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Upper Cretaceous-middle Eocene aged olistrostromal pelagic units in the Biga Peninsula (NW Anatolia); Balıkkaya formation

Serdar AKGÜNDÜZ[a*] and İzver ÖZKAR ÖNGEN[a]

[a]*İstanbul University-Cerrahpaşa, Faculty of Engineering, Department of Geological Engineering, İstanbul, Turkey*

Research Article

Keywords:
Balıkkaya formation, Biga Peninsula, Pelagic foraminifera, Late Cretaceous-middle Eocene, Extensional tectonic regime.

ABSTRACT

Balıkkaya formation consists of olistostromal units with a burgundy coloured mudstone, siltstone and pelagic limestone matrix containing various sizes of UpperJurassic-Lower Cretaceous limestone (Bilecik Limestone) blocks and Triassic Karakaya Complex blocks, which crop out in the west, south and southwest of Biga Town in Biga Peninsula (NW Anatolia). The matrix of Balıkkaya formation, of which age and sedimentary environment are controversial, contains Late Cretaceous (Maastrichtian) Abathomphalus mayaroensis (Bolli), *Abathomphalus* sp., *Rosita fornicata* (Plummer), Globotruncanidae, early Paleocene (Danian) Morozovella pseudobulloides (Plummer), late Paleocene (Thanetian) *Morozovella velascoensis* (Bolli), early Eocene *Acarinina pentacamarata* (Subbotina), middle Eocene *Turborotalia frontosa* (Subbotina), *Turborotalia cerroazulensis* (Cole), *Orbulinoides beckmanni* (Saito), *Hantkenina* sp. pelagic foraminifera and Radiolariafossils representing the deep marine environment. These paleontological, lithological and sedimentological data obtained from Balıkkaya formation show that Balıkkaya formation developed in a deep marine environment under tectonic control starting from Late Cretaceous and ending in early-middle Eocene. This pelagic unit indicates the presence of a extensional tectonic regime on the Biga Peninsula and the fault activity along the southeastern edge of the Thrace Basin in the Late Cretaceous-Middle Eocene time interval.

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1. Introduction

The term olistostrom was first used by Flores (1955) to describe heterogeneous sedimentary deposits composed of blocks in a matrix fabric. Blocks in these chaotic units are called olistoliths. The blocky levels in the olistostromes can be found as interlayers with the normal stratified levels of a sedimentary sequence. Olistostromes are the geological masses that have a critical role in the study of old orogenic belts, subduction zones and multi-phase deformation events. Olistostromes, which provide excellent markers for tectonic and climatic events, can be effectively used for basin analysis and modeling (Festa et al., 2016).

The area of investigation is located in Biga Peninsula (NW Anatolia), in the South-Southwest of Biga District. Biga Peninsula is the only area where Balıkkaya formation consisting of late Mesozoic - early Cenozoic olistostromal sedimentary units crops out (Figure 1-2). There is no study indicating the existence of a similar unit in the vicinity of Biga Peninsula. There are only a few studies on the age of Balıkkaya formation, the environmental conditions in

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**Corresponding author: Serdar AKGÜNDÜZ, serdar.akgunduz@istanbul.edu.tr*

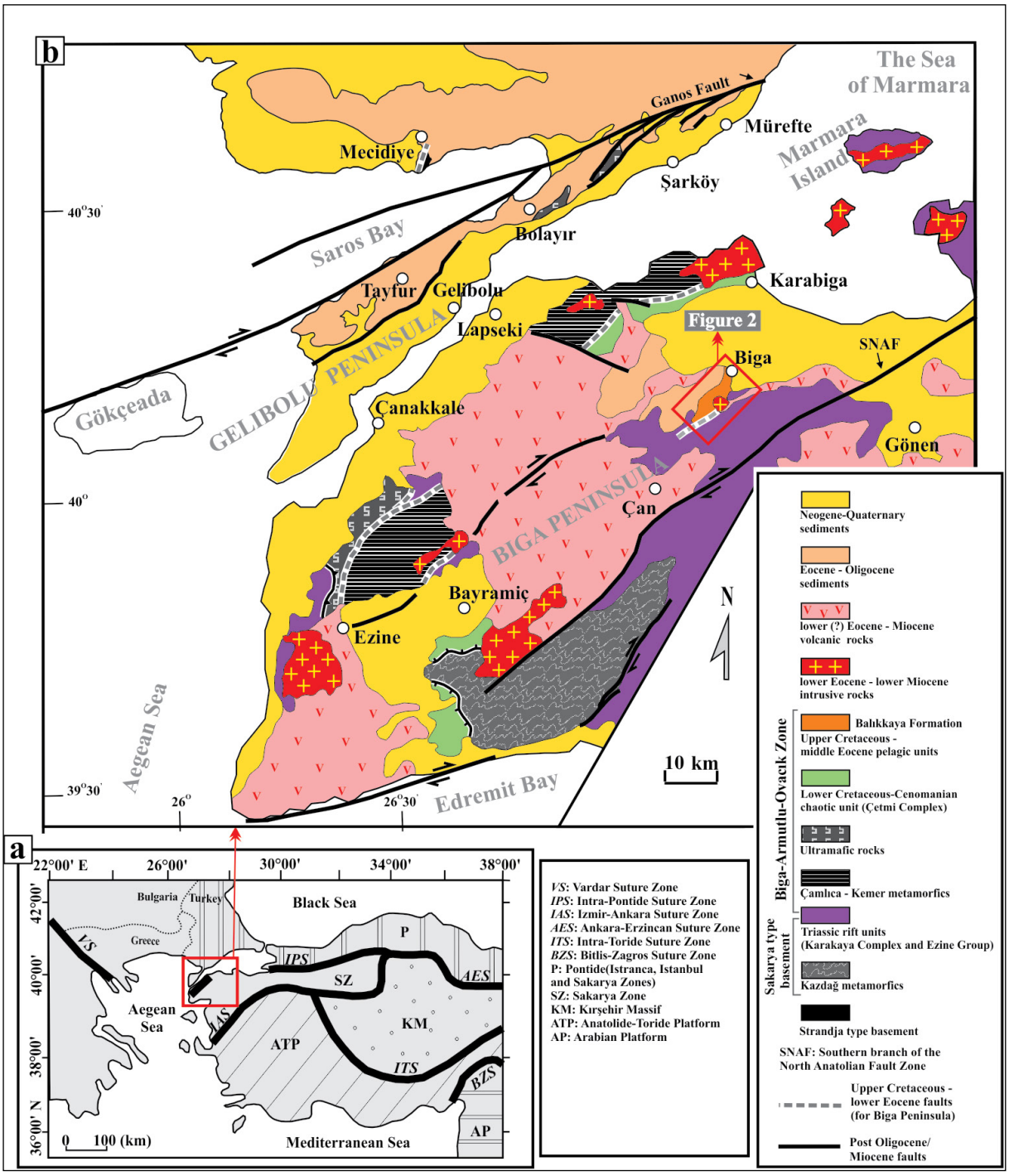

Figure 1- (a) Major tectonic units and suture zones of Turkey and its vicinity (Altunkaynak and Genç, 2007; Genç, 2004; Elmas, 2012; Karacık et al., 2008; Yılmaz et al., 2001) (b) generalized geological map in the Biga and Gelibolu Peninsulas (modified from Elmas, 2012 and Gürer et al., 2016).

which it developed and on its stratigraphy; these are limited to only two studies carried out by Yıkılmaz et al. (2002) and Atabey and Erdoğan (2003), and contain results that contradict each other. The formation was first named by Yıkılmaz et al. (2002) as Balıkkaya formation and presented as a Palaeocene-aged pelagic unit. As for Atabey and Erdoğan (2003), they indicated that there is no such a unit that can be called as a formation in this region, and the blocked units in this region that crop out only contains fossils pertaining to Late Cretaceous, and suggested that the existence of Balıkkaya formation is controversial. Although

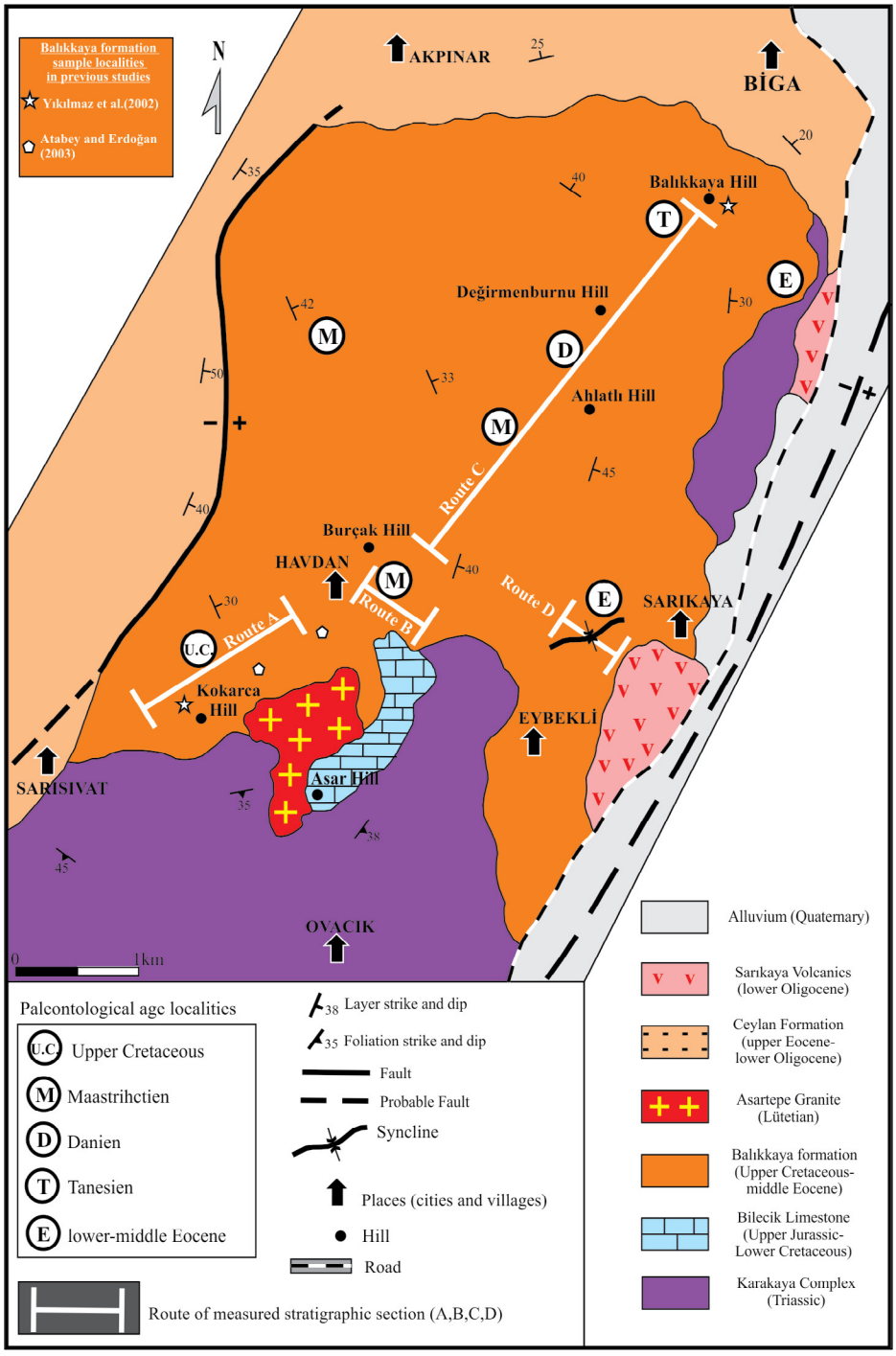

Figure 2- The geologic map of the Biga town and its surrounding area.

Yıkılmaz et al. (2002) indicate the unit is exposed in an area of 2km^2 and has a thickness over 100m, Atabey and Erdoğan (2003) suggest that there is not an outcrop as such for his formation. Besides, Atabey and Erdoğan (2003) have not provided a type locality and a type section for this unit. In this study, the name of Balıkkaya formation is used for this olistostromal unit that crops out in the South-Southwest of Biga district, in dedication to Balıkkaya Hill where the unit is best exposed.

The Biga Peninsula, where the Balıkkaya formation is exposed, is located on the junction of different continental fragments (Rhodope-Istranca

and Sakarya fragments) (Figure 1). Therefore, these olistosromal sediments are of critical importance to learn about the orogenic history of the region, the tectonic regime affecting the region and the expansion of the Thrace basin.

Within the scope of this study, for the purpose of clarifying the controversial age and sedimentary environment of Balıkkaya formation, the relationship between the surrounding units and contact was examined, measured stratigraphic sections were taken through four different routes (Figure 2), and new paleontological and stratigraphic data were obtained by collecting rock samples from matrix sections along the whole thickness in a way that they represent each section of Balıkkaya formation both laterally and vertically. The geological time interval and environmental conditions in which the unit developed were determined in the light of paleontological and stratigraphic data obtained from Balıkkaya formation.

2. Geology of Study Area

In Turkey, six main tectonic units are distinguished that are separated by different oceans (Figure 1a). These Istranca, İstanbul and Sakarya Zones, Anatolide-Tauride Platform and Arabian Platform (Şengör and Yılmaz, 1981; Şengör, 1982; Okay et al., 1994; Okay and Tüysüz, 1999). Istranca, İstanbul and Sakarya Zones that are located in the northern part of Turkey are collectively named as Pontides and are of Laurasia origin (Şengör and Yılmaz, 1981). Biga Peninsula are situated in the western most part of the Sakarya Zone, and limited from northwest with İstanbul, Rodop-Istranca zones and Thrace Basin along the Intra-Pontide Zone (Şengör and Yılmaz, 1981; Okay and Tüysüz, 1999; Bayrak et al., 2004; 2006). Pre-Cenozoic basic units in Biga Peninsula where the area of examination is located consist of Kazdağ Metamorphics, Karakaya Complex-Ezine Group, Çamlıca and Kemer metamorphics, Pre-Upper Cretaceous ophiolitic rocks (Denizgören Ophiolites), and Aptian-Cenomanian aged Çetmi Complex (Okay et al., 1991; Elmas, 2012) (Figure 1b).

Late Cretaceous-middle Eocene aged Balıkkaya formation that crops out it the South, Southwest and West of Biga town, sits on the Permo-Triassic aged Karakaya Complex at the bottom (Figure 1b, figure 2). On top, Balıkkaya formation is covered by late Eocene-early Oligocene Ceylan formation, early Oligocene Sarıkaya volcanics (Işıkeli volcanics; Aysal et al., 2011) and Quaternary deposits. Units pertaining to Balıkkaya formation in Asartepe locality in South-southwest of Biga (Figure 2) are cut by Lutetian aged Asartepe Granite (Akgündüz et al., 2012). Balıkkaya formation consists of olistostromal units with a burgundy coloured mudstone, siltstone and pelagic limestone matrix, which containing mainly Late Jurassic-Early Cretaceous aged limestone blocks and less amount belong to Karakaya Complex blocks (Figure 3).

3. Materials and Methods

Samples each weighing ca. 1 kg were collected for paleontological purposes. The samples were first crushed in a porcelain mortar, followed by washing in a sieve with mesh size of 63μ to remove its clay and mud. The samples were then treated with 10% HCl in porcelain vessels for 24 hours. This was followed by washing of the samples with pressurized water and then drying, in an oven set to 200°C. The dried samples were then sieved and size fraction below 500 μm were examined under binocular microscope. Fossils were handpicked, determined and photographed using Scanning Electron Microscope (FE-SEM) in İstanbul University-Cerrahpaşa Engineering Faculty Chemical Engineering Department, Process and Reactor Division Research Laboratory. The fossils were placed in their position on four measured stratigraphic sections, and temporal and spatial interpretations were made.

4. Paleontological Findings

Stratigraphic sections have been measured along four different routes (Figure 2, Route A, B, C, D) from the area where Balıkkaya formation crops out in order to determine the time lapse and environment in which the unit developed (Sarısıvat-Havdan Section, figure 4; Havdan Section, figure 5; Burçak Hill-Balıkkaya Hill Section, figure 6; Sarıkaya Section, figure 7); and rock samples were collected from the matrix of Balıkkaya formation consisting of mudstone, shale, silt stone, sandstone and pelagic limestone lithologies during these section measurements, and then subjected to detailed paleontological examination.

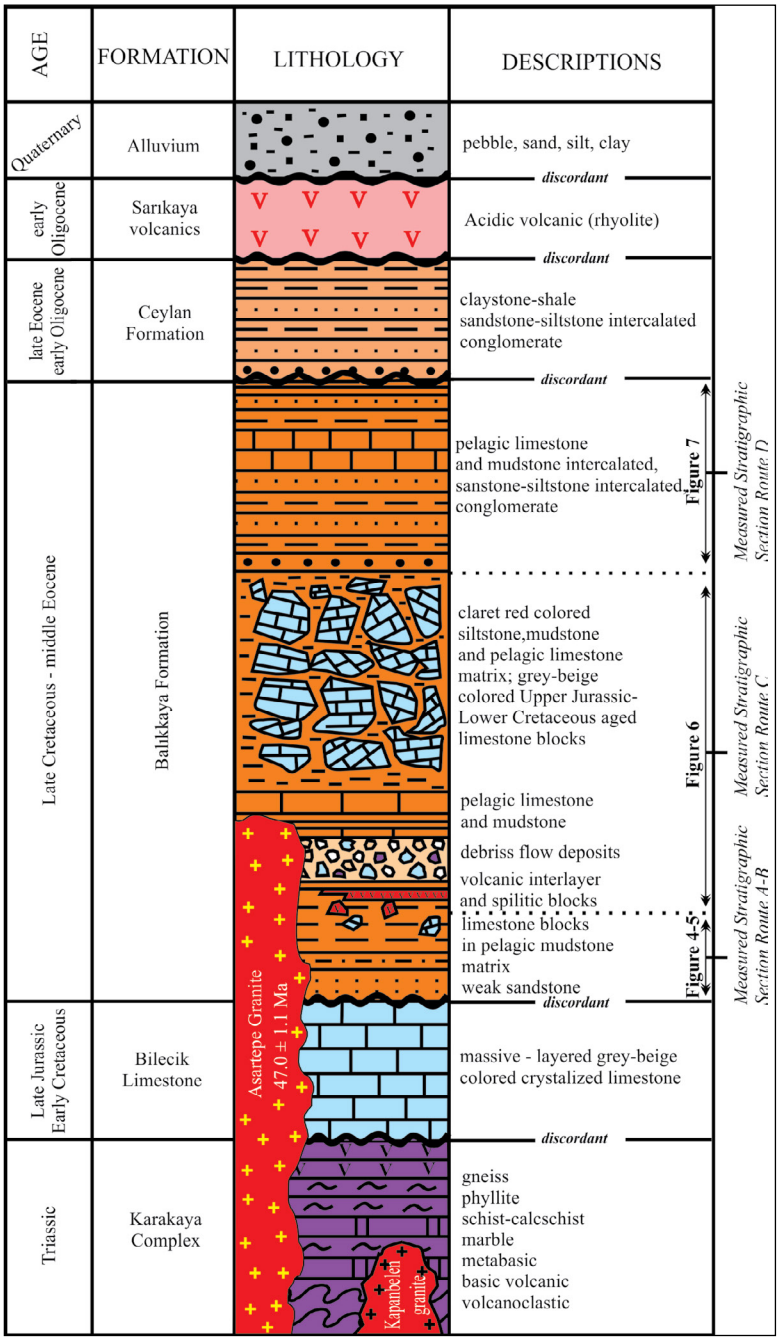

Figure 3- Generalized stratigraphic section of Biga Town and its surrounding area.

4.1. Measured Stratigraphic Sections

4.1.1. Sarisivat - Havdan Section (Route A)

This is the measured stratigraphic section taken from the route that extends from Southwest to Northeast from Sarısıvat village located in the north-northwest of Asar hill in the southwest of Biga district to Havdan village in the North of Asar hill (Figure 2, GPS coordinates: 40°11.090'N / 27°10.514'E - 40°11.817'N / 27°11.825'E). The total thickness of Sarısıvat-Havdan section is 300 metres (Figure 4). Along the route from Sarısıvat village to Havdan village (Route A), Balıkkaya formation consists of burgundy and greenish mudstones – siltstones matrix (Figure 8a) containing Upper Jurassic-Lower Cretaceous limestone blocks and the layers are generally inclined towards the northeast. Along the

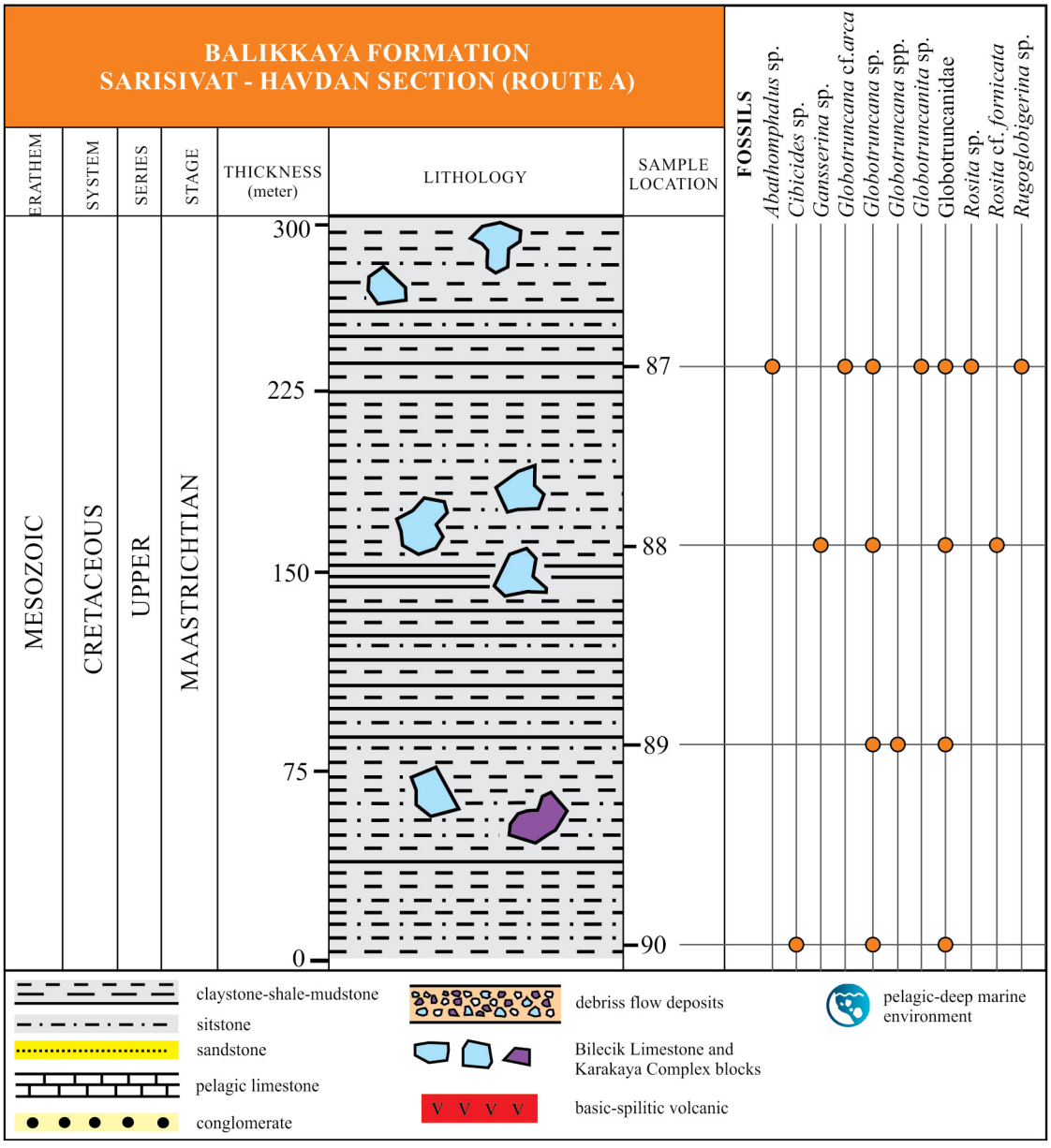

Figure 4- Sarısıvat-Havdan measured stratigraphic section (Route A, see figure 2. GPS coordinates: 40°11.090'N / 27°10.514'E - 40°11.817'N / 27°11.825'E).

section, grain and rock samples from a total of 4 different levels were collected from Balıkkaya formation matrix. Within this section, different planktonic foraminifera species were detected from *Abathomphalus* sp., *Gansserina* sp., *Globotruncana* cf. *arca* (Cushman), *Globotruncana* sp., *Globotruncanita* sp., *Rosita* cf. *fornicata* (Plummer), *Rosita* sp., *Rugoglobigerina* sp., *Cibicides* sp. and Globotruncanidae belonging to Late Cretaceous (Maastrichtian) (Figure 4, Plate I).

Yıkılmaz et al. (2002) indicated that the thin section of a micritic limestone taken from the southwest of Havdan village contain *Planorotalites compresssa* (Plummer), *Planorotalites* sp., *P. Morozovella* sp., *Globoconusa* sp., *Globotruncanita* cf. *stuarti* (d'Lapparent), *Globotruncanita* sp., *Abathomphalus* sp., but stated that the *Globotruncana* species here could have probably been transported.

4.1.2. Havdan Section (Route B)

This is the measured stratigraphic section taken from the route that extends from Southeast to Northwest from the north-northeast of Asartepe

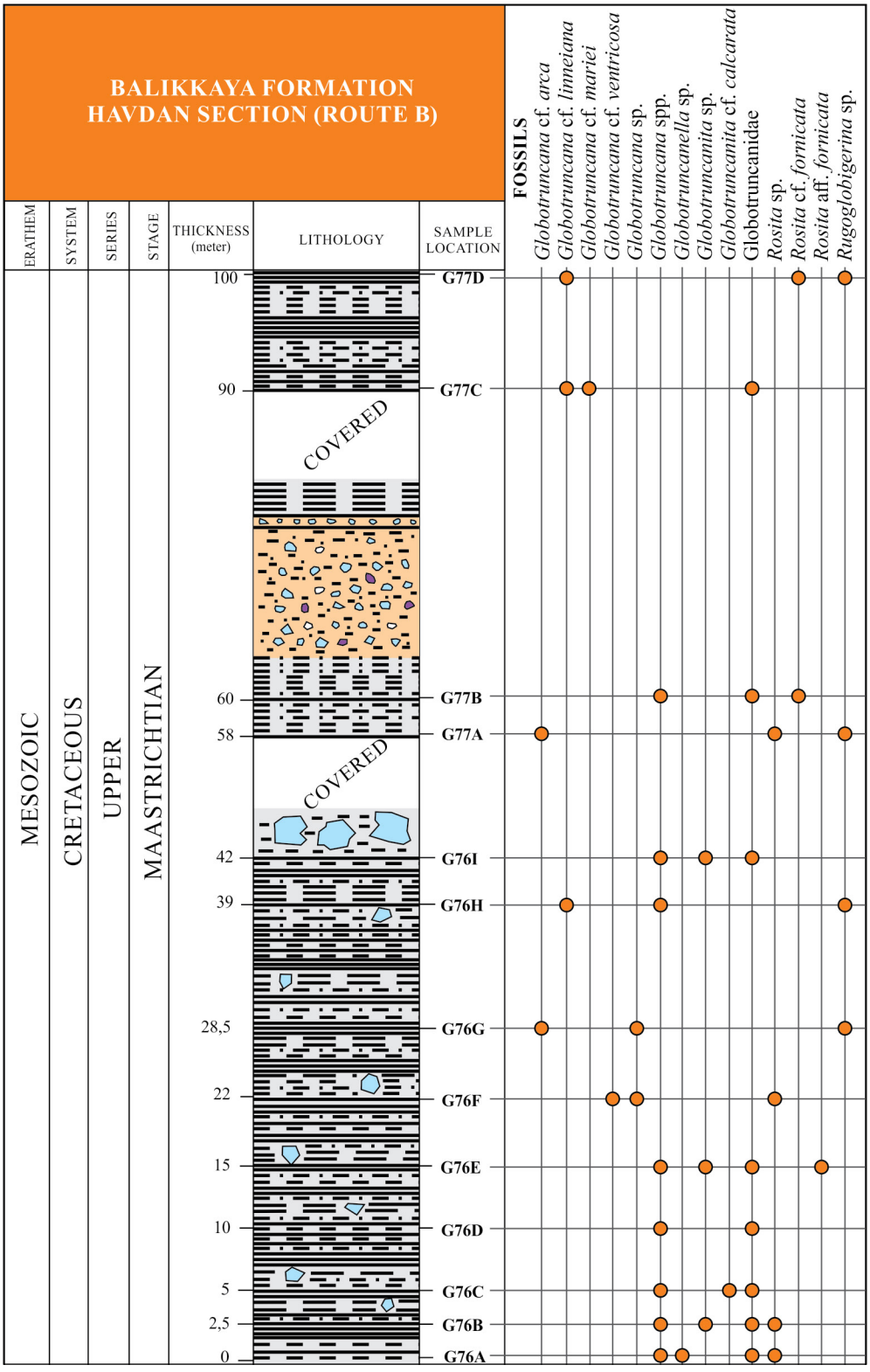

Figure 5- Havdan measured stratigraphic section (Route B, see figure 2. GPS coordinates: 40°11.564'N / 27°12.358'E - 40°11.851'N / 27°12.081'E).

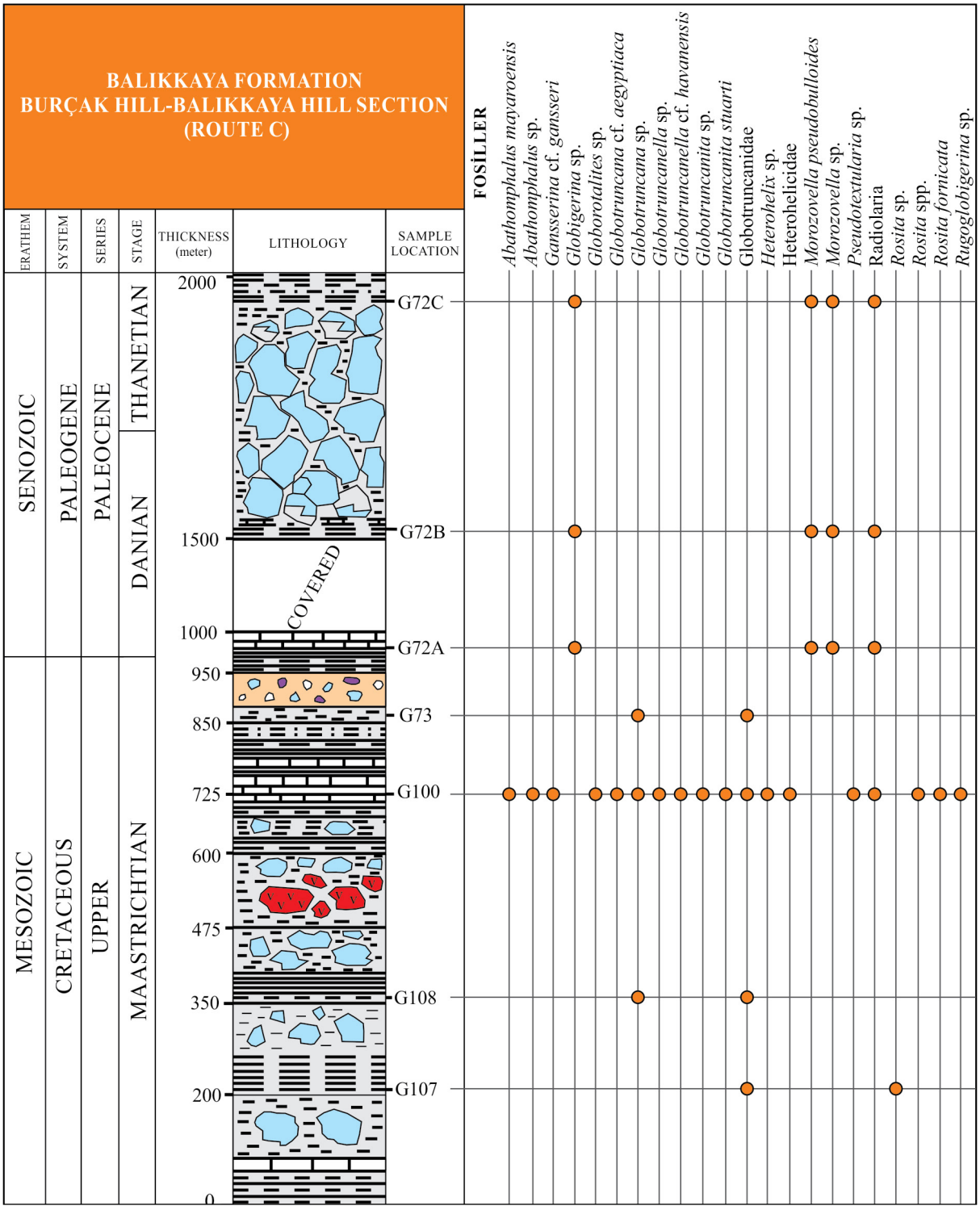

Figure 6- Burçak Hill-Balıkkaya Hill measured stratigraphic section (Route C, see figure 2. GPS coordinates: 40°11.990'N / 27°12.100'E - 40°13.454'N / 27°13.800'E).

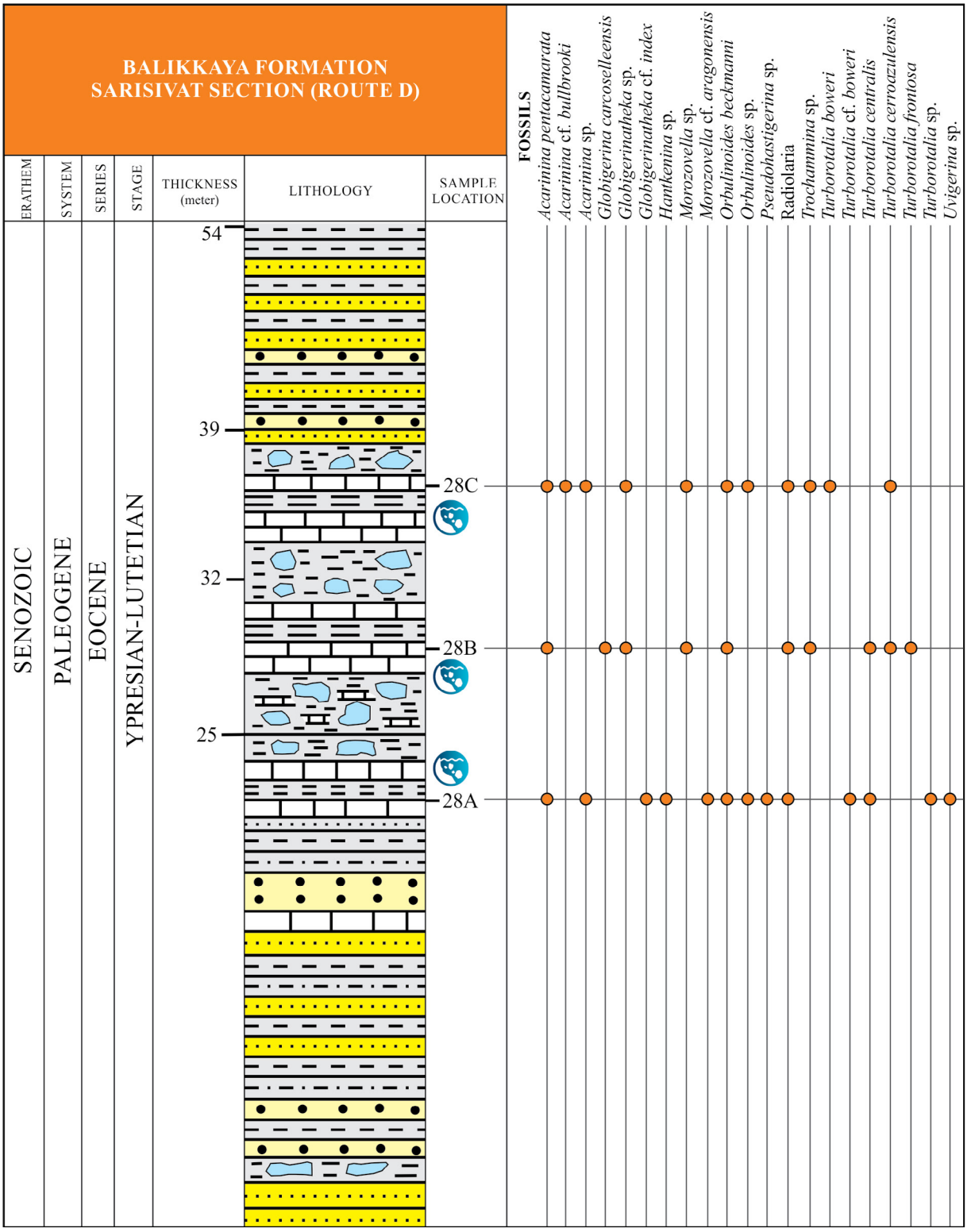

Figure 7- Sarıkaya measured stratigraphic section (Route D, see figure 2. GPS coordinates: 40°11.641'N / 27°13.307'E - 40° 11.658'N / 27° 13.073'E).

Figure 8- Field photographs belonging to different stratigraphic levels of Balıkkaya formation. (a) Pelagic mudstone matrix (North of Kokarca Hill). (b) conglomerate in pelagic matrix (Havdan village). (c) debris flow deposits, volcanic and pelagic mudstone levels (Ahlatlı Hill).

to Havdan village in the Southwest of Biga District (Figure 2, GPS coordinates: 40°11.564'N / 27°12.358'E - 40°11.851'N / 27°12.081'E). The total thickness of Havdan section is 100 metres (Figure 5). In Havdan section, Balıkkaya formation consists mainly of pink-purple coloured mudstone, siltstone, and partly, greenish-gray-coloured siltstones that contains Late Jurassic-Early Cretaceous aged limestone and gravels and blocks from Permo-Triassic aged Karakaya Complex, and rarely of gravelly levels (Figure 8b). The gravels in these gravelly levels consist of gray and burgundy coloured mudstones, gray siltstones, chert, and brown-beige-coloured fine-grained sandstones. Along the section, grain and rock samples were taken from 13 different levels in Balıkkaya formation matrix along the section. This section contains Late Cretaceous aged (Maastrichtian) *Globotruncana* cf. *arca* (Cushman), *Globotruncana* cf. *linneiana* (d Orbıgny), *Globotruncana* cf. *mariei* (Banner ve Blow), *Globotruncana* cf. *ventricosa* (White), *Globotruncana* sp., *Globotruncana* spp., *Globotruncanita* cf. *calcarata* (Cushman), *Globotruncanita* sp., *Globotruncanella* sp., *Rosita*cf. *fornicata* (Plummer), *Rosita* aff. *fornicata* (Plummer), *Rosita* sp. and *Rugoglobigerina* sp. planktonic foraminifera (Figure 5, Plate I).

Atabey and Erdoğan (2003) expressed that the red pelagic limestone samples they collected from the matrix of Balıkkaya formation in the North of Sarısıvat Village, and south and northeast of Havdan Village contain foraminifera with pelagic biofacies of the families *Globotruncana* gr. *linneiana* (d'Orbigny), *Globotruncana arca* (Cushman), *Globotruncanita stuartiformis* (Dalbiez) that are Maastrichtian aged, and *Globotruncanella citae* (Bolli), *Globotruncanella havanensis* (Voorwijk), *Abathomphalus* sp., *Rugoglobigerina rugosa* (Plummer) and Heterohelicidae that are late Maastrichtian aged.

4.1.3. Burçak Hill – Balıkkaya Hill Section (Route C)

This is the measured stratigraphic section taken from the route that extends from southwest to northeast from Burçak Hill in the north-northwest of Havdan Village to Balıkkaya Hill in the Southwest of Biga District (Figure 2, GPS coordinates: 40°11.990'N / 27°12.100'E - 40°13.454'N / 27°13.800'E). The section consists of grayish-beige coloured Jurassic-Cretaceous limestone blocks around Burçak Hill, and light yellowish-beige-coloured mudstones-siltstones and pink-purple coloured mudstones-pelagic limestone. There is a debris flow surface in the vicinity of Ahlatlı Hill (Figure 8c). The samples taken from burgundy coloured mudstones, siltstones and pelagic limestone between Burçak Hill and Ahlatlı Hill contain the Maastrichtian aged *Abathomphalus* sp., *Gansserina* cf. *gansseri* (Bolli), *Globorotalites* sp., *Globotruncana* cf. *aegyptiaca* (Nakkady), *Globotruncana* sp., *Globotruncana* spp., *Globotruncanella* cf. *havanensis* (Voorwijk), *Globotruncanella* sp., *Globotruncanita stuarti* (d Lapparent), *Globotruncanita* sp., Globotruncanidae, *Heterohelix* sp., Heterohelicidae, *Pseudotextularia* sp., *Rosita fornicata* (Plummer), *Rosita* sp., *Rugoglobigerina* sp., *Rugoglobigerina* spp.planktonic foraminifera and Radiolaria fossils (Figure 6, Plate I). Samples taken from pinkish-purple coloured pelagic mudstones, shales and limestone that crop out in the northeast of Ahlatlı hill and the southwest of Değirmenburnu hill contain early Paleocene (Danian) aged *Globigerina* sp., *Morozovella pseudobulloides* (Plummer), *Morozovella* cf. *bulloides* (Plummer), *Morozovella* sp. planktonic foraminifera and Radiolariafossils (Figure 6, Plate II).

In Balıkkaya hill locality, Balıkkaya formation consists of a stratigraphic level that is abundant in blocks. These Upper Jurassic-Lower Cretaceous limestone blocks are united among themselves, bluish grey-grayish beige in colour, grain supported, with variable sizes, rising up to 15-20 metres (Figure 9a-b). Towards the western slope of Balıkkaya hill, the rate of matrix among the blocks increases. The matrix in the position of the binder of the blocks consists of pink-burgundy coloured mudstones-siltstones and limestone (Figure 9c). Burgundy coloured pelagic limestone taken from the vicinity of Balıkkaya hill contains early Paleocene (Danian) aged *Globigerina* sp., *Morozovella pseudobulloides* (Plummer) planktonic foraminifera and Radiolaria (Figure 6, Plate II). Yıkılmaz et al. (2002) indicated that the fine sections of three micritic limestone samples taken from the vicinity of Balıkkaya hill contain *Morozovella pseudobulloides* (Plummer), *M.uncinata* (Bolli), *M.* cf. t*rinidadensis* (Bolli), *Morozovella* sp., *Planorotalites compressa* (Plummer), *Planorotalites* sp. *Globigerina triloculinoides* (Plummer), *Globigerina* sp., *Bolivina* sp. and Radiolaria that give the age of early Paleocene (Danian); again, a micritic limestone sample taken from the vicinity of Balıkkaya hill contains *Morozovella velascoensis* (Bolli), *Planorotalites* sp. and Radiolaria that gives the age of late Paleocene (Thanetian).

4.1.4. Sarıkaya Section (Route D)

This is the measured stratigraphic section taken from the route that extends from Southeast to Northwest from Balıkkaya formation, which crops out in a small area between the west-southwest of Sarıkaya Village and northeast of Eybekli Village (Figure 2, GPS coordinates: 40°11.641'N / 27°13.307'E - 40° 11.658'N / 27° 13.073'E). The total thickness of Sarıkaya Section is 54 metres (Figure 7) and the units in this area makes up a synclinal extending from northeast to southwest (Figure 2). In this section, Balıkkaya formation consists of yellowish beige coloured - middle layered gravel, sandstone-siltstone sequence and burgundy coloured pelagic limestone and mudstones (Figure 9d). These units correspond to the highest levels of Balıkkaya formation stratigraphically.

In Sarıkaya section, grain and rock samples were taken in three different points from burgundy coloured pelagic limestone and mudstones. Grain and rock samples taken contain *Acarinina* cf. *bullbrooki* (Bolli), *Acarinina pentacamarata* (Subbotina), *Acarinina* sp., *Bulumina* sp., *Clavulina* sp., *Cibicides*

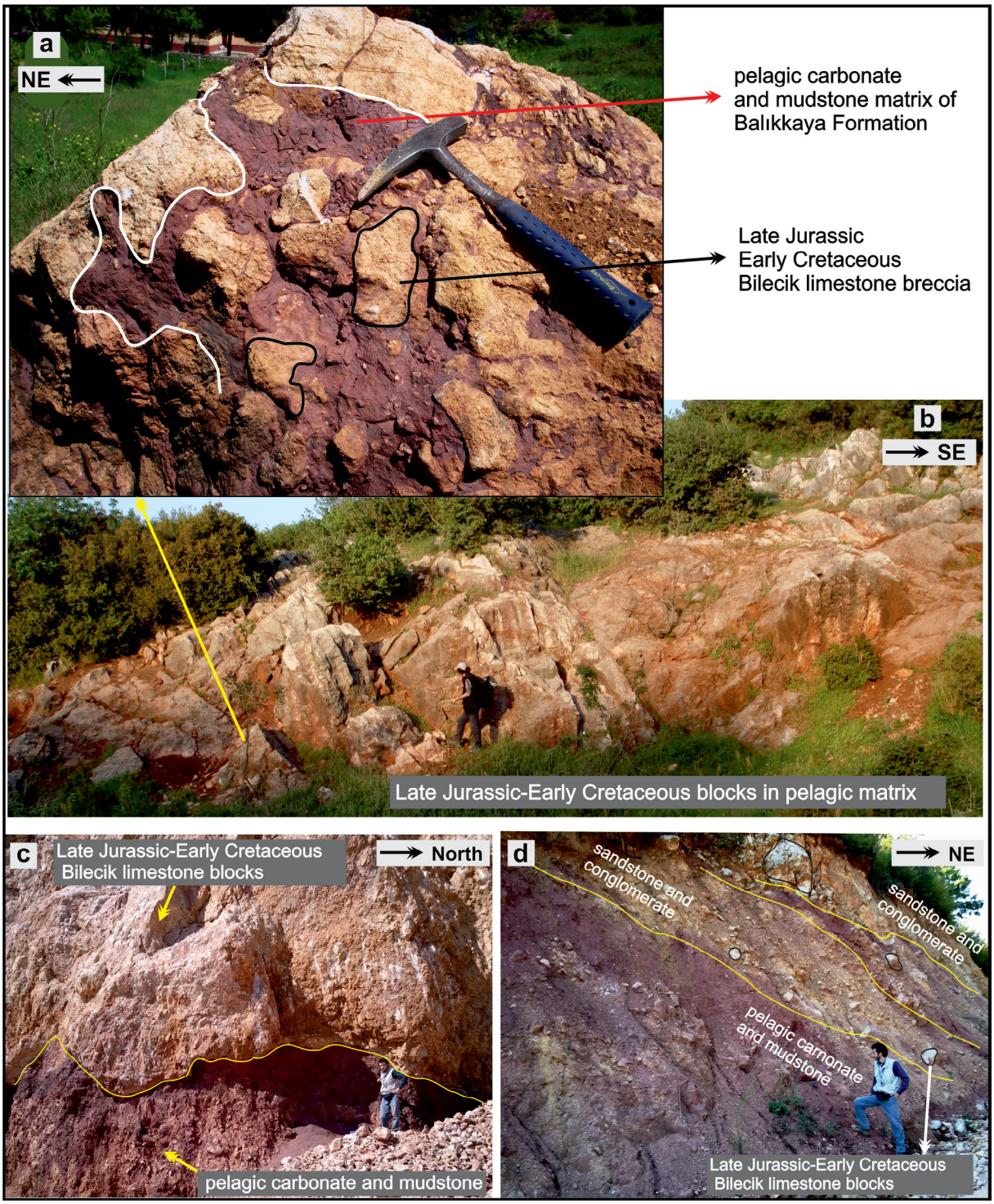

Figure 9- Field photographs belonging to different stratigraphic levels of Balıkkaya formation. (a-b) abundant and large blocky level (Balıkkaya Hill). (c) Bilecik Limestone blocks in pelagic carbonate and mudstone matrix (SW of Balıkkaya Hill). (d) Intercalated of pelagic limestone-mudstone and sandstone-conglomerate (West of Sarıkaya village).

sp., *Dentalina* sp., *Dorothia (Areneblumina)* sp., *Globigerina carcoselleensis* (Toumarkine ve Bolli), *Globigerinatheka* cf. *index* (Finlay), *Globigerinatheka* sp., *Hantkenina* sp., *Lagena* sp., *Morozovella* cf. *aragonensis* (Nutta 2), *Morozovella* sp., *Orbulinoides beckmanni* (Saito), *Orbulinoides* cf. *beckmanni* (Saito), *Orbulinoides* sp., Osanguliridae, *Pseudohastigerina* sp., *Trochammina* sp., *Turborotalia boweri* (Bolli),

Turborotalia cf. *boweri* (Bolli), *Turborotalia frontosa* (Subbotina), *Turborotalia centralis* (Cushman ve Bermudez), *Turborotalia* cf. *cerrazulensis* (Cole), *Turborotalia cerroazulensis* (Cole), *Turborotalia* sp., *Uvigerina* sp. planktonic foraminiferaand Radiolaria fossilsfrom early-middle Eocene (Figure 7, Plate II, Plate III, Plate IV).

5. Discussions

Balıkkaya formation that crops out in the south, southwest and west of Biga town in northwest Anatolia mainly consists of Late Jurassic-Early Cretaceous aged limestone blocks of varying sizes and at a lower degree, units with a burgundy coloured mudstone, siltstone and pelagic limestone matrix, which contain blocks from Karakaya Complex. The formation was first named by Yıkılmaz et al. (2002) as Balıkkaya formation in dedication to the hill that is considered to best outcrop. However, Atabey and Erdoğan (2003) stated that the name of the hill was not Ballıkaya but Balıkkaya and for that reason they used Balıkkaya in parenthesis when they referred to the formation. Similarly, for the formation termed Ballıkaya by Yıkılmaz et al. (2002), the name Balıkkaya was preferred in this study.

Yıkılmaz et al. (2002) gave the age of Balıkkaya formation as Paleocene (Danian-Thanetian) by the foraminifera in pelagic limestone (Table 1). They interpreted the *Globotruncana* forms in these foraminifera as transported from Upper Cretaceous. Atabey and Erdoğan (2003) indicated the age of the unit, of which existence they deem disputable, is late Maastrichtian by the *Globotruncana* forms obtained from burgundy coloured fine layered limestone, and did not encounter any fauna related to the Paleocene (Table 1). Yıkılmaz et al. (2002) gave the Paleocene age they obtained from the study they carried out in accordance with the fossils determined from 1 micritic limestone sample collected from the vicinity of Kokarca Hill and 3 micritic limestone samples from Balıkkaya Hill (Figure 2). In relation to the unit existence of which they find disputable, Atabey and Erdoğan (2003) indicated that the units in question are of Late Cretaceous age according to paleontological data they collected from the vicinity of Havdan and Sarısıvat villages (Figure 2). However, Balıkkaya formation is not solely limited to these localities and have a wider expansion (Figure 2). Moreover, there is no detailed information about stratigraphic, sedimentological and environmental conditions of the Balıkkaya formation in these studies (Yıkılmaz et al., 2002; Atabey and Erdoğan, 2003).

According to field observations in this study, Balıkkaya formation stratigraphically starts with a weak, yellowish-reddish sandstone level at the bottom (Figure 3). This weak sandstone level that does not contain any fossil was interpreted as Balıkkaya formation started to deposit in a terrestrial-shallow setting (Figure 10a). But the pelagic carbonates and mudstones overlying the terrestrial sandstones have been found to Late Cretaceous pelagic foraminifera. The starting age of Balıkkaya formation can be given as Late Cretaceous. The Upper Cretaceous time for the Biga Peninsula, where the Balıkkaya formation is exposed, is a geologically critical time. The northeast of the Vardar Ocean, which separates the Rhodope and Sakarya continents in Anatolia, closes in this period. Following the collision of the Rhodope and Sakarya continents, this suture zone acts as a strike-slip fault zone (Western Pontide Fault Zone) and begins to open the Thrace basin with the transtensional tectonic regime in the end of Late Cretaceous (Elmas, 2012). This transtensional tectonic regime was active during the Late Cretaceous-Paleocene period in the Norhteastern Vardar Zone while it was active until the early-middle Eocene in the Armutlu-Ovacık zone to the east (Elmas, 2012). Balıkkaya formation developed under this transtensional tectonic regime and strike-slip fault system during the Late Cretaceous-middle Eocene (Figure 10a-d).

Blocky levels are more abundant in the Maastrichtian and Paleocene sections of this pelagic unit (Figure 6, figure 11). Furthermore, that the blocked levels within the Balıkkaya formation are mainly grain supported and poorly sized. This indicates the presence of the proximal source area and the sedimentation under the tectonic control in the pelagic environment (Figure 10b-c). However, blocky levels decrease at the upper levels of the sequence and a more regular sedimentation of pelagic limestone-mudstone and sandstone-conglomerate is observed (Figure 7, figure 11). This indicates that fault activity is not effective during the early-middle Eocene period in this region (Figure 10d).

6. Conslusion

Abathomphalus sp., *Abathomphalus mayaroensis* (Bolli), *Rosita fornicata* (Plummer) and different species of Globotruncanidae characterizing Upper

Table 1- Paleontological age data belonging to Balıkkaya formation.

Age	Yıkılmaz et al. (2002)	Atabey and Erdoğan (2003)	This study	
early – middle Eocene			*Acarinina* cf. *bullbrooki* (Bolli) *Acarinina pentacamerata* (Subbotina) *Acarinina* sp. *Bathysiphon* cf. *eocenicus* (Cushman ve Hanna) *Bulumina* sp. *Clavulina* sp. *Cibicides* sp. *Coskinolina* sp. *Dentalina* *Dorethia (Areneblumina)* sp. *Globigerina carcoselleensis* (Toumarkine ve Bolli) *Globigerina linaperta* (Finlay) *Globigerina* cf. *senni* (Beckmann) *Globigerina* sp. *Globigerinatheka* cf. *index* (Finlay) *Globigerinatheka* spp. *Hantkenina* sp. *Marginulinopsis* sp. Miliolidae *Morozovella* cf. *aragonensis* (Nuttall) *Morozovella* cf. *crassata* (Cushman)	*Morozovella* sp. *Orbulinoides beckmanni* (Saito) *Orbulinoides* sp. Osangularidae *Pseudohastigerina* sp. Radiolaria *Trochammina* sp. *Turborotalia* sp. *Turborotalia frontosa* (Subbotina) *Turborotalia* cf. *boweri* (Bolli) *Turborotalia centralis* (Cushman and Bermudez) *Turborotalia cerroazulensis* (Cole) *Turborotalia* spp. *Truncoroides* sp. *Uvigerina* sp. Verneullinidae *Verneullina* sp.
Tanesian	*Morozovella velascoensis* (Bolli)			
Danian	*Bolivina* sp. *Globigerina* sp. *Globigerina triloculinoides* (Plummer) *Globoconusa* sp. *Morozovella* sp. *Morozovella pseudobulloides* (Plummer) *M. uncinata* (Bolli) *M.* cf. *trinidadensis* (Bolli) *Planorotalites compressa* (Plummer) Radiolaria		*Morozovella pseudobulloides* (Plummer) *Morozovella* cf. *pseudobulloides* (Plummer) *Morozovella* sp. *Morozovella* spp. *Planorbulina* sp.	
Late Cretaceous		*Abathomphalus* sp. *Globotruncana arca* (Cushman) *Globotruncana* gr. *linneiana* (d Orbigny) *Globotruncanella citae* (Bolli) *Globotruncanella havanensis* (Voorwijk) *Globotruncanita stuatiformis* (Dalbiez) *Heterohelicidae* *Rugoglobigerina rugosa* (Plummer)	*Abathomphalus* sp. *Gansserina* cf. *gansseri* (Bolli) *Gansserina* sp. *Globorotalites* sp. *Globotruncana* cf. *aegyptiaca* (Nakkady) *Globotruncana* cf. *arca* (Cushman) *Globotruncana* cf. *bulloides* (Vogler) *Globotruncana* cf. *linneiana* (d Orbigny) *Globotruncana* cf. *mariei* (Banner and Blow) *Globotruncana* cf. *ventricosa* (White) *Globotruncana* sp. *Globotruncana* spp. *Globotruncanella* cf. *havanensis* (Voorwijk) *Globotruncanella* sp. *Globotruncanita* cf. *calcarata* (Cushman) *Globotruncanita stuarti* (d Lapparent)	*Globotruncanita* sp. Globotruncanidae *Pseudotextularia* sp. Radiolaria *Rosita fornicata* (Plummer) *Rosita* cf. *fornicata* (Plummer) *Rosita* aff. *fornicata* (Plummer) *Rosita* cf. *plummerae* (Gandolfi) *Rosita* sp. *Rosita* spp. *Rugoglobigerina* sp. *Rugoglobigerina* spp. *Heterohelix* sp. *Lagena* sp. *Lenticulina* sp. Heterohelicidae *Anomalinoides* sp. *Cibicides* sp.

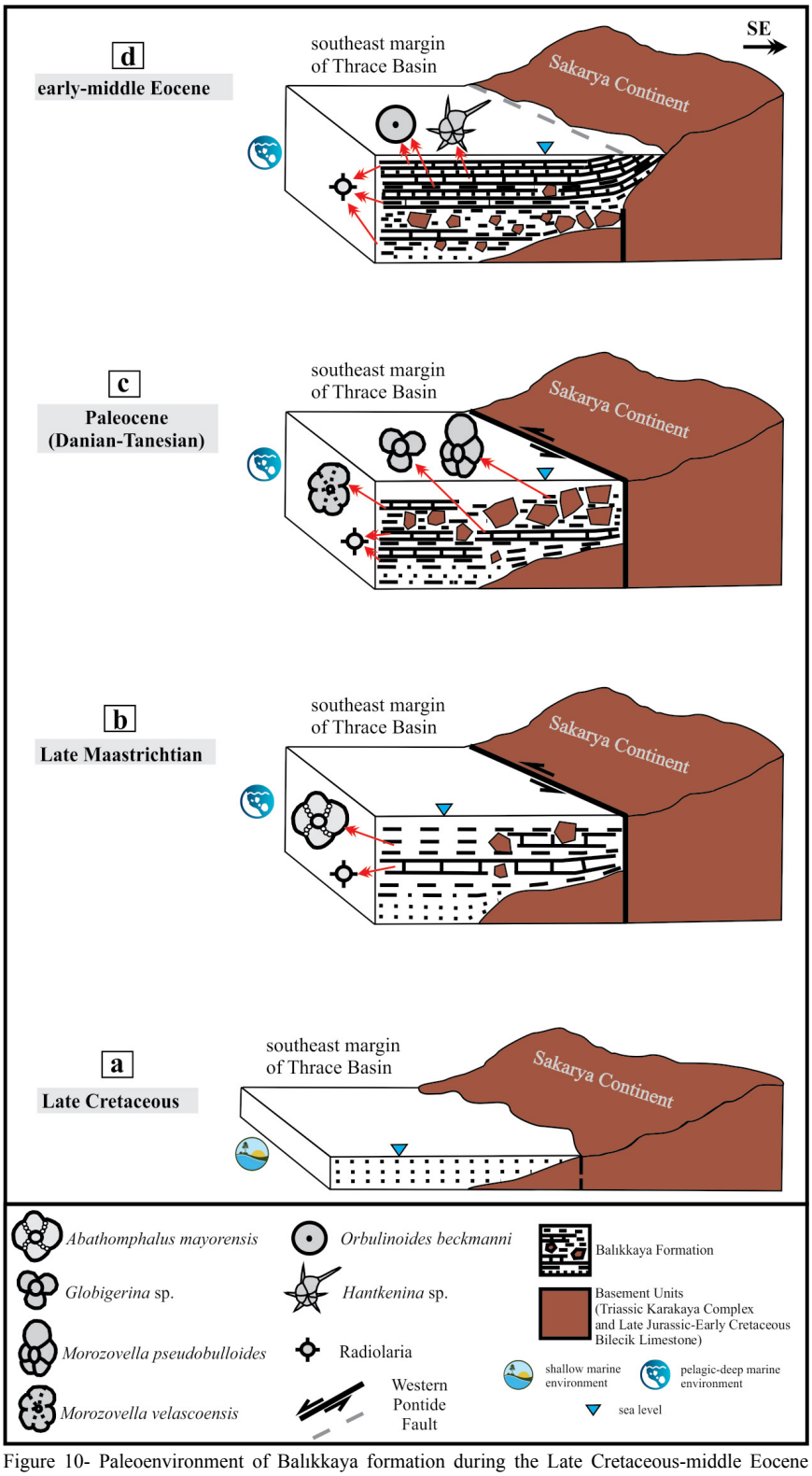

Figure 10- Paleoenvironment of Balıkkaya formation during the Late Cretaceous-middle Eocene interval.

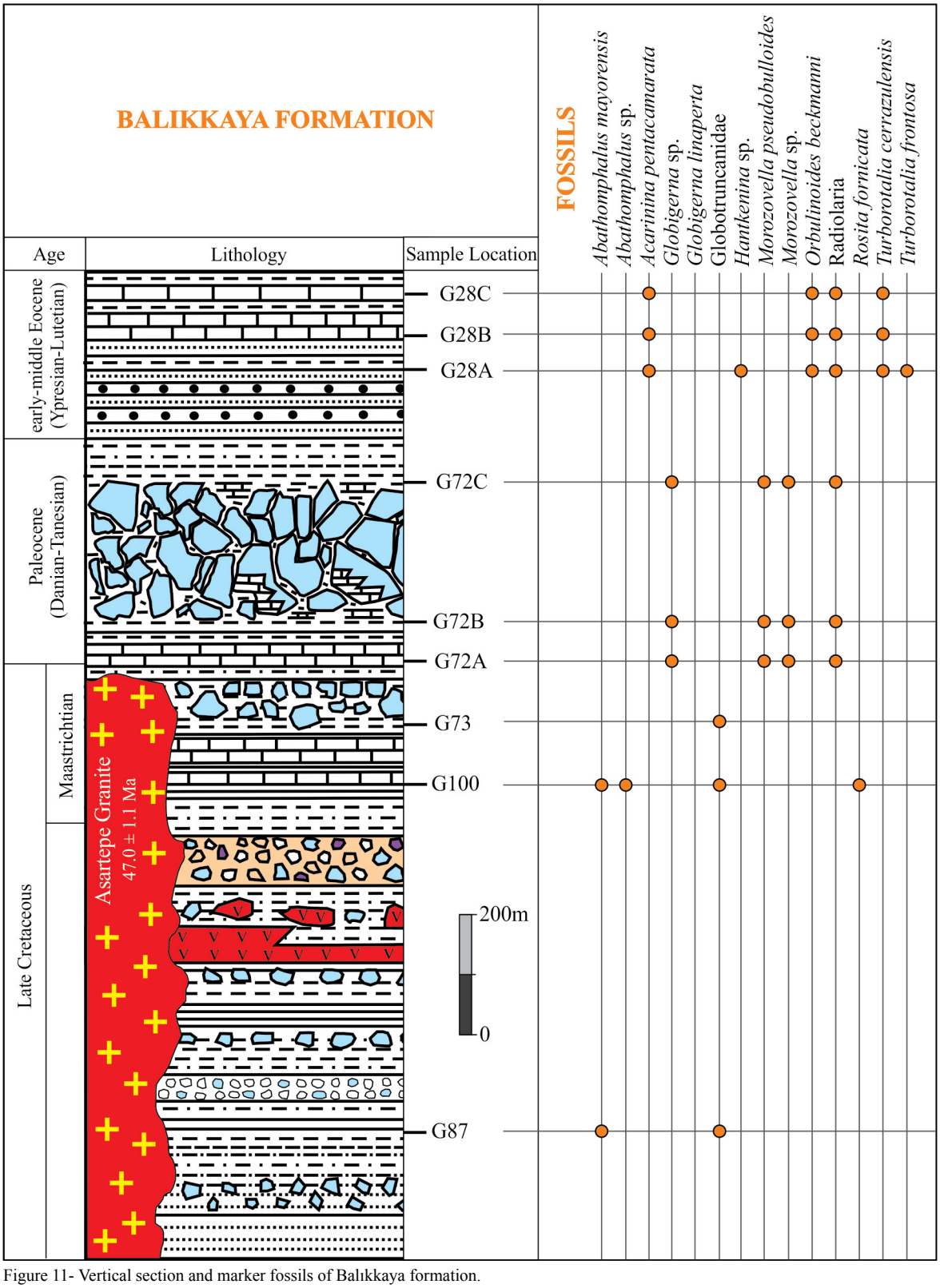

Figure 11- Vertical section and marker fossils of Balıkkaya formation.

Cretaceous (Maastrichtian) were determined in the section close to the bottom of Balıkkaya formation; *Morozovella pseudobulloides* (Plummer) and different species of *Globigerina* symbolizing lower Paleocene (Danian) were determined in the upper sections of the formation that are abundant in blocks; and *Acarinina pentacamarata* (Subbotina) pointing to the lower Eocene, and *Orbulinoides beckmanni* (Saito), *Turborotalia cerroazulensis* (Cole), *Turborotalia frontosa* (Subbotina), *Turborotalia boweri* (Bolli), *Globigerina linaperta* (Finlay) and *Hantkenina sp.* pelagic foraminifera species that are the biozone fossils characterizing the middle Eocene were determined in the stratigraphically highest levels of the unit (Plate I-II-III-IV, Table 1). According to these paleontological data, the age of Balıkkaya formation is given is Late Cretaceous – middle Eocene. Furthermore, Radiolaria fossilssymbolizing deep marine environment were determined from the bottom to the top of Balıkkaya formation (from the Upper Cretaceous to middle Eocene).

As a result, according to paleontological and sedimentological data obtained, Balıkkaya formation age and environment of which is disputable, represents a deep marine environment under the control of tectonism that developed following a short terrestrial precipitation period and lasted from Late Cretaceous to middle Eocene. This pelagic unit indicates the presence of an extensional tectonic regime on the Biga Peninsula and the fault activity along the southeastern edge of the Thrace Basin during the LateCretaceous-middle Eocene time interval.

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PLATES

Plate I. Fossil photos from Sarısıvat-Havdan section (a, e), Havdan section (b) and Burçak Hill-Balıkkaya Hill section (c, d, f, g, h, ı, i, j). Sample number; a: 90, b: G76F, c-d-f-g-h-ı-i-j: G100, e:87.

a-b. *Globotruncana* sp., Late Cretaceous.

c. *Globotruncana stuarti* (de Lapparent), Maastrichtian.

d-e. *Abathomphalus* sp., Maastrichtian.

f. Heterohelicidae, Late Cretaceous.

g. *Rogoglobigerina* sp., Late Cretaceous.

h-ı. Radiolaria.

i. *Abathomphalus mayaroensis* (Cole), Late Maastrichtian.

j. *Globorotalites* sp., Late Cretaceous.

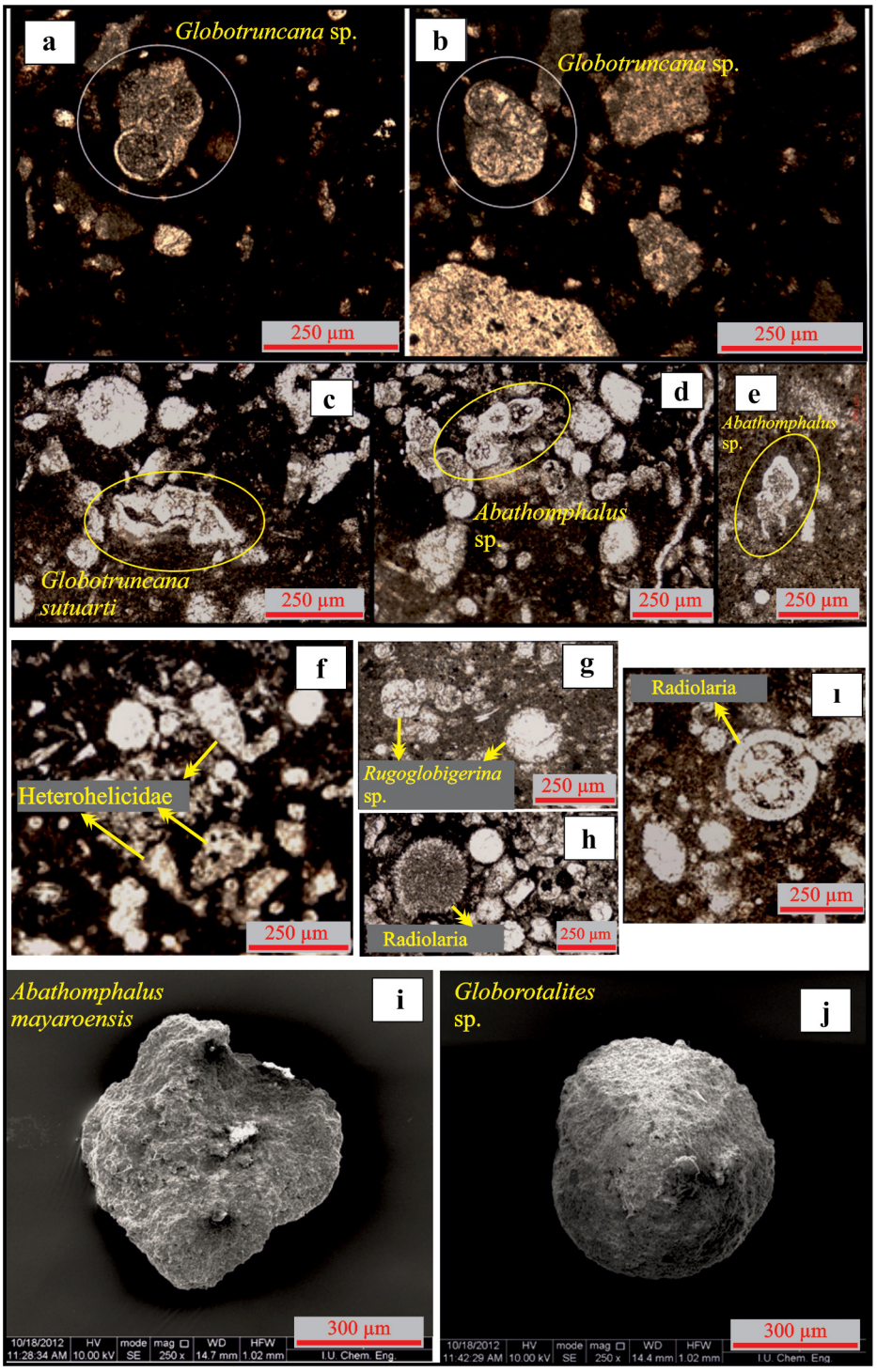

a
Globotruncana sp.
250 µm
b
Globotruncana sp.
250 µm
c
Globotruncana sutuarti
250 µm
d
Abathomphalus sp.
250 µm
e
Abathomphalus sp.
250 µm
f
Heterohelicidae
250 µm
g
Rugoglobigerina sp.
250 µm
h
Radiolaria
250 µm
ı
Radiolaria
250 µm
i
Abathomphalus mayaroensis
300 µm
10/18/2012 11:28:34 AM HV 10.00 kV mode SE mag 250 x WD 14.7 mm HFW 1.02 mm I.U. Chem. Eng.
j
Globorotalites sp.
300 µm
10/18/2012 11:42:29 AM HV 10.00 kV mode SE mag 250 x WD 14.4 mm HFW 1.02 mm I.U. Chem. Eng.

Plate II. Fossil photos from Burçak Hill-Balıkkaya Hill section (a, b, c, d) and Sarıkaya section (e). Sample number; a: G72A, b-c-d: G72C, e: 28A.

a. *Globigerina* sp.*,* Paleocene.

b-c. *Morozovella pseudobulloides* (Plummer), Danian**.**

d. *Globigerina* sp., Paleocene.

e. *Acarinina pentacamarata* (Subbotina), early Eocene.

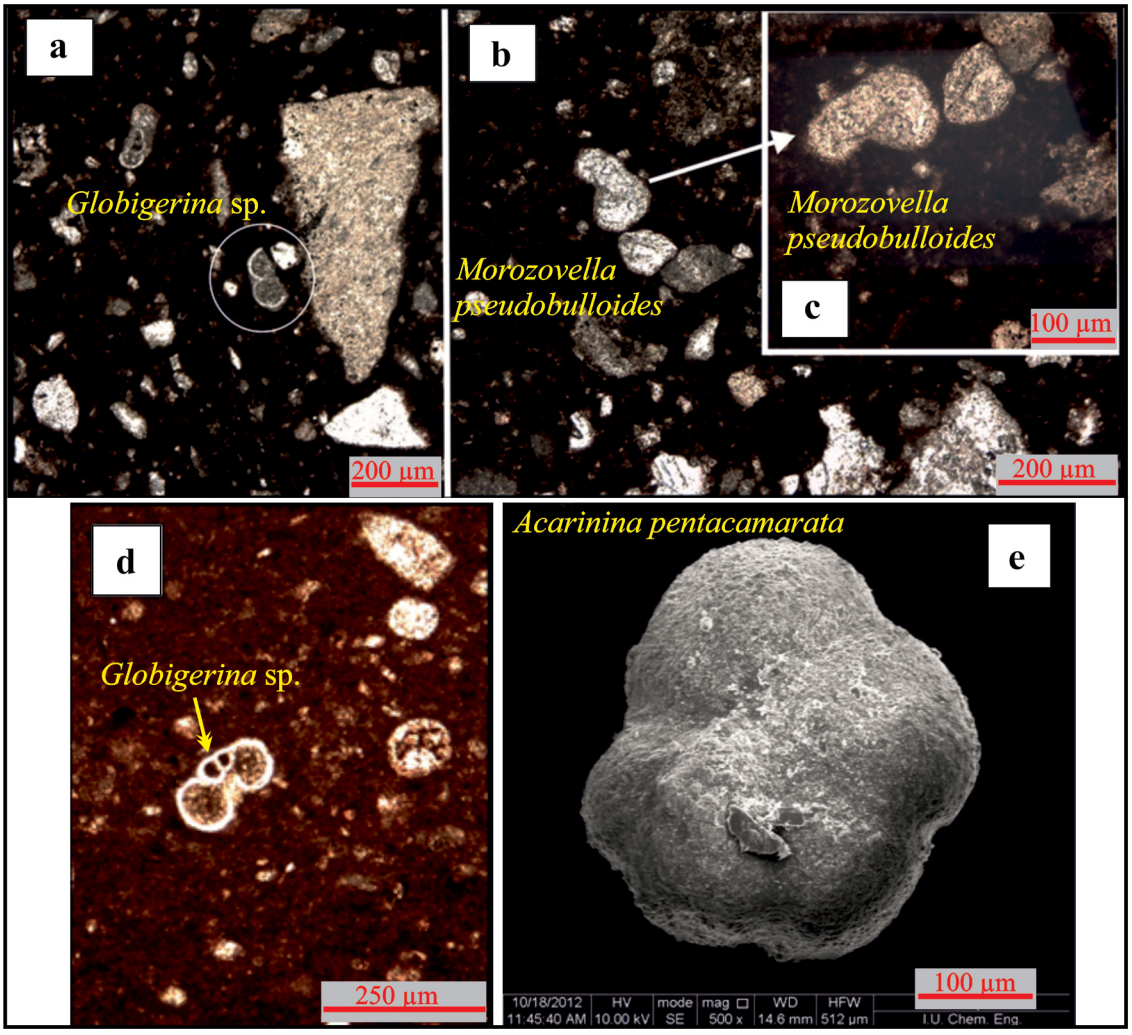

a
Globigerina sp.
200 µm
b
Morozovella pseudobulloides
c
Morozovella pseudobulloides
100 µm
200 µm
d
Globigerina sp.
250 µm
Acarinina pentacamarata
e
100 µm
10/18/2012 11:45:40 AM
HV 10.00 kV
mode SE
mag 500 x
WD 14.6 mm
HFW 512 µm
I.U. Chem. Eng.

Plate III. Fossil photos from Sarıkaya section (a-f). Sample number; a-b: 28A, c-d: 28B, e-f: 28C.

a-b. *Hantkenina* sp., middle-upper Eocene.

c-d. *Turborotalia frontosa* (Subbotina), middle Eocene.

e. *Turborotalia cerroazulensis* (Cole), middle Eocene.

f. *Orbulinoides beckmanni* (Saito), middle Eocene.

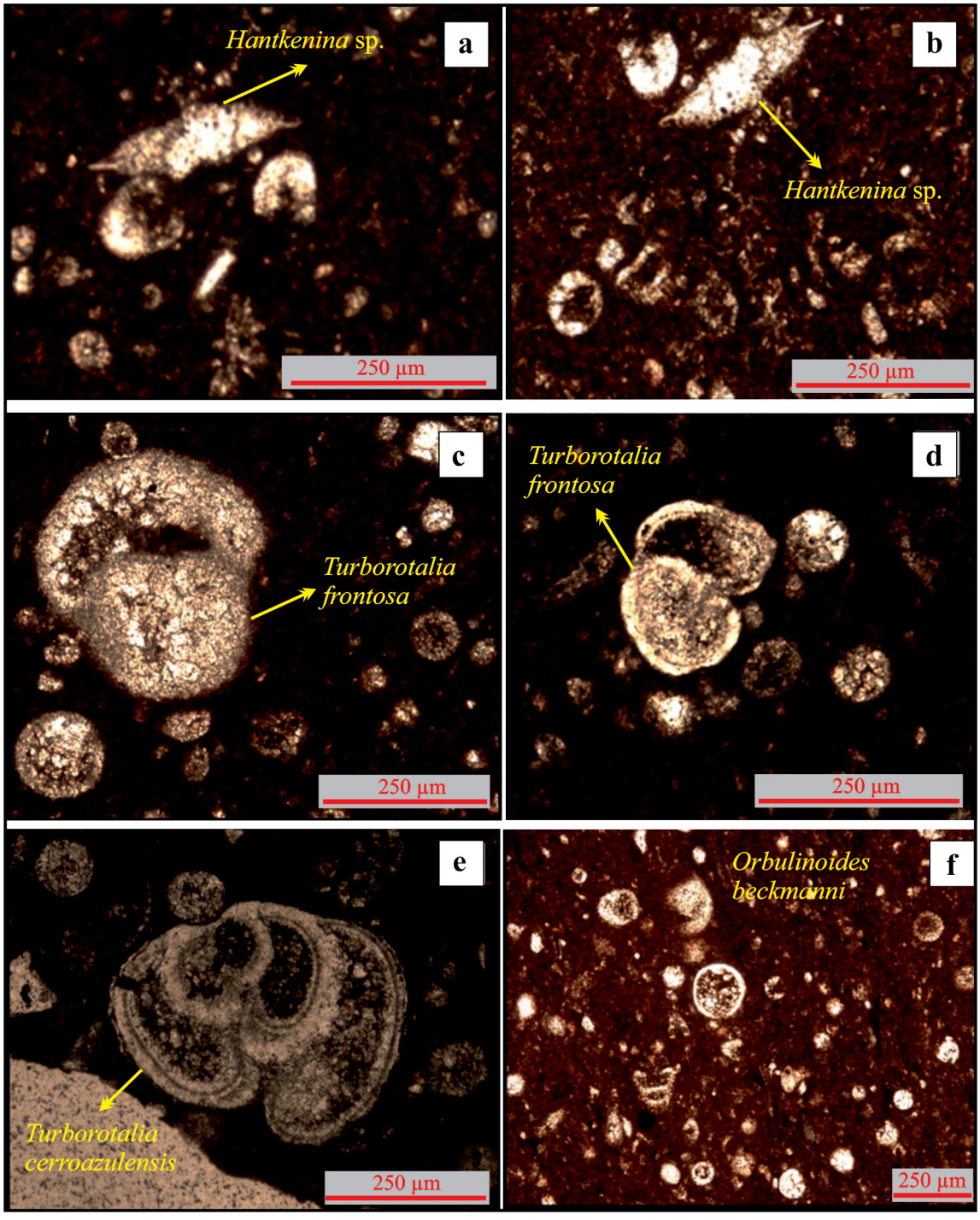
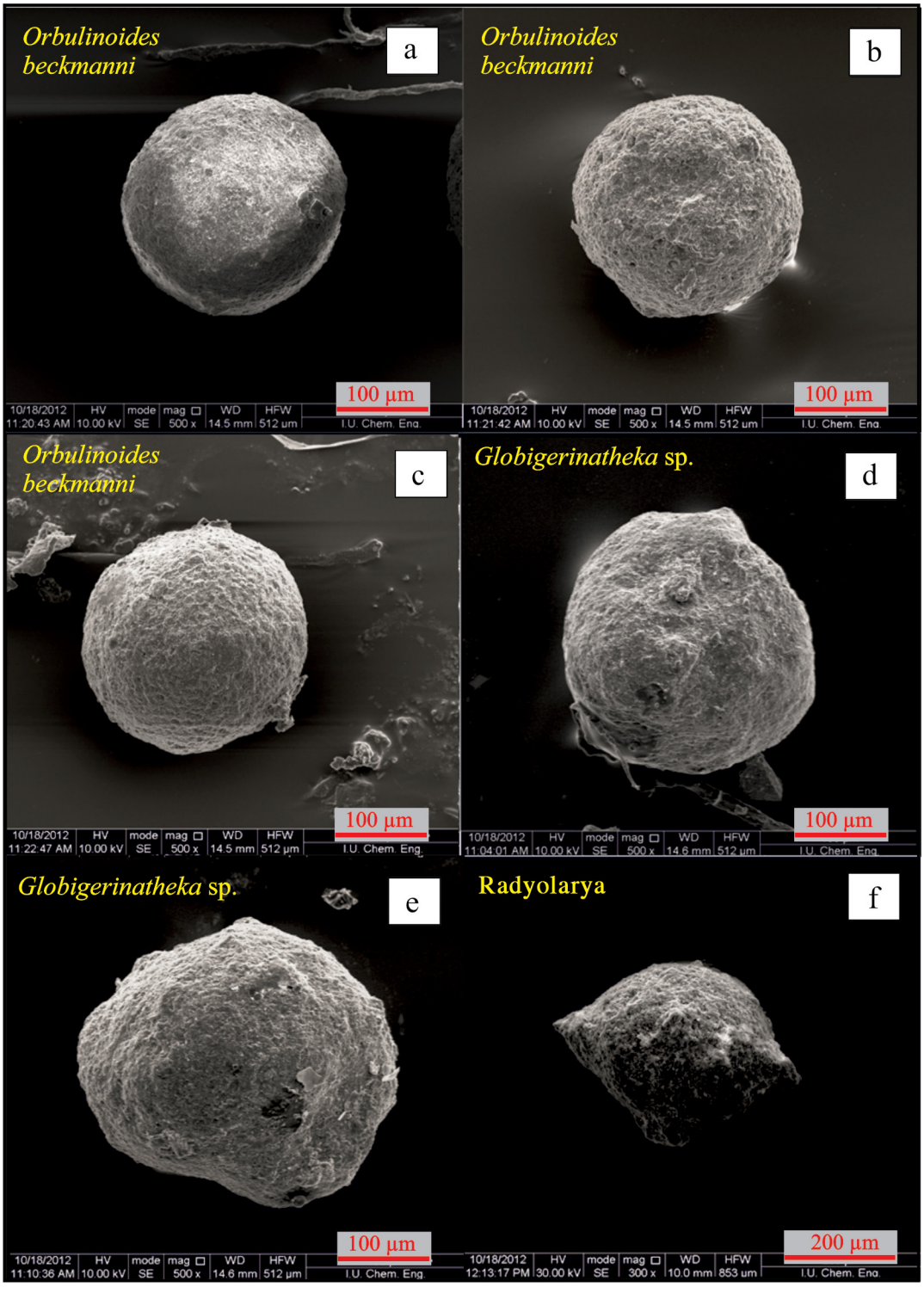

Hantkenina sp.
a
250 µm
b
Hantkenina sp.
250 µm
c
Turborotalia frontosa
250 µm
d
Turborotalia frontosa
250 µm
e
Turborotalia cerroazulensis
250 µm
f
Orbulinoides beckmanni
250 µm

Plate IV. Fossil photos from Sarıkaya section (a-f). Sample number; a: 28A, b-d: 28B, c-e: 28C, f: 28C

a-b-c. *Orbulinoides beckmanni* (Saito), middle Eocene.

d-e. *Globigerinatheka* sp., middle Eocene.

f. Radiolaria


Orbulinoides beckmanni
a
100 µm
Orbulinoides beckmanni
b
100 µm
Orbulinoides beckmanni
c
100 µm
Globigerinatheka sp.
d
100 µm
Globigerinatheka sp.
e
100 µm
Radyolarya
f
200 µm