

## ***Dictyoconus aydimi* (Gallardo-Garcia and Serra-Kiel, 2016) comb. nov., larger benthic foraminifera from the Middle-Upper Eocene of the Middle East (SE Turkey, Iraq, SW Iran, Oman): New evidence for Arabian Plate faunal provincialism**

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**Abstract:** *Rogerella aydimi* Gallardo-Garcia and Serra-Kiel was described from the Priabonian Haluf Member of the Aydim Formation, Oman. Based on new finds from the Bartonian Hoya Formation of SE Turkey and the Jahrum Formation of Iran, its taxonomic status is discussed herein. It is concluded that it represents a species of *Dictyoconus* with a simple subepidermal network (1 rafter, 1 intercalary beam) below a thin epiderm. The stratigraphic range of *D. aydimi* known thus far is Bartonian-Priabonian or Shallow Benthic Zone 17–20. The distribution of *D. aydimi* gives further evidence for a Middle-Late Eocene faunal provincialism of the Arabian Plate (Somalia, Oman, Iran, Iraq, SE Turkey).

**Key words:** Benthic foraminifera, taxonomy and systematics, biostratigraphy, paleobiogeography, Eocene, SE Turkey

### **1. Introduction**

Larger agglutinated conical benthic foraminifera are a typical constituent of Paleogene inner platform carbonates (e.g., Hottinger and Drobne, 1980; Vecchio and Hottinger, 2007; Powell, 2010). As in the Lower and Upper Cretaceous (e.g., Cherchi et al., 1981), the representatives of the Dictyoconinae displayed a biogeographic distribution pattern during the Paleogene with different assemblages on both sides of the Atlantic Ocean (e.g., Caribbean Bioprovince, Hottinger and Drobne, 1980; Goldbeck and Langer, 2009, Figure 27) for this group of agglutinated conical foraminifera. Paleocene taxa (e.g., *Coskinon*, *Dictyoconus*, *Fallotella*, and *Karsella*) have been reported from the Taurides of Turkey (provinces of Elazığ and Kars) (e.g., Sirel, 2015). Assemblages of Middle Eocene (Bartonian) larger benthic foraminifera (LBF), including Orbitolinidae, have been studied from the Hoya Formation in SE Turkey (north eastern Diyarbakır), belonging to the northernmost part of the Arabian Plate (Özgen-Erdem and Sinanoğlu, 2016; Sallam et al., 2018). Large-sized dictyoconids, previously referred to as *Dictyoconus aegyptiensis* (Chapman), usually occur above limestones with *Somalina stefaninii* Silvestri. They have been recognized as *Rogerella aydimi* Gallardo-Garcia

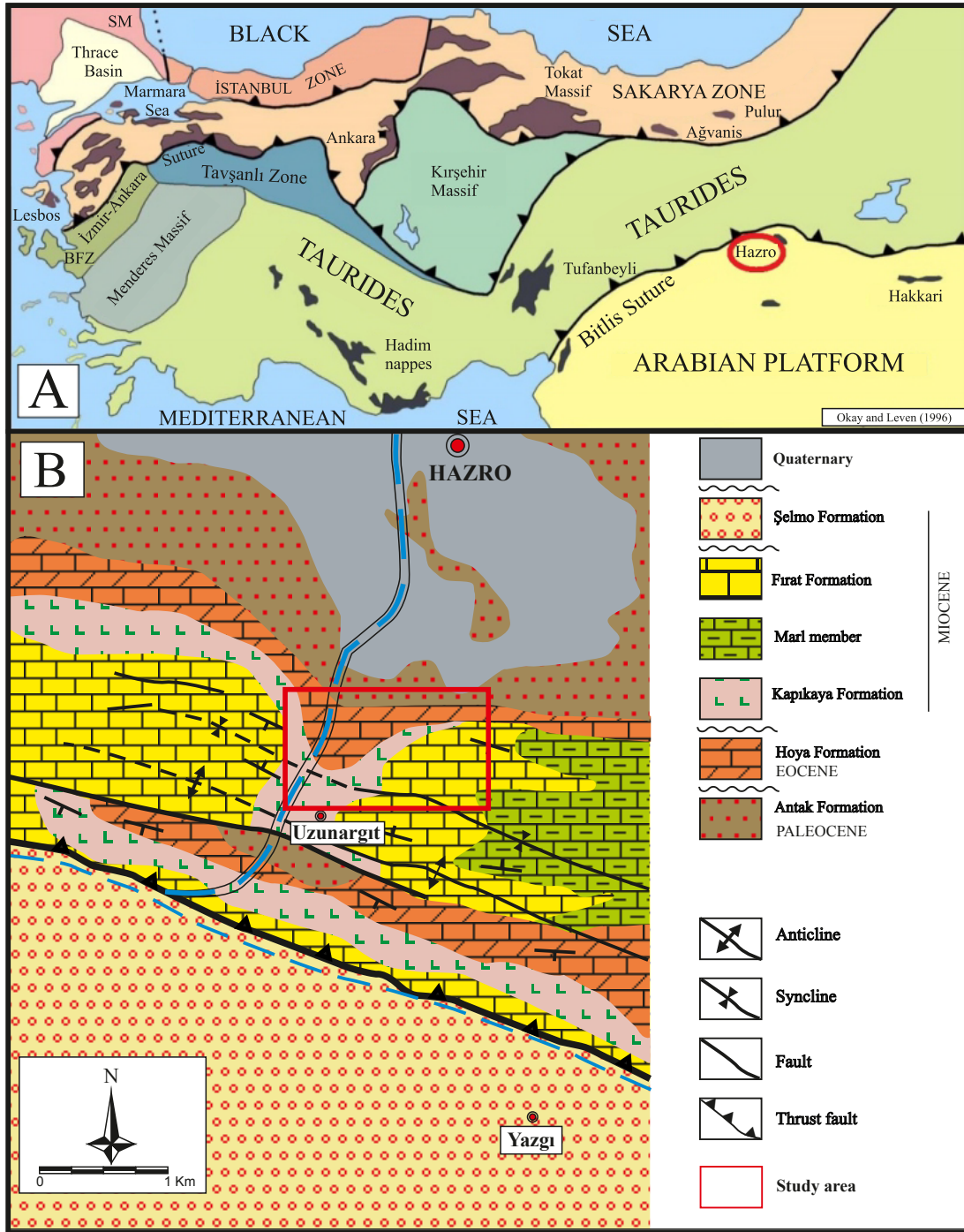
and Serra-Kiel, as described recently in Serra-Kiel et al. (2016), from the Middle-Upper Eocene of Oman. The present findings from Turkey represent the first discovery of its type-locality. The aim of the present study was to 1) comment and revise its taxonomic status and 2) constrain its paleobiogeographic distribution, also including further specimens from the Jahrum Formation in Iran.

### **2. Geological setting**

#### **2.1. Geological overview**

The south eastern Anatolian region forms the northern part of the Arabian Platform (Figure 1A) and consists of the Bitlis-Pütürge Crystalline Melange, Precambrian Basement, and Early Paleozoic-Cenozoic sedimentary deposits (Rigo de Righi and Cortesini, 1964; Sungurlu, 1974; Şengör and Yılmaz, 1981). The geological framework of this region was shaped by the Late Mesozoic and Cenozoic closure of the multibranched Neotethyan Ocean (Şengör and Yılmaz, 1981). Important folding structures developed during the Neotectonic period as a result of the N-trending compressional tectonic regime. The Cambrian, Aptian-Cenomanian, Campanian-Maastrichtian, and Middle Eocene periods are represented by marine sequences, which indicate widespread transgression

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**Figure 1.** Geological and geographic setting of the Hazro section in SE Turkey. A: Geotectonic situation and location on the north-western boundary of the Arabian Platform (after Okay and Leven, 1996). B: Geological map of the study area and surroundings (modified from MTA, 2008).

processes throughout the region. In the middle Eocene-Oligocene, shallowing took place in the south eastern Anatolian region, followed by a continuous deposition of carbonates.

In the semi-closed basins that developed as a result of the rapid closure of the Neotethys, shallow-marine conditions prevailed, and carbonates alternating with evaporites were deposited (Ziegler, 2001). By the end of the Oligocene, the

Arabian Platform was subjected to highly tectonic pulses that resulted in significant palaeogeographical changes in this region (Perinçek, 1980). The Eocene-Oligocene deposits are generally represented by carbonate platform sediments that display lateral and vertical facies changes. The Lower Eocene units consist of conglomerates, sandstones, siltstones, and clayey limestones. The Middle Eocene–Lower Oligocene sequences are composed of thin- to thick-bedded, massive limestones and dolomites. The Upper Oligocene consists of limestones, marls, cherty limestones, and evaporites (Duran et al., 1988; Çoruh et al., 1997).

## 2.2. Studied section and biostratigraphic framework

The Hazro Section is located about 2 km southwest of the town of Hazro in the Diyarbakır district of Turkey (Figure 1B). Coordinates of the section are 65°54'75" E and 42°33'41.9" N. In the study area, the oldest exposed rocks belong to the Paleocene Antak Formation, which unconformably underlies the Hoya Formation. The Lower Miocene carbonates of the Kapıkaya and Fırat formations overlie unconformably the Hoya Formation. The Hoya Formation (~45-m-thick) consists mainly of cream-colored micritic limestones, alternating with partly dolomitic limestone beds at the lower and upper parts. Assemblages of LBF from this locality were reported by Özgen-Erdem and Sinanoğlu (2016) and Sallam et al. (2018).

The rich assemblages of LBF observed in the Hoya Formation are represented by alveolinids, soritids, and orbitolinids (Figure 2). In the basal part of the Hazro section, small- to medium-sized miliolids and textulariids occur. The LBF show an increase in terms of diversity and quantity, starting from the midsection towards the upper part of the section, especially, the alveolinids and soritids, together with the orbitolinids (Figures 2a–2c). The porcelaneous taxa are represented by *Rhabdorites malatyaensis* (Sirel), *Haymanella paleocenica* Sirel, *Somalina stefaninii* Silvestri, *Alveolina fragilis* Hottinger, *Alveolina fusiformis* Stache, *Alveolina stercusmuris* Mayer-Eymar, *Alveolina nuttali* Davies, *Idalina* sp., and *Spirolina* sp. Agglutinated taxa include *Dictyoconus aydimi* (Gallardo-Garcia and Serra-Kiel) comb. nov. (Figure 3), *Cribobulimina* sp., and *Valvulina* sp. *D. aydimi* is observed in the middle part of the Hazro Section within an interval that attains a thickness of 3.5 m. This species occurs in association with *R. malatyaensis*, *H. paleocenica*, *Alveolina fragilis*, *Orbitolites* sp., and *Cribobulimina* sp.

*A. fragilis* is a biomarker for shallow benthic zone 17 in the zonation provided by Serra-Kiel et al. (1998). *R. malatyaensis* was documented in the Bartonian from some localities of Turkey (Sirel, 1976; Sirel and Acar, 1993). It is associated with characteristic Middle Eocene species, such as *Fabiana cassis* (Oppenheim), *Halkyardia*

*minima* (Liebus), and *Chapmania gassinensis* Silvestri. *R. malatyaensis* was also recorded in the Middle Eocene of Iran (Rahaghi, 1978) and Greece (Fleury, 1997). This species was defined in the Bartonian horizons in association with *Malatyna vicensis* Sirel and Acar, *H. minima*, *Orbitolites* cf. *cotentinensis* Lehmann from the Vic region (Spain) by Sirel and Acar (1998).

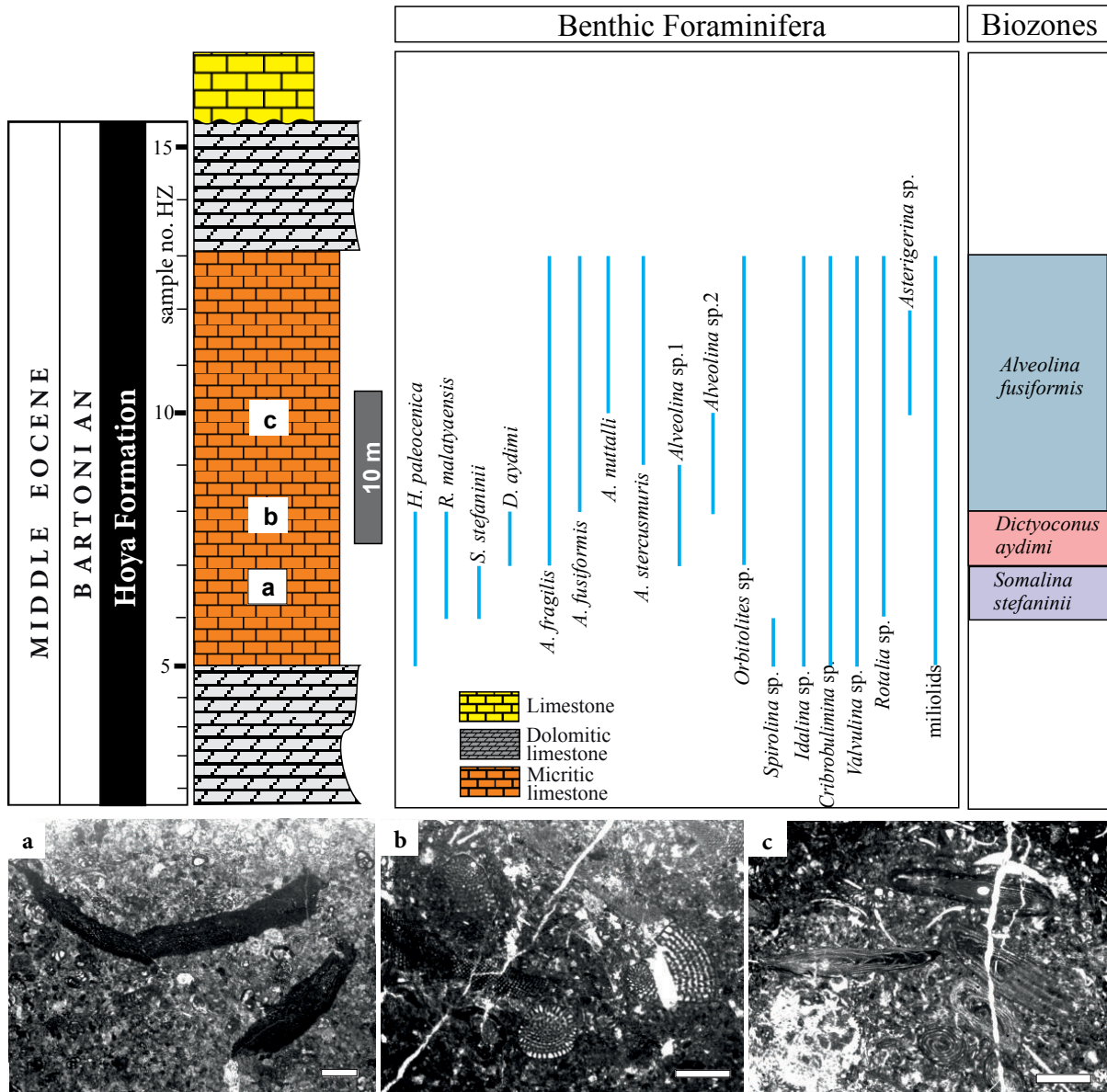
## 4. Materials and methods

The samples containing *Dictyoconus aydimi* (Gallardo-Garcia and Serra Kiel) comb. nov. were collected from the Hazro Section (SE Turkey). Altogether, 15 rock samples were collected, from which about 130 thin sections were prepared. Due to the hard lithology of the limestones, the identification of benthic foraminifera in this study was mainly based on unoriented thin sections. The thin sections of the Hazro Section were deposited in the Özgen-Erdem collection at the Department of Geological Engineering, Sivas Cumhuriyet University (Sivas, Turkey). The specimens, kindly provided by Iranian colleagues, are from the Middle-Upper Eocene of the Jahrum Formation, which crops out in the Zagros Zone of SW Iran (e.g., Nafarieh et al., 2019). They are housed within the micropaleontological collections of the National Iranian Oil Company (NIOC).

## 5. Results and discussion

### 5.1. Taxonomic remarks

In his PhD on Middle Eocene-Early Miocene LBF from Dhofar (Oman) and Socotra Island (Yemen), Gallardo-Garcia (2015) established some new taxa, and among others, *Dhofarella aydimi* gen. et sp. nov. However, to be considered published according to the International Code of Zoological Nomenclature (ICZN), under article 8.5.3., new taxa must “be registered in the Official register of zoological nomenclature (ZooBank) (see article 78.2.4) and contain evidence in the work itself that such registration has occurred”. Such a procedure, however, has, according to our knowledge, never been undertaken. In any case, the name was already occupied by *Dhofarella* Sigé et al., 1994, a genus of bats established from teeth in Oligocene marls of the Ashawq Formation of Oman. Based on the same material with the same illustrations and holotype, Serra-Kiel et al. (2016) introduced *Rogerella aydimi* gen. et sp. nov., without mentioning *Dhofarella* Gallardo-Garcia, 2015 (or its homonym). Again, the new genus name was already occupied by *Rogerella* Saint-Seine (1951), an ichnofossil, that is included in the ICZN (see article 1.2.1). The authors were informed about this homonymy (pers. comm. Francois Le Coze, 06/22/20), and given the opportunity to provide a replacement name (see Code of ethics, Appendix A of the ICZN).



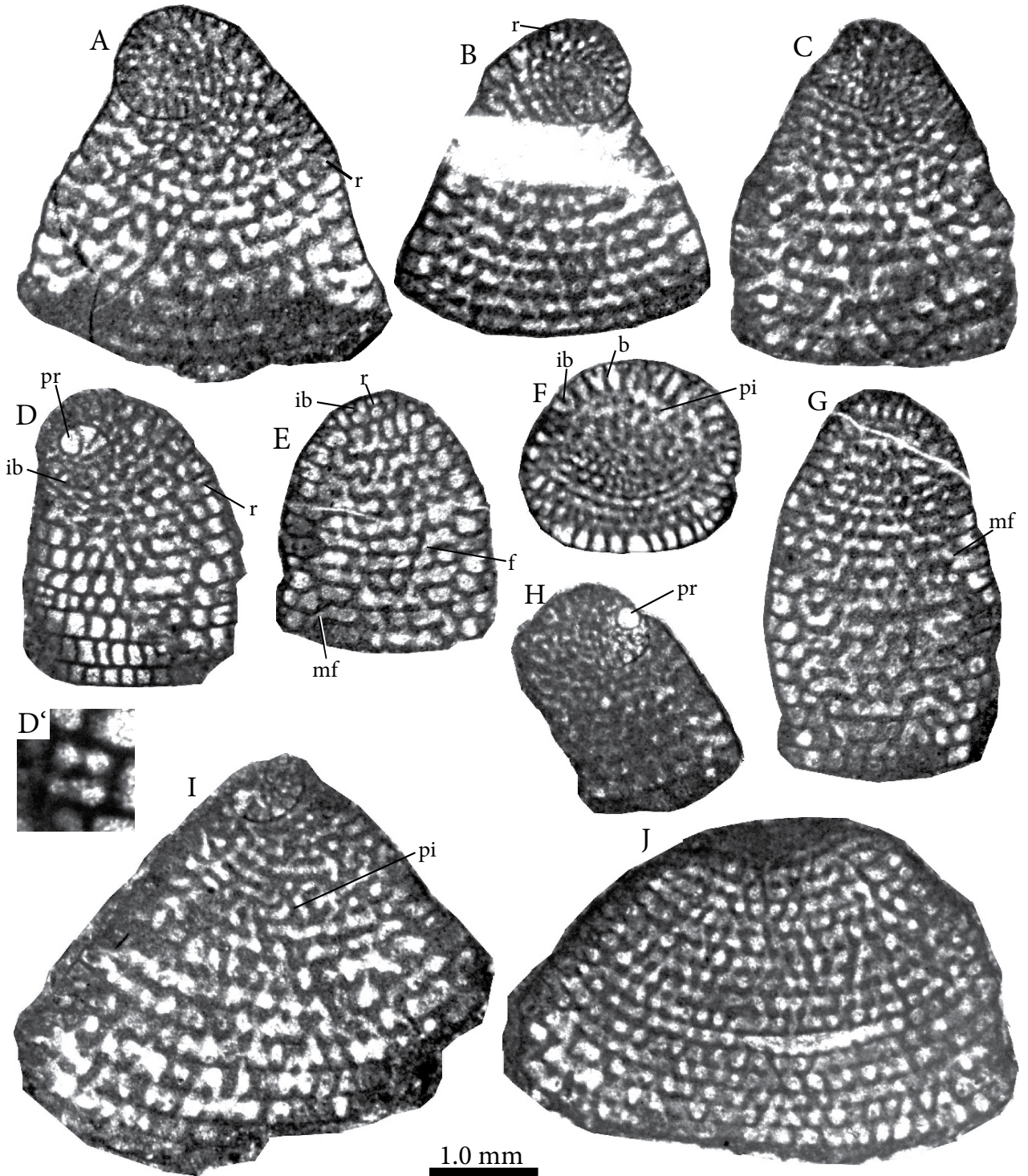
**Figure 2.** Lithostratigraphic log of the Hazro section, SE Turkey (modified from Özgen-Erdem and Sinanoğlu, 2016) showing the lithostratigraphy, biofacies, and distribution of the LBF (scale bar: 1.5 mm for a and b, and 2.5 mm for c)

As summarized in Table 1 of the research of Serra-Kiel et al. (2016), *Rogerella* should differ from *Dictyoconus* Blanckenhorn by 1) a pseudo-keriothecal wall, 2) the absence of a subepidermal network, 3) a planispiral initial coil, and 4) an embryo (protoconch + deuterioconch) that lacks skeletal elements.

**Wall structure:** The pseudo-keriothecal wall structure is not discernible in any of the specimens of *Rogerella aydini* illustrated by Serra-Kiel et al. (2016),

an observation also remarked by Cruz-Abad (2018) in her critical revision of the Orbitolinidae. It is worth mentioning, however, that *Rogerella* was regarded as a valid taxon by Cruz-Abad (2018). In conical agglutinated taxa, a thin wall “with a pseudo-keriothecal structure” (Serra-Kiel et al., 2016) exclude each other. Usually, a pseudo-keriothecal wall is thick and either found in taxa with alcores (Hottinger, 2006, for definition), such as the late Cretaceous *Lepinoconus* (see Cruz-Abad et al.,



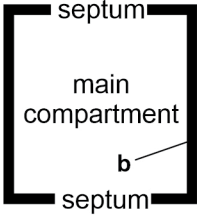
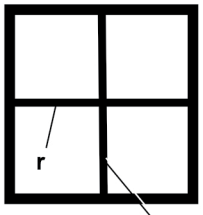
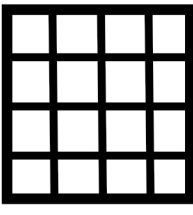


**Figure 3.** *Dictyoconus aydimi* (Gallardo-Garcia and Serra-Kiel, 2016) comb. nov. from the Bartonian Hoya Formation of SE Turkey. A–C, I) Axial sections, samples HzBA1, Hz8b, Hz8-9B2, and HZ8e2. D) Oblique section passing the megalospheric embryo, sample Hz8-20. D') Detail from D showing the moderate simple subepidermal network with 4 alveolar subunits per main compartment. E) Oblique section through the uniserial part, sample c1b. F) Oblique transverse section showing 1 intercalary beam per main compartment, Hz8b1. G) Subaxial section, sample Hz8h1. H) Fragmentary axial section of a megalospheric specimen, sample Hz8b2. J) Subaxial section of a possibly microspheric specimen, sample Hz8f.

2017) or the Eocene *Coleiconus* (Hottinger and Drobne, 1980), or in those lacking any exoskeleton, such as the Paleogene *Coskinolina* Stache (e.g., Hottinger and Drobne, 1980) (Figure 4A). The epiderm covering a subepidermal network is thin (Douglass, 1960; Septfontaine, 1980). Instead, it is the opinion herein that the wall structure of *Rogerella* is homogeneous, finely agglutinated (without any internal structure), as in *Dictyoconus* Blanckenhorn.

**Exoskeleton:** The presence or absence of a subepidermal network in Orbitolinidae may have generic value (e.g., Hottinger and Drobne, 1980), but its grade of complexity is classically considered a specific characteristic (e.g., Arnaud-Vanneau, 1980; Schlagintweit, 2020). In the differences between *Rogerella* and *Dictyoconus*, Serra-Kiel

et al. (2016) stated “the absence of a subepidermal network” and that... “there is only 1 beam intercalated between 2 successive beams and 1 generation of rafters” in the former. An exoskeleton with 1 rafter and 1 intercalary beam occurs, for example, in the Paleogene *Fallotella kochanskae* and *F. persica* (Hottinger and Drobne, 1980). The resulting “subepidermal network with 4 alveolars per unit” (or chamber compartment) can be considered a moderate simple/complex subepidermal network (Figure 4B), but it cannot be appropriate to define *Rogerella* as lacking such a feature. The rafters and intercalary beams of *Rogerella* are both rather short, so that only very shallow tangential sections display the network of 4 compartments (see Figure 3D). The moderate simple/complex subepidermal

alcoves	subepidermal network	
		
no rafters and no intercalary beams	four marginal alveolar subunits per main compartment	three orders of rafters and three orders of intercalary beams
	moderate simple exoskeleton	dense + complex exoskeleton
<b>Examples</b> <b>A:</b> <i>Coskinolinoides texanus</i> Keijzer <i>Daviesiconus basilliei</i> (Davies) <i>Lepinoconus chiocchini</i> Cruz-Abad et al. <i>Paracoskinolina maynci</i> (Chevalier) <i>Simplorbitolina aquitanica</i> (Schroeder) <b>B:</b> <i>Dictyoconus aydimi</i> (Gallardo-Garcia and Serra-Kiel) <i>Fallotella persica</i> Hottinger and Drobne <i>Fallotella kochanskae</i> Hottinger and Drobne <i>Paracoskinolina arcuata</i> (Arnaud-Vanneau) <b>C:</b> <i>Gusicella minima</i> (Henson) <i>Dictyoconus indicus</i> Davies <i>Dictyoconus aegyptiensis</i> (Chapman) <i>Mesorbitolina texana</i> (Roemer)		

**Figure 4.** Schematic drawing of an exoskeleton in the tangential section of the selected agglutinated conical foraminifera (with examples from the Lower/Upper Cretaceous and Paleogene). For terminology see Hottinger (2006). Note that *Dictyoconus aydimi* belongs to type B, and *D. aegyptiensis* and *D. indicus* belong to type C.

network of *Rogerella* is considered as nothing but a specific feature. Other species of *Dictyoconus*, such *D. aegyptiensis* (Chapman) or *D. indicus* Davies, display a rather complex network, consisting of several series of both rafters and intercalary beams (Davies, 1939; Henson, 1948; Hottinger and Drobne, 1980; Hottinger, 2007; Serra-Kiel et al., 2016) (Figure 4C).

**Coiling of initial stage:** Compared to the type-species, *D. aegyptiensis* or also *D. indicus*, *Rogerella aydimi* exhibits a more voluminous initial spire. According to Serra-Kiel et al. (2016), the spire should be trochospiral in *Dictyoconus* when compared to the allegedly planispiral coiling in *Rogerella*. It is the opinion herein that a planispiral coiling was not convincingly clear in the single axial section of the holotype specimen that seemingly passed the spire obliquely. It is also worth mentioning that in the type-species, *D. aegyptiensis* (Chapman), the embryo is “followed by 6–8 almost planispiral chambers” (Hottinger and Drobne, 1980). Moreover, for subsequent works, it would be impossible to make a clear decision without having oriented the sections at hand. Concerning the more prominent coil, this should rather be considered a specific than generic feature.

**Embryo:** Concerning the structure of the embryo, there are some contradictory statements. On the one side, the embryo of *Rogerella* is said to consist of a protoconch + deuteroconch instead of a protoconch + deuteroconch that may have skeletal elements in *Dictyoconus*, respectively *D. indicus* (Table 1 in Serra-Kiel et al., 2016). Referring to the holotype specimen (Figure 38.1 in Serra-Kiel et al., 2016), being the only megalospheric specimen illustrated in the axial section with an embryo, the researchers described the deuteroconch “with beams” (if any, these should be termed rafters?). It is the opinion herein that the deuteroconch is not well discernible in the holotype specimen and the occurrence of several “beams” followed by the neanic chambers, with just 1 rafter and 1 intercalary beam, would be a curious feature. In any case, the presence of skeletal elements in the deuteroconch of *Dictyoconus*, although debatable with respect to suprageneric classification (Orbitolininae vs. Dictyoconinae), is accepted as species criterion (*D. indicus* with and *D. aegyptiensis* without skeletal elements; Davies, 1939; Hottinger and Drobne, 1980; Hottinger, 2007; Serra-Kiel et al., 2016). Again, such a feature is not an adequate criterion for the separation of *Rogerella* from *Dictyoconus*.

In summary, with an appreciation of all aspects, no feature, or a combination of various features, were observed that would permit the establishment of an individual genus clearly distinguished from *Dictyoconus*. Some differences in the type-species, *D. aegyptiensis*, as discussed above, are considered specific features. To conclude, *Rogerella* (Gallardo-Garcia and Serra-Kiel, 2016)

is considered a subjective junior synonym of *Dictyoconus* Blanckenhorn (1900). With respect to the moderate complex subepidermal network and the embryo seemingly lacking any subdivisions, *D. aydimi* can be considered as a simple structured species of the genus.

## 5.2. Systematic description

**Remarks:** The classification of agglutinated foraminifera by Kaminski (2014) was followed herein.

Phylum Foraminifera Eichwald, 1830

Class Globothalamea Pawlowski et al., 2013

Order Loftusiida Kaminski and Mikhalevich in Kaminski, 2004

Suborder Orbitolinina Kaminski, 2004

Superfamily Orbitolinoidea Martin, 1890

Family Orbitolinidae Martin, 1890

Subfamily Dictyoconinae Moullade, 1965

Genus *Dictyoconus* Blanckenhorn, 1900

Type-species: *Patellina aegyptiensis* Chapmann, 1900

*Dictyoconus aydimi* (Gallardo-Garcia and Serra-Kiel, 2016) comb. nov.

(Figures 3A–3J, and 5A–5C).

2012 *Dictyoconus* - Nafarieh et al., Figure 6d (right specimen).

?2013 *Coskinolina* - Zohdi et al., Figure 5i.

2015 *Dhofarella aydimi* n. gen., n. sp. Gallardo-Garcia, p. 112, Figures 4.28.1–4.28.10.

2016 *Rogerella aydimi* n. gen., n. sp. Gallardo-Garcia and Serra-Kiel, p. 50, Figures 38/1–38/10.

2016 *Dictyoconus aegyptiensis* (Chapman) - Özgen-Erdem and Sinanoğlu, pl. 2, Figures 1–3.

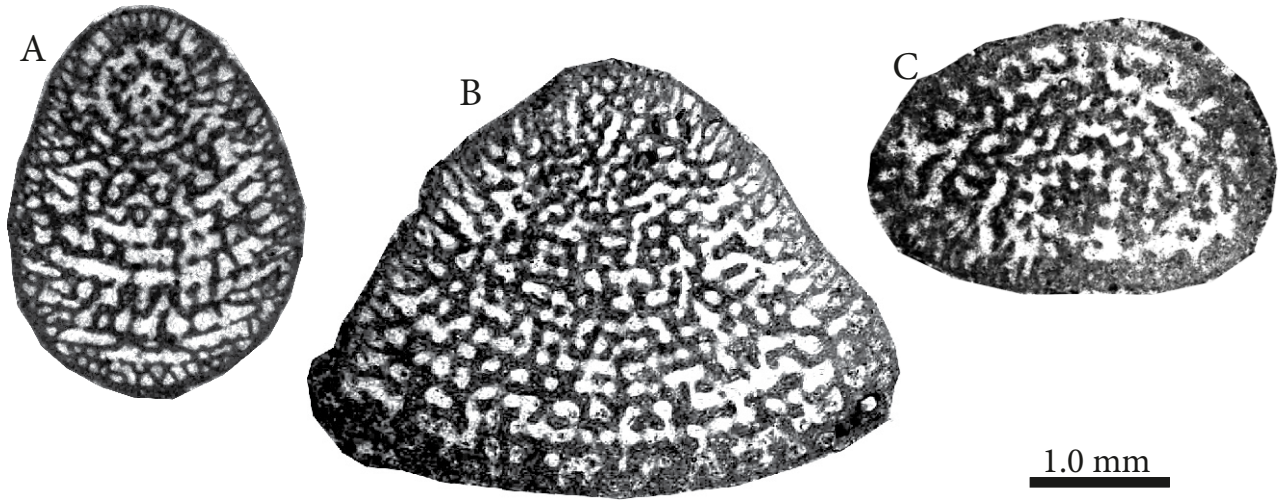
2018 *Dictyoconus aegyptiensis* (Chapman) - Sallam et al., Figures 5a and 5b.

2018 *Dictyoconus indicus* Davies - BouDagher Fadel, pl. 6.2, Figure 9.

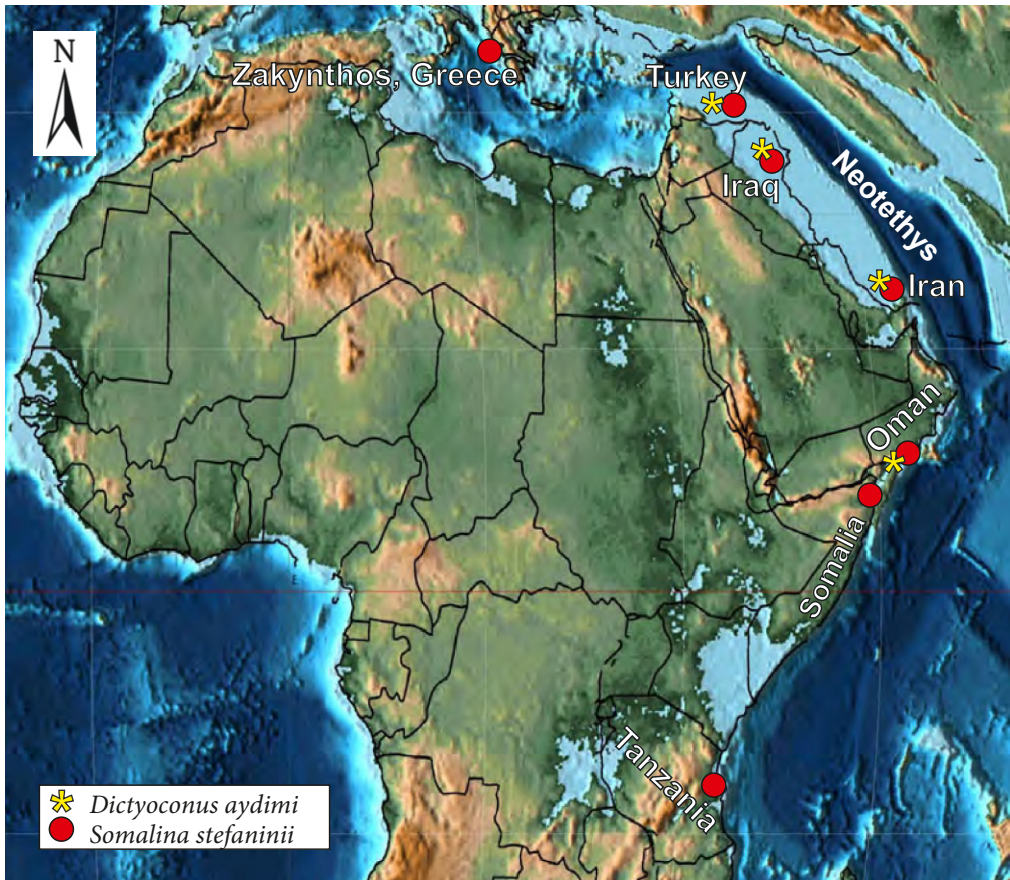
2019 *Daviesiconus balsilliei* (Davies) - Nafarieh et al., p. 281, Figures 9/4, 9/5, and 9/6.

**Descriptions:** Test finely agglutinated, of medium conical shape and convex chamber base throughout ontogeny. Cone surface smooth. The wall lacks any ultrastructure. The embryo [proloculus with diameter ~0.24 mm (2 values) and undivided deuteroconch] is positioned eccentrically with a rather voluminous spire (height up to 1.0 mm) (Figures 3A and 3D). The main part of the cone consists of uniserial chambers, up to 20 in number in large adult specimens. There are 5–6 chambers per 1 mm axial cone length. Specimens that are broader due to a larger apical angle might correspond to the microspheric generation (Figures 3I–3J). The central zone consists of rather dense-set endoskeletal pillars alternating in position between neighbouring chambers. There are 11–13 pillars cut in axial sections when the cone diameter reaches ~2.5 mm. As discernible in transverse sections,





**Figure 5.** *Dictyoconus aydimi* (Gallardo-Garcia and Serra-Kiel, 2016) comb. nov. from the Jahrum Formation of SW Iran. A) Oblique section. B) Subaxial section. C) Oblique section.



**Figure 6.** Bartonian paleomap (modified from Scotese, 2016) showing the distribution of the LBF *Dictyoconus aydimi* (Gallardo-Garcia and Serra-Kiel) comb. nov. and *Somalina stefaninii* Silvestri.

*Somalina*: Zakyntos Island, Greece (Di Carlo and Pignatti, 2009), Egypt (Shamah and Helal, 1994); Iran (Zohdi et al., 2013; Nafarieh et al., 2019); Iraq (Ghafor and Qadir, 2009; Avahah, Dammam fms.); Oman (Serra-Kiel et al., 2016; Dammam Fm.), Somalia (Silvestri, 1939); Tanzania (Cotton, 2012).



the pillars are arranged in concentric rows (Figure 3F). Exoskeleton with alternating main partitions (beams), and 1 rather short intercalary beam (length 80–100  $\mu\text{m}$ ). There is 1 generation of rafters. The exoskeleton subdivides the marginal chamberlets into 4 alveolar compartments (Figures 3D and 4B). The foramina of the central zone display a cribrate distribution. Marginal foramina inclined  $\sim 45^\circ$  to the cone axis (Figures 3E and 3G).

### 5.3. Remarks on the paleobiogeography

In the literature, records were found of *D. aydimi*, either in open nomenclature or belonging to other species of *Dictyoconus* (see synonymy), from SE Turkey (Özgen-Erdem and Sinanoğlu, 2016), Iraq, Iran (Zagros Zone; e.g., Nafarieh et al., 2019; see Figure 5), Iraq (BouDagher-Fadel, 2018), and Oman (Serra-Kiel et al., 2016). All of these occurrences were part of the Arabian Plate, with carbonate platform sedimentation during the Paleogene at the southern Neotethyan margin (Figure 6).<sup>1</sup> In several of these localities, the sections containing *D. aydimi* also delivered specimens of *Somalina stefaninii* Silvestri (Figure 6). In Turkey, Iran, and Oman, the *Somalina* levels occurred below the first appearances of *D. aydimi*. These *Somalina* wacke-/floatstones were clearly dominated by porcelaneous taxa and were interpreted as an internal infralittoral environment, like the Eocene “*Spirolina* facies” of the Adriatic Carbonate Platform (see Vecchio and Hottinger, 2007, Figure 5). *S. stefaninii* displays a wider distribution than *D. aydimi*, with additional reports from Tanzania (Cotton, 2012), Somalia (Silvestri, 1939), and far from there, the Zakynthos Island of Greece (Di Carlo and Pignatti, 2009). The spatial distributional pattern of *D. aydimi* reflects a faunal provincialism of the Dictyoconinae for the Arabian Plate reported previously from the Cenomanian (e.g., Henson, 1948; Bernaus and Masse, 2006; Schlagintweit and Rashidi, 2017, Table 1; Schlagintweit and Yazdi-Moghadam, 2020; Yazdi-Moghadam and Schlagintweit, 2020) and Maastrichtian

(Schlagintweit et al., 2016). The Gulf of Aden was still closed in the Eocene, forming in the Oligocene-Miocene (e.g., d’Ecremont et al., 2005). During the Eocene, Somalia exhibited a continuous coastline with Oman; hence, the occurrence of *D. aydimi* can be expected there. Species of *Dictyoconus* have been reported by various researchers from the Eocene of Somalia (Nuttall and Brighton, 1931; Silvestri, 1939; Azzaroli, 1952). Silvestri (1939), for example, reported a species with a moderate complex exoskeleton, displaying 1 rafter and 1 intercalary beam, as *Dictyoconus aegyptiensis* (Chapman) var. *walnutensis* (Carsey). It is the opinion herein, however, that the available sections did not allow for a final conclusion.

In addition to *Dictyoconus aydimi* (Gallardo-Garcia and Serra-Kiel) comb. nov., there are further Eocene species endemic to the Arabian Plate, such as *Reticulotaberina jahrumiana* Nafarieh et al. (2019) (Iran), *Neorhipidionina spiralis* Hottinger (2007) (Iran), *Macetadiscus incolumnatus* Hottinger et al. in Serra-Kiel et al. (2016) (Oman), *Omanodiscus tenuissimus* Hottinger et al. in Serra-Kiel et al. (2016) (Oman), *Rotaliconus persicus* Hottinger (2007) (Iran), *Globoreticulina iranica* Rahaghi (1978) (Iran), *Neotaberina neaniconica* Hottinger (2007) (Iran), and *Penarchaias glynnjonesi* (Henson, 1950) (Iraq). Further data are required to determine whether this endemism is related to the indicated species or also includes the higher taxonomic level (genus).

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### Contribution of authors

Felix Schlagintweit and Nazire Özgen-Erdem wrote the results and discussion section.

<sup>1</sup> Scotese CR (2016). PALEOMAP PaleoAtlas for GPlates and the PaleoData Plotter Program, PALEOMAP Project [online]. Website <http://www.scotese.com>.

### References

- Arnaud-Vanneau A (1980). L’Urgonien du Vercors septentrional et de la Chartreuse. Géologie Alpine Mémoire 11 (3): 874 (in French).
- Azzaroli A (1952). I macroforaminiferi della serie del Carcàr (Eocene medio e superiore) in Somalia e la loro distribuzione stratigrafica. Palaeontographia Italica 17: 99-131. (in Italian)
- Bernaus JP, Masse JP (2006). *Carinoconus iraqiensis* n. sp. (Foraminifera) a new orbitolinid species from the Mishrif Formation of the oil fields of southeastern Iraq. Micropaleontology 52 (5): 471-476.
- Blanckenhorn M (1900). Neues zur Geologie und Paläontologie Aegyptens. II. Das Palaeogen. Zeitschrift der Deutschen Geologischen Gesellschaft 52: 403-479 (in German).
- BouDagher-Fadel M (2018). Evolution and Geological Significance of Larger Benthic Foraminifera. London, UK: UCL Press, p. 827.
- Cherchi A, Durand-Delga M, Schroeder R (1981). Aperçu paléogéographique sur les provinces à grands foraminifères du crétacé inférieur dans le cadre structural Méditerranéen. Rapport Commission Internationale Mer Méditerranée 27: 115-119 (in French).

- Cotton L (2012). Paleogene larger benthic foraminifera of Tanzania and the Eocene-Oligocene transition. PhD, University of Cardiff, Cardiff, UK.
- Cruz-Abad E (2018). Textura y Arquitectura de los Orbitolinoideos (Superfamilia Orbitolinoidea): Revisión y Caracterización. PhD, University of Barcelona, Barcelona, Spain (in Spanish).
- Cruz-Abad E, Consorti L, Caus E (2017). *Lepinoconus chiochinii* gen. n. sp., a conical agglutinated foraminifera from the Upper Cretaceous of Italy. *Rivista Italiana di Paleontologia e Stratigrafia* 123 (2): 347-354 (in Italian).
- Çoruh T, Yakar H, Ediger VS (1997). Güneydoğu Anadolu bölgesi otokton istifinin biyostratigrafi atlası. TPAO Araştırma Merkezi Eğitim Yayınları 30: 510 (in Turkish).
- Davies LM (1939). An early *Dictyoconus*, and the genus *Orbitolina*: their contemporaneity, structural distinction, and respective natural allies. *Transactions of The Royal Society of Edinburgh* 59: 773-790.
- D'Ecremont E, Leroy S, Beslier MO, Bellahsen N, Fournier M et al. (2005). Structure and evolution of the eastern Gulf of Aden conjugate margins from seismic reflection data. *Geophysical Journal International* 160: 869-890.
- Di Carlo M, Pignatti J (2009). New records of *Somalina*, *Globoreticulina*, and *Austrotrillina* (Larger Foraminifera) from the Eocene of Zakynthos (Ionian Islands, Greece). In: 62nd Geological Congress of Turkey; Ankara, Turkey. p. 905.
- Douglass RC (1960). Revision of the family Orbitolinidae. *Micropaleontology* 6: 249-270.
- Duran O, Şemşir D, Sezgin İ, Perinçek D (1988). Güneydoğu Anadolu'da Midyat ve Silvan Gruplarının stratigrafisi, sedimantolojisi ve petrol potansiyeli. *Türkiye Petrol Jeologları Derneği (TPJD) Bülteni* 1 (2): 99-126 (in Turkish).
- Fleury JJ (1997). Eocene soritids with ribs and/or faint sub-epidermal partitions: the genera *Spirolina*, *Praerhapydionina* and *Paraspirolina* n. gen. in the middle to upper Eocene "facies a imperfores" of Greece. *Revue de Micropaléontologie* 40: 297-311.
- Gallardo-Garcia A (2015). Middle Eocene-Early Miocene larger foraminifera from Dhofar (Oman) and Socotra Island (Yemen). PhD, University of Barcelona, Barcelona, Spain.
- Ghafori IM, Qadir MM (2009). Larger foraminifera (Alveolinidae, Soritidae and Nummulitidae) from the former Qulqula Conglomerate Formation, Kurdistan Region, northeastern Iraq. *Iraqi Journal of Earth Sciences* 9 (1): 35-54.
- Goldbeck EJ, Langer M (2009). Biogeographic provinces and patterns of diversity in selected Upper Cretaceous (Santonian-Maastrichtian) larger foraminifera. In: Demchuk TD, Gray AC (editors). *Geologic problems solving with microfossils: a volume in honour of Garry D. Jones*. SEPM Special Publications 93: 187-232.
- Henson FRS (1948). Larger imperforate Foraminifera of south-western Asia. Families Lituolidae, Orbitolinidae and Meandropsinidae. Monograph British Museum (Natural History): p. 127.
- Henson FRS (1950). Middle Eastern Tertiary Peneroplidae (Foraminifera): with remarks on the phylogeny and taxonomy of the family. Wakefield, England: West Yorkshire Printing Co. Ltd., p. 70.
- Hottinger L (2006). Illustrated glossary of terms used in foraminiferal research. *Carnets de Géologie / Notebooks on Geology – Memoir* 2006 (2): 126.
- Hottinger L (2007). Revision of the foraminiferal genus *Globoreticulina* Rahagi, 1978, and of its associated fauna of larger foraminifera from late Middle Eocene of Iran. *Carnets de Géologie / Notebooks on Geology – Article* 2007 (6) (CG2007\_A06).
- Hottinger L, Drobne K (1980). Early Tertiary conical imperforate foraminifera. *Razprave IV razr. SAZU* 22: 188-276.
- Kaminski MA (2014). The year 2010 classification of the agglutinated foraminifera. *Micropaleontology* 60 (1): 89-108.
- Maden Tetkik ve Arama Genel Müdürlüğü (2008). Geological map of Turkey 1:100.000 Muş L45 sheet and explanatory text, Ankara (in Turkish).
- Nafarieh E, Vaziri-Moghadam H, Taheri A, Ghabeishavi A (2012). Biofacies and palaeoecology of the Jahrum Formation in Lar area, Zagros Basin, (SW Iran). *Iranian Journal of Science & Technology A1*: 51-60.
- Nafarieh E, Boix C, Cruz-Abad E, Ghasemi-Nejad E, Tahmasbi A et al. (2019). Imperforate larger benthic foraminifera from shallow-water carbonate facies (middle and late Eocene), Zagros Mountains, Iran. *Journal of Foraminiferal Research* 49 (3): 275-302.
- Nuttall WLF, Brighton AG (1931). Larger foraminifera from the Tertiary of Somaliland. *The Geological Magazine* 68 (4): 49-65.
- Okay AI, Leven A (1996). Stratigraphy and palaeontology of the upper Palaeozoic sequence in the Pulur (Bayburt) region, Eastern Pontides. *Turkish Journal of Earth Sciences* 5: 145-155.
- Özgen-Erdem N, Sinanoğlu D (2016). Biostratigraphic and paleogeographic approach on the Bartonian benthic foraminifera of the Hoya Formation (Hazro-Diyarbakir). *TAPG Bulletin* 28 (1): pp. 1-17 (in Turkish).
- Perinçek D (1980). Arabistan kıtası kuzeyindeki tektonik evrimin, kıta üzerinde çökelen istifteki etkileri. In: *Türkiye Beşinci Petrol Kongresi, Jeoloji-Jeofizik Bildirileri*; Ankara, Turkey. pp. 77-93. (in Turkish)
- Powell JB (2010). Larger foraminiferal biostratigraphy, systematics and paleoenvironments of the Avon Park Formation and Ocala Limestone, Highlands County, Florida. PhD, Florida International University, Miami, FL, USA.
- Rahaghi A (1978). Paleogene biostratigraphy of some parts of Iran. *Publications of the National Iranian Oil Company Geological Laboratories* 7: 1-165.
- Rigo De Righi M, Cortesini A (1964). Gravity tectonics in foothills structure belt of southeast Turkey. *AAPG Bulletin* 48 (12): 1911-1937.
- Saint-Seine R de (1951). *Mimétisme ou "Pseudomorphose" chez des Lamellibranches fixés sur Echinides*. *Bulletin de la Société géologique de France Sér.4* 1: 653-656 (in French).
- Sallam ES, Özgen-Erdem N, Sinanoğlu D, Ruban DA (2018). Mid-Eocene (Bartonian) larger benthic foraminifera from southeastern Turkey and northeastern Egypt: new evidence for the palaeobiogeography of the Tethyan carbonate platforms. *Journal of African Earth Sciences* 41: 70-85.

- Schlagintweit F (2020). Taxonomic use of the exoskeleton in the family Orbitolinidae (Foraminifera): a plea for a uniform Cretaceous/Paleogene approach. *Micropalaeontology* 66 (1): 75-81.
- Schlagintweit F, Rashidi K (2017). *Persiella pseudolituus* n. gen., n. sp., and *Flabelloperforata tarburensis* n. gen., n. sp., two new larger benthic foraminifera from the Upper Maastrichtian of Iran. *Acta Palaeontologica Romaniae* 13 (2): 3-19.
- Schlagintweit F, Rashidi K, Babadipour M. (2016). Orbitolinid foraminifera from the Late Maastrichtian of the Tarbur Formation (Zagros Zone, SW Iran). *Acta Palaeontologica Romaniae* 12 (2): 29-46.
- Schlagintweit F, Yazdi-Moghadam M (2020). *Orbitolinopsis cenomaniensis* n. sp., a new larger benthic foraminifera (Orbitolinidae) from the middle-late Cenomanian of the Sarvak Formation (SW Iran, Zagros Zone): a regional marker taxon for the Persian Gulf area and Oman. *Revue de Micropaléontologie* 67: 100413.
- Septfontaine M (1980). Les Foraminifères imperforés des milieux de plate-forme au Mésozoïque: détermination pratique, interprétation phylogénétique et utilisation biostratigraphique. *Revue de Micropaléontologie* 23: 169-203 (in French).
- Serra-Kiel J, Gallardo-Garcia A, Razin Ph, Robinet J, Roger J et al. (2016). Middle Eocene Early Miocene larger foraminifera from Dhofar (Oman) and Socotra Island (Yemen). *Arabian Journal of Geoscience* 9: 1-95.
- Shamah K, Helal S (1994). Larger Foraminifera from the Eocene sediments of Shabrawet area Cairo-Suez district, Egypt. *Revue de Paléobiologie* 14 (1): 21-33.
- Sigé B, Thomas H, Sen S, Gheerbrant E, Roger JZ et al. (1994). Les chiroptères de Taqah (Oligocène inférieur, Sultanat d'Oman): premier inventaire systématique. *Münchner geowissenschaftliche Abhandlungen* 26: 35-48 (in French).
- Silvestri A (1939). Foraminiferi dell'Eocene della Somalia. *Palaeontographia Italica* 32 (3): 49-89 (in Italian).
- Sirel E (1976). Description of the species *Rhapydonina liburnica* Stache, *Rhapydonina malatyaensis* n. sp. and new observations on the genus of *Rhapydonina* Stache. *Bulletin of the Mineral Research and Exploration Institute in Turkey*: 86: 101-106.
- Sirel E (2015). Reference sections and key localities of the Paleogene stages and discussion C-T, P-E and E-O boundaries by the very shallow-shallow water Foraminifera in Turkey. *Ankara Üniversitesi Yayınları* 461: 171.
- Sirel E, Acar Ş (1993). *Malatyna* a new foraminiferal genus from the Lutetian of Malatya region (East Turkey). *Geologia Croatica* 46: 181-188.
- Sirel E, Acar Ş (1998). *Malatyna vicensis*, a new foraminiferal species from the Bartonian of Vic region (northeastern Spain). *Revue de Paléobiologie* 17 (2): 373-379.
- Sungurlu O (1974). VI. Bölge kuzey sahalarının jeolojisi. *Türkiye 2. Petrol Kongresi Tebliğleri*: 85-107 (in Turkish).
- Şengör AMC, Yılmaz Y (1981). Tethyan evolution of Turkey: a plate tectonic approach. *Tectonophysics* 75: 181-241.
- Vecchio E, Hottinger L (2007). Agglutinated conical foraminifera from the Lower-Middle Eocene of the Trentinara Formation (southern Italy). *Facies* 53: 509-533.
- Yazdi-Moghadam M, Schlagintweit F (2020). *Persiconus sarvaki* n. gen. n. sp., a new complex orbitolinid (Foraminifera) from the Cenomanian of the Sarvak Formation (SW Iran, Zagros Zone). *Cretaceous Research* 109: 104380.
- Ziegler MA (2001). Late Permian to Holocene paleofacies evolution of the Arabian Plate and its hydrocarbon occurrences. *GeoArabia* 6: 445.
- Zohdi A, Mousavi-Harami R, Moallelemi SA, Mahboubi A, Immenhauser A (2013). Evolution, paleoecology and sequence architecture of an Eocene carbonate ramp, southeast Zagros Basin, Iran. *GeoArabia* 18: 49-80.