UPPER CRETACEOUS FORAMINIFERA MURGEINA APULA (LUPERTO SINNI, 1968): A METHUSALEM AND CENOMANIAN-TURONIAN BOUNDARY SURVIVOR TAXON

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Abstract The benthic foraminifera Murregina apula (Luperto Sinni), originally described as Nummofallotia apula from the Upper Cretaceous of southern Italy, represents a common taxon in the middle-upper Cenomanian Sarvak Formation of southwestern Iran as well as the Campanian-early Maastrichtian of Croatia. The specific identity of the Iranian and Italian as well as Croatian specimens is confirmed by equivalent biometric data and identical test structure. The agglutinated wall (inner part) of M. apula excludes its assignment to the porcelaneous Nummofallotia Barrier & Neumann. Nummofallotia is currently placed in the family Meandropsinidae Henson, while for Murregina with its bilamellar wall inclusion in the Ventrolaminidae Weynschenk is favoured. Nummofallotia cenomana Luperto Sinni, described from the Cenomanian of southern Italy and lacking any hard facts for species discrimination (e.g., dimensions, inner structure) is herein considered tentatively a junior synonym of Murregina apula requiring re-examination of the type-material. M. apula represents another survivor of the Cenomanian-Turonian boundary extinction event and, with a long stratigraphic range from the middle Cenomanian to the (early) Maastrichtian, is similar to another Methusaalem taxon such as Moncharmontia apenninica (De Castro) with a comparable range.

Keywords: Benthic Foraminifera, Zagros Zone, systematic, biostratigraphy, Cenomanian

INTRODUCTION

Luperto Sinni (1968) described a benthic foraminifer as Nummofallotia apula from ‘Senonian’ shallow water carbonates of the Murge area, south Italy. Later, this species has been reported from the peri-mediterranean and Middle East areas in strata ranging in age from the Cenomanian to the Campanian (see synonymy in the Systematic part). The wall structure was indicated as microgranular, sometimes with a thin hyaline outer layer (Luperto Sinni, 1968, 1985). This feature however contradicts the wall structure of the genus Nummofallotia Barrier & Neumann, 1959 that is defined as “calcareous, porcelaneous, but with umbonal plug of varied size appearing hyaline and fibrous” (Bilotte & Decrouez, 1979; Loeblich & Tappan, 1987. p. 374; Hottinger & Caus, 2009) (Fig. 1). Bilotte & Decrouez (1979) noted that the wall structure of ‘N.’ apula is different: respectively its composition of two layers: an inner microgranular and an outer hyaline (radial) layer thickened at the umbo. Furthermore, they observed that this hyaline layer is rather thin at the test periphery or may completely be absent there. With these fundamental differences to Nummofallotia, Bilotte & Decrouez (1979) created the genus Murregina with its type-species Nummofallotia apula. The inconsistent use of the generic status of the Italian species however is present still today in the literature. The present contribution therefore aims to add some new data about the much disputed Murregina apula (Luperto Sinni) from the Cenomanian Sarvak Formation of southwestern Iran, supplemented by material from the Campanian of Brač Island, Croatia.

GEOLOGICAL SETTING

The material of this study comes from two surface sections of the Cenomanian Sarvak Formation in the Zagros belt: the Tang-e Sarvak section (coordinates: 30° 58´ 29˝ N, 50° 07´ 1˝ E) and the Maymand section (coordinates: 31° 09´ 15˝ N, 51° 11´ 53˝ E) (Fig. 2). This data is compared with material coming from the early-mid Campanian of Brač Island, Croatia.

Tang-e Sarvak section, SW Iran

The Tang-e Sarvak section is located at southern flank of the Bangestan anticline, in the southern part of the Izeh Zone, approximately 57 kilometer north of Behbahan city. It represents the type-locality of the Sarvak Fm. (James & Wynd, 1965, fig. 21). The 830-m-thick Sarvak Formation in this area rests conformably on thinly-bedded argillaceous limestones of the Kazhdumi Formation and is unconformably overlain by thinly-bedded argillaceous limestones and marls of the Gurpi Formation. The lower 145 m part of the Sarvak Formation consists of thin to medium bedded hemipelagic limestones containing calcisphaerulids, thalamelinites, and hederbergellids. The upper 685 m of the formation is composed of medium- to thickly-bedded shallow marine bioclastic limestones (packstone) containing a rich assemblage of benthic foraminifera and calcareous green algae. Murregina apula (Luperto Sinni) was recorded in the upper 196 m part of the Sarvak Formation associated with Neodubrovnikella turonica (Said & Kenawy), Pseudolitonella reicheli Marie, Cisalveolina fraasi (Gümbel).

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Multspirina iranensis Reichel, Dicyclina schlumbergeri Munier-Chalmas, Praetaberina bingistani (Henson), Rajkanna hettlingerinaformis Schlagintweit & Rigaud, Pseudorhapydionina dubia (De Castro), Chrysalidina gradata d’Orbigny, and Nezzazata simplex Omara. The occurrence of C. fraasi and P. bingistani refer the part containing M. apula to the late Cenomanian (Schroeder & Neumann, 1985; Parente et al., 2008; Consorti et al., 2015).

Maymand section, SW Iran

The Maymand section is located in the Izeh Zone, close to the High Zagros Fault, south of the town of Semirion. It represents the type locality of the orbitolinid foraminifer Persiconus sarvaki Yazdi-Moghadam & Schlagintweit (2020). The section is located approximately 13 km to the NE of Maymand village (Fig. 2C). The 332-m-thick Sarvak Formation in this area rests conformably on thinly-bedded argillaceous limestones of the Kazhdumi Formation and is unconformably over lain by thickly-bedded neritic limestones of the Ilam Formation. The Sarvak Formation itself is composed of two lithotypes. The lower 285 m of the formation consists of medium to thick bedded shallow marine bioclastic limestones containing benthic foraminifera and calcareous green algae and its upper 47-m-thick interval is composed of thin to medium bedded argillaceous hemipelagic limestones rich in calcispheres and planktonic foraminifera documenting the platform drowning of the Sarvak Formation (Fig. 3). Detailed biostratigraphic data and micropaleontological inventory of this section have been discussed by Yazdi-Moghadam & Schlagintweit (2020). Murgeina apula was observed near the top of the Sarvak Formation (Sample DB 14550) (Mishrif Member) in a packstone facies associated with Rajkanna hettingerinaformis, Praealveolina simplex Reichel, Cisalveolina fraasi, Persiconus sarvaki Yazdi-Moghadam & Schlagintweit, Chrysalidina gradata

Reticulina reicheli Cuvillier et al., Biconcava bentori Hamaoui, and Nezzazata simplex.

Brač Island, Croatia

Brač Island, Croatia represents a part of the Adriatic Carbonate Platform (AdCP) with especially favourable conditions for the development of assemblages of larger benthic foraminifera, including Murgeina apula, in Campanian inner platform facies (Gornji Humac and Pučišća formations) (Gušić & Jelaska, 1988; Cvetko, 1994; Cvetko Tešović et al., 2001, 2020). From here, rare specimens of M. apula were also observed in the Maastrichtian Sumartin Formation (Fig. 4). It is worth mentioning that already five new taxa (including four new genera) have been described from thin section material of Brač Island: Neobalkhania bignoti Cherchi, Radićič & Schroeder, 1991, Fleuryana adriatica De Castro, Drobné & Gušić, 1994, Reticulina reicheli Cvetko, Gušić & Schroeder, 1997, Cretaciclavulina gusici Schlagintweit & Cvetko Tešović, 2016, and Braciina jelaskai Cvetko, Tešović & Cvetko, 2017.

MATERIAL, METHODS AND REPOSITORY

The Cenomanian material of this study is based on specimens from random cuts of 18 thin sections belonging to 9 cemented carbonate rock samples (wacke- to packstone) of the Sarvak Formation. Murgeina apula has been observed in eight samples (including 16 thin sections) from the Tang-e Sarvak section and in one sample (including 2 thin sections) from the Maymand section (Fig. 3). All the samples and thin sections are housed in the collection of National Iranian Oil Company Exploration Directorate (NIOCXP) under the acronyms of BF (Tang-e Sarvak section) and DB (Maymand). The investigated samples from Brač Island, Croatia are the property...
Upper Cretaceous foraminifera *Margeina apula* (Luperto Sinni, 1968)

Fig. 2 A Simplified geological map of Iran (modified after Schlagintweit & Yazdi-Moghadam, 2021) showing the main tectonic subdivisions. B-C Position of the studied sections. D Tectono-stratigraphic units of the Zagros belt (modified after Yazdi-Moghadam & Schlagintweit, 2021) with position of the Anneh section. Abbreviations: BF Balarud Fault, CEIM Central East Iran Microplate, HZF High Zagros Fault, KZF Kazerun Fault, MFF Mountain Front Fault, MZRF Main Zagros Revers Fault, MZT Main Zagros Thrust, SSZ Sanandaj-Sirjan Zone, UDMA Uromia Dokhtar Magmatic Arc, ZFTB Zagros Fold Thrust Belt.
Fig. 3 Lithological log of the Maymand section with distribution of larger benthic foraminifera (including Murgeina apula Luperto-Sinni) (after Schlagintweit & Yazdi-Moghadam, 2020). a Nezzazata gr. gyra-conica (Smout), b Nezzazata simplex Omara, c Murgeina apula (Luperto-Sinni), d Orbitolina gr. concava Orbigny, e Rajkanella hottingeriformis Schlagintweit & Rigaud, f Biconcava bentori Hamaoui & Saint-Marc, g Praealveolina simplex Reichel, h Chrysalidina gradata Orbigny, i Cisalveolina fraasi (Gümbel), j Persiconus sarvaki Yazdi-Moghadam & Schlagintweit.
of the Croatian Geological Survey and their repository is currently in the Geological-Paleontological Department of the Croatian Natural History Museum, Zagreb, Croatia.

**SYSTEMATIC PALAEONTOLOGY**

The higher rank classification is adopted from Vachard et al. (2010, 2013).

Phylum Foraminifera d’Orbigny, 1826
?Class Fusulinata Maslakova, 1990
?Subclass Fusulinana Maslakova, 1990

**Remarks:** According to Rigaud et al. (2015, p. 2), double-layered foraminifera (‘paroi composée’, Septfontaine, 1978) such as Protopeneproplis Weynschenk, 1950 (Aalenian-Barremian; Bassoulet, 1997, Bucur, 1993 and pers. comm.) or Murgeina Bilotte & Decrouez, 1979 (middle Cenomanian–early Maastrichtian) may be considered as possible post-Triassic Fusulinana that exhibit a discontinuous stratigraphic record.

?Order Endothyrida Luskenko, 1958
?Superfamily Endothyroidea Brady, 1884

**Remarks:** Murgeina has been placed previously within an unknown family belonging to the superfamily Endothyrida Brady, 1884 (Bilotte & Decrouez, 1979), later into the Nautiloculinidae Loeblich & Tappan, 1985 (Loeblich & Tappan, 1987; Kaminski, 2014). The wall of this family has been defined as ‘microrugulate calcareous, agglutinated, simple and without exoskeletal or endoskeletal structures, single layered except for septa which are secondarily doubled’ (Loeblich & Tappan, 1985, p. 92). For the genus Murgeina, Loeblich & Tappan (1987, p. 71) described the wall as ‘calcareous finely granular, with radial calcite forming a thickened umboal region on both sides of the test’. The presence of the outer thin calcite layer of the wall and also the septa has not been taken into consideration. Due to its double-layered wall and septa, Murgeina can therefore not be placed within the Nautiloculinidae. This feature however would place Murgeina into the Ventrolaminidae Weynschenk, 1950 together with genera such as Protopeneproplis Weynschenk, 1950 (Fig. 5). Such a suprageneric status had already been briefly mentioned, but not followed up, by Luperto Sini (1999). The inclusion of the Ventrolaminidae into the order Involutinida Hohenegger & Piller, 1977 by Loeblich & Tappan (1987) is rejected herein. It is common consensus that involutins have an aragonitic shell composition (e.g., Rigaud et al., 2013). Note that the inclusion of the Ventrolaminidae into the Endothyroidea was envisaged by Septfontaine (1978) and followed by Bilotte & Decrouez (1979) for Murgeina however leaving open the family belonging. Finally, it is worth mentioning that Nummofallotia is instead classified as a member of the family Meandropsinidae Henson, 1948 with a porcelaneous test and an umbo with radial-fibrous mineralogy/appearance (Loeblich & Tappan, 1987; Hottinger & Caus, 2009) (Fig. 1).

**Murgeina apula** (Luperto Sini, 1968)

Figs. 3c, 5d, 6-7

The references from the Cenomanian are highlighted in bold letters.

*1968 Nummofallotia apula* n. sp. – Luperto Sini, p. 7, pls. 1-3.

1970 Nummofallotia apula Luperto Sini – Hamaoui & Saint-Marc, pl. 33 pars.


1976 Nummofallotia apula Luperto Sini – Luperto Sini, pl. 48, figs. 4-5.

1976 Nummofallotia apula Luperto Sini – Charvet et al., pl. 7, figs. 6, 12.


1978 Nummofallotia apula Luperto Sini – Radoičić, pl. 4, figs. 7-8.

1979 Murgeina apula (Luperto Sini) – Bilotte & Decrouez, p. 38, pl. 1, figs. 3-8 (synonymy).

1980 Nummofallotia apula Luperto Sini – Fleury, pl. 3, fig. 6.

1981 Nummofallotia apula Luperto Sini – Bismuth et al., pl. 4, figs. 6-8.

1982 Nummofallotia apula Luperto Sini – Mouty & Saint-Marc, pl. 3, fig. 5.

1985 „Nonion“ sp. – Bilotte, pl. 11, figs. 4-6.

1985 Nummofallotia apula Luperto Sini – Luperto Sini, pl. 100, pl. 48.

1988 Nummofallotia apula Luperto Sini – Gušić & Jelaska, pl. 14, fig. 7.

1991 Nummofallotia apula Luperto Sini – Schlagintweit & Weidich, pl. 1, fig. 6.

1992 Murgeina apula (Luperto Sini) – Schlagintweit, p. 330, pl. 1, figs. 1–3 (synonymy).

1992 Nummofallotia apula Luperto Sini – Mavrikas, pl. 1, fig. 28.

1994 Nonion senonicus (Perebaskine) – Ramírez del Pozo & Martín-Chivelet, pl. 1, fig. 4.

1994 Murgeina apula (Luperto-Sini) – Chiocchini et al., pl. 22, figs. 9–13.

?1999 Nummofallotia cenomana sp. – Luperto Sini, p. 2, fig. 1, pl. 1, figs. 1-9, pl. 1, figs. 9-11 as Nummofallotia apula.

2001 Murgeina apula (Luperto Sini) – Cvetko Tešović et al., fig. 9B-E.

2002 Nummofallotia sp. – Bauer et al., pl. 3, fig. 12.
Fig. 4 Lithostratigraphic column of the Upper Cretaceous strata of the Island of Brač, Croatia showing distribution of selected benthic foraminifera including *Murgemia apula* (Luperto Sinni).
2003 Murgeina apula Luperto Sinni – Polavder, fig. 4.3.
2003 Murgeina apula (Luperto Sinni) – Aguileram-Franco, pl. 1, fig. i3.
2004 Murgeina apula (Luperto Sinni) – Bravi et al., fig. 13b (synonymy).
2006 Murgeina apula (Luperto Sinni) – Perugini, p. 71, pl. 2.
2010 Nummofallotia apula Luperto Sinni – Cavin et al., Fig. 9i-j.
2014 Nummofallotia apula Luperto Sinni – Afghab et al., fig. 11G.
2017 Murgeina apula – Jamalpour et al., pl. 2, fig. e.
2019 Murgeina apula – Kiarostami et al., pl. 1, fig. m.
2021 Murgeina apula – Dousti Mohajer et al., fig. 9a.

Description: Test lenticular, planispirally-involute coiled in up to three whorls, biumbonate with angular periphery and umbonal plug of hyaline and fibrous calcite. Proloculus almost spherical and enveloped by a wall differentiated into a thin microgranular inner and thick radial-calcitic outer layer. In axial sections, the outer layer almost completely surrounds the proloculus (Fig. 6b, i). The chambers of elongate quadrangular shape gradually increase in size as added. In axial sections, the last whorl attains a width, about double the one observed in the penultimate whorl. The foramina are single, interiomarginal and in equatorial sections some kind of a short tooth-plate is occasionally observable at the distal end of the septum (Figs. 6r-s, 7d). The wall and the septa are bilamellar with a dark microgranular (finely agglutinated?) inner and hyaline fibrous-calcitic outer layer.

Dimensions: The dimensions of the specimens from the Cenomanian Sarvak Formation of Iran are summarized in Table 1 and compared with the data from Luperto Sinni (1968) from the ‘Senonian’ Altamura Limestone of S-Italy. For other data on dimensions of M. apula in the literature see Schlagenheit (1992), Cvetko Tešović et al., 2001, and Perugini (2006).

Remarks: Not mentioned previously (Luperto Sinni 1968, 1985, 1999; Perugini, 2006), some kind of a short tooth plate may be present preferentially in the latest whorl(s) of adult specimens (Fig. 6r-s). It is also discernible in the good quality equatorial section provided by Saint-Marc (1974, pl. 8, fig. 16), that also shows 14 chambers in the last whorl (see discussion in Comparisons). Luperto Sinni (1985, p. 100) mentioned a ‘courte canal flexostyle’, that in some alveolinid taxa represents a tubular extension following the proloculus (Hottinger, 2006). Although not explicitly highlighted in any image by Luperto Sinni (1985), it might well belong to recrystallized neanic chambers or a shallow tangential sectioning of the umbo (e.g., Fig. 6q, s).

Comparisons: With respect to the dimensions, there are no differences between the Cenomanian and the later Cretaceous (i.e., Campanian) forms of Murgeina apula (Tab. 1). As a possible difference, both Luperto Sinni (1968) and Perugini (2006) noted 16 to 20 chambers in the final whorl of Campanian forms which differs from the Cenomanian forms studied herein with a maximum number of 15. However, the only illustrated specimen in Luperto Sinni (1968, pl. 3, fig. 6) that allows the chambers in the last whorl to be counted shows a number of 14, and thus overlapping with the data from the Cenomanian forms. In 1999, Luperto Sinni described another species as Nummofallotia cenomanana from the Cenomanian of the same area (Murge, south Italy) displaying 14 to 16 chambers in the last whorl. In our opinion, this minor difference (that has not been further discussed by Luperto Sinni, 1999) is not suitable as a criterion for species discrimination. It can reasonably also be considered as an intraspecific variation in time. As her main criterion for discrimination of ‘N.‘ apula and ‘N.‘ cenomanana, Luperto Sinni (1999, p. 2) stressed the thinning of the outer hyaline-calcareous layer towards the test periphery (up to its complete absence in this area) in the former. In ‘N.‘ cenomanana instead it is said to be always present. In fact, the specimens of Murgeina apula from the Campanian of Croatia show that this feature is variable with only a thin
Table 1. Biometric data (in mm for d, h, d. pr.) of *Murgeina apula* (Luperto Sinni) from the Cenomanian Sarvak Fm. of Iran, the early-middle Campanian of Brač Island, Croatia, compared to Luperto Sinni (1968, 1985), Upper Cretaceous of South Italy. Abbreviations measurements: d = test diameter in axial section, h = height in axial section (= equatorial diameter), d. pr. = diameter of proloculus, no. w. = number of whorls, ch = total number of neanic chambers, ch. L. w. = number of chambers in the last whorl. Abbreviations section plane: e. s. = equatorial section, a. s. = axial section, o. = oblique. * = measured from original illustrations.

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*Murgeina apula* (Luperto Sinni), early-middle Campanian of Croatia

| a. s. | 0.20 | 0.39 | 0.51 | 0.042 | 2.5 | - | - |
| o. s. | - | 0.48 | - | - | - | - | - |
| a. s. | 0.16 | 0.31 | 0.52 | 0.046 | 2.0 | - | - |
| a. s. | 0.22 | 0.40 | 0.55 | 0.066 | 2.5 | - | - |
| a. s. | 0.20 | 0.33 | 0.61 | 0.058 | 2.5 | - | - |
| a. s. | 0.12 | 0.19 | 0.63 | 0.054 | 1.5 | - | - |
| o. s. | - | - | - | 0.073 | - | - | - |
| o. s. | - | - | - | 0.069 | - | - | - |
| a. S. | 0.21 | 0.41 | 0.51 | 0.066 | - | - | - |
| No. data | - | 6 | 7 | 6 | 8 | 5 | - |
| max. | - | 0.22 | 0.48 | 0.61 | 0.073 | 2.5 | - | - |
| min. | - | 0.12 | 0.19 | 0.51 | 0.054 | 1.5 | - | - |
| mean | - | 0.18 | 0.56 | 0.55 | 0.059 | - | - | - |

Luperto Sinni 1968, 1985

| 0.18 | 0.35 | - | 0.04-0.08 | 2-3 | 25* | 13-14* |
Upper Cretaceous foraminifera *Murgeina apula* (Luperto Sinni, 1968)

Fig. 6 *Murgeina apula* (Luperto Sinni) from the Cenomanian Sarvak Formation of SW Iran. a-h, d, f-i, l, n, s, t Axial sections, partly slightly oblique. Note the double-layered septa in s.  c, j, k, m, r, v Oblique sections. e Slightly oblique subaxial section. q, s, u Equatorial sections. Note the double-layered septa in q. Abbreviations: fo = foramen, pr = proloculus, se = septum, t.pl. = tooth plate, um = umbo. Thin sections: DB 14550 (a), BF 86 (b-c), BF 37 (d, v), BF 56 (e, g), BF 70 (f), BF 48 (h), BF 33 (i-l, p, s), BF 82 (m), BF 40 (n), BF 37 (o, q, u), BF 46 (r), BF 56 (t).
(Fig. 7j) or thicker outer layer (Fig. 7a) and therefore again not suitable for species discrimination. It is worth mentioning, that this observation has also been made by Perugini (2006) studying a comparably rich assemblage from the Altamura Limestone of the Murge area. The third characteristic to be mentioned refers to the test dimensions. For the holotype of ‘N.’ *cenomana*, Luperto Sinni (1999, p. 2) indicated 0.09 mm for the thickness and 0.05 mm for the diameter. The indicated values are considered as seemingly incorrect, and much too small. If correct, then it would be rather curious that Luperto Sinni (1999) did not highlight it in the discussion on species differences. Summarizing, there appear to be no characters that would justifiably separate a Cenomanian (= ‘N.’ *cenomana*) and a post-Cenomanian (= ‘N.’ *apula*) species, resulting in an assumed synonymy of both with *Murgeina apula* having priority.

**Biostratigraphy:** Luperto Sinni (1968, p. 96) assigned the strata containing ‘N.’ *apula* to the ‘Upper Senonian’, mostly to the Maastrichtian. Among the species associated with *M. apula*, Luperto Sinni (1968, p. 95) indicated also *Accordiella conica* Farinacci, that has a middle Coniacian to early middle Campanian age according to new results from southern Italy published by Frijia et al., (2015). Also, the occurrence of orbitolinids in the type strata of *M. apula* (fide Luperto Sinni, 1968) can be considered as further evidence for a Campanian age (see Schlagintweit, 2021). *M. apula* has been reported by Cvetko Tešović et al. (2001) from the (early) Maastrichtian of the Sumartin Formation of Croatia that should correspond to its youngest record. Summarizing, *M. apula* represents a methusalean taxon with a recorded early Cenomanian–(early) Maastrichtian range, almost comparable to another simple structured small presumably r-strategist taxon, *Moncharmontia apenninica* (De Castro) (Table 2). For both taxa there is a gap in the record following the Coniacian–Turonian boundary extinction (e.g., Parente et al., 2008). While *M. apenninica* is reported from upper Turonian strata, *M. apula* re-appears later in the early Coniacian (Chiocchini et al., 2012, fig. 10).

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Tabel 2. Approximate time ranges of selected (pp. larger) benthic foraminifera: Methusalem and biostratigraphic marker taxa compared. Note that biostratigraphic marker taxa often exhibit complex inner structure but not necessarily.

<table>
<thead>
<tr>
<th>Methusalem taxa</th>
<th>Approximate range</th>
<th>Ma</th>
<th>Reference</th>
<th>Test structure</th>
<th>LAD affected by extinction event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montcharmontia apennica</td>
<td>Late middle Cenomanian–Middle Campanian</td>
<td>~19.5</td>
<td>Frijia et al., 2015; Schlagintweit &amp; Yazdi Moghadam, 2021</td>
<td>simple</td>
<td>no</td>
</tr>
<tr>
<td>(De Castro)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murgeina apula (Luperto Sinni)</td>
<td>Late early Cenomanian–early Maastrichtian</td>
<td>~28.6</td>
<td>Cvetko Tešović et al., 2001; this work</td>
<td>simple</td>
<td>no</td>
</tr>
<tr>
<td>Cribellopsis neoelongata</td>
<td>Late Berriasian–early Aptian</td>
<td>~19</td>
<td>Clavel et al., 2014; Schlagintweit &amp; Bucur, 2022</td>
<td>complex</td>
<td>?</td>
</tr>
<tr>
<td>(Cherchi &amp; Schroeder)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biostratigraphic marker taxa</td>
<td>Range</td>
<td>Ma</td>
<td>Reference</td>
<td>Test structure</td>
<td>LAD affected by extinction event</td>
</tr>
<tr>
<td>Pavlovecina allobrogensis</td>
<td>Part of late Berriasian</td>
<td>~2.0</td>
<td>Virgone, 1997; Granier, 2019</td>
<td>complex</td>
<td>no</td>
</tr>
<tr>
<td>(Steinhauser et al.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Campanellula capuisensis</td>
<td>Late Hauterivian–earliest Barremian</td>
<td>~2.5</td>
<td>Amodio et al., 2020</td>
<td>simple</td>
<td>no</td>
</tr>
<tr>
<td>De Castro</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Praeorbitolina wienandsi</td>
<td>Late early Aptian</td>
<td>~0.4</td>
<td>Schroeder et al., 2010</td>
<td>complex</td>
<td>?</td>
</tr>
<tr>
<td>Schroeder</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Reticulinella kaeveri</td>
<td>Late middle–late Turonian</td>
<td>~1.4</td>
<td>Frijia &amp; Parente, 2008; Frijia et al., 2015</td>
<td>complex</td>
<td>no</td>
</tr>
<tr>
<td>Cherchi et al.</td>
<td></td>
<td></td>
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<tr>
<td>Cisalveolina frasii</td>
<td>Part of late Cenomanian</td>
<td>&lt;1.0</td>
<td>Parente et al., 2008</td>
<td>complex</td>
<td>yes</td>
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<tr>
<td>(Güm-bel)</td>
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<tr>
<td>Siderolites calcitradoide</td>
<td>Late Maastrichtian</td>
<td>~3</td>
<td>Robles-Salcedo et al., 2018</td>
<td>complex</td>
<td>yes</td>
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<td>Lamarck</td>
<td></td>
<td></td>
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