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DANIAN (SBZ2) LARGER FORAMINIFERA FROM THE BECIRMAN FORMATION (SOUTHEASTERN TURKEY) AS EVIDENCE OF ROTALIIDS DIVERSITY IN LOWER PALEOCENE SHALLOW-WATER ENVIRONMENTS

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Abstract. An important shallow marine deposit is described and illustrated with focus on the systematics and biostratigraphy of larger foraminifera from three stratigraphic sections of the Becirman Formation from the Batman and Siirt regions (Southeastern Turkey). A quite diverse association, mostly dominated by rotaliids (11 species belonging to 7 genera) and subordinate porcelaneous and agglutinated taxa, is documented as well. The fossil assemblage, including *Elazigina dienii*, *Rotospirella conica*, *Praelockhartia* cf. *neoakbari*, *Cuvillierina* cf. *sireli* associated with *Mardinella daviesi* and *Idalina sinjarica,* indicates the late Danian SBZ2.

The abundance of rotaliids is linked, in this time frame, to the recovery of the shallow benthic communities after the K/Pg extinction including increase of surface water temperatures and oligotrophy. This was possibly due to the climatic warming recorded at the end of the Danian (Latest Danian Event), thus promoting a rapid adaptative radiation of rotaliids at genus rank.

Introduction

The Paleogene represents a period in Earth's history that is characterised by high climatic variability. After the end-Cretaceous mass extinction, the Danian was an epoch of recovery for larger foraminifera (LF), i.e., benthic foraminifera with large size (more than 1 mm in diameter), inner complex structure and reproductive dimorphism, since only a few genera passed the K/Pg boundary and only small and simple tests are usually recorded (e.g., Drobne et al. 2007; Serra-Kiel et al. 2020), with the exception of the genus *Laffitteina* (e.g., Benedetti & Papazzoni 2022; Sirel 2015, 2018). Successively, up to the Late Paleocene, LF increased in number and colonized shallow-water tropical environments, acquiring a great importance for biostratigraphy, in particular nummulitids, alveolinids and orthophragminids during the Eocene (Drobne 1977; Schaub 1981; Less 1987; Serra-Kiel et al. 1998; Simmons

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and Aretz 2020). Among LF, rotaliids represent the most important taxonomic group, in addition to a few porcelaneous genera such as *Idalina*, that crossed the K/Pg crisis and occupied the vacant niches (Hottinger 2014; Consorti & Rashidi 2018; Consorti et al. 2021; Benedetti & Papazzoni 2022). Because of their abundance, variation and evolutionary rates, rotaliids play an important biostratigraphic and environmental role for age-dating and interpreting the shallow marine sediments of the Neo-Tethyan Paleocene (Hottinger 2014; Kahsnitz et al. 2016).

Danian shallow-water facies are generally poorly documented in the western Neo-Tethys, with the exception of the periadriatic platform (e.g., Drobne et al. 2007) and Pyrenees (e.g., Serra-Kiel et al. 2020), whereas they are more widespread in Iran (Consorti & Köroğlu 2019; Schlagintweit & Rashidi 2019; Schlagintweit et al. 2020) and Turkey (Sirel 2012, 2015, 2018; Acar 2019).

In this paper, we focus on the study of the Paleocene Becirman Formation (Maxon 1936), a thin limestone succession, cropping out in southeastern Anatolia (Turkey), rich in shallow-water foraminifera (especially rotaliids). Previous studies focused mainly on the general geology, stratigraphy and basin analysis (Rigo de Righi & Cortesini 1964; Perinçek 1978, 1979; Şaroğlu & Yılmaz 1984; Köylüoğlu 1986; Duran 1988; Güven et al. 1988; Yılmaz & Duran 1997; Çoruh et al. 1997; Siyako et al. 2013, 2015), whereas only few micropaleontological analyses have been attempted. Köylüoğlu (1986) recorded *Kathina* sp., *Lockhartia* sp., *Miscellanea* sp. from this unit, and therefore he assigned it vaguely to the Paleocene. Meriç & Çoruh (1991) described megalospheric specimens of *Mardinella shirazensis* (Rahaghi) in assemblage with *Miscellanea* cf. *primitiva* (Rahaghi), *Miscellanea* sp., *Lockhartia diversa* Smout, *Kathina major* Smout, *Rotalia* sp., *Periloculina* sp., unidentified miliolids, ataxophragmiids and algae. Coruh et al. (1997) and Yılmaz & Duran (1997) reported larger foraminiferal assemblages characterized by *Mardinella shirazensis*, *Miscellanea minuta* Rahaghi, *Miscellanea* cf. *primitiva*, *Kathina* sp., *Lockhartia* sp., *Assilina* sp. and referred them to the Middle-Late Paleocene. Siyako et al. (2013; 2015) assigned the unit to the Paleocene according to the occurrence of *Lockhartia diversa*, *Lockhartia* sp., *Coskinolina* sp. associated to miliolids, textulariids, valvulinids, unidentified rotaliids, *Acicularia* sp., echinoderms and dasycladales. Meriç & Çoruh (1998) described the new species *Neosivasella sungurlui* from a level of the Becirman Formation cropping out near the Zengan village, in the Mardin Province (Southeastern Turkey), and assigned it to the Late Paleocene on the base of the occurrence of *M. shirazensis, K. major, L. diversa, Lockhartia* sp., *Sakesaria* sp. and *Miscellanea* sp.

The main objective of this work is to study in detail the systematics and biostratigraphic distribution of the Paleocene LF of the Becirman Formation exposed in the Batman and Siirt regions, in order to provide a new detailed time constrain of the investigated sedimentary succession based on the Shallow Benthic Zones (SBZ) defined by Serra-Kiel et al. (1998) and recently updated for the Paleocene by Serra-Kiel et al. (2020).The systematic analysis is also pivotal to understand the biodiversity of the investigated assemblages with speciel emphasis on the species of rotaliids.

Geological setting

The Southeastern Anatolia Region forms the northern part of the Arabian Platform. Several sedimentary successions of varying thickness and lithologies are observed in the region from Precambrian to Paleogene. The main structure of the geology of the Southeastern Anatolia Region has been controlled by the relative motions of the Arabian and Anatolian plates over time. With the closure of the Tethys ocean since the Campanian, the carbonate platforms have undergone a sudden deepening (Siyako et al. 2013; Sinanoğlu et al. 2020). Deep sea carbonates (Bozova Formation) continued to be deposited further south of the platform. The carbonate platform, that originated in the Maastrichtian around Batman and Siirt, persisted during the Paleocene and carbonate deposition kept on in this area (Siyako et al. 2015; Sinanoğlu et al. 2020). In the investigated area, Paleocene shallow-water carbonates are known as Becirman Formation (Maxon 1936; Güven et al. 1991) that is considered synonym of the upper Sinan Formation (Blakslee et al. 1960). As a result of the Late Paleocene regression, fluvial sedimentary successions, belonging to Antak and Gercüş Formation, were deposited. A further prograding phase lead to the deposition of terrestrial units, followed by a regional erosional phase (Siyako et al. 2015).

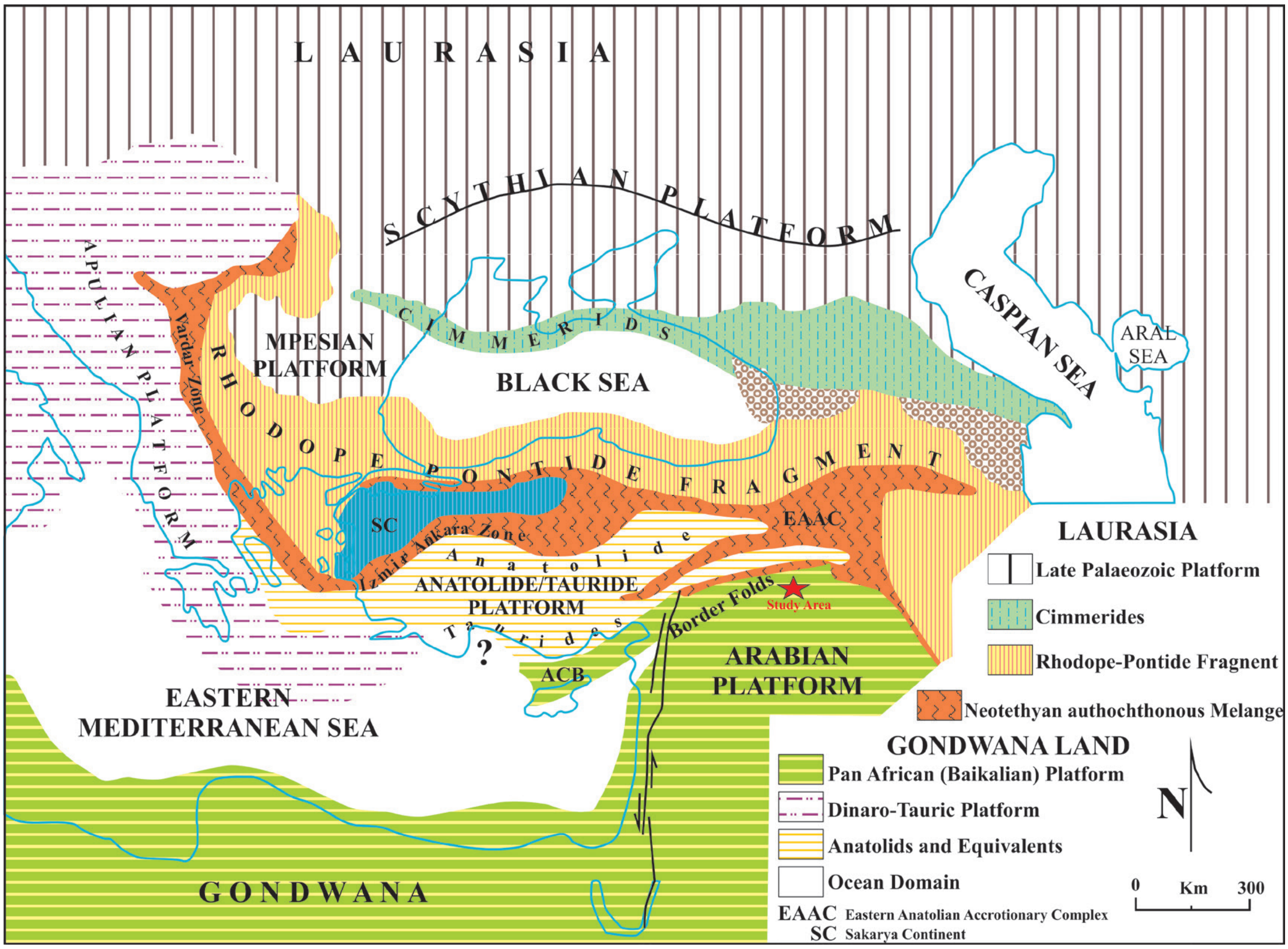

Fig. 1 - Tectonic map showing the continental blocks involved in the evolution of Turkey. Modified by Şengör and Yılmaz (1981).

The Becirman Formation was first proposed by Maxon (1936) on a section near the village of Becirman, which is located 20 km northeast of Gerçüş district (Figs. 1-2). This formation generally shows a variable thickness, reaching a maximum of 150 m, and it consists of dirty white, cream, yellowish coloured, lumpy, medium-to-thick-bedded, sandy shallow-water limestones, characterized by abundant microfossils routinely assigned to Paleocene. These marine carbonates conformably overlie the marls and conglomerates of the Germav Formation, and are covered by the Antak Formation, both considered of fluvial-lacustrine origin.

Biostratigraphy

LF are widely distributed in shallow-water Palaeogene carbonates, and they are routinely used for biostratigraphical purposes, since they evolved gradually, with a succession of species (often recognized biometrically) belonging to several phylogenetic lineages (especially in alveolinids, nummulitids, orthophragmines and lepidocyclinids). Their systematics and biostratigraphy have been extensively studied (e.g., Hottinger 1960; Drobne 1977; Shaub 1981; Less 1987) culminating in the identification of a total of 26 Shallow Benthic Zones (SBZ; Cahuzac & Poignant 1997; Serra-Kiel et al. 1998). As concerns the Paleocene-Eocene interval, 20 zones have been identified (Serra-Kiel et al. 1998) based on the concomitant occurrence of phylogenetically unrelated shallow-water benthic foraminiferal taxa (Pignatti & Papazzoni 2017). SBZ are Oppelzones and they do not depend from the total range of a single taxon. In addition, their boundaries are not strictly fixed, although recently some recalibrations on Paleocene (Scheibner & Speijer 2009; Serra-Kiel et al. 2020; Papazzoni et al. submitted) and Eocene (Rodríguez-Pintó et al. 2012, 2013; Mochales et al. 2012; Costa et al. 2013; Luciani et al. 2019) contributed to improve the resolution of this zonation.

Fig. 2 - Field pictures of the Becirman Formation cropping out in southeast Turkey: A) thin bedded limestone exposed near Beykent village; B, D) macrofossil-rich (echinoderm and coral) clayey limestone exposed near Yeşilkonak village; C) medium-bedded limestone from Gercüş district.

In this study, the biostratigraphic scheme proposed by Serra-Kiel et al. (1998) for the Neo-Tethyan Paleocene and Eocene SBZs, recently recalibrated for the Paleocene (Serra-Kiel et al. 2020), is adopted as follows: the lower part of Danian, usually considered barren of LF, with the exception of *Laffitteina* that passed the K/Pg boundary, is referred to SBZ1; the SBZ2 spans into the rest of the Danian stage; the SBZ3 characterizes the whole Selandian stage and the lowermost Thanetian; finally the SBZ4 ranges into the rest of Thanetian up to the Paleocene/Eocene boundary (Scheibner & Speijer 2009).

Material and method

The studied samples originate from a shallow-water carbonate succession rich in foraminifera and dascylad algae, cropping out from southeastern Anatolian, at the north of the Arabian Platform. A total of three sections, one from Batman province (GBC-Fig. 2C) and two from Siirt province (BC-Fig. 2B,D and BBC-Fig. 2A), and one spot samples (YGA) from the Batman province, have been sampled for micropaleontological analysis. Due to the nature of material, i.e., compact limestone, the identification of benthic foraminifers in this study is exclusively based on randomly oriented LF tests from thin-sections of hard rocks (Fig. 2), since no isolated free-matric individuals have been obtained. A total of 27 samples were collected from the three sections, 11 from GBC, 5 from BC and 8 from BBC. Detailed analysis was carried out on the oriented sections obtained from these samples. All axial, equatorial and oblique sections of LF specimens were photographed under transmitted light stereomicroscope to investigate selected taxonomic characters. The thin sections (labelled BC, BBC, GBC and YGA) described and shown in this study are stored in the geological collection of Cumhuriyet University, Faculty of Engineering, Department of Geological Engineering, Sivas (Turkey).

The identification of the foraminiferal taxa was mainly based on the monograph by Hottinger (2014) as concerns rotaliids, and secondarily on Hottinger & Drobne (1980), Di Carlo et al. (2010), Vicedo et al. (2021), Sirel (2015; 2018), Benedetti et al. (2018) and other articles listed in the systematic paleontology section. The description of morphological features follows the terms employed by Hottinger (2006).

Description of sections

The investigated sections are exposed in the Batman and Siirt areas (Fig 1), southeastern Anatolia (Turkey), as specified below and in Figure 3.

GBC section: It was sampled near Kirkat village in the Gercüş district (37°33'55.34"N; 41°22'17.95"E; Fig. 3A, D); it is 15 m-thick and at the base consists of nodular and limestones, whereas from the lower to the upper parts it is characterized by sandy and fossiliferous bioclastic limestones (Fig. 2C). In the study area, the Antak Formation, which is routinely referred to Paloecene and underlies unconformably the Hoya Formation, conformably overlies the Becirman Formation. Abundant fragments of corals and gastropod shells are observed in the lower parts of the section. The upper part of the GBC section mainly consists of sandy and fossiliferous bioclastic limestone beds. From this locality, Siyako et al. (2013) first reported miliolids, rotaliids, textulariids, conical agglutinated foraminifera, dasycladales and echinoderms.

BC section: It was sampled near Yeşilkonak (37°52'26.83"N; 41°43'59.73"E; Fig. 3C); it reaches a thickness of 5 m and yielded abundant fossil assemblages. In this section, the Becirman Formation consists of gray coloured, thick fossiliferous marly limestones (Fig. 2B-D). Carbonate content increases up section, where traces of dolomitization have been rarely observed. The Antak Formation conformably overlies the Becirman Formation also in this outcrop. Macrofossils, such as echinoderms and coral fragments, are common throughout the section.

BBC section: It measures about 10 m and it was sampled near the Beykent village (37°52'21.91"N; 41°41'46.60"E; Fig. 3C); it is characterized at the base by thin-bedded sandy-limestones (Fig. 2A), whereas up section a massive 5 m-thick fossiliferous limestone bed occurs. Nodular limestones are rarely observed scattered throughout the section as well. As seen in the other sections, the Paleocene Antak Formation conformably overlies the Becirman Formation. In the lower part, dasyladacean green algae (*Trinocladus* sp.) predominate, along with LF and small textulariids; the middle part becomes rich in coral fragments, whereas rotaliids dominate again through the upper part of the section.

YGA sample: One spot sample has been collected near Kirkat village, from Gercüş area (37°34'0.45"N-41°15'45.41"E; Fig. 3A, D). Abundant rotaliids and dasycladacean algae (mainly *Trinocladus* sp.) were observed in these limestone samples.

Results

The investigated samples are dominated by shallow-water taxa such as LF and calcareous algae (not systematically described in this work). A total of 19 benthic foraminiferal taxa has been identified at generic and species rank (some left in open nomenclature). Among LF, porcelaneous taxa, such as *Idalina sinjarica* and *Mardinella daviesi*, and rotaliids, with 11 species belonging to 7 genera, dominate the assemblages.

The spot sample YGA is characterized by the occurrence of *Elazigina dienii, Rotorbinella hensoni, Cuvillierina* cf. *sireli, Praelockhartia* cf. *neoakbari, Kathina aquitanica, Valvulina triangularis, Idalina sinjarica, Mardinella daviesi, Rotospirella* sp., *Ornatorotalia* sp. and dasycladacean algae (*Trinocladus* sp.). The presence of *Elazigina dienii* is sufficient to restrict the assemblage to SBZ2 (Hottinger 2014; Benedetti et al. 2018; Consorti & Köroglu 2019; Serra-Kiel et al. 2020), i.e., late Danian (Serra-Kiel et al. 2020), whereas *Cuvillerina sireli* usually occurs from SBZ2 to SBZ3. *Mardinella daviesi* has been originally described as *Mardinella shirazensis* (Meriç & Çoruh 1991) from the Becirman Formation and it spans from SBZ2 to SBZ4 (e.g., Serra-Kiel et al. 2016; Schlagintweit et al. 2019; Consorti et al. 2020; Consorti & Sinanoğlu in press). Two new taxa belonging to the genera *Rotospirella* and *Ornatorotalia* will require detailed taxonomic analysis to relate them to extant species or phyletic lineages.

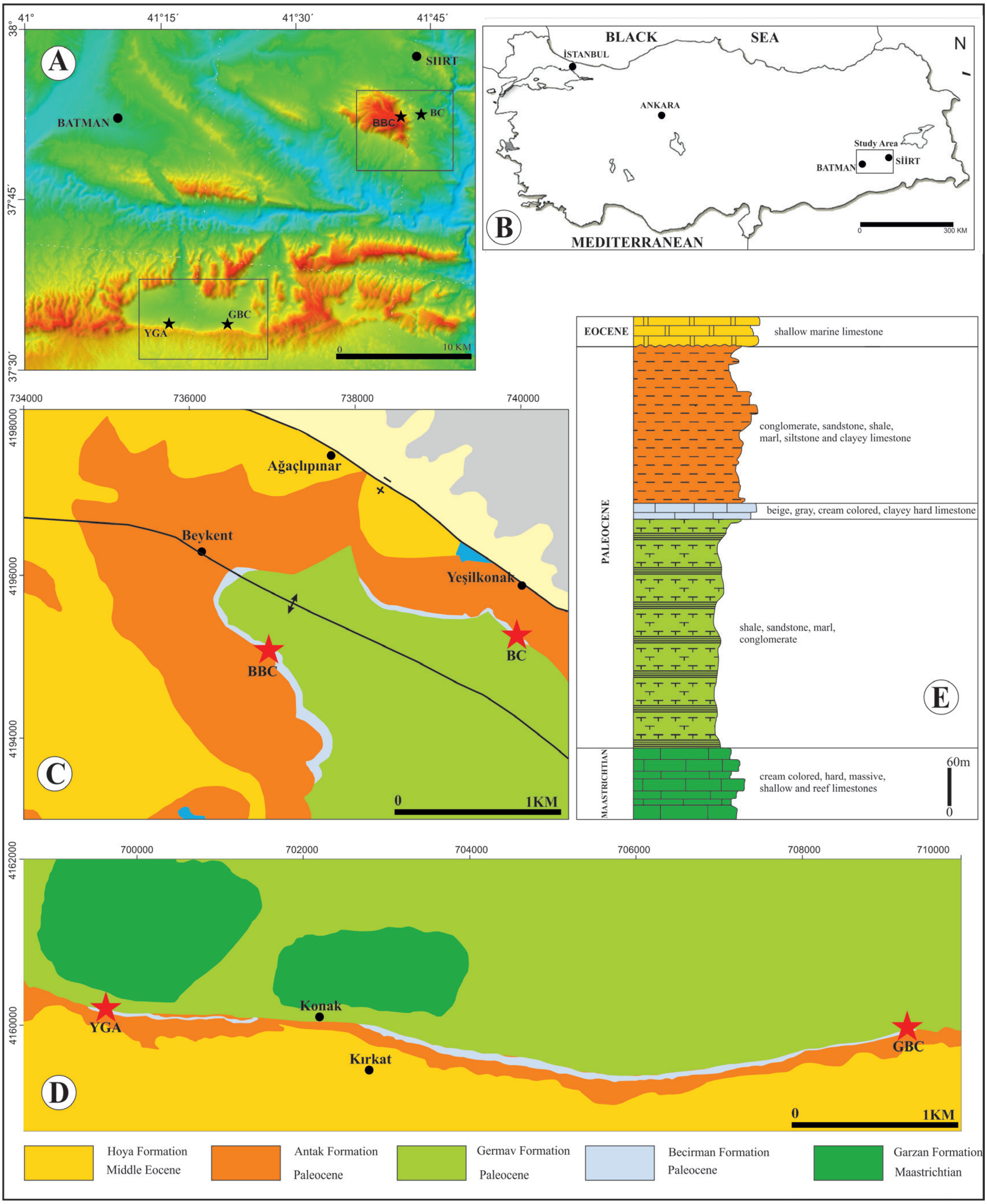

Fig. 3 - Location maps (A, B), geological map (C, D) and general stratigraphic section (E) of the studied area.

The eight samples from the section BBC are, similarly to above, dominated by rotaliids, porcelaneous foraminifera and algae. However, as concerns benthic foraminifera, the sample BBC1 contains only agglutinated taxa such as *Valvulina triangularis* and *Cribrobulimina* sp. that have no biostratigraph-

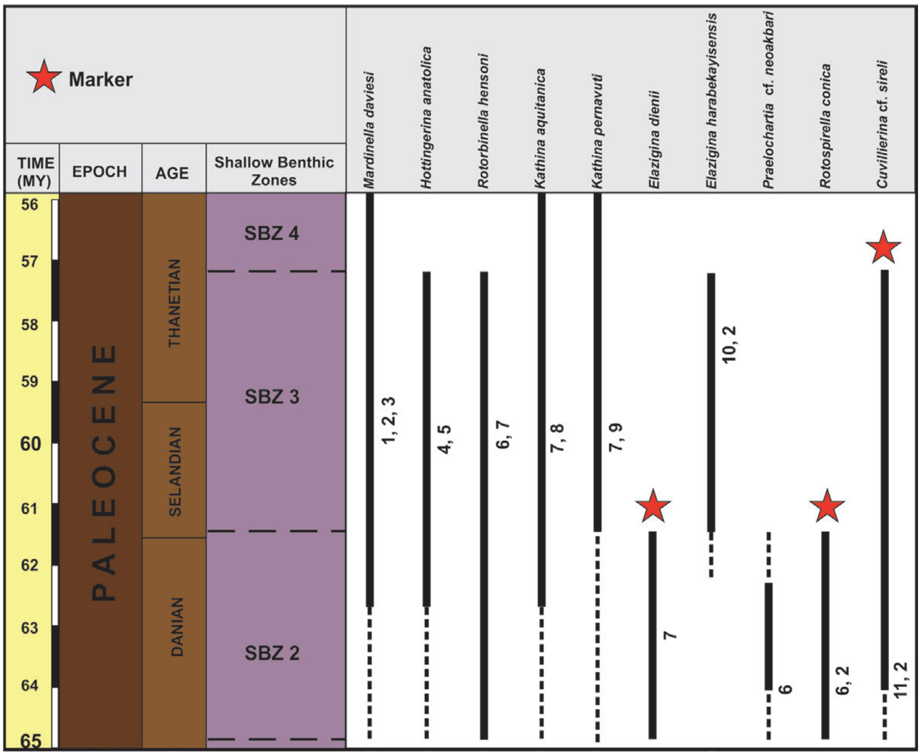

Fig. 4 - General stratigraphic succession and distribution of LF in the Becirman Formation (1: Benedetti et al. 2020; 2: Serra-Kiel et al. 2016; 3: Consorti et al. 2020; 4: Di Carlo et al. 2010; 5: Sirel 2018; 6: Vicedo et al. 2021; 7: Hottinger 2014; 8: Serra-Kiel et al. 2020; 9: Zhang et al. 2013; 10: Sirel 2012; 11: Benedetti et al. 2018).

ic importance, but suggesting very shallow-water mesotrophic setting. From sample BBC3 to BBC8, the occurrence of *Idalina sinjarica* associated to *Rotospirella conica,* which is commonly known only from SBZ2 (Serra-Kiel et al. 2020; Vicedo et al. 2021), constrained the assemblages to late Danian. The uppermost sample is again dubitatively assigned to SBZ2, although the occurrence of *Idalina sinjarica* associated to *Hottingerina anatolica* could indicate also Middle to Late Paleocene (for detail see the systematic paleontology).

The samples from BC section are mostly characterized by rotaliids, such as *Rotospirella conica*, *Elazigina dienii, Kathina* sp., porcelaneous tests (mainly *Idalina sinjarica*) and accompanying agglutinated taxa, such as *Fallotella* cf. *kochanskae, Cribrobulimina* sp. and *Coskinon* sp.*,* thus restricting the age of the formation to late Danian.

Also, the ten samples from GBC section, yielded rotaliid-dominated assemblages, characterized by *Elazigina dienii*, *E. harabekayisensis*, *Kathina pernavuti* associated to *Haddonia* sp. and the algae *Polystrata alba*, but the uppermost sample GBC10 is dominated by *Mardinella daviesi.*

Although reported in previous works on the Becirman Formation (Meriç & Çoruh 1991; Çoruh et al. 1997; Yılmaz & Duran 1997), no miscellaneids have been found in the investigated samples. *Miscellanea* and *Miscellanites* (also known from Turkey under its junior synonym *Akbarina* Sirel, 2009) are in fact generally widespread since the SBZ2 (e.g., Hottinger 2009; Benedetti et al. 2018; Consorti & Köroğlu 2019). Probably, tangential cuts of the piles of the ventral side of *Elazigina dienii* have been erroneously interpreted as piles of *Miscellanea* in previous studies on the Becirman Formation. A second possibility is that the small low-trochospiral *Ornatorotalia* has been interpreted as a planispiral miscellaneid. Anyway, further micropaleontological works on taxonomy and autecological significance of such LF are needed to clarify the absence of *Miscellanea* from our samples.

Systematic paleontology

The micropaleontolgical analysis of LF was carried out on microphotographs according to a typological approach, i.e., identifying a species by comparing the investigated individuals to a type specimen (e.g., Hottinger 2013) although some biometric measurements are given to furnish data useful for further analysis.

Some species are left in open nomenclature (cf. according to Bengtson 1988). The identified LF allow us biostratigraphic constraints according to the shallow benthic zones (SBZs) proposed by Serra-Kiel et al. (1998) for the Paleocene-Eocene interval and recently recalibrated by Serra-Kiel et al. (2020).

The suprageneric classification follows Loeblich & Tappan (1987, 1992) with integration taken from Kaminski (2014).

Order **Loftusiida** Kamiski and Mikhalevich, 2004
Superfamily Coscinophragmatoidea Thalmann, 1951
Family Haddoniidae Saidova, 1981
Gen. *Haddonia* Chapman, 1898

Haddonia praeheissigi Samuel, Köhler & Borza, 1977
Pl. 1, Figs. 1, 2(?)

1977 *Haddonia praeheissigi* Samuel, Köhler and Borza, pl. 48, figs. 1, 2; pl. 49, figs. 1, 2; pl. 50, figs. 1, 2.
2008 *Haddonia praeheissigi* Samuel, Köhler and Borza – Pignatti et al., p. 7, fig. 5.
2010 *Haddonia praeheissigi* Samuel, Köhler and Borza – Di Carlo et al., p. 50, pl. 1, fig. 1; pl. 3, figs. 1, 2.
2018 *Haddonia praeheissigi* Samuel, Köhler and Borza – Schlagintweit et al., fig. 2m.
2020 *Haddonia praeheissigi* Samuel, Köhler and Borza – Serra-Kiel et al., p. 32, fig. 19F.

Material: a single specimen incrusting on *Polystrata alba* from sample GBC2 and a possible specimen from BBC4.

Description. Test large, attached, wall coarsely agglutinated. The early stage is not distinguishable, the chambers appear irregularly coiled and they slowly increase in size. The test is composed by two different layers; the outer layer agglutinates mostly quartz grains in a calcitic cement, whereas the inner layer is thin, black under microscope, and composed of a micritic pseudochitinose mixture. The maximum measured length is about 1.9 mm.

Distribution. Found in SBZ2 from Zakynthos Island (Greece) by Di Carlo et al. (2010), from Danian (SBZ1-2) of Austria (Schlagintweit et al. 2018), but known from Campanian to Paleocene of the Carpathian Mountains (Samuel et al. 1977). It has no biostratigraphic importance according to Serra-Kiel et al. (2020).

Remarks. *Haddonia* is typical of reef environments (Chapman 1898) and possibly seagrass meadows (Serra-Kiel et al. 2020), due to their attached mode of life.

Superfamily Coskinolinoidea Moullade, 1965
Family Coskinolinidae Moullade, 1965
Genus *Coskinon* Hottinger and Drobne, 1980

Coskinon sp.
Pl. 1, Fig. 3

Material: a single incomplete specimen from sample BC5.

Description. Agglutinated conical test with convex apertural face. The chambers are arranged in a low trochospire. The embryonal apparatus and the adult uniseriate stage are not visible from our material. The few preserved chambers are lacking of an exoskeleton as typical of the genus, and no endoskeletal pillars occur, since they are usually documented only in the adult stage.

Distribution. It occurs in assemblage with *Fallotella* cf. *kochanskae*, *Idalina sinjarica*, *Cribrobulimina* sp. and to subapical sections attributed to *Rotospirella conica* in a possible SBZ2 assemblage.

Remarks. The few chambers occurring in the single investigated specimen resemble the juvenile stage of *Coskinon rajkae* (Hottinger & Drobne, 1980) marker of SBZ3, but the absence of further oriented sections prevent any speculation at species level.

Superfamily Orbitolinoidea Martin, 1890
Family Orbitolinidae Martin, 1890
Genus *Fallotella* Mangin, 1954

Fallotella cf. ***kochanskae*** Hottinger & Drobne, 1980
Pl. 1, Fig. 4

cf. 1980 *Fallotella (Fallotella) kochanskae* Hotinger & Drobne, p. 52, pl. 2, fig. 4; pl. 15, figs. 1-14, text-fig. 2.

Material: Two specimens from sample BC5 in oblique section.

Description. Test agglutinated, elongated to almost cylindrical. The exoskeleton consists of simple beams with secondary partitions (intercalary beams) about half in length as the former. The marginal chamber appears thus alveolar, reflecting the occurrence of these structural elements, but without any other ultrastructure. The endoskeleton consists of alternating pillars. No other elements are visible from the recovered specimens.

Distribution. The species was originally described from SBZ3 (*Glomalveolina primaeva* zone) and reported by Di Carlo et al. (2010) from Zakynthos (Greece) in an assemblage with *Coskinon rajikae*, *Fallotella alavensis*, *Vania anatolica*, *Glomalveolina primaeva, Periloculina slovenica, Hottingerina anatolica* and *Elazigella altineri*. In our sample it occurs associated to specimens dubitatively attributed to *Rotospirella conica* and with *Idalina sinjarica*, *Cribrobulimina* sp. and *Coskinon* sp., possibly from SBZ2.

Remarks. Our specimens in uncentered sections don't allow us to assign them unambiguously to the species *Fallotella kochanskae*.

Order **Textulariida** Delage & Hérouard, 1896
emended Kaminski, 2004
Superfamily Eggerelloidea Cushman, 1937
Family Valvulinidae Berthelin, 1880
Genus *Cribrobulimina* Cushman, 1927

Cribrobulimina sp.

Pl. 1, Figs. 5-6

Material: two uncentered specimens from samples BBC1 and BC5.

Description. Agglutinated conical test. Chambers are inflated and undivided, with sutures depressed. The type of section prevents the identification of any other taxonomical characters.

Distribution. It occurs in assemblage with *Valvulina triangularis, Coskinon* sp., *Fallotella* cf. *kochanskae* and *Idalina sinjarica*.

Genus *Valvulina* d'Orbigny 1826

Valvulina triangularis d'Orbigny in Guérin-Méneville, 1832

Pl. 1, Figs. 7-8

1826 *Valvulina triangularis* d'Orbigny, p. 270, *nomen nudum*.
1832 *Valvulina triangularis* d'Orbigny - Guérin-Méneville, p. 9 pl. 2 fig. 15.
2018 *Valvulina triangularis* d'Orbigny – Sirel, p. 167, pl. 58, figs. 10-16.

Material: two specimens from samples YGA19B and BBC1 in horizontal section and one from BC3 in transversal section.

Description. Test conical, triseriate, with a triangular section. Wall agglutinated. Chambers are inflated and undivided, with angular margin.

Distribution. It occurs in assemblage with *Cribrobulimina, Cuvillierina* cf. *sireli*, *Elazigina dienii*, *Rotorbinella hensoni*, *Ornatorotalia* sp. and *Idalina sinjarica* in SBZ2.

Remarks. *V. triangularis* was originally described from the Eocene, but it is also documented from Paleocene of Turkey (e.g., Sirel 2015, 2018) and from the Maastrichtian of Spain (Granero et al. 2019). Septfontaine et al. (2019) consider the species listed by Sirel (2015, illustrated in Sirel 2018) under the new genus *Pachycolumella,* species *P. acuta*, spanning from late Cretaceous through the Paleocene. Granero et al. (2019) suggested that *Pachycolumella* is a junior synonym of *Valvulina*. The oblique section of specimen from sample BC3 seems to show a columellar structure, but in absence of more detailed material, we prefer to adopt a conservative nomenclature for our specimens.

Order **Miliolida** Delage and Hérouard, 1896
emended Pawlowski et al., 2013
Superfamily Soritoidea Ehrenberg, 1839
Family Soritidae Ehrenberg, 1839
Genus *Mardinella* Meriç and Çoruh, 1991

Mardinella daviesi (Henson, 1950)

Pl. 1, Figs. 9-10

1950 *Taberina daviesi* Henson, p. 51; pl. 1 figs. 1-2; pl. 2 figs. 1-3.
1983 *Orbitolites shirazensis* Rahaghi, p. 46, pl. 18, figs. 1-3.
1991 *Mardinella shirazensis* (Rahaghi) - Meriç and Çoruh, p. 166, pl. 1, figs. 1-8).
2015 *Azzarolina daviesi* (Henson) - Vicedo & Serra-Kiel, p. 372, figs. 2–7.
2019 *Mardinella daviesi* (Henson) – Schlagintweit et al., pl. 1, fig. 4.
2020 *Mardinella daviesi* (Henson) – Consorti et al., figs. 2A-E. 3A-H,

Material: a single specimen from sample GBC8; six specimens from sample GBC10; five specimens from YGA19A; three from YGA19B; one from YGA19C and five from YGA19D.

Description. Test flattened discoidal, biconcave in axial section, wall porcelaneous. The diameter ranges between 2.0 mm and 4.8 mm (mean 3.6 mm, n=4) for a total of 16-36 chambers (mean 28).

The megalospheric form is characterized by a bilocular embryo (diameter 0.35-0.46 mm; mean 0.41 mm) constituted by a protoconch and a deuteroconch followed by one to two reniform chambers; later chambers are cyclic and envelop the entire embryo-nepionic apparatus. The cyclic, annular chambers are partially subdivided by exoskeletal beams.

Distribution. Meriç and Çoruh (1991) reported *Mardinella shirazensis* from Becirman in assemblage with *Miscellanea* cf. *primitiva*, *Miscellanea* sp., *Lockhartia diversa*, *Kathina major*, *Rotalia* sp., *Periloculina* sp. marking late Thanetian. It occurs in the Qorban member of Sachun Formation (Shiraz, Iran) associated to *Elazigina* cf. *lenticula*, *Elazigina harabekayisensis, Miscellanea* cf. *juliettae*, *Miscellanites iranicus*, *Miscellanites* cf. *minutus*, *Schroedericonus turriculus*, *Assilina* cf. *yvettae*, *Kathina delseota, Dictyokathina simplex, Idalina sinjarica*, *Lockhartia retiata*, *Daviesina langhami*, *Daviesina intermedia* and *Ornatorotalia pila* of Thanetian age, i.e., SBZ3-4 (Benedetti et al. 2020; Consorti et al. 2020). It is also reported from Oman in assemblage with *Pseudofallotella persica*, *Dictyoconus* cf. *turriculus*, *Anatoliella ozalpiensis*, *Ercumentina sayqensis*, *Lacazinella rogeri*, *Lockhartia haimei*, *Lockhartia retiata* and *Kathina* sp. (SBZ2-3 according to Serra-Kiel et al. 2016).

At Becirman it occurs in SBZ2 (late Danian according to Serra-Kiel et al. 2020) in assemblage with *Elazigina dienii.* At Kirkat it occurs associated to *Idalina sinjarica, Elazigina dienii*, *Cuvillierina* cf. *sireli*, *Kathina aquitanica, Rotorbinella hensoni, Praelockhartia* cf. *neoakbari* and *Rotospirella* sp.

Remarks. The generic attribution of this species has been debated for a long time. Pignatti (1992) adopted the informal terms "Pseudo-*Taberina*"; Vicedo et al. (2015) recognized *Orbitolites shirazenis* Rahaghi as fully synonym with *Taberina daviesi* Henson, and erected the new genus *Azzarolina*. Because of priority, the genus *Mardinella* Meriç and Çoruh should be preferred (e.g., Schlagintweit et al. 2019; Consorti et al. 2020).

Genus *Hottingerina* Drobne, 1975

Hottingerina cf. ***anatolica*** Sirel, 1999

Pl. 1, Fig. 11

cf. 1999 *Hottingerina anatolica* Sirel, p. 134, pl. 8, figs. 1-8; pl. 9, figs. 1-9.
2008 *Hottingerina anatolica* Sirel - Pignatti et al., pl. 5, fig. 7; pl. 7, figs. 9a, 10.
2010 *Hottingerina anatolica* Sirel - Di Carlo et al., p. 64, pl. 3, fig. 7B; pl. 5, figs. 29-33.

Material: a single specimen from sample BBC8 in subaxial section.

Description. Test lenticular, involute, planispirally coiled with about four whorls. Wall porcelaneous, without external ornamentation, but with very short subepidermal partitions inside the chambers (poorly preserved in the investigated specimen). The maximum equatorial measured diameter is 1.22 mm, whereas the axial diameter reaches 0.65 mm. Our specimen is not centered, thus we cannot measure proloculus size.

Distribution. *Hottingerina anatolica* has been described from the Thanetian of Eastern Turkey and in association with *Glomalveolina primaeva*, *Vania anatolica, Haymanella paleocenica*, *Miscellanea yvettae*, *Coskinon rajkae Postbroeckinella flabelliformis*. It is reported in SBZ3 from Zakynthos (Di Carlo et al. 2010) associated with *Coskinon rajkae*, *Fallotella alavensis*, *F. kochanskae*, *Cribrobulimina* cf. *carniolica*, *Vania anatolica*, *Glomalveolina primaeva*, *Periloculina slovenica* and *Elazigella altineri*. Sirel (2018) documented its rare occurrence also from SBZ2 with *Akbarina yarisliensis* (=*Miscellanites primitivus* according to Serra-Kiel et al. 2020), *Bolkarina aksarayensis, Pseudolacazina oeztemueri, Burdurina selandinica* and *Sistanites iranicus*. In our material *Hottingerina* cf. *anatolica* occurs associated only to *Idalina sinjarica*.

Remarks. The single specimen prevents an accurate comparison with previously described types of *H. anatolica*. *Hottingerina lukasi* Drobne differs evidently from our individual in having longer and well-developed superpidermal partitions.

Superfamily Milioloidea Ehrenberg, 1839
Family Hauerinidae Schwager, 1876
Subfamily Idalininae Mikalevich, 1988
Genus *Idalina* Munier-Chalmas & Schlumberger, 1885

Idalina sinjarica Grimsdale, 1952

Pl. 1, Figs. 12-13

1952 *Idalina sinjarica* Grimsdale, pl. 20, figs. 11-14.
2010 *Idalina sinjarica* Grimsdale – Di Carlo et al., p. 54, pl. 4, figs. 1-19.
2020 *Idalina sinjarica* Grimsdale – Serra-Kiel et al., p. 23, figs. 16.A-16.D (cum syn).

Material: rare individuals from samples BB4, BBC7, BBC8, BC3, BC5, YGA19B and YGA19C.

Description. Wall porcelaneous, oval to ovoid test with mioline-type arrangement of chambers.

The megalosphaeric form shows a diagnostic elliptical equatorial section. In our specimens the

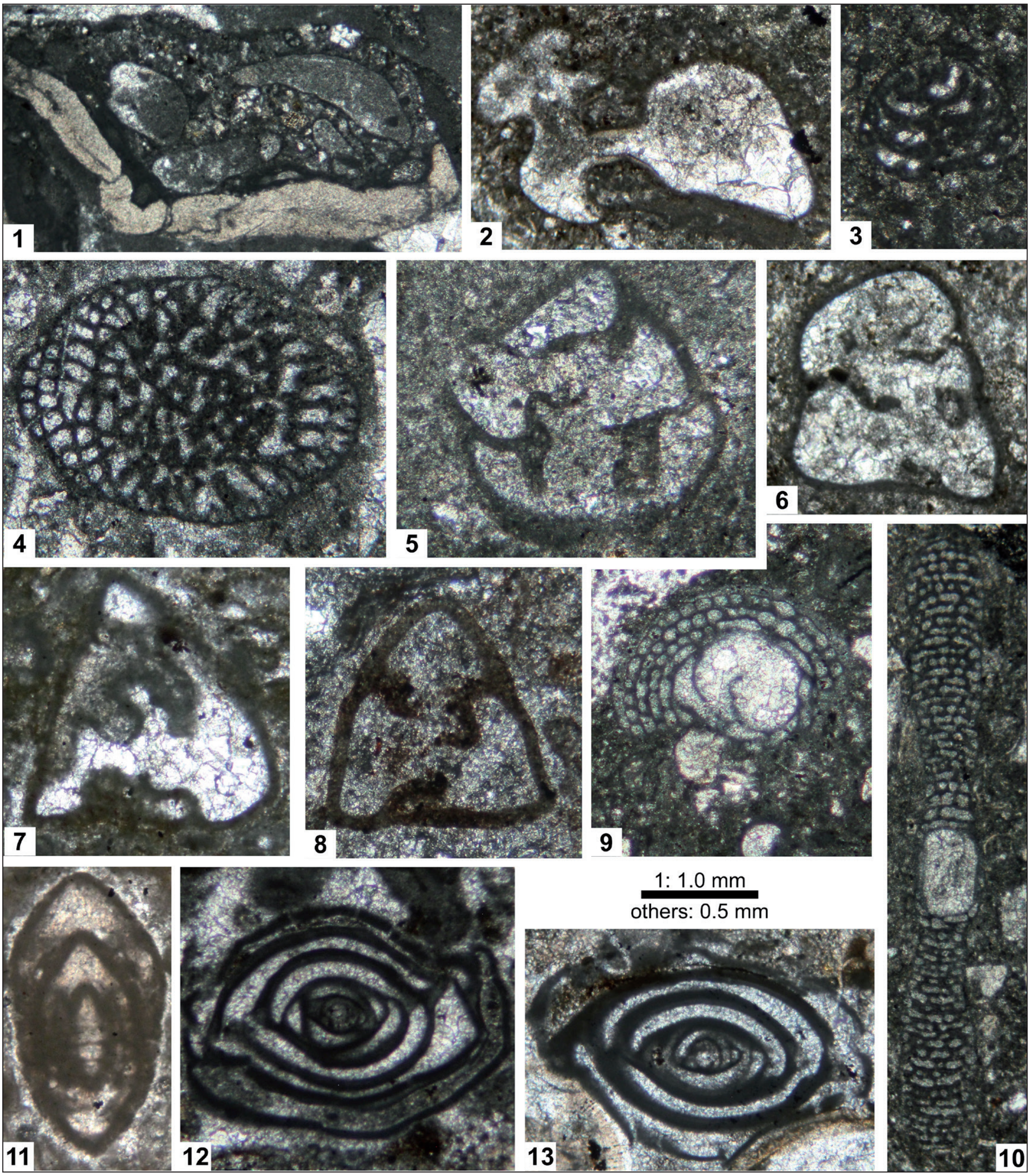

Plate 1

1) *Haddonia praeheissigi* encrusting on *Polystrata alba*, sample GBC2; 2) transversal section of a specimen dubitatively assigned to *Haddonia*, BBC4; 3) *Coskinon* sp., oblique section, BC5; 4) *Fallotella* cf. *kochanskae*, oblique section, BC5; 5-6) *Cribrobulimina* sp., 5. uncentered subaxial section, BC5; 6. oblique section, BBC1; 7-8) *Valvulina triangularis*, 7. transversal section, BC1; 8. transversal section, YGA19B9; 9-10) *Mardinella daviesi*, GBC10; 9, subequatorial section showing the embryonic apparatus; 10. axial section of megalospheric specimens; 11) *Hottingerina anatolica*, subaxial section, BBC8; 12-13) *Idalina sinjarica*; 12. BBC7; 13. YA19C. Scale bar measure 1 mm for figure 1, 0.5 mm for other figures.

internal proloculus reaches 0.10 mm in diameter, whereas the maximum measured diameter is 1.25 mm for a total of five whorls. The biloculine adult stage is not well-preserved in our material. The thick basal layer is about half the total height of the chamber.

Distribution. Serra-Kiel et al. (2020) found this species only associated to SBZ3 assemblages, although according to Serra-Kiel et al. (1998) extended the range up to SBZ6. Inan & Inan (2008) described *I. sinjarica* from SBZ 1 in assemblage with *Laffitteina bibensis* and *Stomatorbina binkhorsti*. At Becirman it occurs in assemblage with *Fallotella* cf. *kochanskae*, *Coskinon* sp., *Cribrobulimina* sp. and *Rotosprella conica* in SBZ2. At Kirkat (samples YGA) it occurs associated with *Elazigina dienii*, *Kathina aquitanica* and *Rotospirella* sp.

Order **Rotaliida** (Delage and Hérouard, 1896)
Superfamily Rotalioidea Ehrenberg, 1839
Family Rotaliidae Ehrenberg, 1839
Subfamily Rotaliinae Ehrenberg, 1839
Genus *Rotorbinella* Bandy, 1944

Rotorbinella hensoni (Smout, 1954)
Pl. 2, Figs. 1-2

1954 *Rotalia hensoni* Smout, p. 45, pl. 15, fig. 8.
2019 *Rotorbinella hesoni* (Smout) – Consorti & Köroğlu, fig. 8.F, G, J, K, N, Q.
2021 *Rotorbinella hensoni* Smout – Vicedo et al., p. 3, fig. 3.
2021 *Rotorbinella hensoni* (Smout) – Vršič et al., p. 7, fig. 9.1-9.2.

Material: one specimen from sample YGA19B and one from YGA19C.

Description. Test conical, the ventral side appears flat. Periphery acute, surface of the spiral side smooth and without ornamentations. The diameter of the figured specimen is 0.82 mm, and the axial height 0.37 mm for about 3 whorls (D/T=2.2). The small proloculus measures about 0.05 mm. The umbilical area is characterized by a single pile, not well-preserved in our material, that forms a compact plug. Umbilical plates separate the plug and the chambers, thus generating a system of spiral canals.

Distribution. Vicedo et al. (2021) described *R. hensoni* from SBZ2 of Oman. According to Hottinger (2014), *R. hensoni* extends from SBZ2 to SBZ3, whereas the primitive *R. detrecta* is typical of SBZ1-2 (Hottinger 2014). At Kirkat it occurs in SBZ2 in assemblage with *E. dienii.*

Remarks. Vicedo et al. (2021) consider *Rotorbinella detrecta* Hottinger (2014) as synonym with *R. hensoni* Smout. Our material prevents any further systematic analysis of the species.

Subfamily Kathininae Hottinger, 2014
Genus *Kathina* Smout, 1954

Kathina aquitanica Hottinger, 2014
Pl. 2, Fig. 3

2014 *Kathina aquitanica* Hottinger, p. 100, pl. 4.4, figs. 1–14; pl. 6.2, figs. 1–7.
2020 *Kathina aquitanica* Hottinger – Serra-Kiel et al., p. 38, fig. 20I'-P'.

Material: one specimen from sample YGA19D.

Description. Lenticular, almost equally biconvex hyaline trochospirally arranged test. The test surface is smooth, the periphery is acute, but without keels. The umbilical region is filled by a solid umbilical mass pierced by funnels. The diameter measures about 0.5 mm, whereas the axial height reaches 0.24 mm. The small spherical proloculus measures 0.02 mm

Distribution. According to Hottinger (2014) *K. aquitanica* occurs in SBZ3, but Serra-Kiel et al. (2020) extended its range from SBZ2 to SBZ4. Vršič et al. (2021) reported dubiatively a single specimen of *K.* cf. *auitanica* from SBZ3 of Sirt basin (Lybia). Our specimen occurs in association with *Elazigina dienii* in SBZ2.

Kathina pernavuti Sirel, 1972
Pl. 2, Fig. 4

1972 *Kathina pernavuti* – Sirel, p. 289, pl. 5, fig. 7.
2013 *Kathina pernavuti* Sirel – Zhang et al., fig. 6.17.
2014 *Kathina pernavuti* Sirel – Hottinger, p. 101, pl. 64, figs. 1-22.
2020 *Kathina pernavuti* Sirel – Serra-Kiel et al., p. 38, figs. 20Q'-20X'.

Material: a single specimen from sample GBC6.

Description. Lenticular test with a rounded periphery. Chambers are arranged in a low-trochospire dorsally evolute. The ventral side is characterized by a solid massive umbo with few funnels. The very small spherical proloculus measures about 0.02 mm. The diameter of the test measures 0.7 mm and the thickness 0.4 mm (D/T=1.8).

Distribution. SBZ3-4 according to Hottinger (2014), in association with *Miscellanites iranicus*;

Zhang et al. (2013) documented its occurrence also from SBZ2 of Tibet, in assemblage with *Rotorbinella skourensis*, *Rotalia implumis*, *Lockhartia retiata*, *L. prehaimei*, *K. aquitanica*, *K.* cf. *selveri*, and *Daviesina danieli*.

Kathina sp.

Pl. 2, Fig. 5

cf. 2013 *Kathina nammalensis* Smout & Haque – Zhang et al., fig. 6.19

Material: one specimen from sample BC4.

Description. Lenticular, almost equally biconvex hyaline test. The periphery is subacute. The test surface is smooth, without ornamentations. Folia appear almost total fused to the rest of umbilical region The diameter measures about 0.95 mm, whereas the axial height reaches 0.54 mm and D/T ratio is 1.8. The small spherical proloculus measures 0.04 mm

Distribution. Our specimen occurs in association with *Praelockhartia* cf. *neoakbari* and *Rotospirella conica* suggesting to assign the sample to SBZ2.

Remarks: our specimen resembles the specimen illustrated by Zhang et al. (2013) as *K. nammalensis*. Unfortunately, no accurate revision of the type material by Smout & Haque (1956) is available to clarify the characteristic of the species *K. nammalensis* that is considered synonym with *K. selveri* by Hottinger (2014). *Kathina selveri* is characterized by a distinctly less convex, almost flat, dorsal side.

Genus *Elazigina* Sirel, 2012

Type species: *Kathina subsphaerica* Sirel, 1972.

Remarks. As stated by Serra-Kiel et al. (2016) and Benedetti et al. (2018) the nominal taxon *Elazigina* is senior synonym of *Plumokathina* Hottinger (2014). Boukhary and Scheibner (2009) erected the rotaliid *Urnummulites schaubi* on free-matrix tests with abraded surface that require detailed analysis to understand their relationships with known *Elazigina* and *Plumokathina*. Unfortunately, our specimens are inadequately figured and their comparison is hampered by the difficulty to compare the main taxonomic characters of our rotaliids with those figured by Boukhary and Scheiber (2009).

Elazigina dienii (Hottinger, 2014)

Pl. 2, Figs. 6-16

1999 *Plumokathina* sp. Accordi et al., p. 196, pl. 14, fig. 6.
2000 *'Plumokathina dienii'* Peybernés et al., p. 44, fig. 6/5, nomen nudum.
2014 *Plumokathina dienii* Hottinger, p. 110; figs. 3.5J, 6.1A-N; pl. 6.8, figs. 1-21.
2018 *Elazigina dienii* (Hottinger) – Benedetti et al., p. 79, figs. 5A-5G.
2019 *Elazigina dienii* (Hottinger) - Consorti & Köroğlu, fig. 10.C-G.

Material: three specimens from sample GBC8, two from YGA19A, six from YGA19B, six from YGA19C and twelve from YGA19D.

Description. Lenticular, biconvex to planoconvex test. The ventral side is generally more convex than the dorsal side. The periphery of the test is acute; centered axial sections show a distinctive upturned margin in dorsal direction. The specimen shows the deep fathering of the interlocular space (Hottinger, 2014).

Our specimens measure 0.62-0.94 mm in diameter and 0.31-0.53 mm in thickness (D/T=1.8-2.0). The sphaerical proloculus has a diameter of 0.06-0.08 mm. About 9-11 chambers occur in the last whorl.

Distribution. *Elazigina dienii* is a marker of SBZ2 according to Hottinger (2014) and Serra-Kiel et al. (2020). At Kirkat it occurs in assemblage with *Miscellanites primitivus*, *Cuvillierina* cf. *sireli, Idalina sinjarica, Ornatorotalia* sp. In sample GBC8 it occurs in assemblage with *Mardinella daviesi* thus extending the age of the latter species within Danian.

Elazigina harabekayisensis Sirel, 2012

Pl. 2, Fig. 17

2012 *Elazigina harabekayisensis* Sirel, p. 275, text-fig. 7, pl. 3, figs. 1-20,
2016 *Elazigina harabekayusensis* Sirel – Serra-Kiel et al., p. 329, figs. 8.15-8.17
2018 *Elazigina harabekayisensis* Sirel – Sirel, p. 61, pl. 8, figs. 12-18; fig. 21A-F.

Material: a specimen from sample GBC3.

Description. Unequally biconvex hyaline test with subacute margin. Chambers are trochospirally arranged. The ventral side, more convex than the dorsal one, shows a thick umbo formed by pillars separated by funnels. The dorsal side is less ornamented and lacks open vertical canals (in

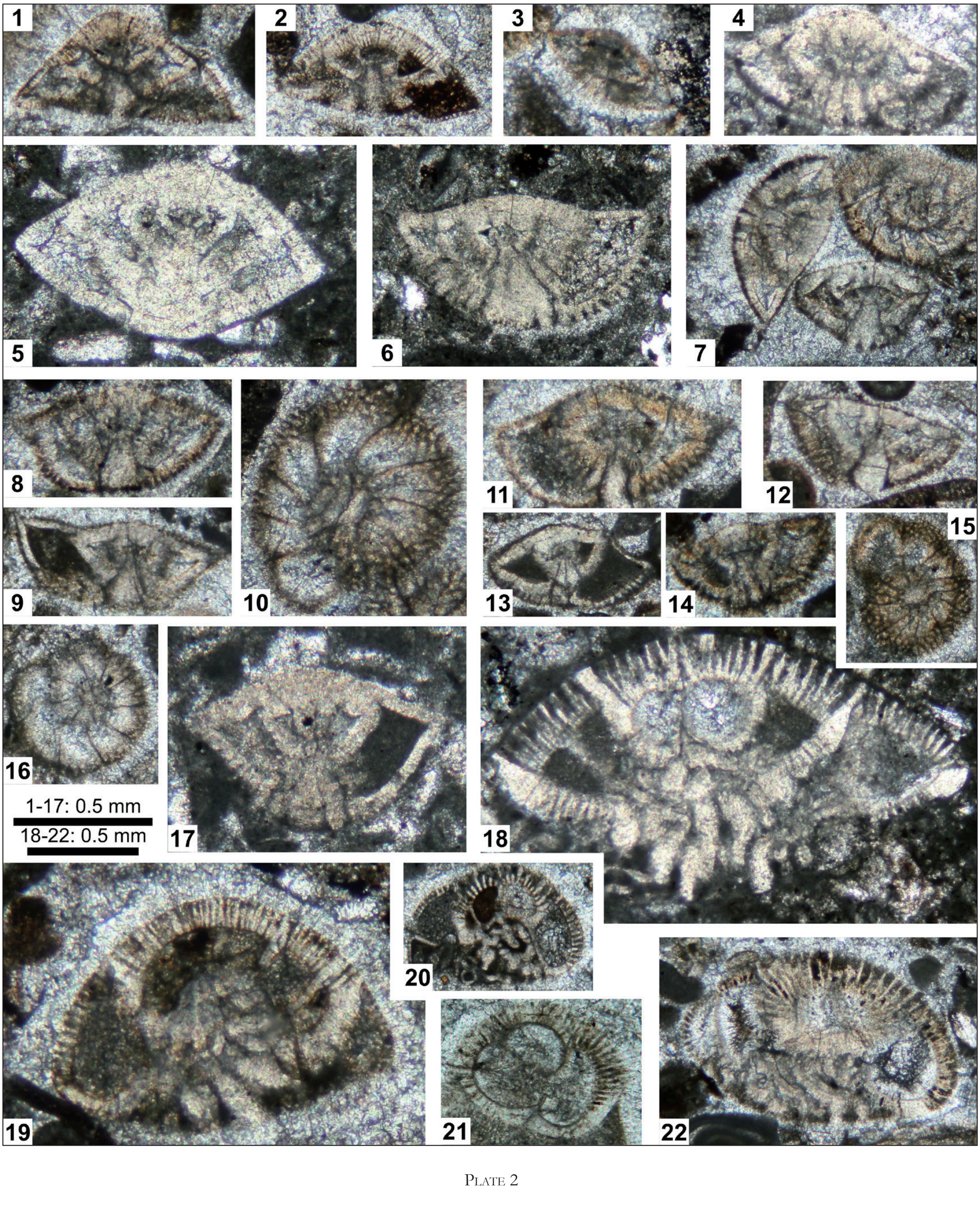

Plate 2

1-2) *Rotorbinella hensoni*, axial sections; 1. YA19 B; 2. YA19C; 3) *Kathina aquitanica*, axial section, YGA19D; 4) *Kathina pernavuti*, almost axial section, GBC6; 5) *Kathina* sp., axial section, BC4; 6-16) *Elazigina dienii*; 6. axial section showing upturned periphery on dorsal side, GBC8; 7. three different sections from sample YGA19A; 8, 12-14. almost centred axial sections, YGA19B; 9. axial section showing uprturned periphery, YGA19C, 15-16, subequatorial sections, YGA19C; 10, transversal section intercepting umbilical piles, YGA19D; 11. axial section showing the typical feathering of the interlocular space, YGA19D; 17) *Elazigina harabekayisensis*, axial section, GBC3;18-22) *Praelockhartia* cf. *neoakbari*, 18. axial section, please note the unperforated spiral sutures, BC4; 19. oblique section, YGA19B; 20-22. oblique sectionss, YGA19A; 21. section passing through the trilocular embryonic apparatus. Scale bars measure 0.5 mm.

contrast to what stated in the description of the genus given by Sirel, 2012). The spherical proloculus measures 0.05 mm. The diameter reaches 0.91 mm and the thickness 0.55 mm.

Distribution. SBZ3 according to Sirel (2012) and Serra-Kiel et al. (2016).

Remarks. Our specimen is smaller with respect to those described by Sirel (2012), but fully comparable with the smaller measurements given by Serra-Kiel et al. (2016).

Subfamily Praelockhartiinae Vicedo and Robles-Salcedo, 2021 in Vicedo et al., 2021
Genus *Praelockhartia* Vicedo and Robles-Salcedo, 2021 in Vicedo et al., 2021

Praelockhartia cf. ***neoakbari*** Vicedo and Robles-Salcedo, 2021

Pl. 2, Figs. 18-22; Pl. 3, Figs. 1-4

cf. 2021 *Praelockhartia neoakbari* Vicedo and Robles-Salcedo, p. 8, figs. 6-8.

Material: a single megalospheric specimen from sample BC4, five from YGA19A, three from YGA19B, two fromYGA19C and three from YGA19D.

Description. Test large, slightly biconvex; the dorsal side is more convex, smooth and evolute, the ventral side is less convex and the umbilical area is characterized by robust piles formed by the fusion of long folia at adaxial tips. The wall appears coarsely perforated except for the chamber sutures visible on the dorsal side. Funnels among piles originate also irregular interpile umbilical cavities. The embryo, in apical section, appears composed of three subspherical chambers (YGA19A12) that is considered a critical taxonomic feature of generic importance according to Vicedo et al. (2021). Later chambers are trochospirally arranged.

The maximum diameter is about 1.7 mm (range 1.07-1.7 mm) and the thickness 1.04 mm (range 0.63-1.04 mm). The large proloculus measures 0.23-0.26 mm

Distribution. *P. neoakbari* was described from SBZ2 of Oman by Vicedo et al. (2021). Our specimen occurs in assemblage with *Elazigina dienii*, *Kathina* sp. and *Rotospirella conica*.

Remarks. Differs from *P. neoakbari* in its larger size and larger proloculus. This calls for a possible new species or possibly to ecological or environmental control on the proloculus and test size in rotaliids as documented in recent nummulitids (Eder et al. 2017) or in Oligocene lepidocyclinids (Benedetti et al. 2010; Benedetti & Pignatti 2013).

Genus *Rotospirella* Hottinger, 2014

Rotospirella conica (Smout, 1954)

Pl. 3, Figs. 5-11

1954 *Lockhartia conica* Smout, p. 53, pl. 4, figs 1–3.
2014 *Rotospirella conica* (Smout) – Hottinger, p. 31, fig. 3.6.
2021 *Rotospirella conica* (Smout) – Vicedo et al., p. 10, fig. 9.

Material: two specimens from BBC3, three in different sections from BBC7, one specimen in axial section and one in apical horizontal section from sample BC1, three from BC4 and two subapical sections from sample BC5.

Description. High conical test with rounded periphery. The large proloculus measures 0.11-0.18 mm in diameter. The dorsal side is strongly convex, evolute with smooth surface, the ventral side is almost flat to convex. The wall is coarsely pierced. Chambers are trochospirally arranged.

Our specimens measure 0.94-1.40 mm in diameter and 0.59-0.86 mm in thickness, with D/T ratio of about 1.4-1.7.

Distribution. In our material it occurs with *Praelockhartia* cf. *neoakbari* and *Kathina* sp. According to Vicedo et al. (2021) and Serra-Kiel et al. (2020) *R. conica* is an SBZ2 marker.

Rotospirella sp.

Pl. 3, Figs. 12-17

Material: three specimens from sample YGA19B, two from YGA19C and a possible subapical section non passing through the embryo from sample YGA19D.

Description. Test low-conical, dorsal side convex with smooth surface, ventral side almost flat with about 4 large piles in the umbilical area. Wall coarsely perforated, without imperforate sutures. Periphery acute, but unkeeled. The umbilicus is filled with parallel piles (about four piles are visible from axial and subaxial sections) separated by funnels. Piles grow on folia and are not mutually adaxially fused. The diameter varies between 0.77 mm to 0.97 mm, the thickness from 0.33 mm to 0.39 mm, the D/T ratio exceeds 2 (2.1-2.5). The small proloculus measures 0.03-0.04 mm.

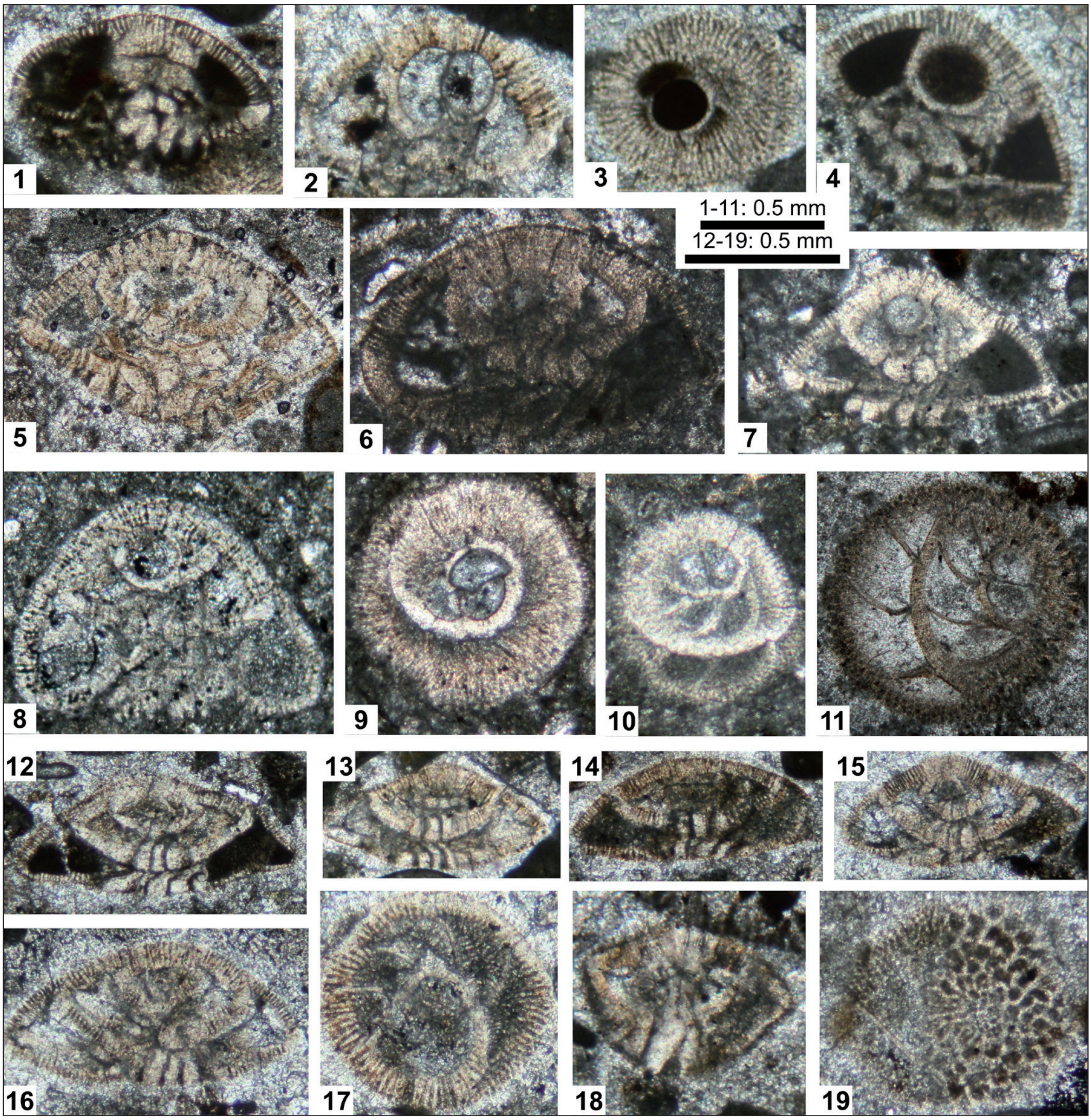

Plate 3

1-4) *Praelockhartia* cf. *neoakbari*, 1, transversal section, YGA19B; 2. subapical section showing the trilocular embryo, YGA19B; 3. subapical section, YGA19C; 4. subaxial section passing through the proloculus, YGA19D; 5-11) *Rotospirella conica*; 5. almost centred axial section, BBC7; 6. transversal section, BBC3; 7. subaxial section, BC4; 8, axial section passing through the embryo, BC1; 9. apical section passing through the embryo, BC1; 10. oblique section intercepting partly the embryo and the first two whorls, BC5; 11. almost transversal section intercepting about two whorls, BBC7; 12-17) *Rotospirella* sp., 12-14. almost centred subaxial sections, YG19B; 15-16) axial sections, YGA19C; 17) transversal section showing the roughly perforated wall, YG19D; 18) subaxial section of *Ornatorotalia* sp., YGA19B; 19) tangential section of *Cuvillierina* cf. *sireli*, YGA19A. All from SBZ2 of Becirman (5-11) and Kirkat (1-4, 12-19). Scale bars measure 0.5 mm.

Distribution. In our material it occurs from SBZ2 in assemblage with *Rotorbinella hensoni, E. dienii*, *Ornatorotalia* sp., *Idalina sinjarica* and *Valvulina triangularis*.

Remarks. The occurrence of unfused piles is the main taxonomic character that allowed us to distinguish this possible new taxon which differs from *R. conica* in having a low conical shell, with more acute periphery, and a distinctly smaller proloculus.

Family Ornatorotaliidae Benedetti, 2015
Subfamily Ornatorotaliinae Benedetti, 2015
Genus *Ornatorotalia* Benedetti, Di Carlo & Pignatti, 2011

Ornatorotalia **sp.**
Pl. 3, Fig. 18

cf. 2018 *Ornatorotalia* sp. Benedetti et al., p. 86, figs. 7.F-7.G.

Material: one single specimen from sample YGA19B.

Description. Test small, biconvex, trochospirally coiled. The ventral side is more convex than the dorsal side. Vertical canals (funnels) occur in both ventral and dorsal side. The diameter measures about 0.59 mm, and the thickness is 0.43 mm. The proloculus is not clearly visible form our uncentered axial section. The periphery of the test is subacute and poorly ornamented. The spine typical of the microspheric generation of the genus are not visible, since the figured specimen is possibly a megalospheric form.

Distribution. It occurs at Kirkat in assemblage with *Elazigina dienii* and *Rotorbinella hensoni* in SBZ2.

Remarks. It differs from *Miscellanites primitivus* in the trochospiral coiling, asymmetrical pillars and in lacking other characters typical of the genus (i.e., multiple foramina). *Ornatorotalia pila* Benedetti et al. (2020) is distinctly larger. *Ornatorotalia* sp. described from SBZ2 of Central Italy by Benedetti et al. (2018) seems comparable with our specimen as concerns the size, but further analysis on well-centered specimens are needed. The small *Ornatorotalia* sp. from Kirkat could be probably the ancestor of *Ornatorotalia pila* known from SBZ3-4 of Turkey and eastern Tethys (Sirel & Devecíler 2017; Benedetti et al. 2020).

Family Cuvillierinidae Loeblich &Tappan, 1964
Subfamily Cuvillierininae Loeblich & Tappan, 1964
Genus *Cuvillierina* Debourle, 1955

Cuvillierina **cf.** ***sireli*** **Inan, 1988**
Pl. 3, Fig. 19

cf. 1988 *Cuvillierina sireli* Inan, pl. 1, figs. 1-9; pl. 2, figs. 1-8.
2018 *Cuviliierina* cf. *sireli* Inan – Benedetti et al., p. 86, fgs 8.D-8.F.

Material: a specimen in tangential section from sample YGA19A.

Description. Test involute, pierced by several funnels among thin pillars on both ventral and dorsal sides. The maximum measurable diameter reaches about 0.78 mm. Our specimen shows only the orifices of the vertical canals on the eternal surface. It is left in open nomenclature in absence of other well-oriented sections.

Distribution. In our sample it occurs in an SBZ2 assemblage with *Elazigina dienii*. *Cuvillerina sireli* is known as a typical SBZ2-3 marker (e.g., Benedetti et al. 2018; Serra-Kiel et al. 2020).

Discussion and conclusion

The Paleocene was a time of considerably climate changes after the abrupt mass extinction at the end of Cretaceous period. During this time span, LF suffered dramatic extinction and turnover since shallow-water communities were drastically reduced both in number and diversity (e.g., Hottinger 2001). In particular K-strategists LF disappeared for the whole lower Danian SBZ1, and only a few genera, such as e.g. *Laffitteina*, *Pararotalia*, *Elazigina* and *Idalina* (Consorti & Rashidi 2018; Consorti et al. 2021; Sirel 2018), overcame the K/Pg boundary.

The Lower Paleocene is usually poorly documented in Neo-Tethyan shallow-water settings because of lacking of well-preserved sedimentary successions, with the exception of the periadriatic platform (e.g., Drobne et al. 2017), Pyrenees (e.g., Serra-Kiel et al. 2020), Northern Italy (Papazzoni et al. submitted), Austria (Schlagintweit et al. 2018; Sanders et al. 2019; Consorti et al. 2020), Iran (e.g., Consorti & Köroğlu 2019) and Turkey (e.g., Sirel 2012, 2015, 2018).

The Becirman Formation documents a late Danian shallow marine succession that records a quite diverse foraminiferal assemblage composed by 11 rotaliid species belonging to 7 genera (taking into account also *Ornatorotalia* and *Cuvillierina* that not are true rotaliids, see also Benedetti & Papazzoni 2022). The investigated sedimentary succession represents a very shallow-water event between two fluvial-lacustrine deposits. The occurrence of miliolids such as *Idalina*, associated to the soritiid *Mardinella* (Consorti & Sinanoğlu in press) calls for the possible occurrence of vegetated sea bottom, because of their epiphytic mode or life (e.g. Langer 1993; Consorti et al. 2020). In particular, large and flattened symbiont-bearing porcelaneous foraminifera, associated to miliolids and other epiphytic taxa, have been described as linked to the well-illuminated and oligotrophic environment with a sandy seafloor colonized by algae (e.g., Benedetti & Frezza 2016). Miliolids and rotaliids (sensu lato) can be moreover found associated in paralic marine-continental transitional environments (Consorti et al. 2021) or on seagrass meadows (Pignatti et al. 2012). Hottinger (2001) hypothesized a time of about 10 Ma to the complete maturation of shallow benthic LF communities. Indeed, with respect to other LF, such as especially orthophragminids, alveolinids and nummulitids that required at least 10 Ma to undertake a high species radiation, rotaliids show a rapid diversification at genus level in SBZ2 (Benedetti & Papazzoni 2022). Rotaliids, among LF, possibly acted as opportunists occupying the vacant niches during the Danian, thus involving a rapid radiation at genus rank. The herein investigated samples are however characterized by K-strategists assemblages as documented by the occurrence of *Mardinella daviesi*, characterized also by a paratrimorphic cycle (Consorti et al. 2020), large-sized *Praelockhartia*, and *Ornatorotalia*, thus leading to a faster recovery of K-strategists than that previously hypothesized. *Elazigina dienii*, abundant in most investigated samples, and considered as K-strategist by Hottinger (2014), should instead considered more likely a moderate K-strategist or fully r-strategist in lacking a real dimorphism, as for its Maastrichtian ancestor *E. siderea* (Consorti & Rashidi 2018). The SBZ2 LF diversification could be linked to the warming climate culminating in the Latest Danian Event (LDE, Quillévéré et al. 2008; Bornemann et al. 2009).

To sum up, the investigated sections of the Becirman Formation are characterized by the occurrence of larger foraminiferal assemblages widely distributed throughout the formation without significant variations. The micropaleontological analysis allows us to conclude that:

a - The Becirman Formation can be referred to late Danian, SBZ2, according to the occurrence of *Elazigina dienii*, *Rotospirella conica*, *Praelockhartia* cf. *neoakbari*, associated with *Mardinella daviesi, Cuvillierina* cf. *sireli* and other taxa;

b - The microfossils assemblage indicates shallow-water vegetated environment;

c - The climatic events after the K/Pg events played an important role in the recovery of shallow benthic communities. The Becirman Formation records a quite diversified assemblage mostly dominated by rotaliids (11 species belonging to 7 genera) and subordinated porcelaneous and agglutinated taxa. In particular, the combination of increase of surface water temperatures and oligotrophic conditions up to LDE could have enhanced shallow-water biodiversity, leading to a rapid radiation of rotaliids at least at genus rank;

d - Two potential new species, left in open nomenclature, i.e., *Rotospirella* sp. and *Ornatorotalia* sp., will require further taxonomic analysis, since they could represent additional SBZ2 markers.

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