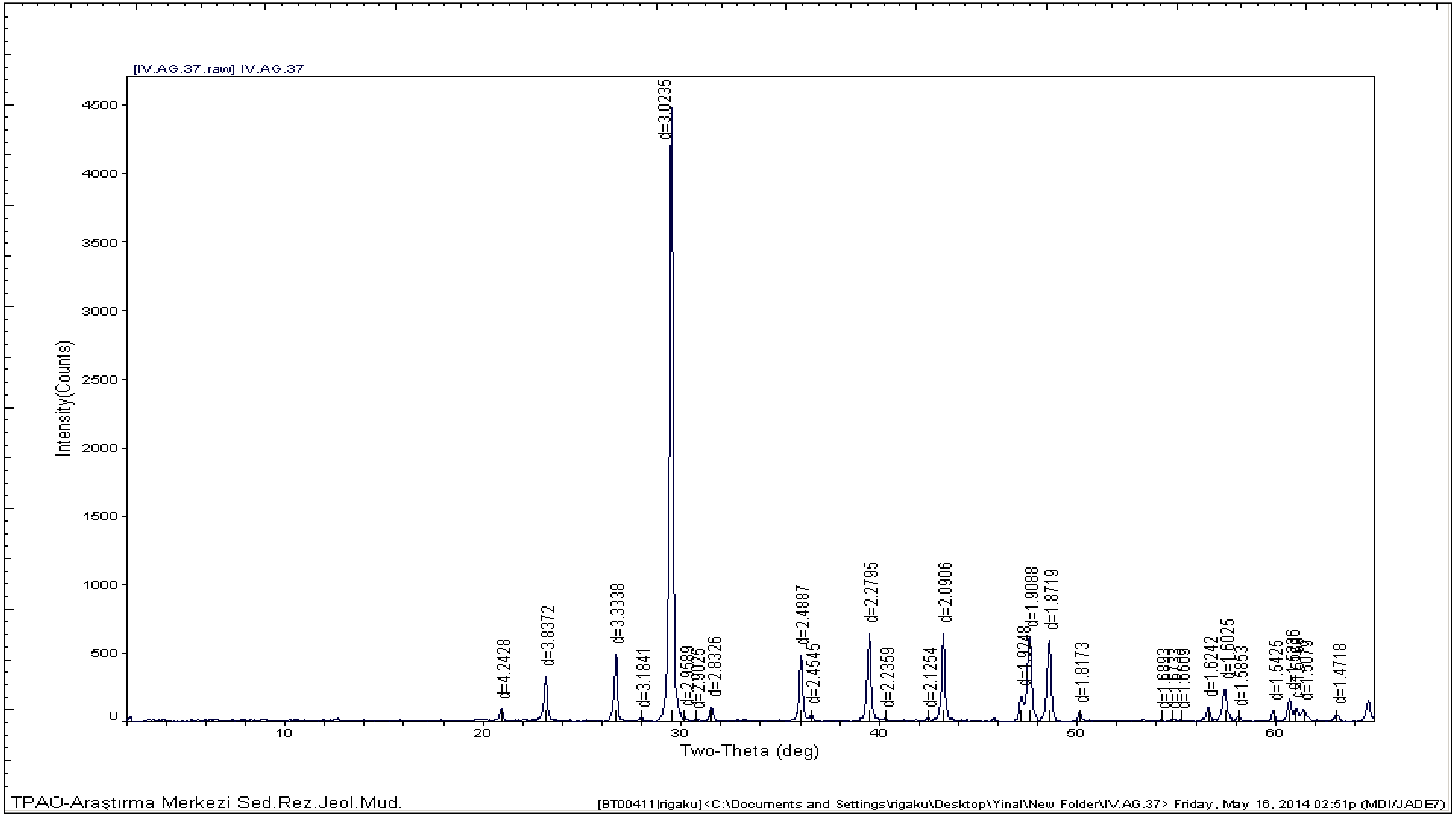


Figure 128. Bulk rock XRD diffractogram for Sample 37 of the Erfelek 1 Section.

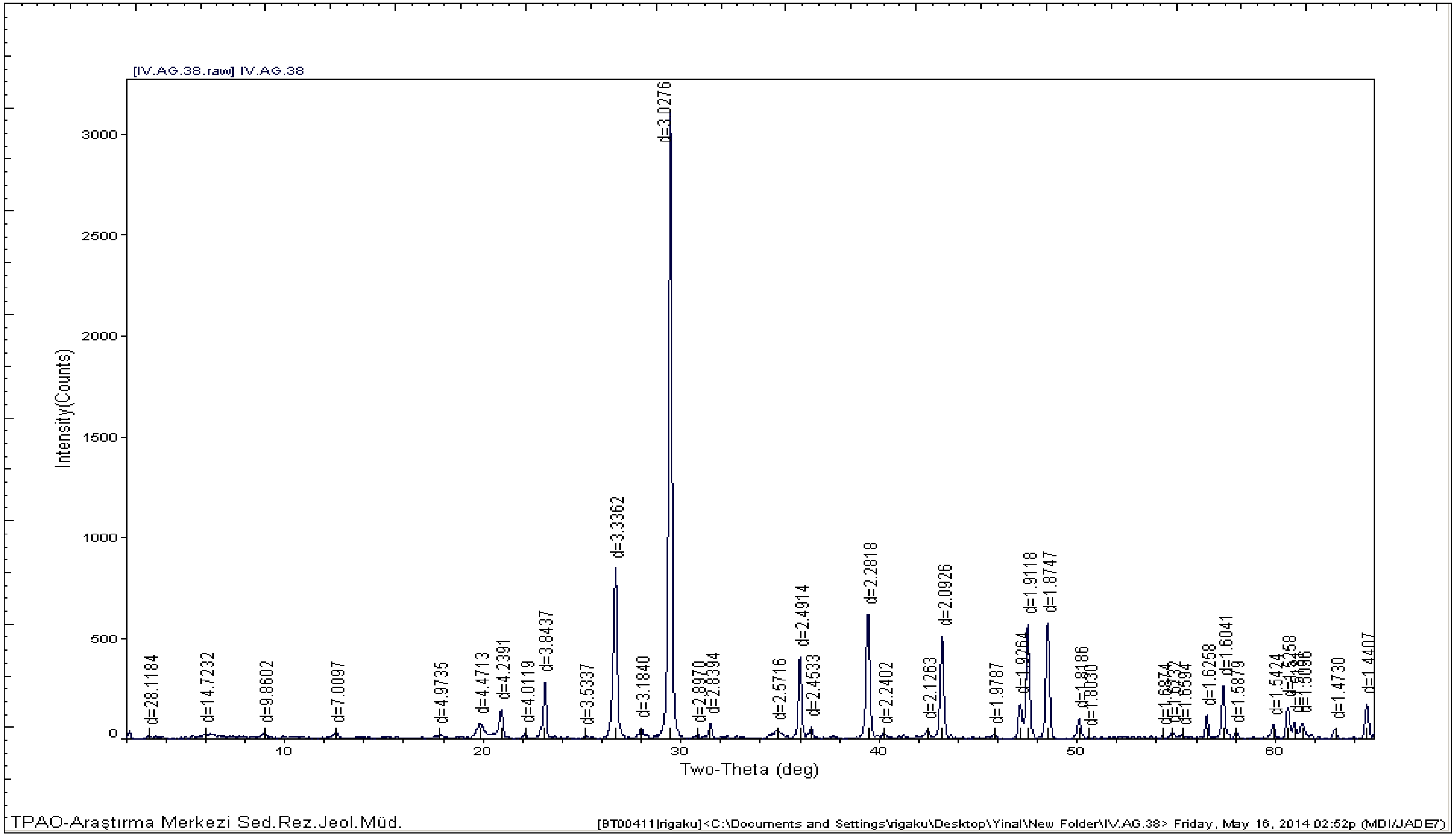


Figure 129. Bulk rock XRD diffractogram for Sample 38 of the Erfelek 1 Section.

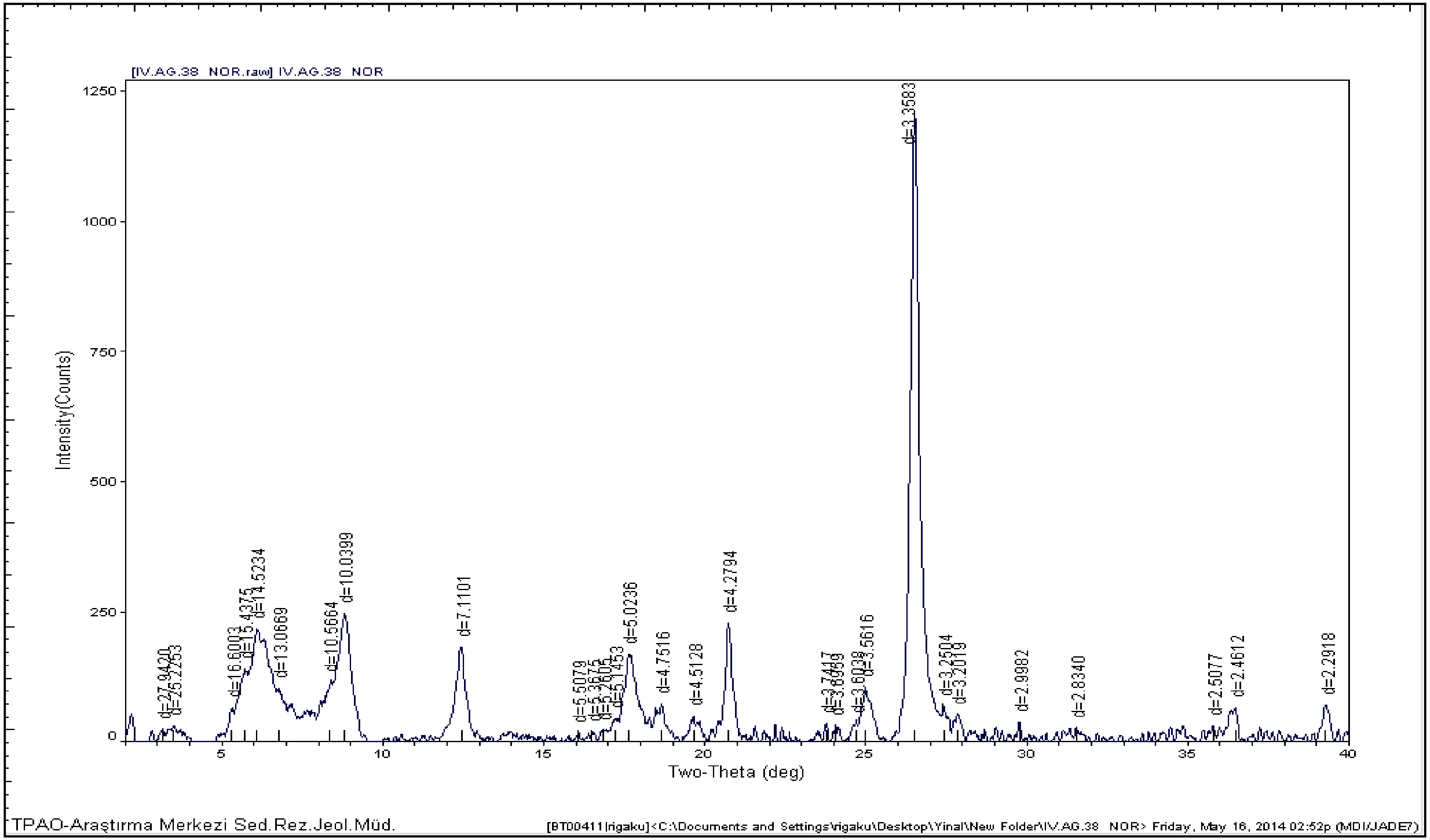


Figure 130. Clay mineral (air dried) XRD diffractogram for Sample 38 of the Erfelek 1 Section.

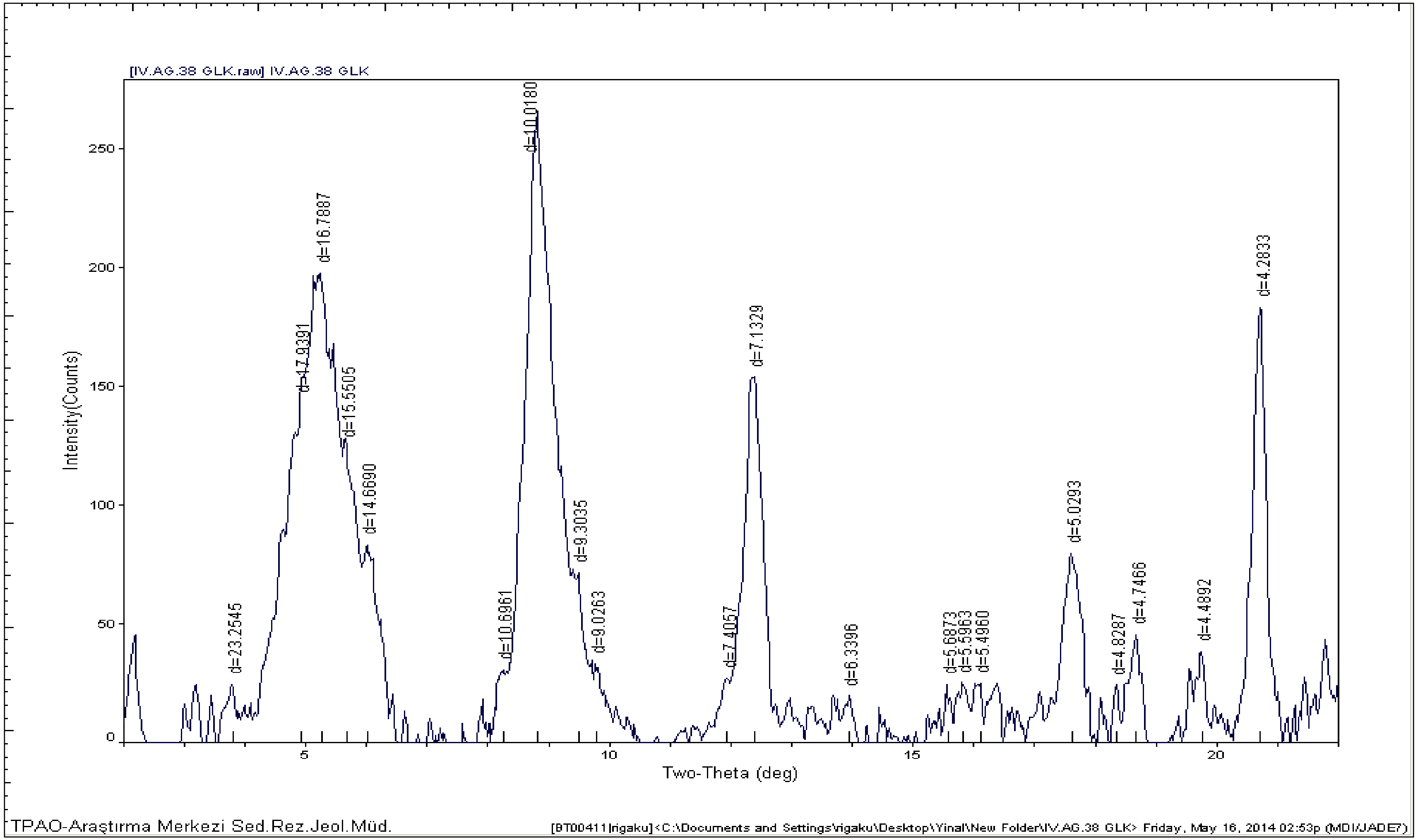


Figure 131. Clay mineral (ethylene glycol) XRD diffractogram for Sample 38 of the Erfelek 1 Section.

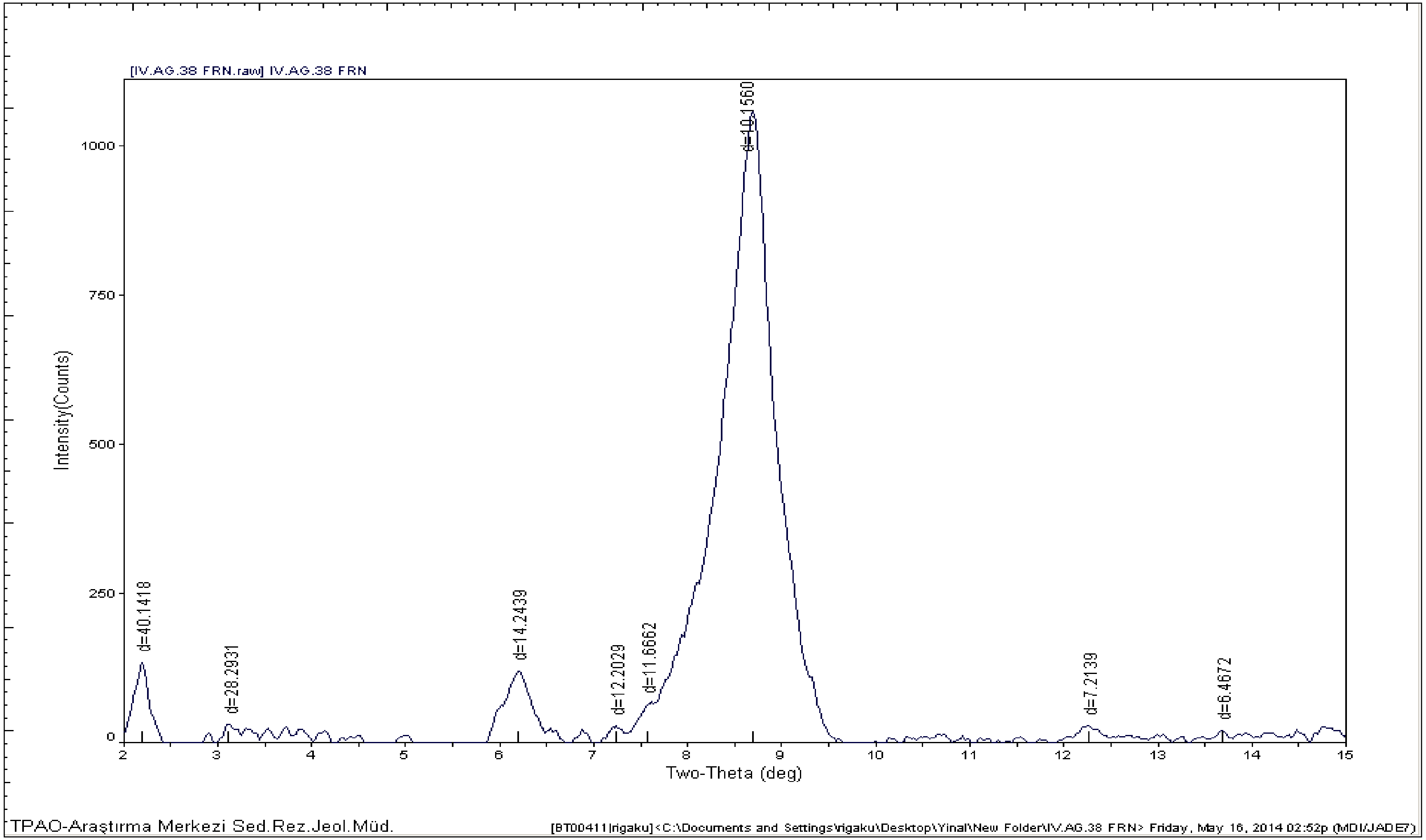


Figure 132. Clay mineral (heated) XRD diffractogram for Sample 38 of the Erfelek 1 Section.

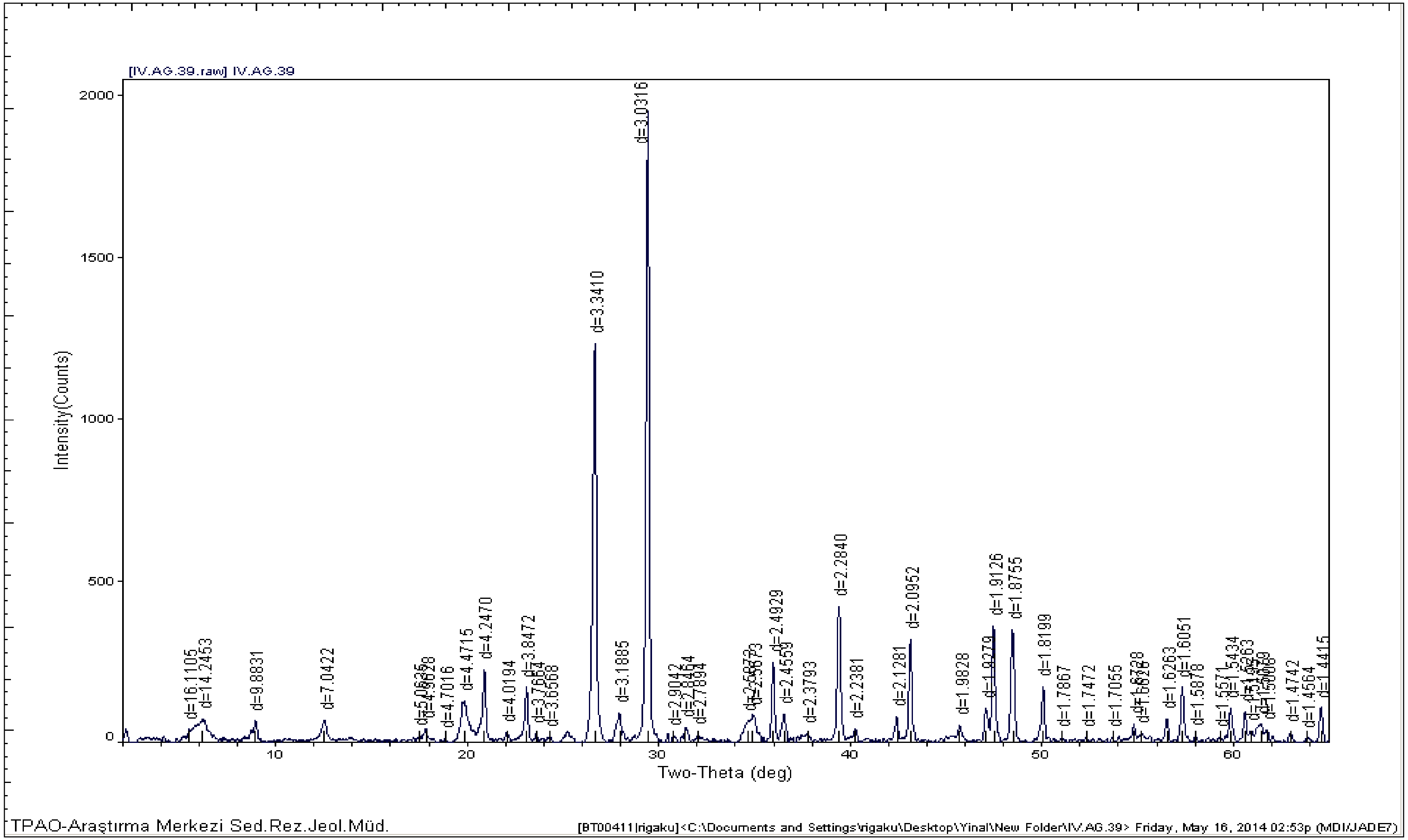


Figure 133. Bulk rock XRD diffractogram for Sample 39 of the Erfelek 1 Section.

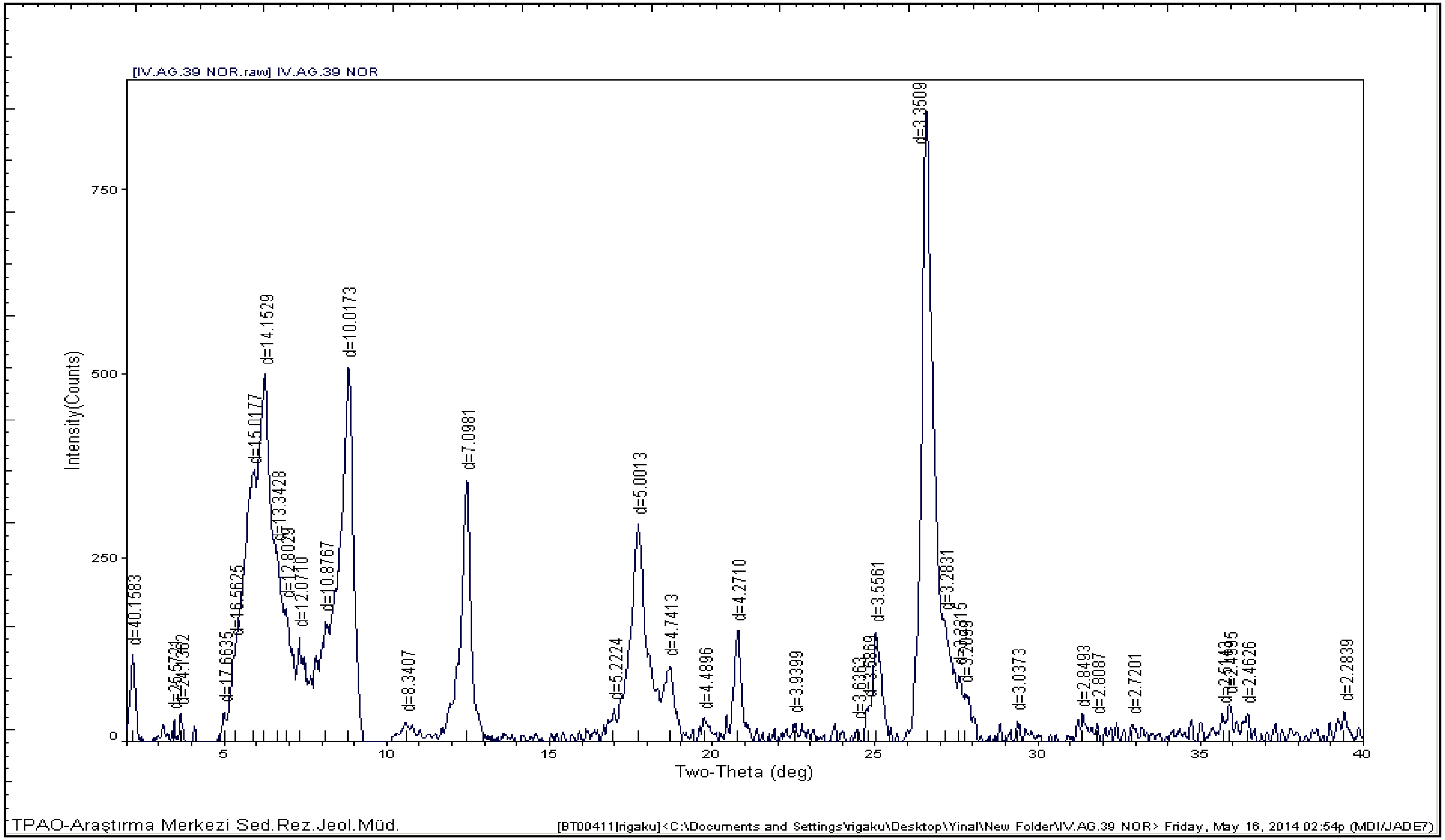


Figure 134. Clay mineral (air dried) XRD diffractogram for Sample 39 of the Erfelek 1 Section.

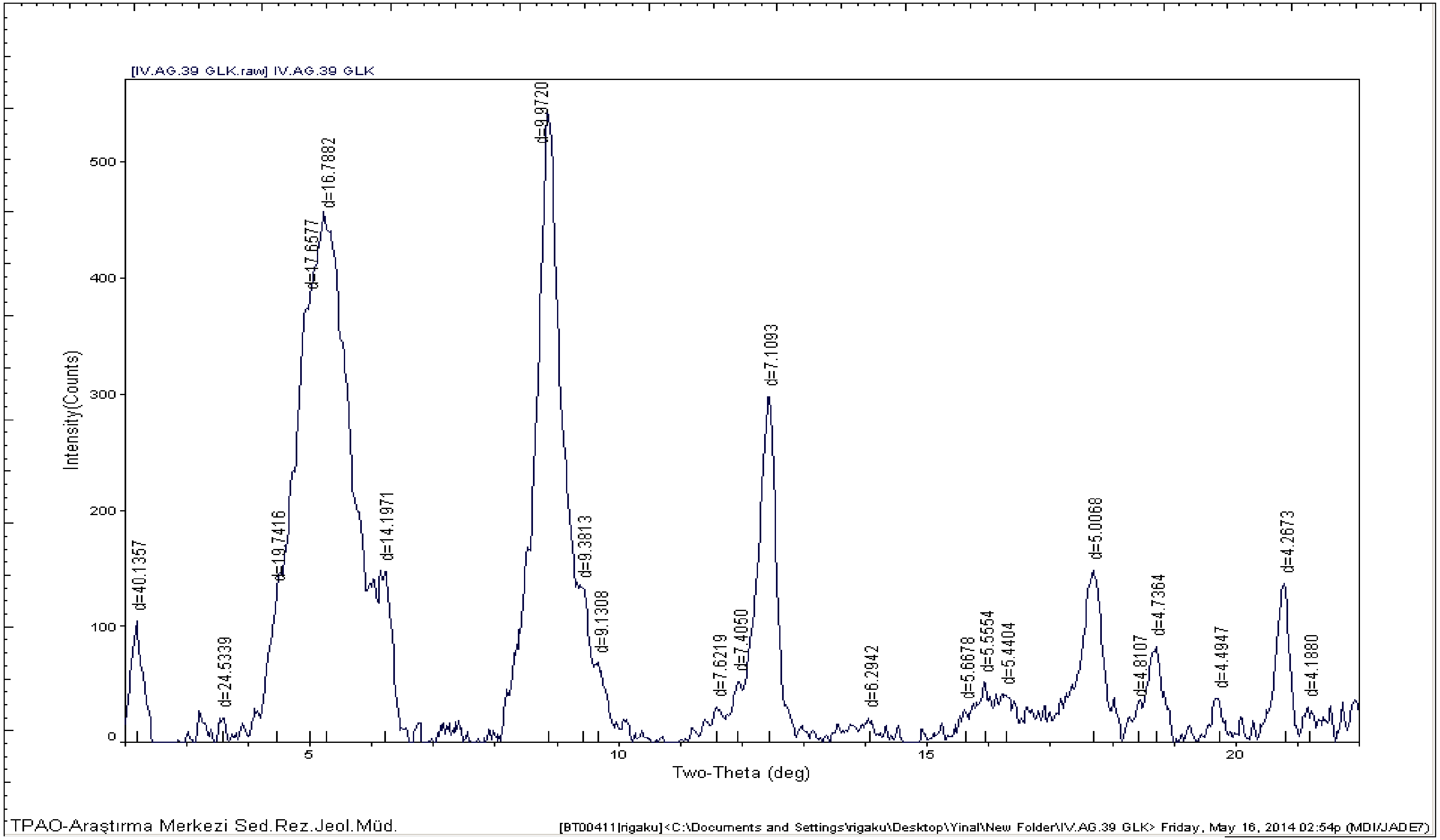


Figure 135. Clay mineral (ethylene glycol) XRD diffractogram for Sample 39 of the Erfelek 1 Section.

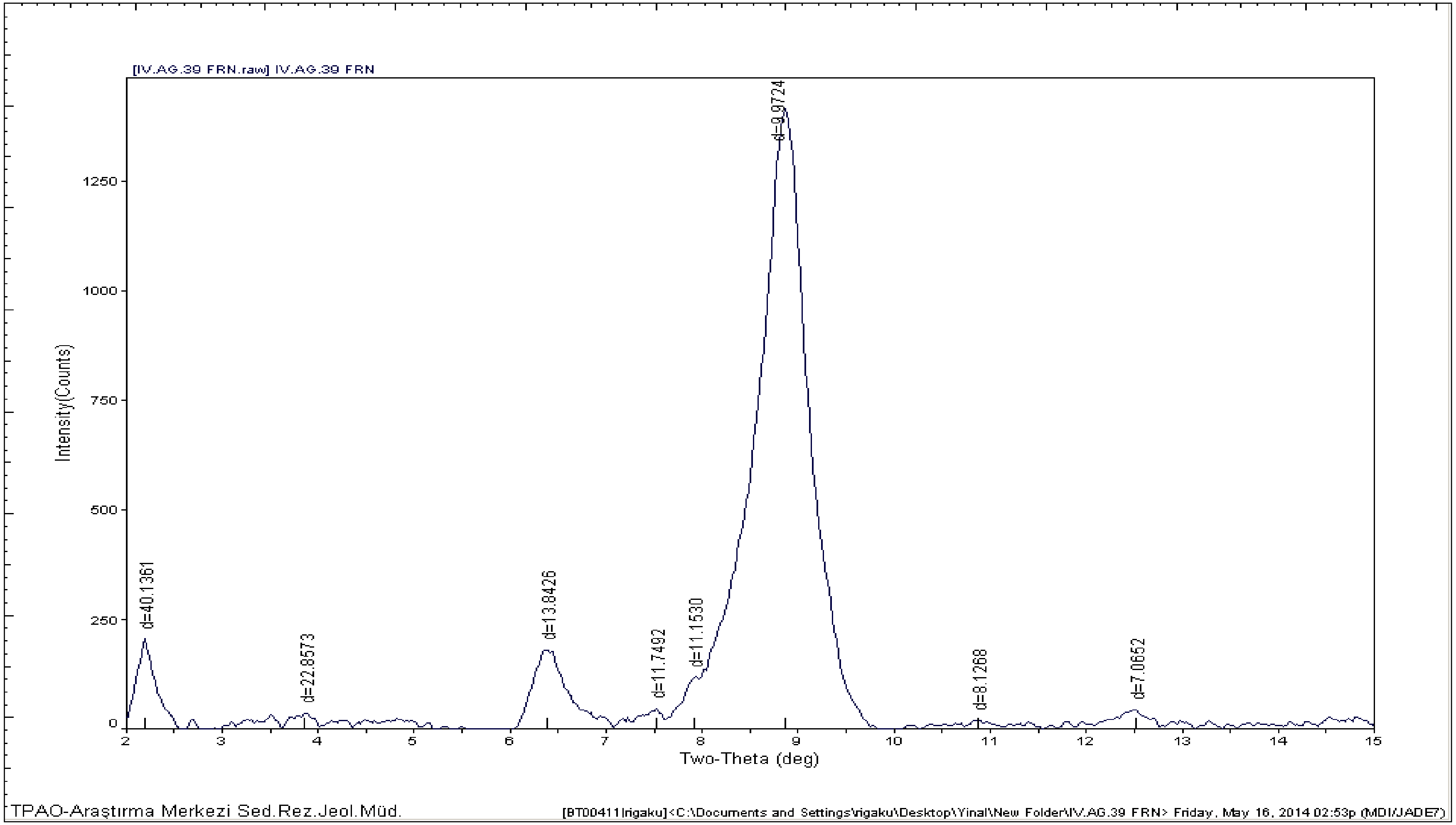


Figure 136. Clay mineral (heated) XRD diffractogram for Sample 39 of the Erfelek 1 Section.

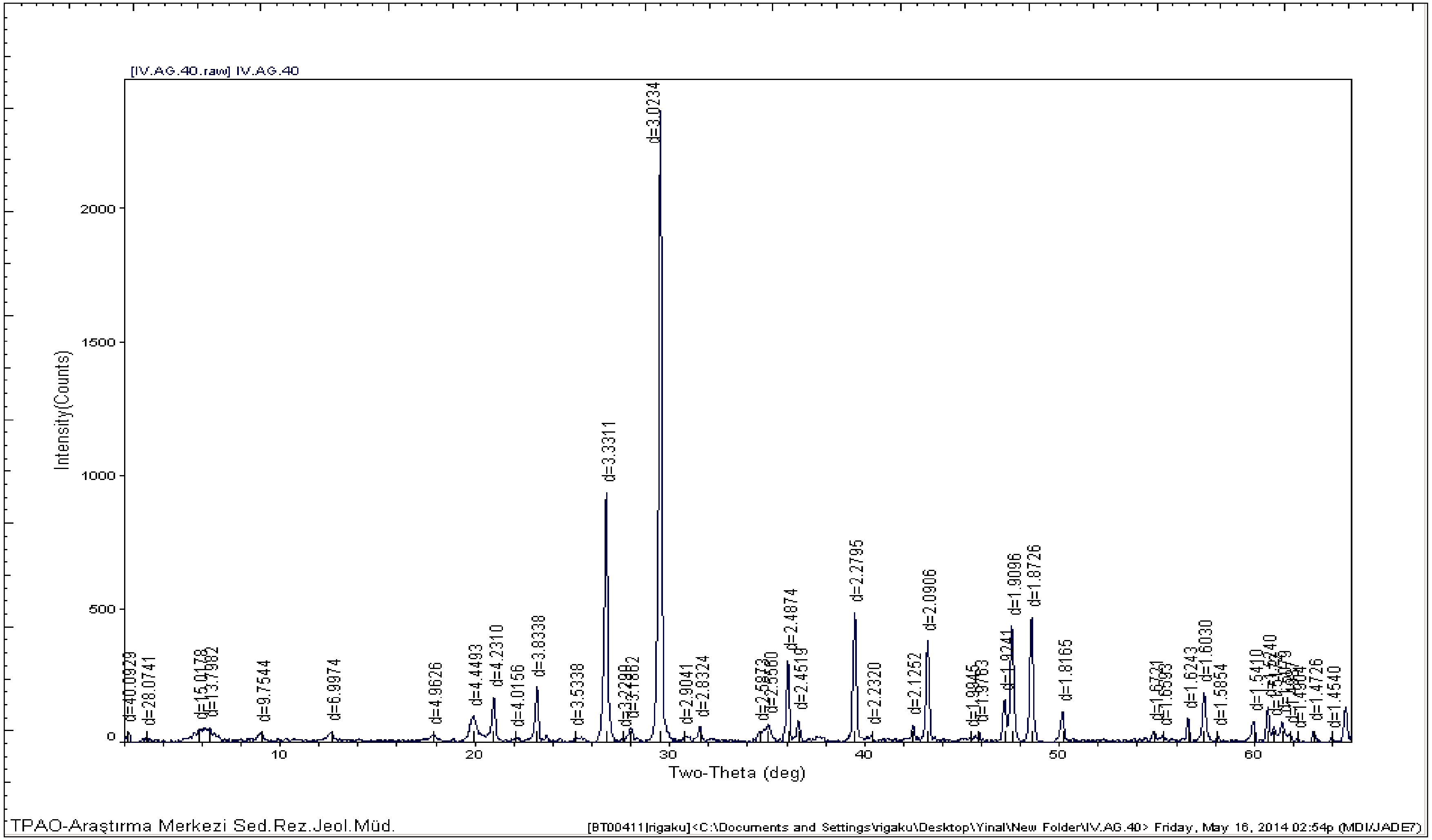


Figure 137. Bulk rock XRD diffractogram for Sample 40 of the Erfelek 1 Section.

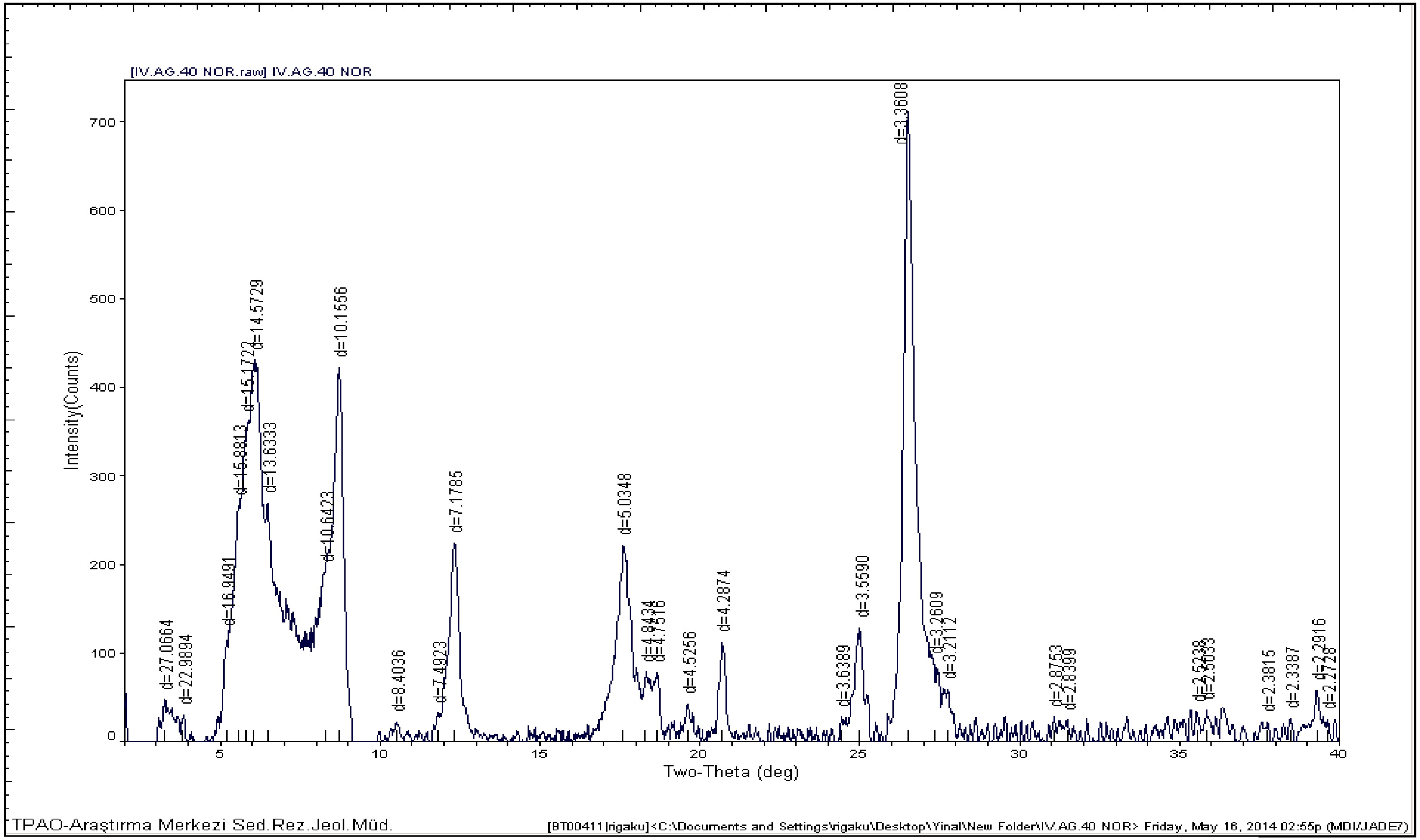


Figure 138. Clay mineral (air dried) XRD diffractogram for Sample 40 of the Erfelek 1 Section.

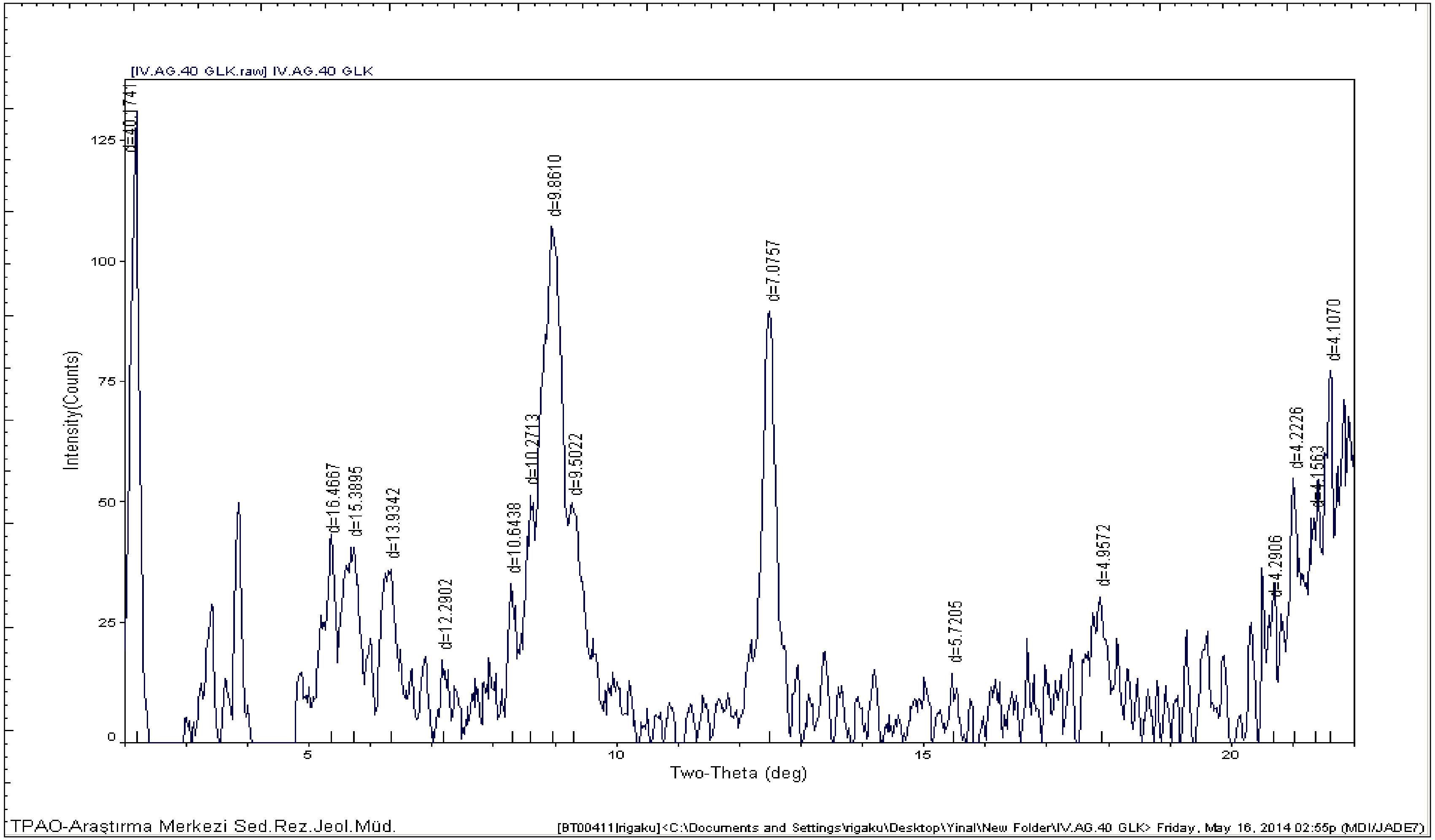


Figure 139. Clay mineral (ethylene glycol) XRD diffractogram for Sample 40 of the Erfelek 1 Section.

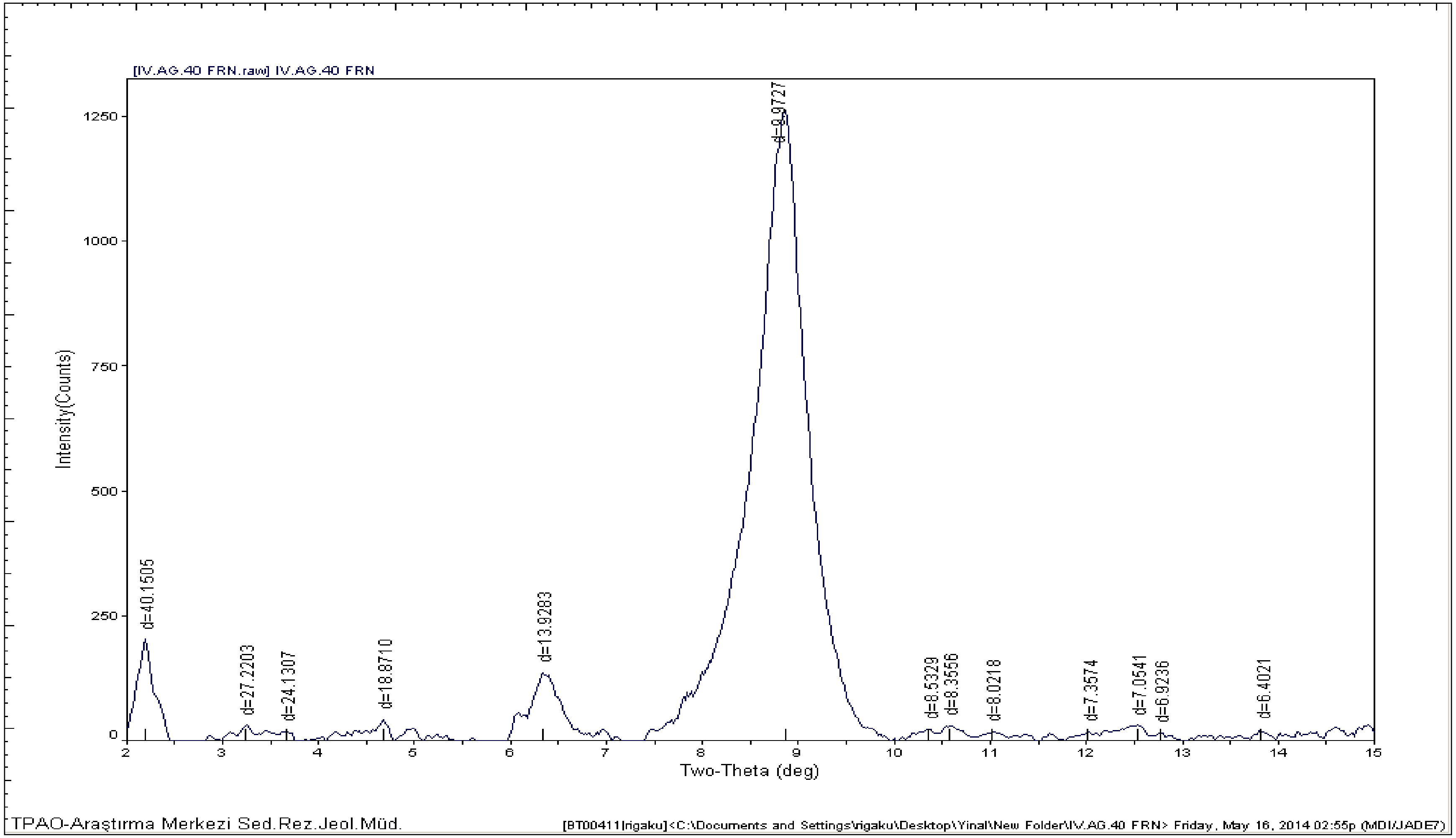


Figure 140. Clay mineral (heated) XRD diffractogram for Sample 40 of the Erfelek 1 Section.

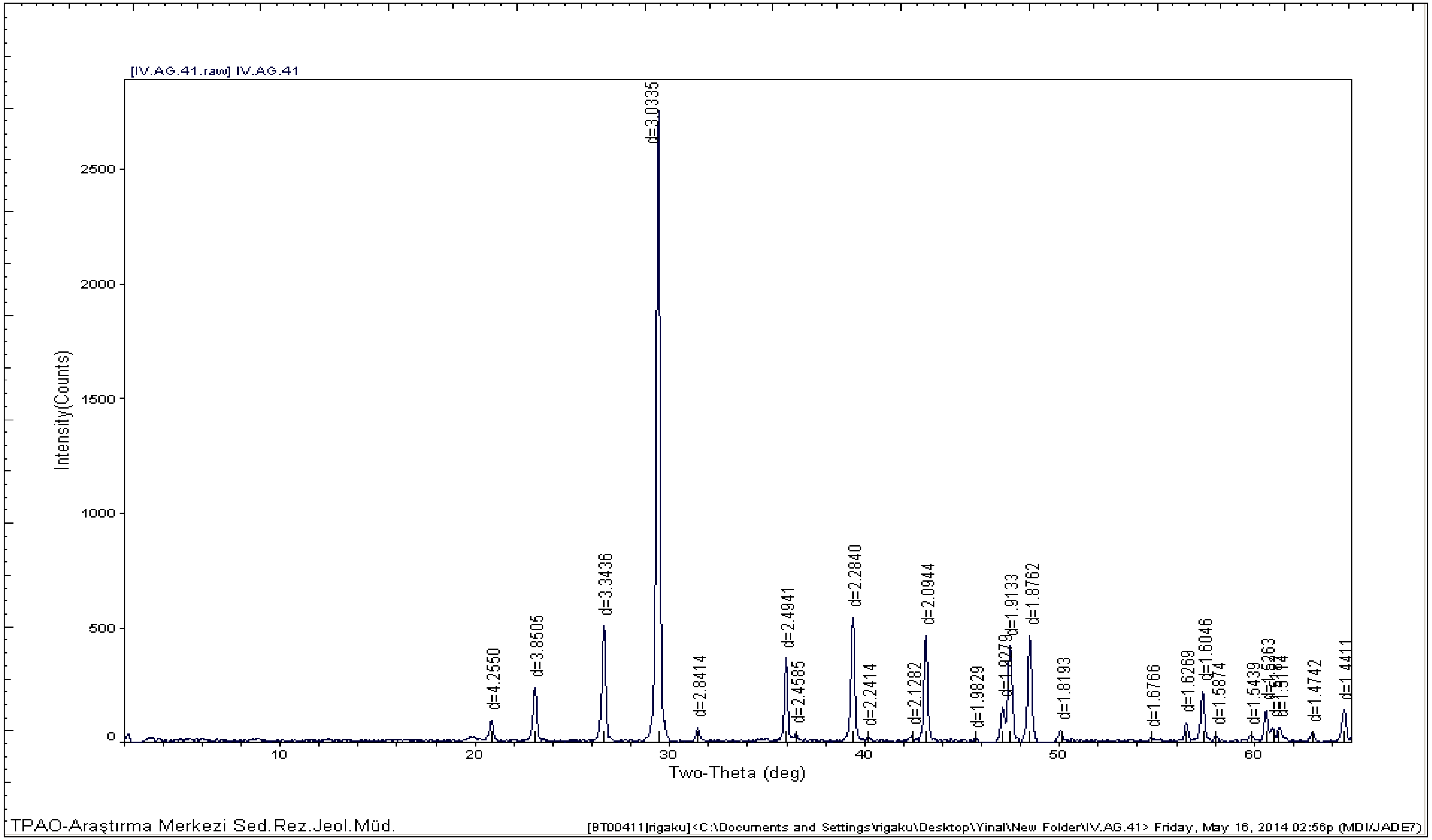


Figure 141. Bulk rock XRD diffractogram for Sample 41 of the Erfelek 1 Section.

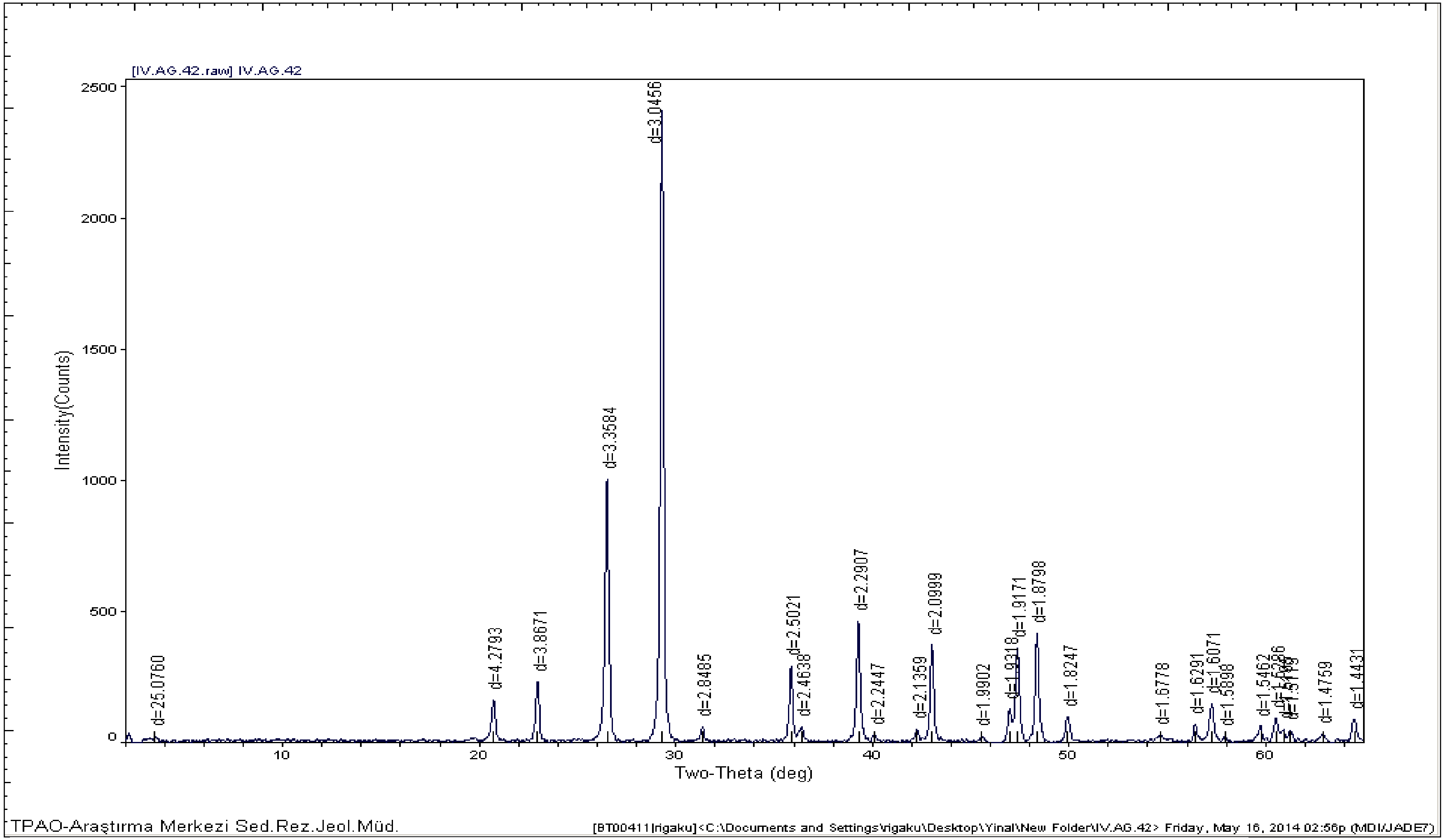


Figure 142. Bulk rock XRD diffractogram for Sample 42 of the Erfelek 1 Section.

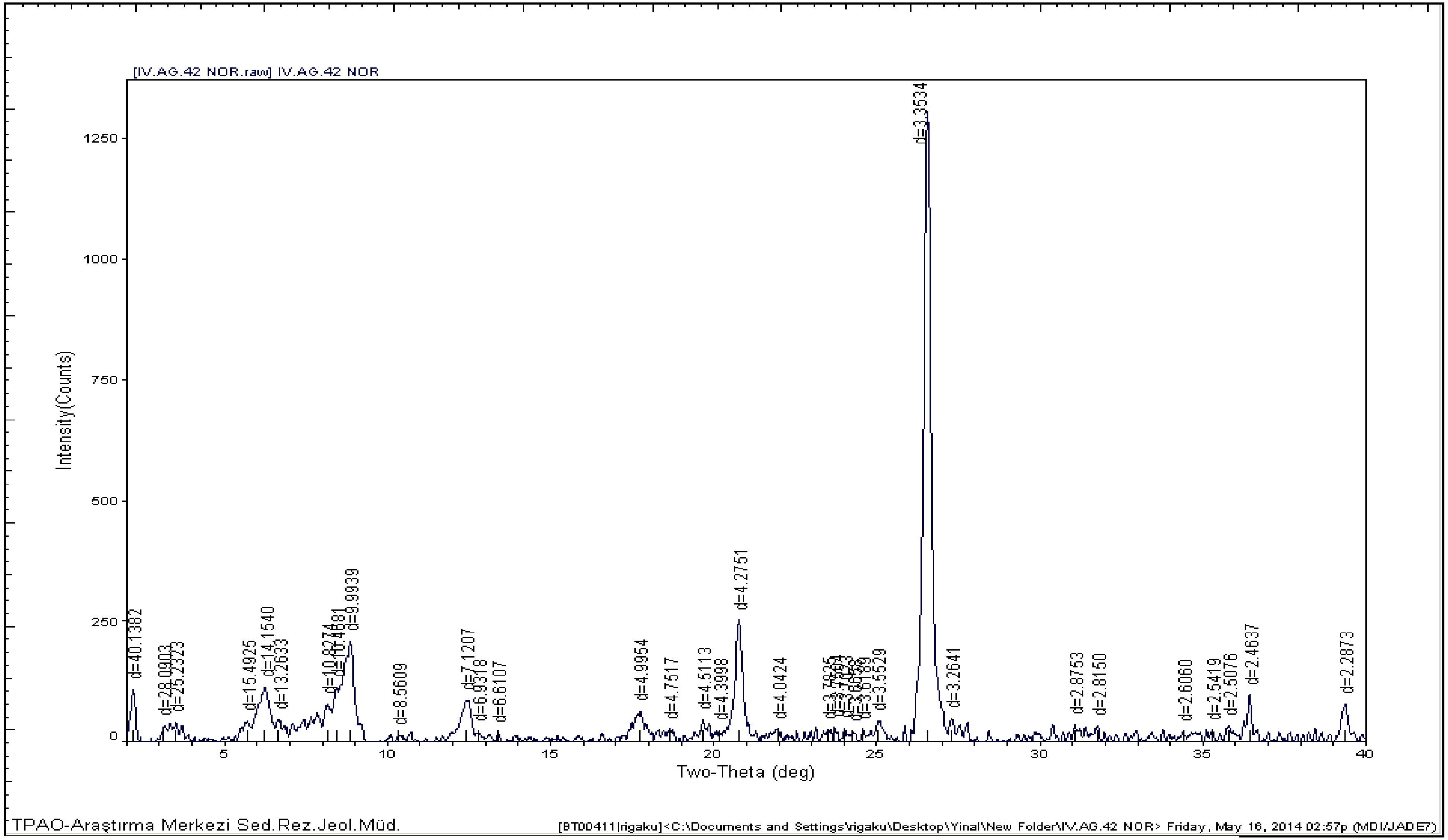


Figure 143. Clay mineral (air dried) XRD diffractogram for Sample 42 of the Erfelek 1 Section.

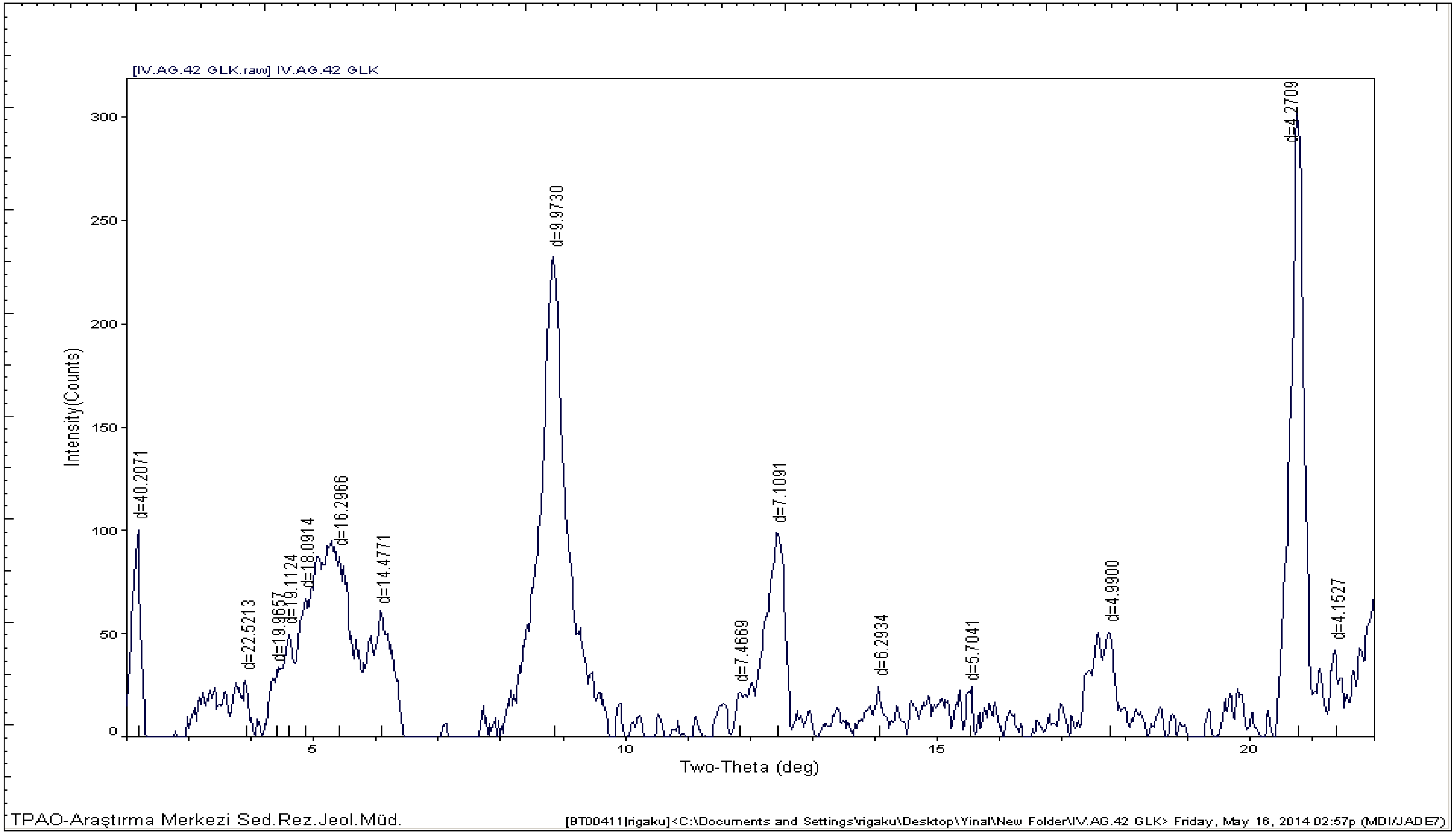


Figure 144. Clay mineral (ethylene glycol) XRD diffractogram for Sample 42 of the Erfelek 1 Section.

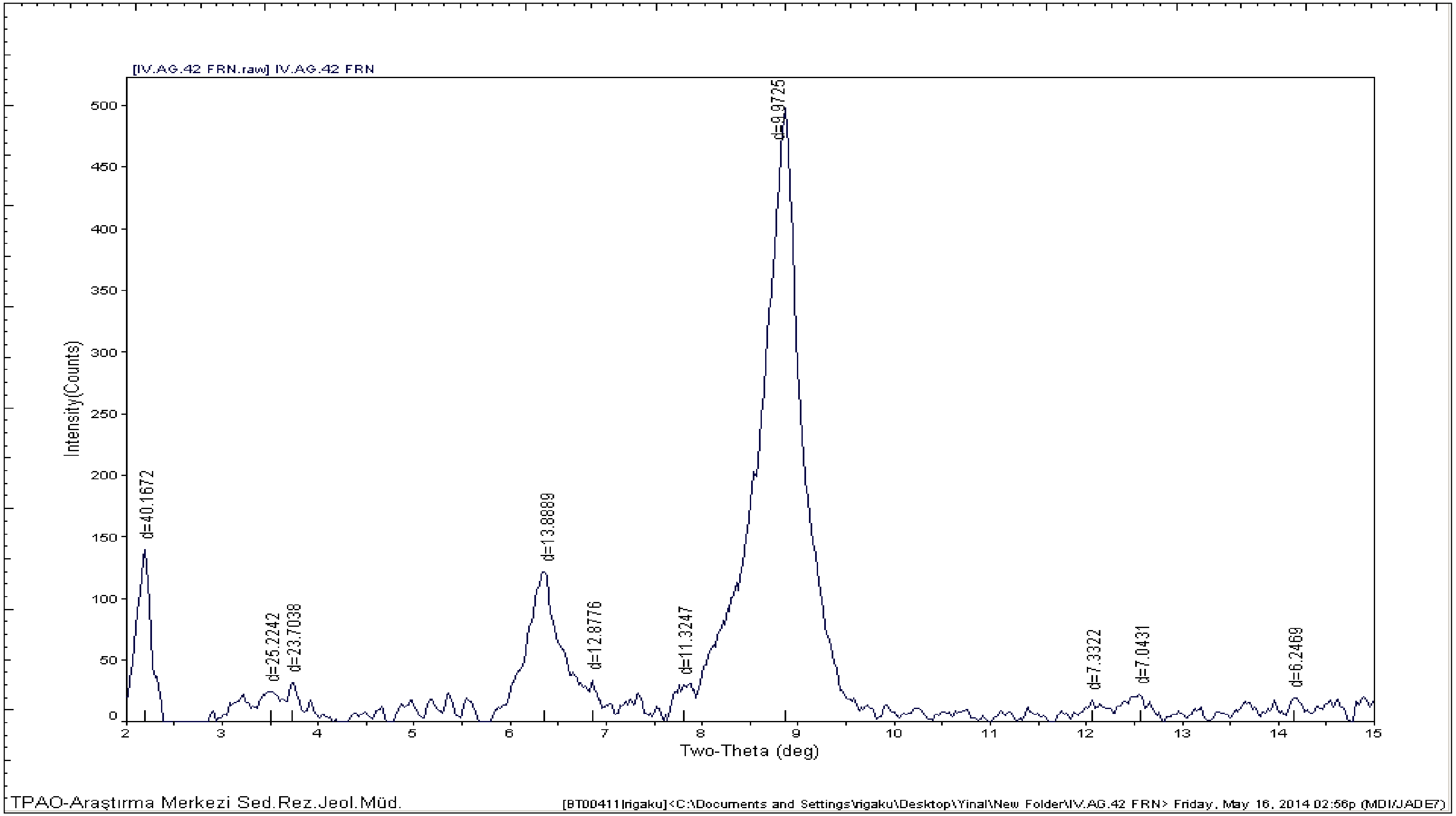


Figure 145. Clay mineral (heated) XRD diffractogram for Sample 42 of the Erfelek 1 Section.

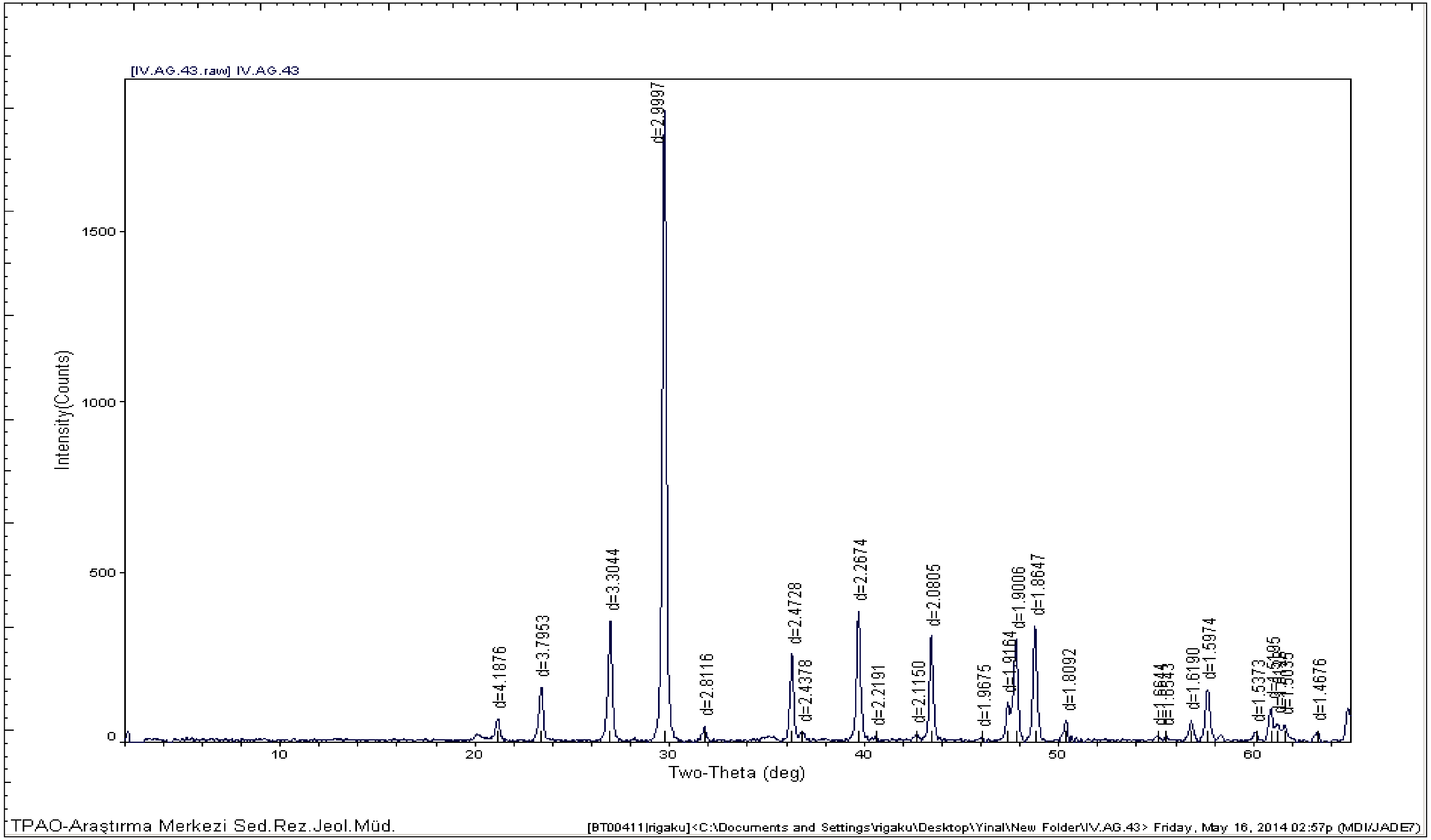


Figure 146. Bulk rock XRD diffractogram for Sample 43 of the Erfelek 1 Section.

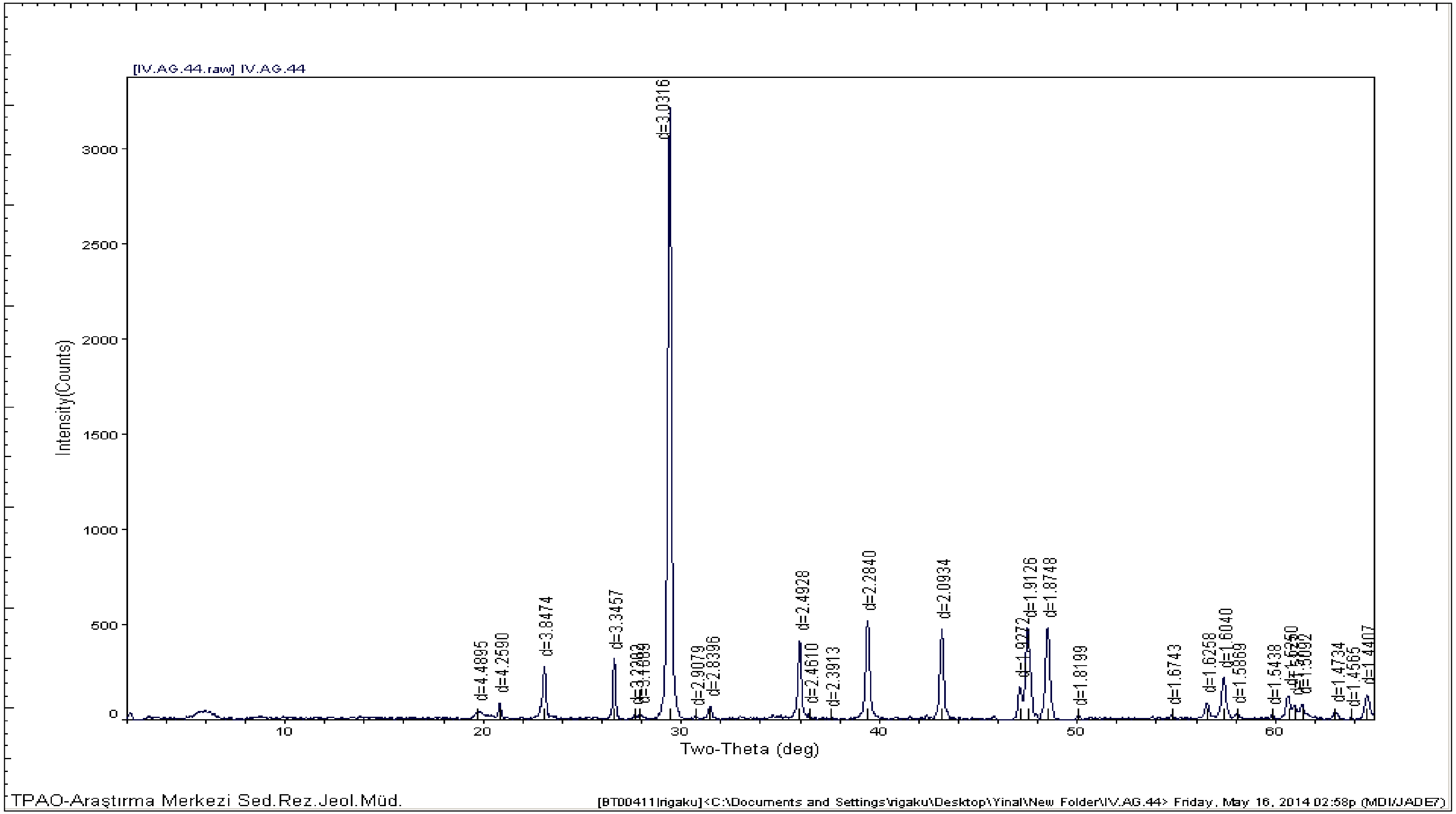


Figure 147. Bulk rock XRD diffractogram for Sample 44 of the Erfelek 1 Section.

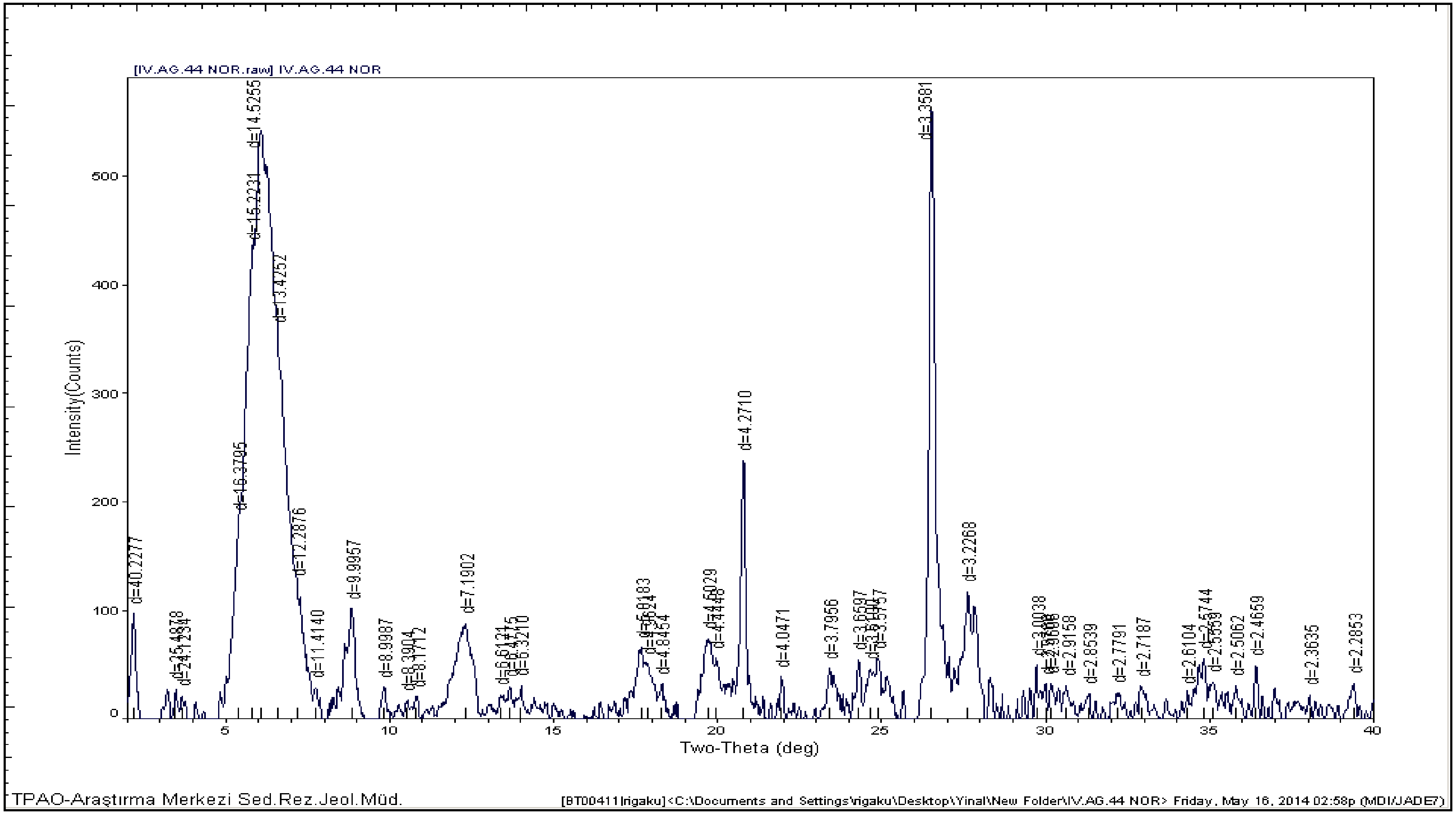


Figure 148. Clay mineral (air dried) XRD diffractogram for Sample 44 of the Erfelek 1 Section.

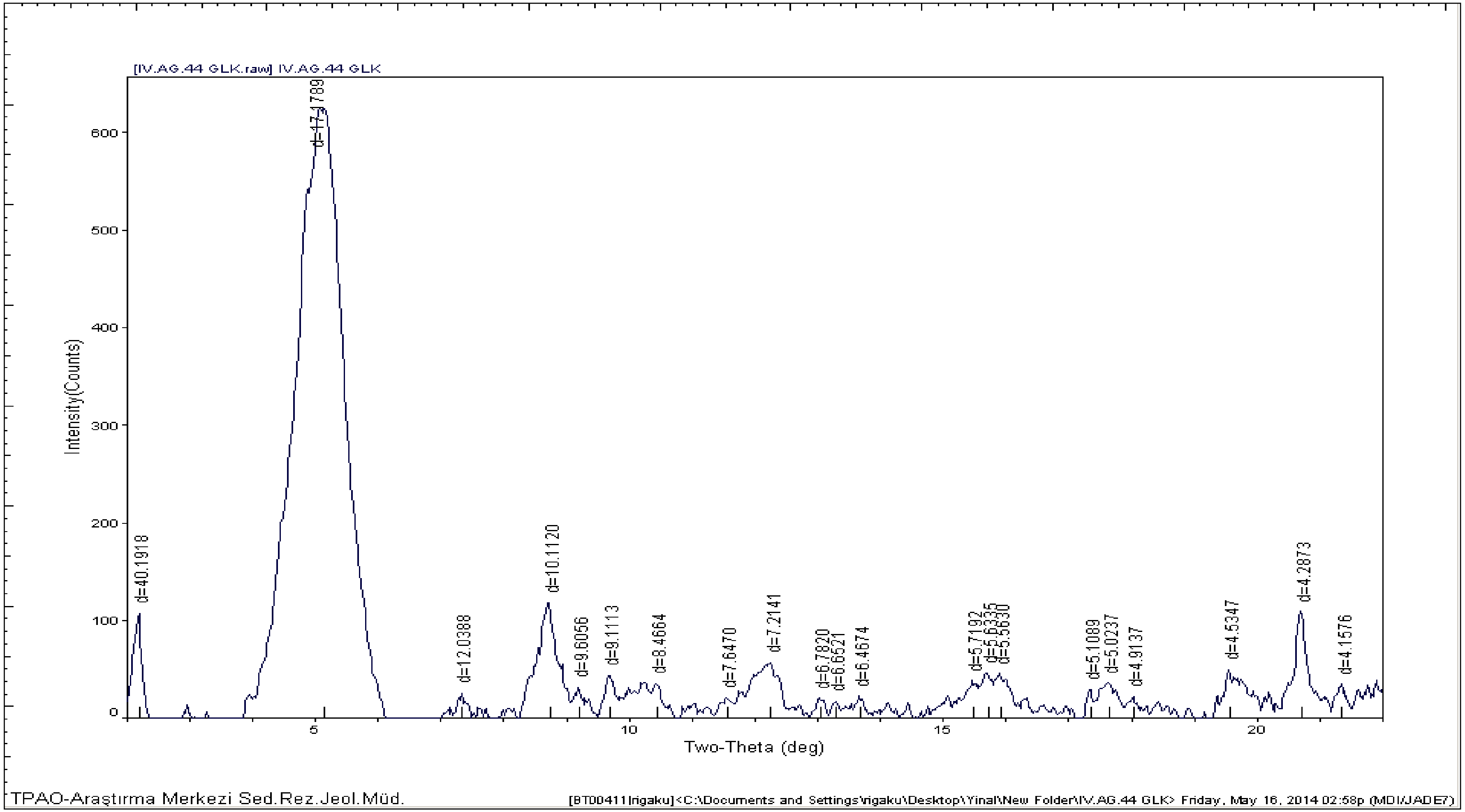


Figure 149. Clay mineral (ethylene glycol) XRD diffractogram for Sample 44 of the Erfelek 1 Section.

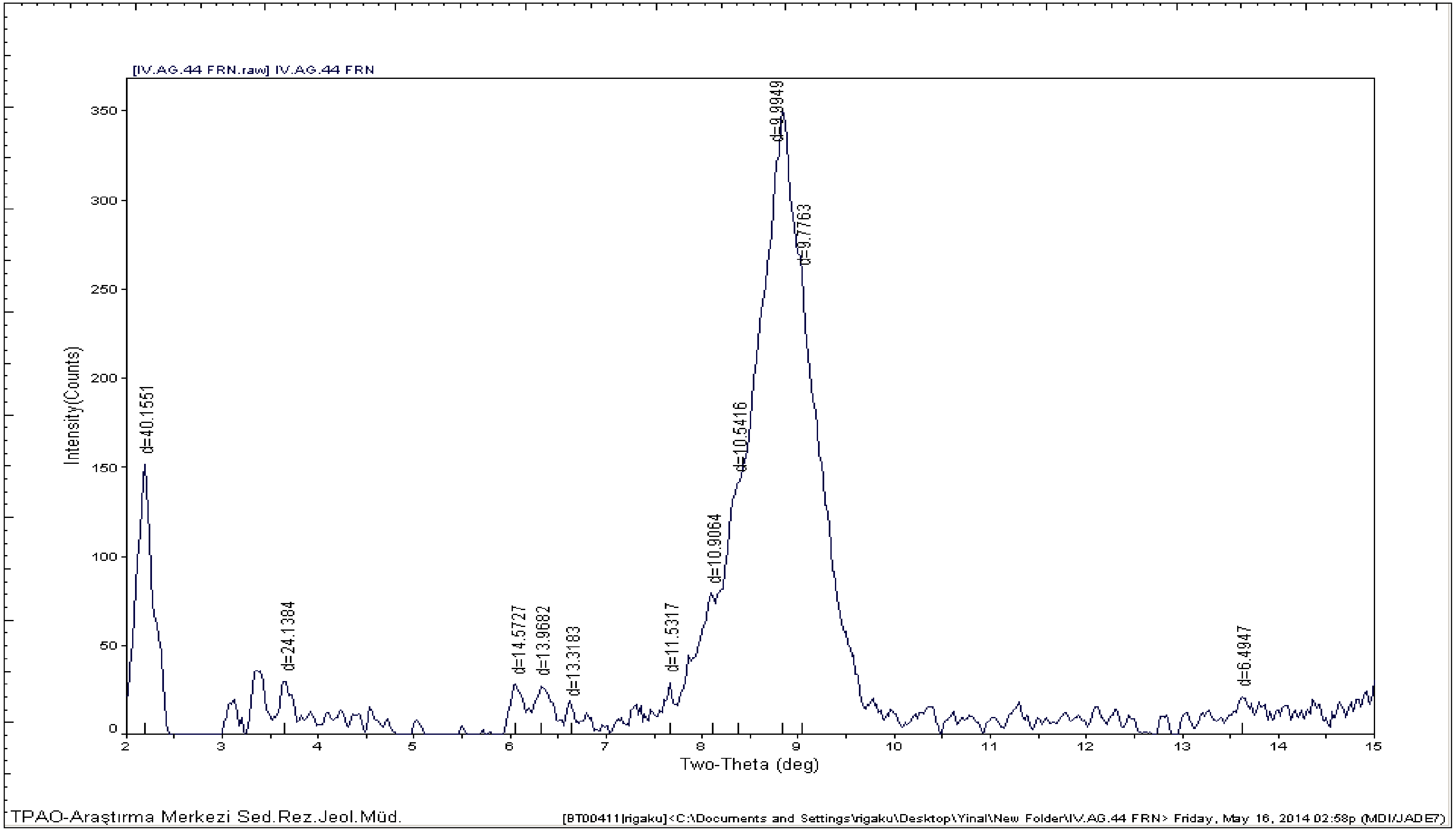


Figure 150. Clay mineral (heated) XRD diffractogram for Sample 44 of the Erfelek 1 Section.

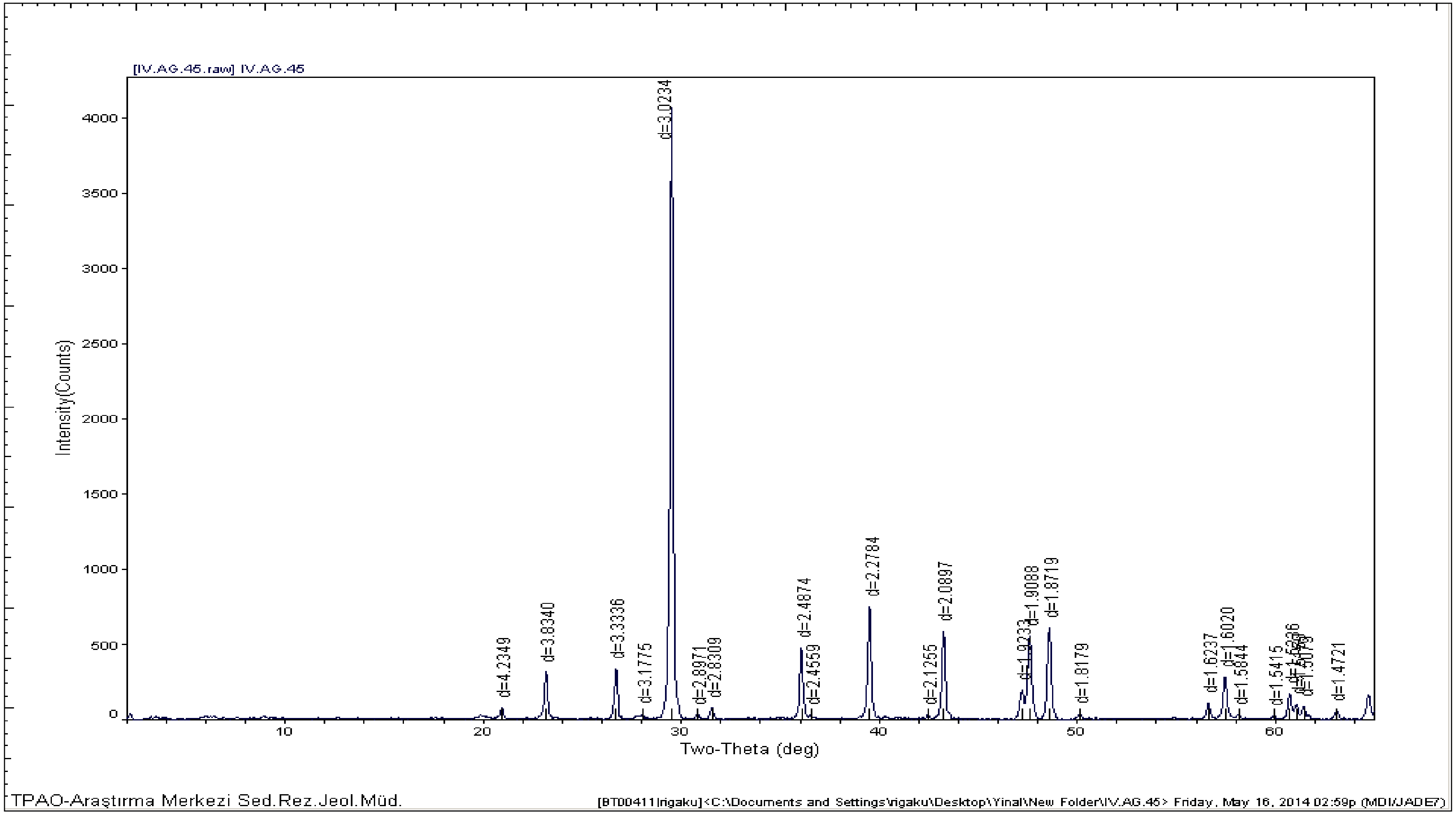


Figure 151. Bulk rock XRD diffractogram for Sample 45 of the Erfelek 1 Section.

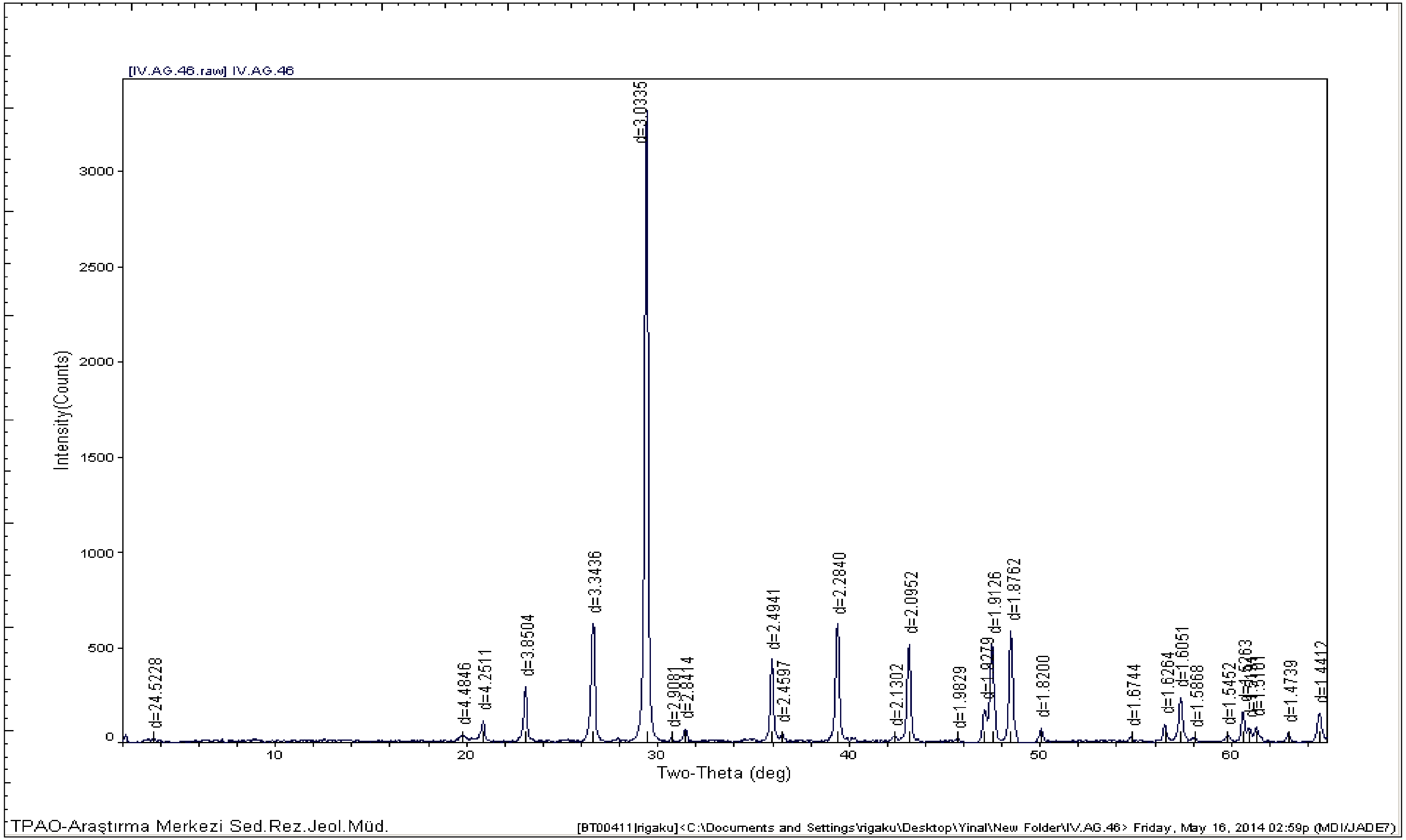


Figure 152. Bulk rock XRD diffractogram for Sample 46 of the Erfelek 1 Section.

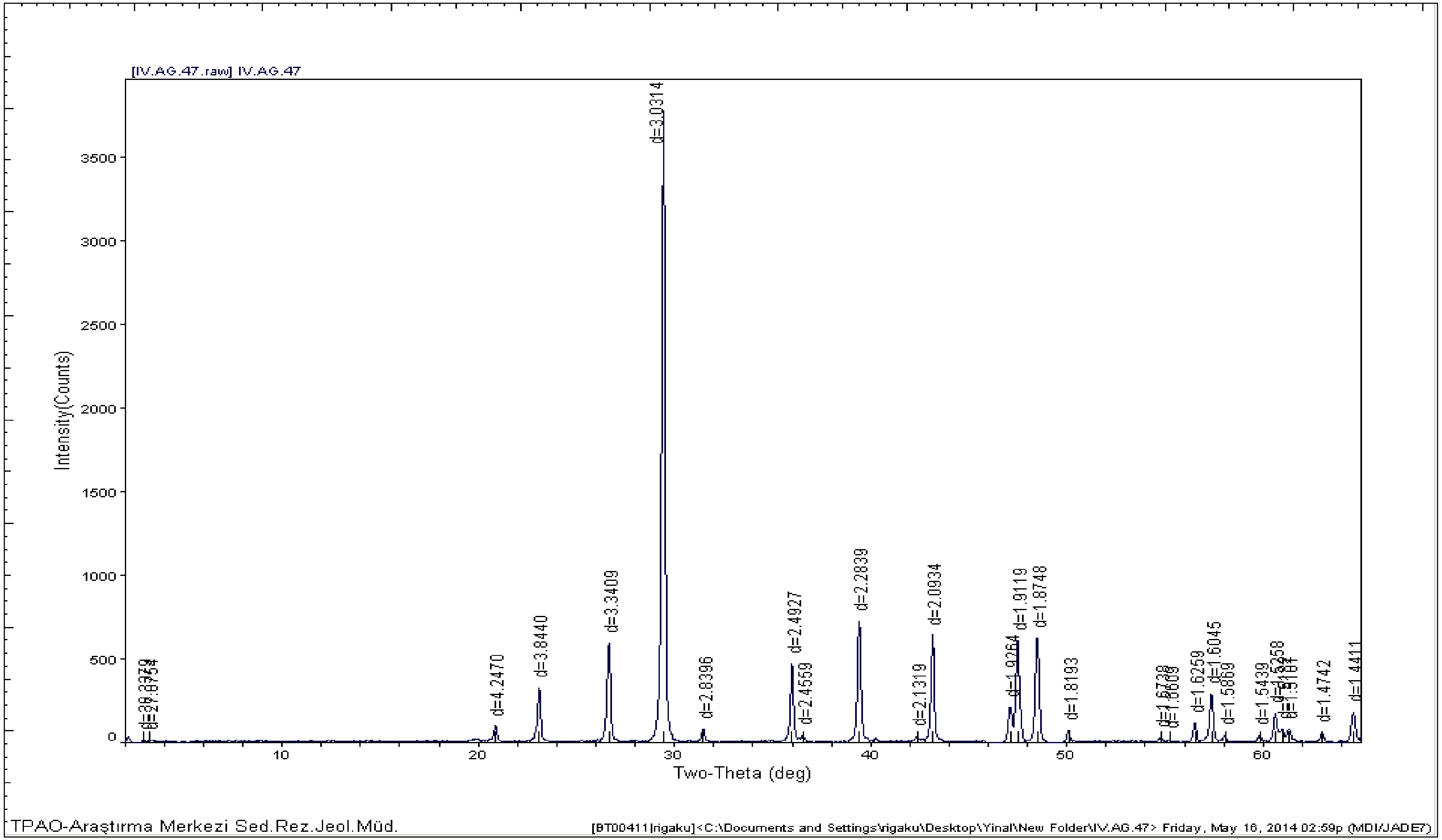


Figure 153. Bulk rock XRD diffractogram for Sample 47 of the Erfelek 1 Section.

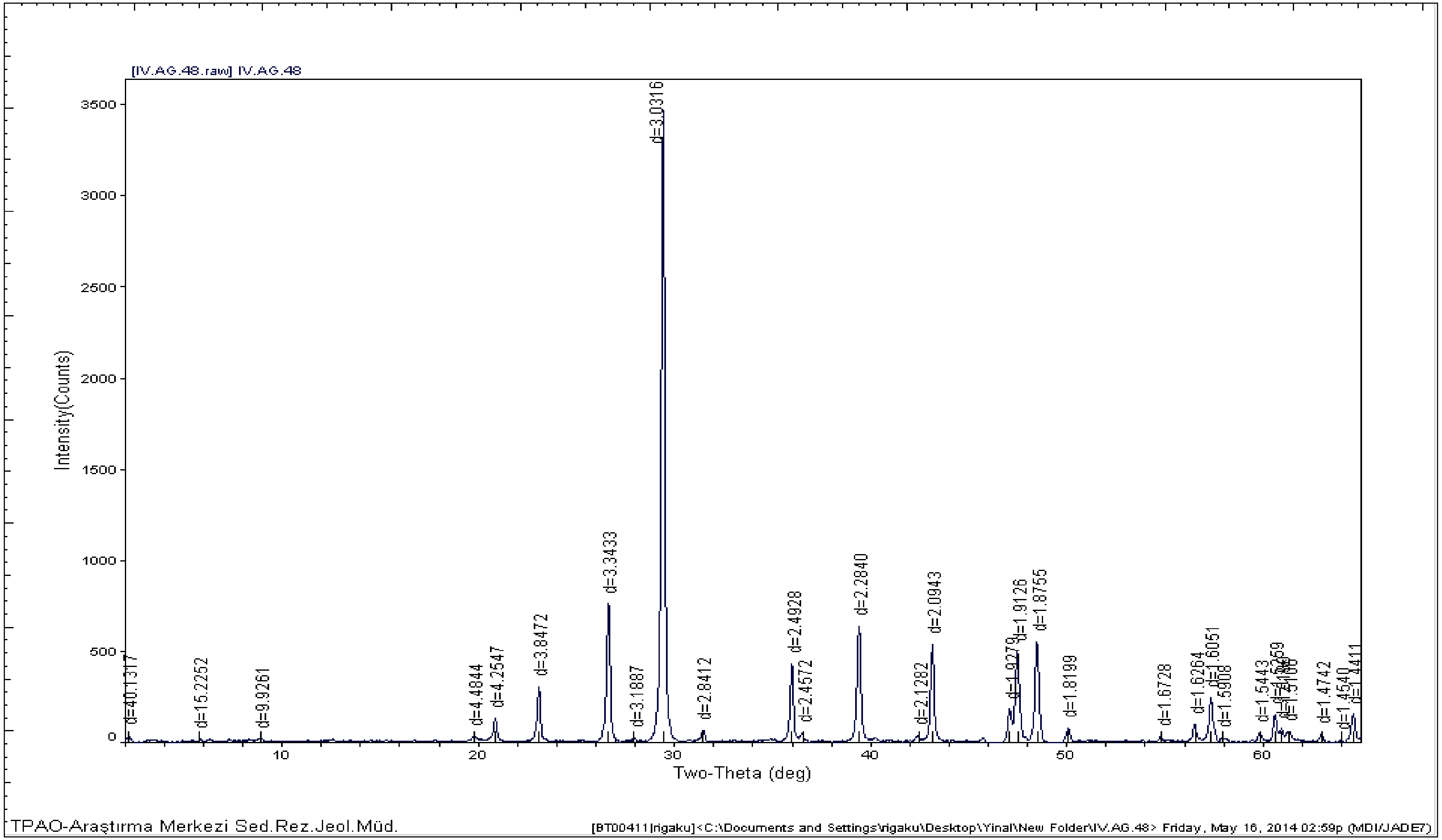


Figure 154. Bulk rock XRD diffractogram for Sample 48 of the Erfelek 1 Section.

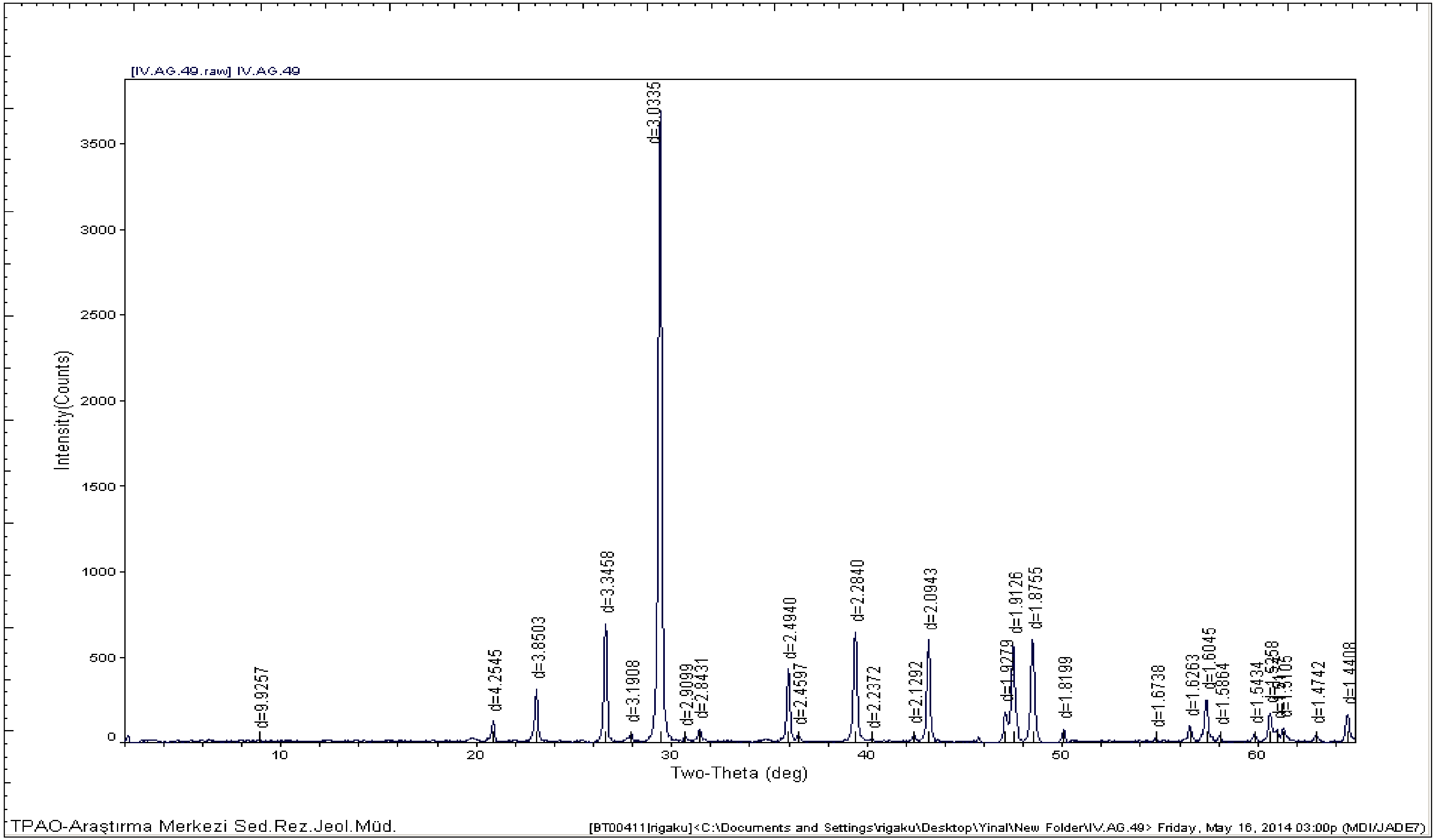


Figure 155. Bulk rock XRD diffractogram for Sample 49 of the Erfelek 1 Section.

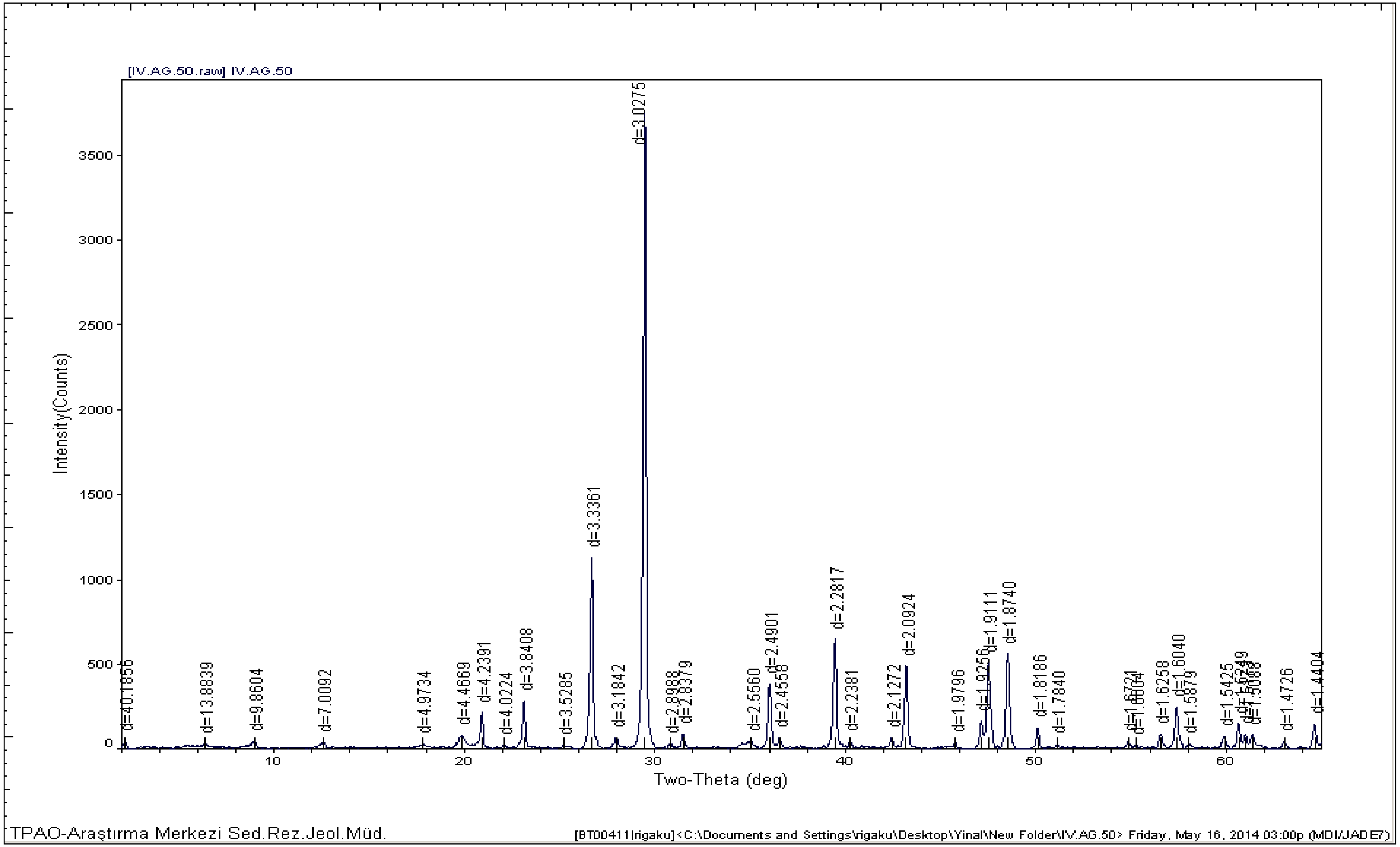


Figure 156. Bulk rock XRD diffractogram for Sample 50 of the Erfelek 1 Section.

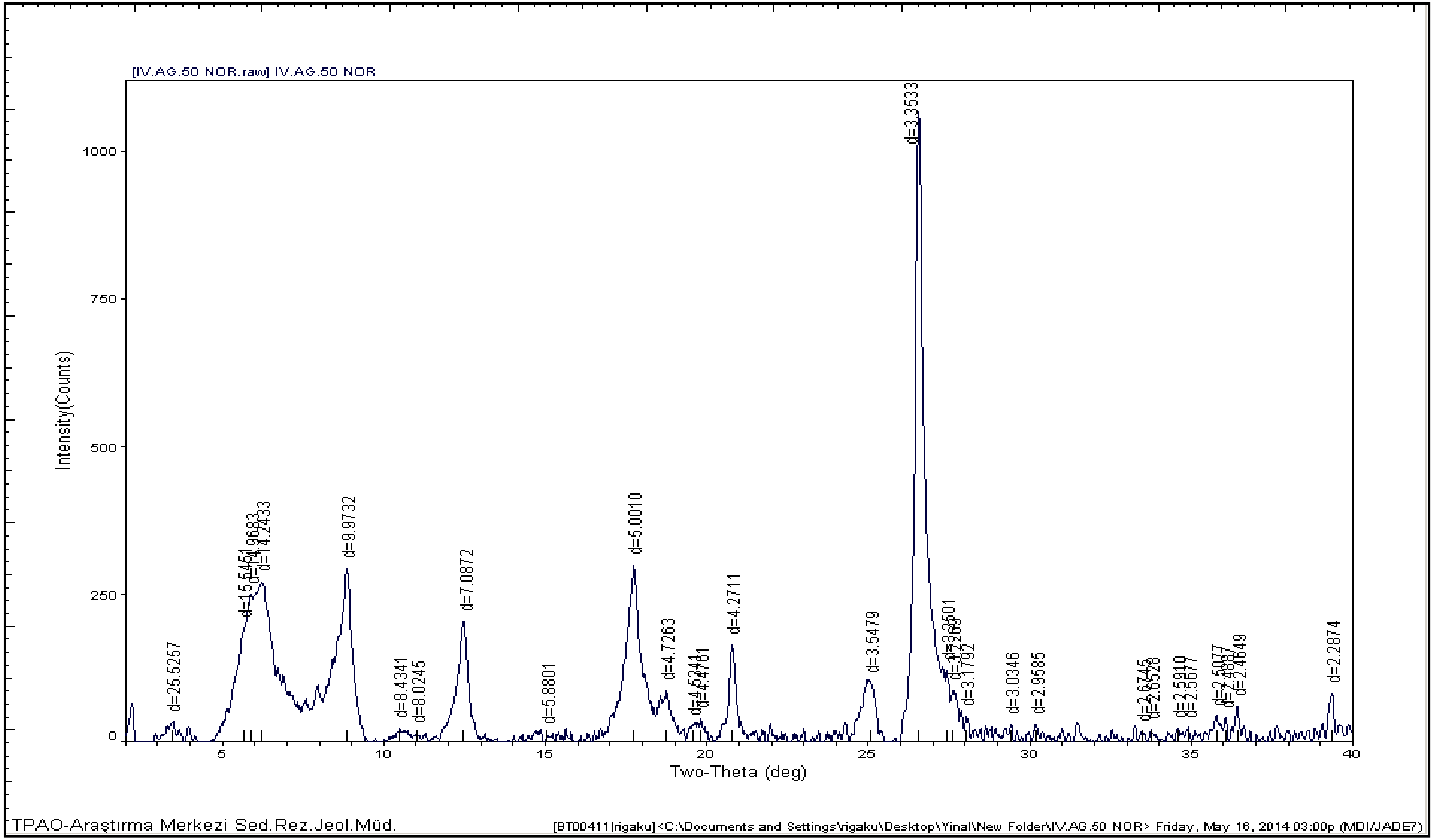


Figure 157. Clay mineral (air dried) XRD diffractogram for Sample 50 of the Erfelek 1 Section.

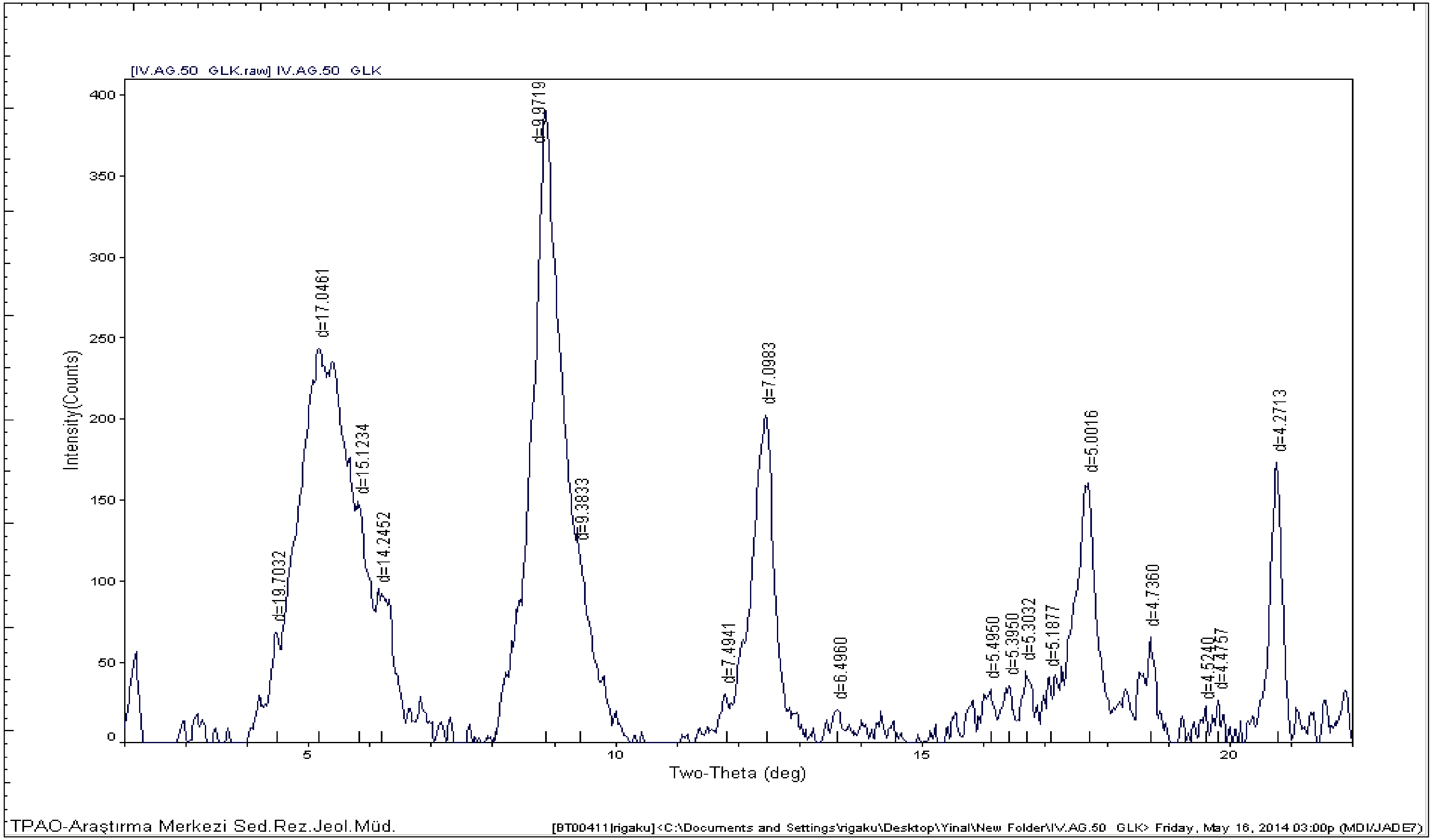


Figure 158. Clay mineral (ethylene glycol) XRD diffractogram for Sample 50 of the Erfelek 1 Section.

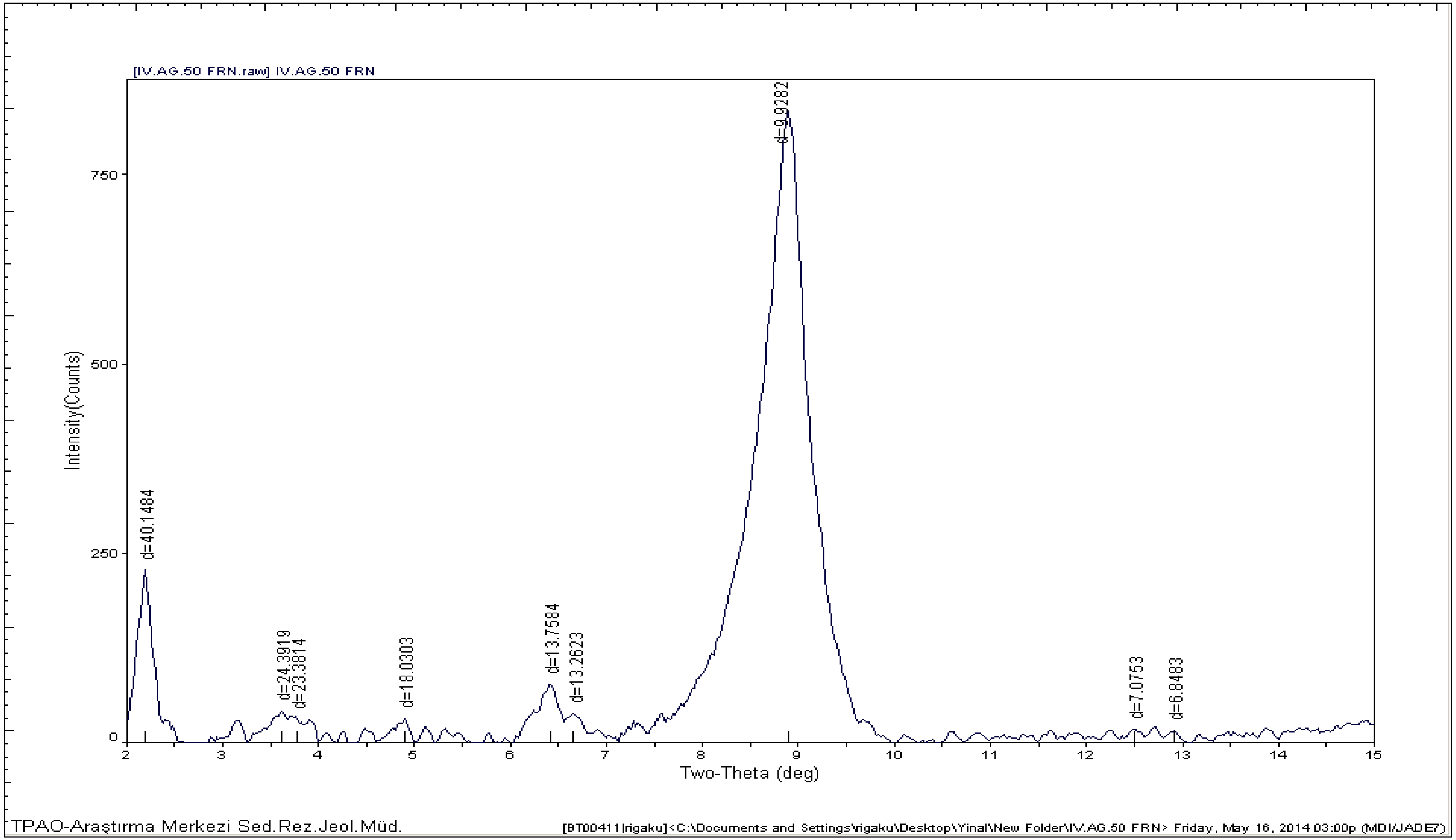


Figure 159. Clay mineral (heated) XRD diffractogram for Sample 50 of the Erfelek 1 Section.

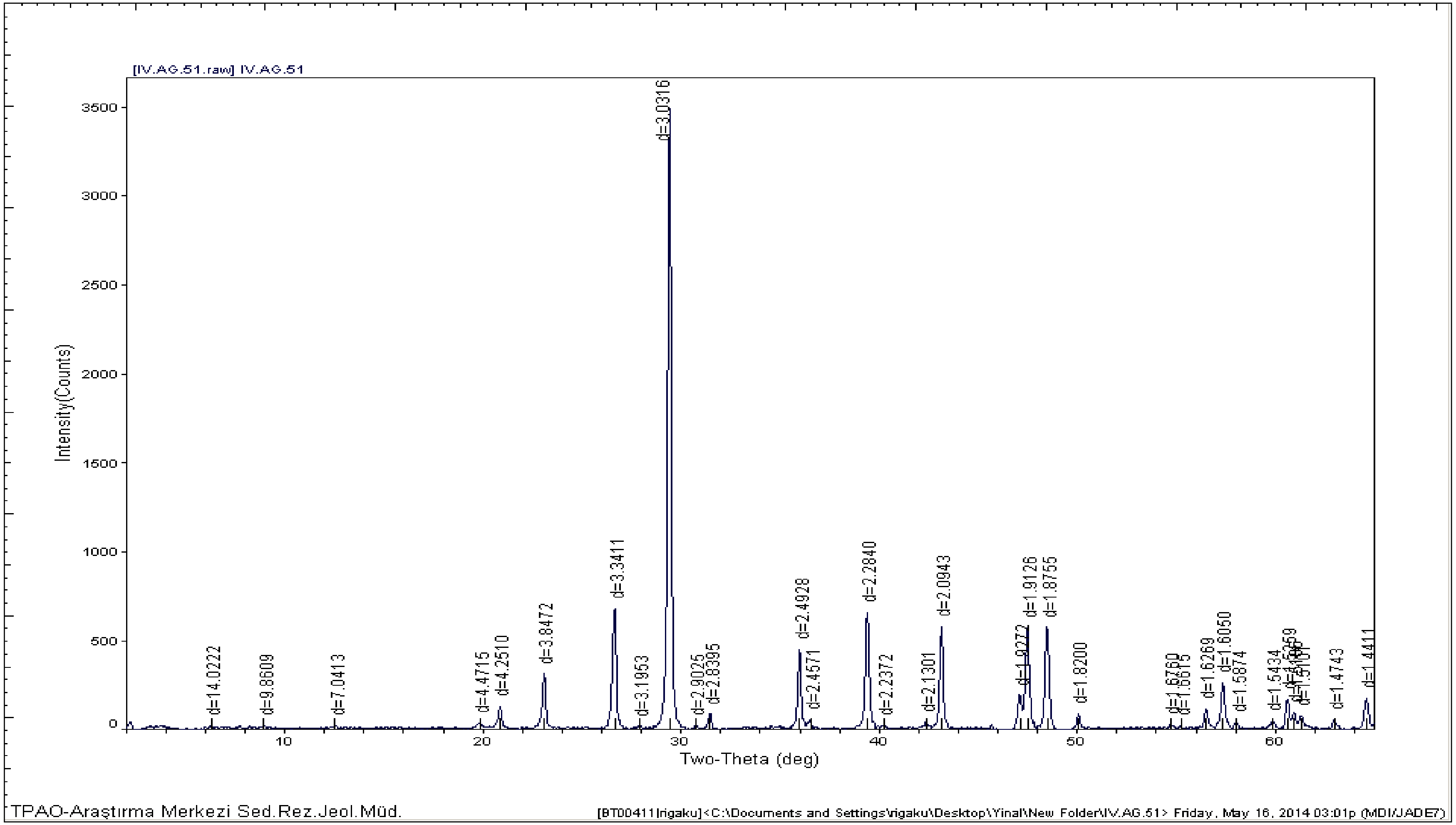


Figure 160. Bulk rock XRD diffractogram for Sample 51 of the Erfelek 1 Section.

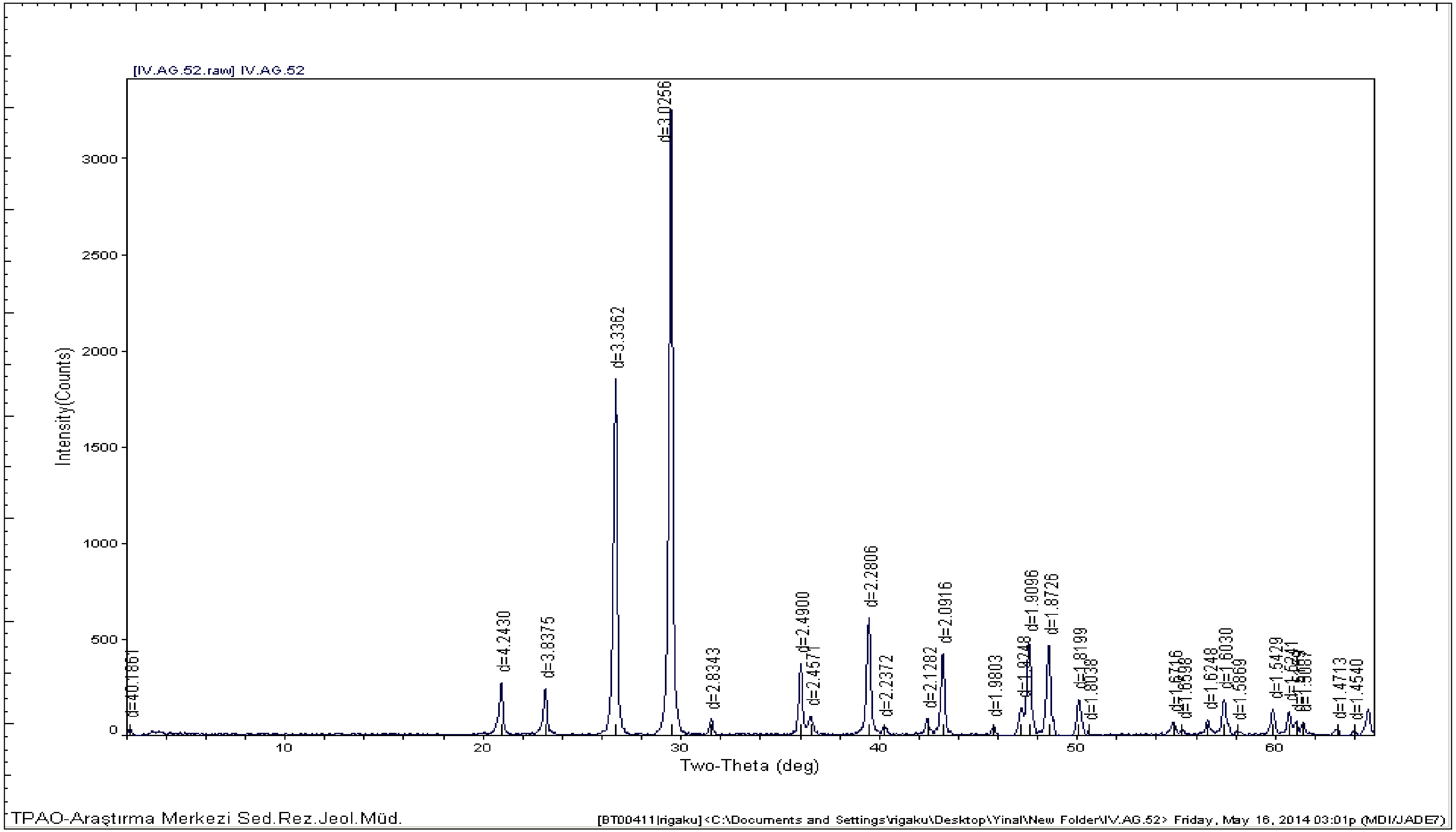


Figure 161. Bulk rock XRD diffractogram for Sample 52 of the Erfelek 1 Section.

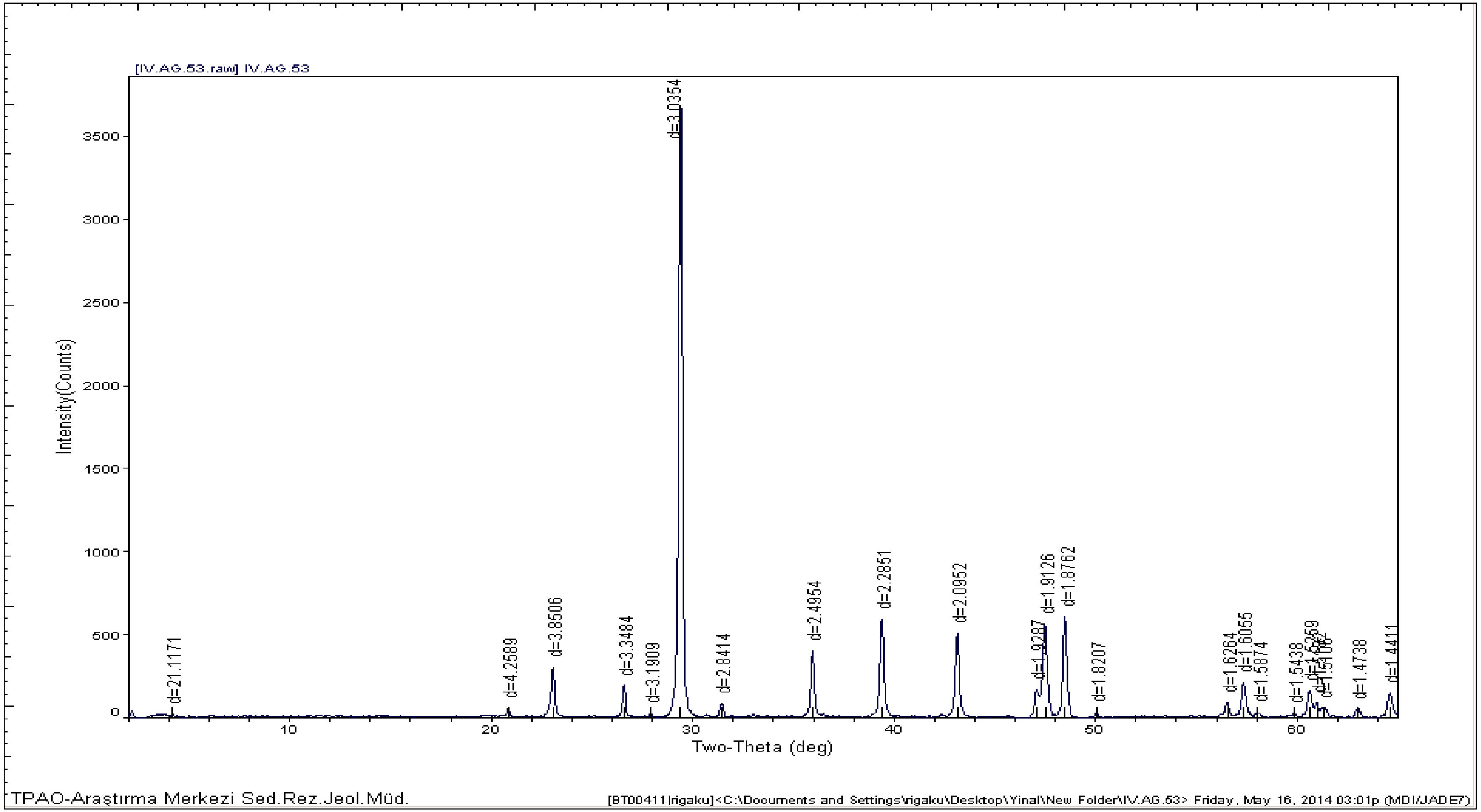


Figure 162. Bulk rock XRD diffractogram for Sample 53 of the Erfelek 1 Section.

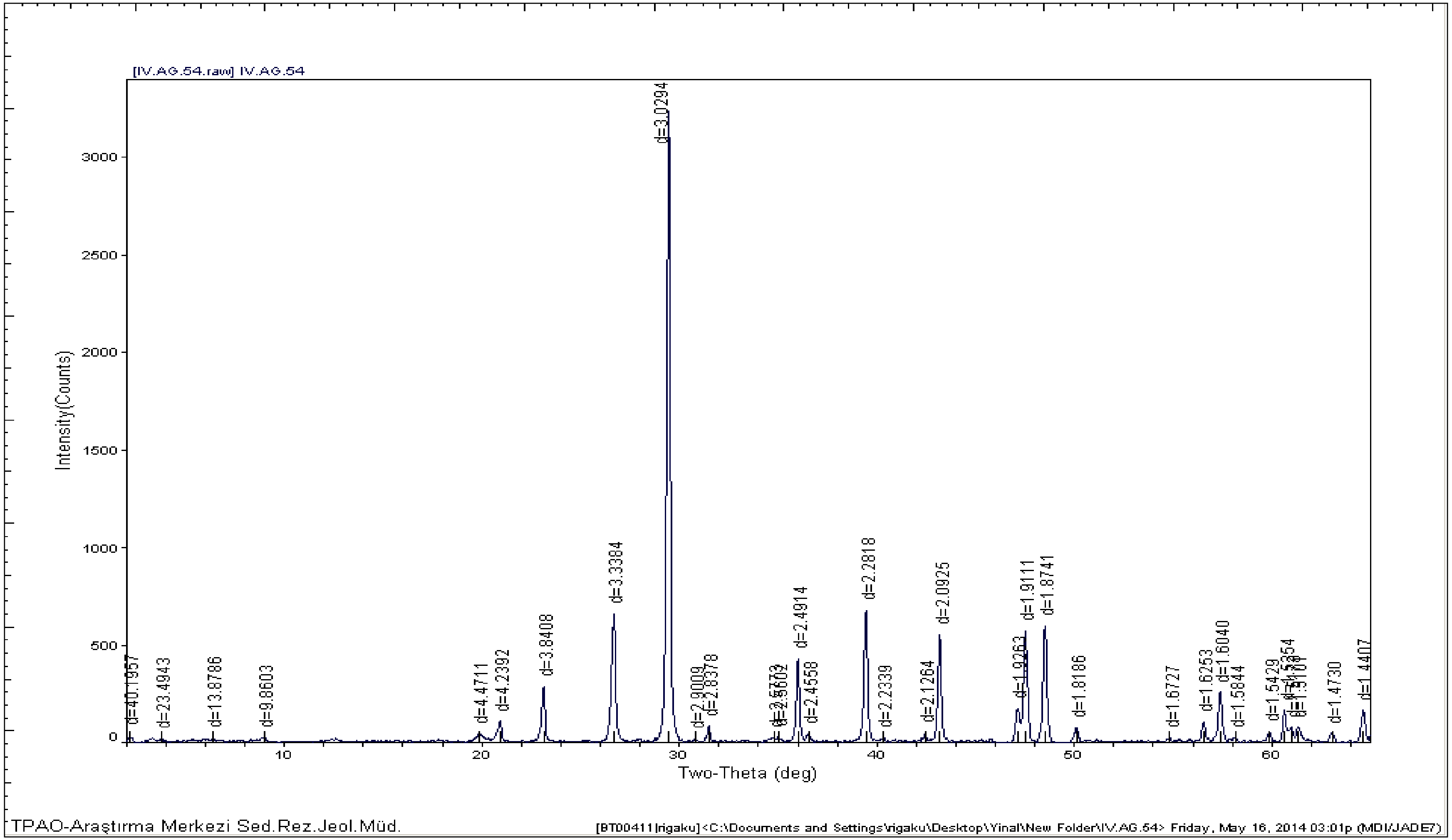


Figure 163. Bulk rock XRD diffractogram for Sample 54 of the Erfelek 1 Section.

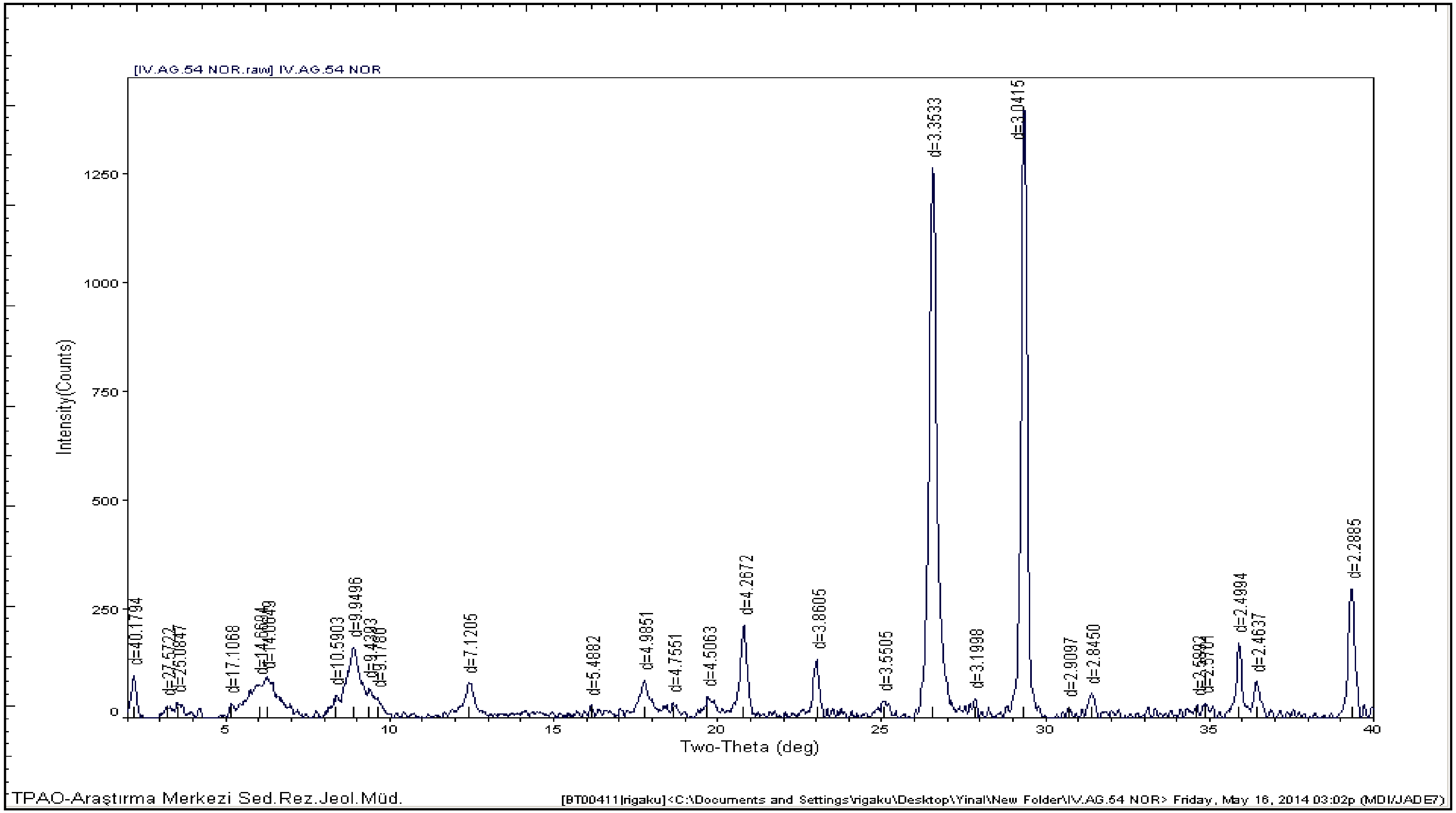


Figure 164. Clay mineral (air dried) XRD diffractogram for Sample 54 of the Erfelek 1 Section.

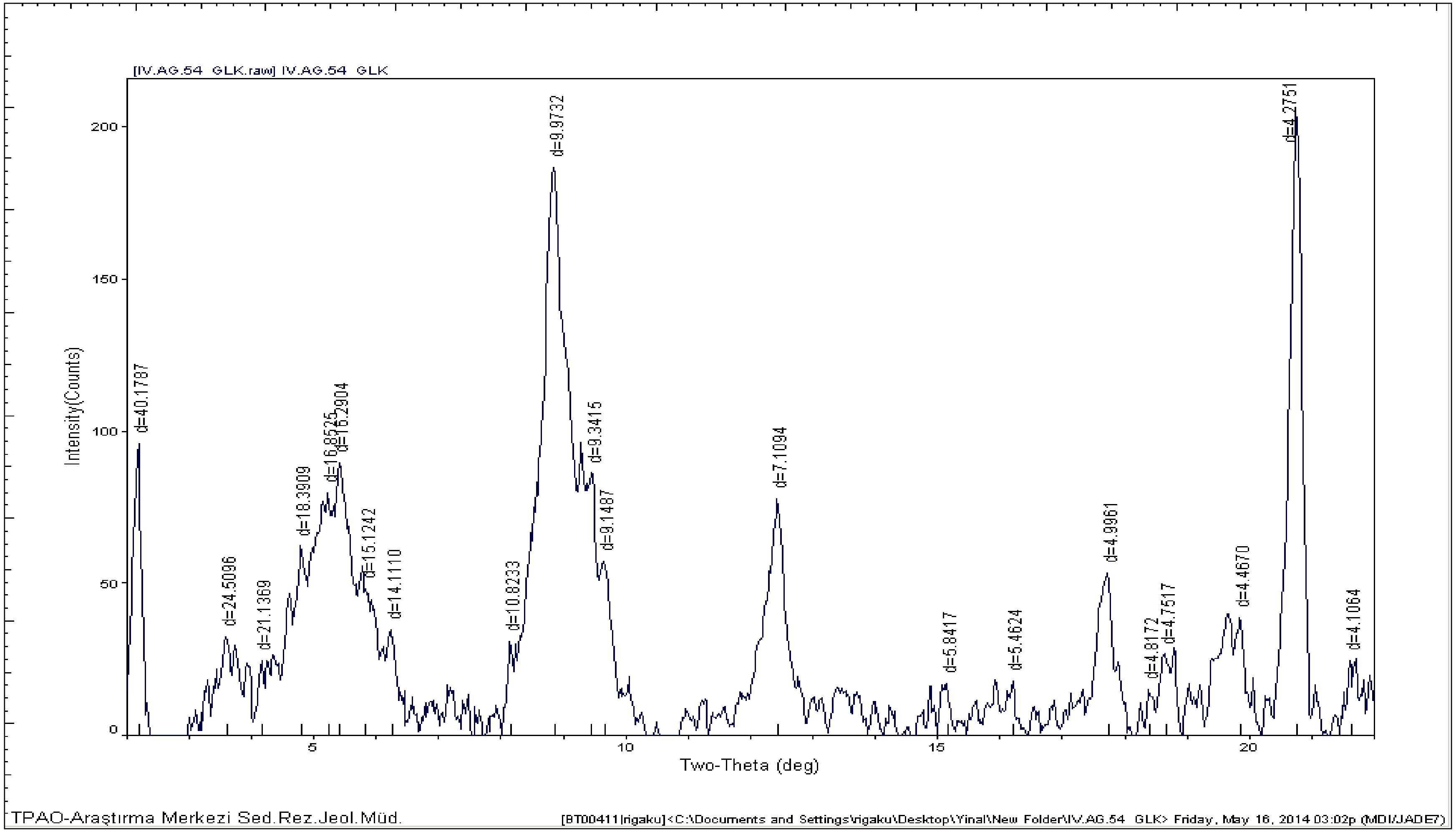


Figure 165. Clay mineral (ethylene glycol) XRD diffractogram for Sample 54 of the Erfelek 1 Section.

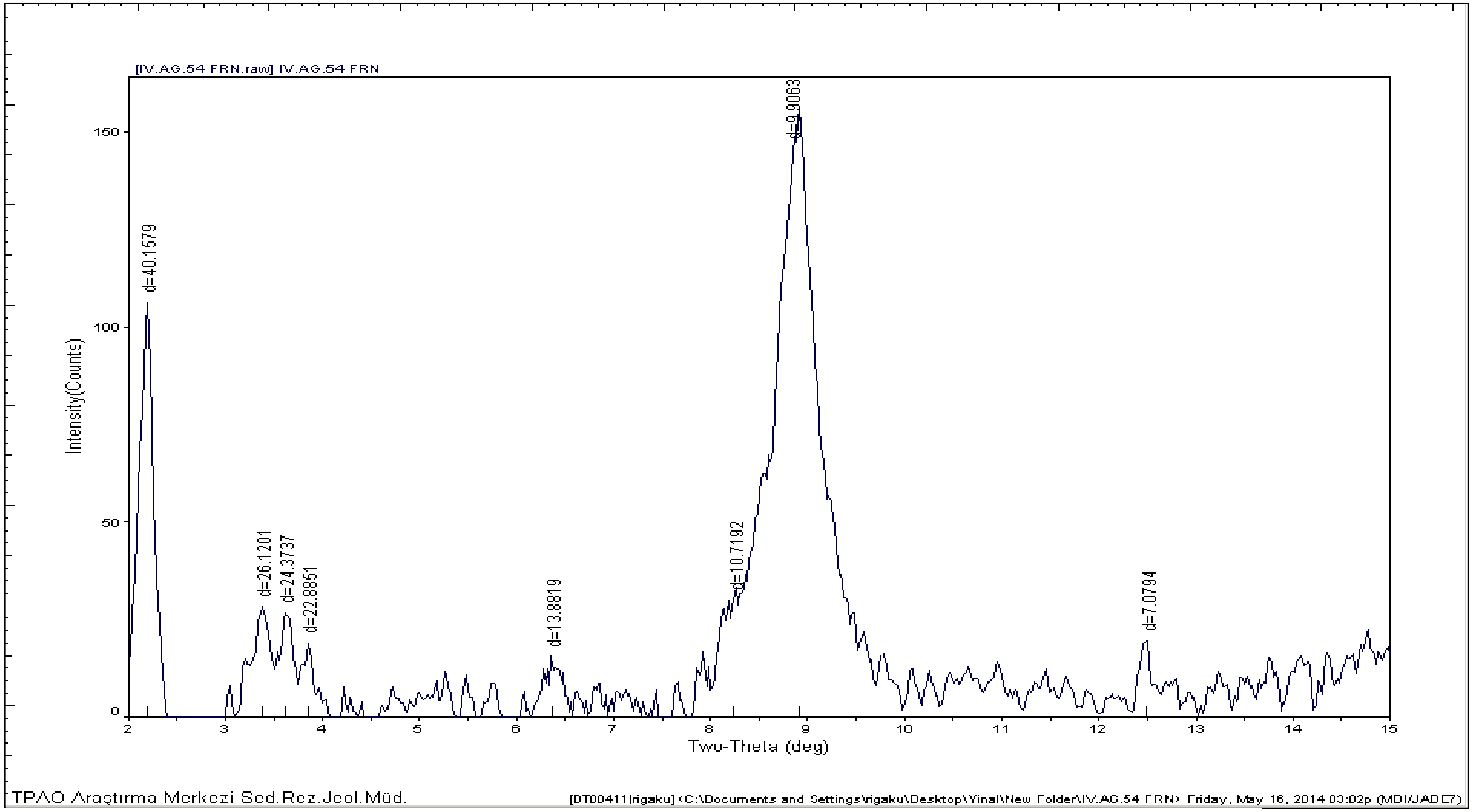


Figure 166. Clay mineral (heated) XRD diffractogram for Sample 54 of the Erfelek 1 Section.

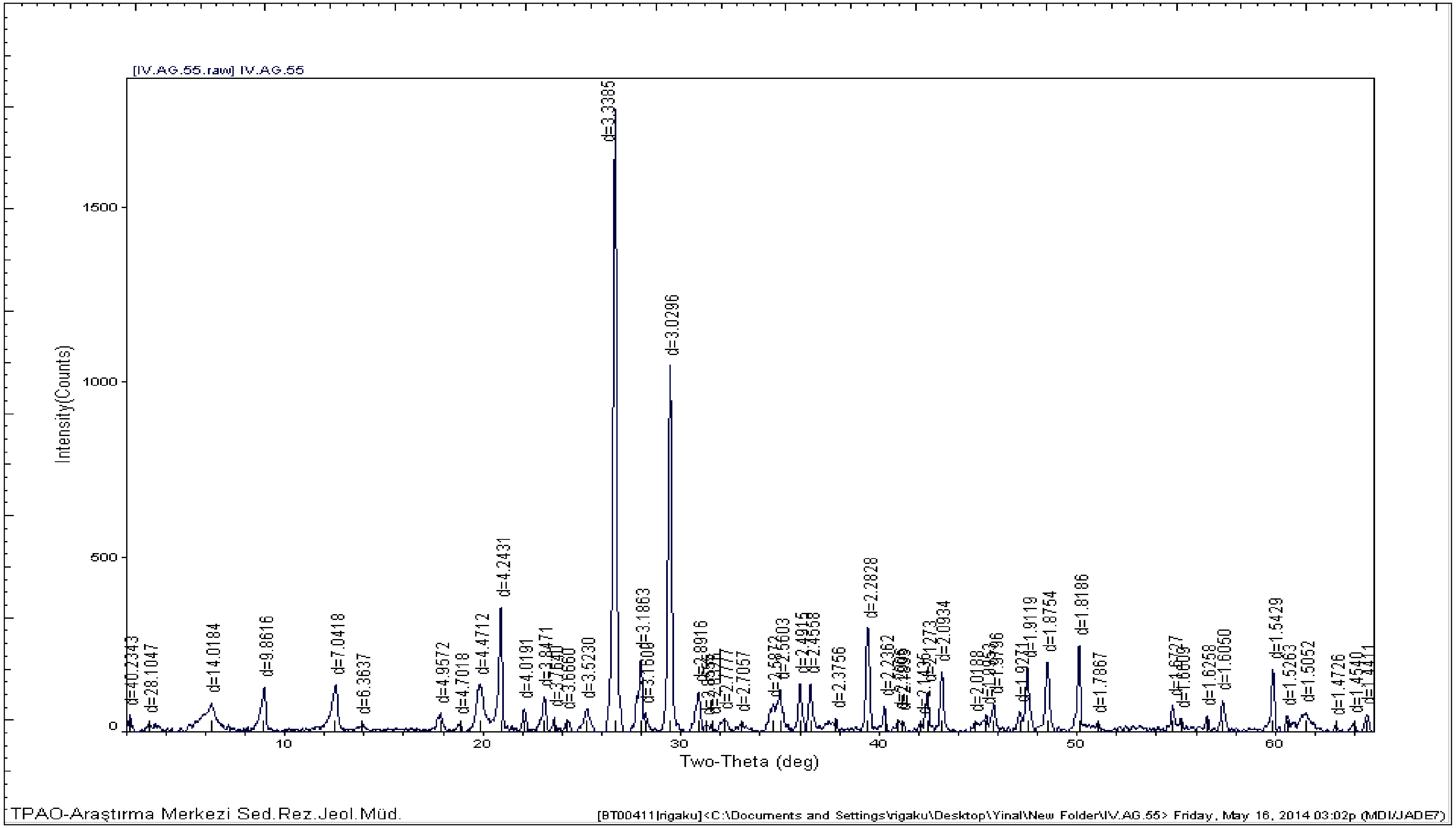


Figure 167. Bulk rock XRD diffractogram for Sample 55 of the Erfelek 1 Section.

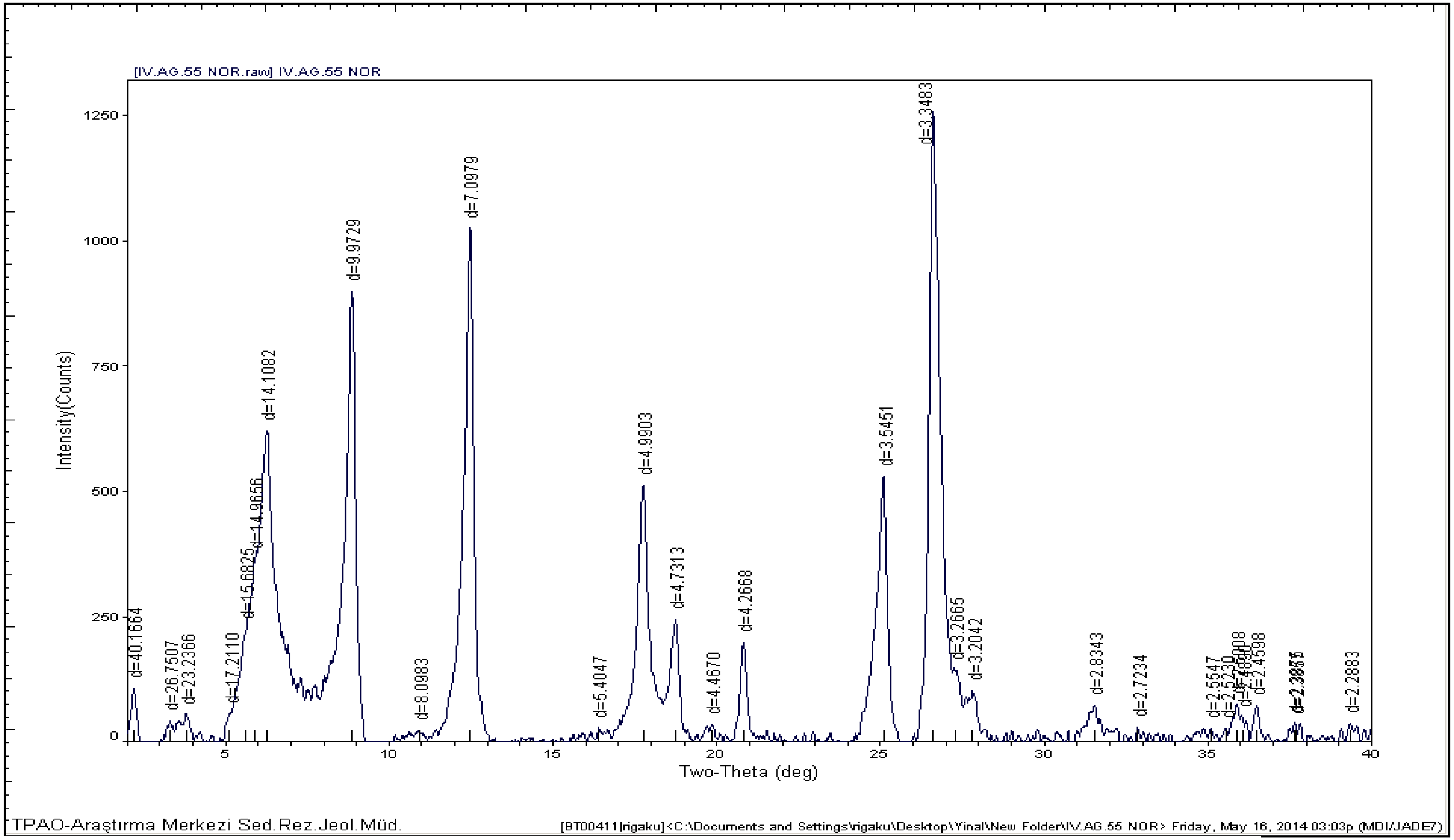


Figure 168. Bulk rock XRD diffractogram for Sample 55 of the Erfelek 1 Section.

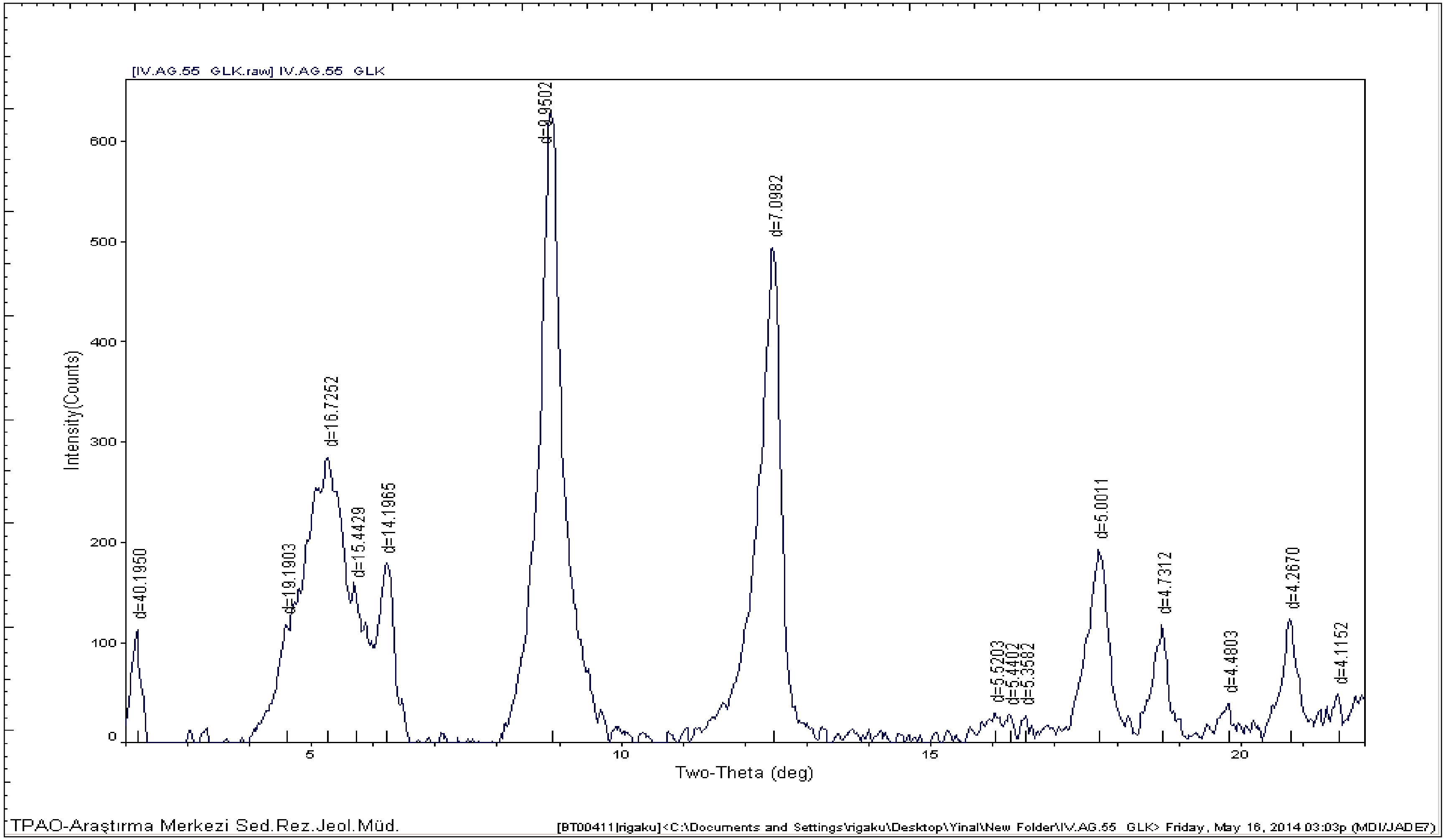


Figure 169. Clay mineral (air dried) XRD diffractogram for Sample 55 of the Erfelek 1 Section.

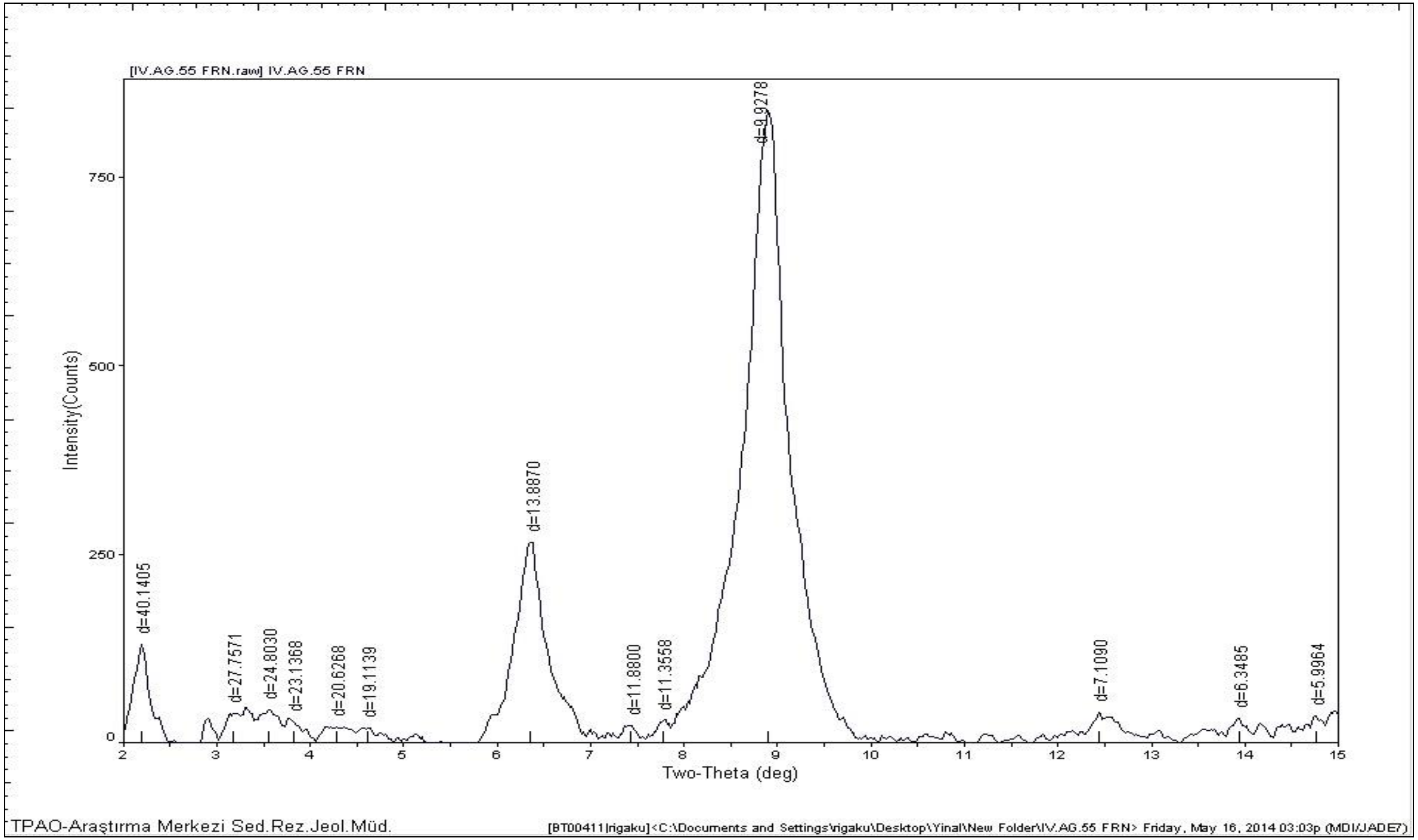


Figure 170. Clay mineral (ethylene glycol) XRD diffractogram for Sample 55 of the Erfelek 1 Section.

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: GÜRAY, Alev

Nationality: Turkish (TC)

Date and Place of Birth: 1 February 1981, Ankara

Phone: +90 (312) 207 25 52

Email: alevg@tpao.gov.tr

EDUCATION

2006 Middle East Technical University

Geological Engineering Department

Ms. in Micropaleontology

Thesis Supervisor: Assoc. Prof. Dr. Sevinç ÖZKAN ALTINER

Thesis Title: Campanian-Maastrichtian planktonic foraminiferal investigation and biostratigraphy (Kokaksu section, Bartin, NW Anatolia): Remarks on the Cretaceous paleoceanography based on quantitative data

2003 Middle East Technical University

Geological Engineering Department (B.S)

1998 Özel Arı Fen Lisesi, Ankara

WORK EXPERIENCE

2007 – Present Geological Engineer

TPAO Research Center, Stratigraphy Department

2004 – 2005 Research student in METU for TUBITAK project

Project Supervisor: Assist. Prof. Dr. İ. Ömer Yılmaz

Project name: YDABÇAG - 104Y010 and IGCP Project No. 494 (Sedimentological, micropaleontological and geochemical records of global oceanic anoxic and oxic events in the lower Cretaceous (Aptian-

Albian) and upper Cretaceous (Cenomanian-Turonian) sedimentary successions (NW, SW, and NW Turkey)

Summer 2002 Intern engineering student at MTA

Summer 2001 Intern engineering student at TPAO

FOREIGN LANGUAGES: English (Fluent)

COMPUTER SKILLS: Microsoft Office, Corel Draw, Freehand, Photoshop, Stratabugs

ORAL PRESENTATIONS

1. **GÜRAY A.,** ÖZKAN-ALTINER S., Sayısal veriye dayalı Kampaniyen-Maastrihtiyen Paleoşinografisi (Kokaksu Kesiti, Bartın, KB Anadolu): Planktonik foraminifer biyostratigrafisi üzerine notlar (Campanian-Maastrichtian paleoceanography based on quantitative data (Kokaksu Section, Bartın, NW Anatolia): Remarks on the planktonic foraminiferal biostratigraphy). 60. Türkiye Jeoloji Kurultayı, 16-22 April 2007, Ankara. Abstracts (2007), p. 412.
2. **GÜRAY A.,** TEYMUR PİNÇE S., IŞIK U., SANCAY R.H., Messiniyen Tuzluluk Krizi (Messinian Salinity Crisis). 8. Paleontoloji – Stratigrafi Çalıştayı. 2007, Çanakkale.
3. **GÜRAY A.,** ÖZKAN-ALTINER S., Üst Kretase Planktonik Foraminifer Biyostratigrafisi ve Kampaniyen-Maastrihtiyen Sınırının Belirlenmesi (Kokaksu Kesiti, Bartın, Batı Karadeniz Bölgesi). Stratigrafi komitesi 7.çalişţayi; Türkiye'de kat siniri çalişmalari, 22-23 November 2007, Ankara. Abstracts.
4. **GÜRAY A.,** ÖZKAN-ALTINER S., Campanian-Maastrichtian planktonic foraminiferal biostratigraphy and evaluation of quantitative data (Kokaksu Section, Bartın, NW Anatolia). 8th International Symposium on the Cretaceous System. 6-12 September 2009, Plymouth, İngiltere.
5. SHIKHLINSKY, S., BATI, Z., GÜRGEY, A., **GÜRAY A.,** ALAYGUT, D., AKÇA, N., SANCAY, R.H., Karadeniz Eosen çökellerinin değerlendirilmesinde yeni bulgular ve planktik foraminifer topluluklarinin stratigrafik özellikleri. 10. Paleontoloji – Stratigrafi Çalıştayı. 2009, Kemaliye-Erzincan.
6. **GÜRAY A.,** ÖZKAN-ALTINER, S., ATAKUL ÖZDEMİR, A., Multivariate analyses of the Campanian-Maastrichtian planktonic foraminiferal assemblages of Kokaksu Section (Bartın, NW Turkey). 9th International Symposium on the Cretaceous System. 1-5 September 2013, Ankara, Turkey.

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1. **GÜRAY A.,** ÖZKAN-ALTINER S., YILMAZ İ.Ö., Uppermost Cretaceous biozonation in the Bartın region, NW Anatolia, Turkey: remarks on the abundance and diversity of

planktonic foraminifera. *"International Earth Sciences Colloqium on the Aegean Regions, IESCA 2005, 4-7 October 2005, İzmir "*, Abstracts, (2005), p.45.

2. SHIKHLINSKY, S., BATI, Z., SANCAY, R.H., GÜRGEY, A., ÇAPTUĞ, A., ALAYGUT, D., AKÇA, N., **GÜRAY, A.,** İZTAN, Y.H., TEKIN, T., 2009. D. Anadolu, Karadeniz ve Kafkas Maykop Çökellerinin Stratigrafik Korelasyonu. 17. Türkiye Uluslararası Petrol ve Doğalgaz Kongresi (The 17th International Petroleum and Natural Gas Congress and Exhibition), 13-15 Mayıs 2009. Ankara.

3. GÜL, M.A., KIRICI., S., TÜRESİN, F.M., ÇETİN ARIKAN, G., GÜZEL, A., ALTINSOY, B., GENİŞ A.E., **GÜRAY, A.**, 2014. Mardin-Mazıdağı-Derik yörelerinde Mesozoyik yaşlı birimlerin litostratigrafisi ve fasiyes özellikleri (Lithostratigraphy and facies characteristics of the Mesozoic units in Mardın-Mazidağı and Derik Region). 67. Türkiye Jeoloji Kurultayı, 14-18 April 2014, Ankara.

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1. SHIKHLINSKY S., BATI Z., ALAYGUT D., GÜRGEY A., **GÜRAY A.,** AKÇA N., SANCAY R.H., Karadeniz kara ve deniz alanları Eosen çökelleri planktik foraminifer topluluklarının biyostratigrafik özellikleri. 17. Türkiye Uluslararası Petrol ve Doğalgaz Kongresi (The 17th International Petroleum and Natural Gas Congress and Exhibition), 13-15 Mayıs 2009. Ankara.