MORPHOMETRIC APPROACH TO DETERMINATION OF LOWER JURASSIC SIPHOVALVULINID FORAMINIFERA

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Keywords: Lower Jurassic; Dinarides; Apennines; carbonate platform; Siphovalvulina; Radoicicina ciarapicae; Siphovalvulinidae; morphotype.

Abstract. Siphovalvulina is among the first foraminifera that appear on carbonate platforms of the Lower Jurassic, forming a conspicuous element of low-diversity assemblages prior to recovery after the end-Triassic biotic crisis. The high morphologic variability of species of this genus is usually not documented, which makes the determination of species difficult and subjective. We demonstrate the variability in five morphotypes of Siphovalvulina in Sinemurian and Pliensbachian carbonate rocks from the Dinarides and the Southern Apennines. Due to the different interpretation of its architecture, an emendation of the genus Siphovalvulina is proposed. One morphotype has been left in open nomenclature and could belong to either S. variabilis Septfontaine or to S. beydouni BouDagher-Fadel & Noujaim Clark. Three morphotypes, differing in apical angle and/or size belong to S. ex gr. gibraltarensis BouDagher-Fadel, Rose, Bosence & Lord. We also describe a new genus and species, Radoicicina ciarapicae gen. n., sp. from the lower Sinemurian of the Southern Apennines. We suggest a close phylogenetic relationship between the two genera and introduce a new family, Siphovalvulinidae fam. n. of the superfamily Eggerelloidea.

INTRODUCTION

Following a significant disappearance of taxa at the end of the Triassic (e.g., Hautmann et al. 2008), the earliest Jurassic foraminiferal associations consist of a few opportunistic survivors, which were soon joined by a small number of newly-evolved genera (Chiocchini et al. 1994; Barattolo & Romano 2005; Mancinelli et al. 2005; BouDagher-Fadel et al. 2001; BouDagher-Fadel & Bosence 2007). The most characteristic among the earliest Jurassic newcomers is likely the genus Siphovalvulina Septfontaine. So far, two species of this genus have been described from the lowermost Jurassic - Siphovalvulina colomi and S. gibraltarensis (BouDagher-Fadel et al. 2001). Siphovalvulina variabilis, originally described from the Middle Jurassic (Septfontaine 1980, 1988) is also cited from the Lower Jurassic, while only some Callovian and Oxfordian specimens have been attributed to the fourth (and currently last) species, S. beydouni (Noujaim Clark & BouDagher-Fadel 2004; Granier et al. 2016).

Although long stratigraphic ranges do not point to Siphovalvulina as biostratigraphically important, its occurrence in fossil-poor and often restricted environments in the lowermost Jurassic does nevertheless make it potentially useful in distinguishing and/or subdividing the lowermost Jurassic (see Septfontaine 1986; BouDagher-Fadel & Bosence 2007; BouDagher-Fadel 2008). The main obstacle in recognizing the application of Siphovalvulina species in biostratigraphy is the high morphologic variability of the few described species and the occasional small number of specimens presented as type material, leaving much room for interpretation and subjective assessment. On this account, the stratigraphic ranges of some species might have been over-extended.

The aim of this paper is to demonstrate the morphological variability in Siphovalvulina from selected samples of Sinemurian and Pliensbachian beds of the Dinarides and the Southern Apennines.
We distinguish several morphotypes of *Siphovalvulina* and try to relate them to the currently described species. Recognising morphological variability and correct identification of species is a prerequisite for any biostratigraphic study attempting to subdivide lowermost Jurassic shallow-marine carbonates. This contribution will thus help to easier determine *Siphovalvulina* species and may serve as a sound basis for future biostratigraphic studies and correlations.

**Geological settings**

The investigated thin sections come from carbonate platform successions of the Southern Apennines and the northern Dinarides (Figs 1-2). The section ages are based on foraminiferal zonation work by BouDagher-Fadel & Bosence (2007) and Velić (2007). The succession from the Dinarides comprises shallow marine carbonates from the margin of the former Adriatic Carbonate Platform (Vlahović et al. 2005), now incorporated into folded and internally-thrust structure of the External Dinarides (Placer 1999). From the Upper Triassic to the Middle Jurassic the following units can be distinguished (Dozet & Strohmenger 2000; Miler & Pavšič 2008; Dozet 2009): 1) the Norian-Rhaetian Main Dolomite, comprising medium- to thick-bedded dolomite, stromatolitic dolomite, and intraclastic breccia; 2) the Lower Jurassic Podbukovje Formation, recording a gradual transition from peritidal limestone and dolomite (Hettangian-Sinemurian) to mostly medium-bedded micritic, oolitic, bioclastic and lithiotid limestone, locally capped by red claystone surfaces (emersion horizons in Martinuš et al. 2012); the uppermost part
of the Podbukovje Formation consists of platy and nodular limestone, presumably of Toarcian age (Dozet 2009); and followed by 3) the Middle Jurassic oolitic limestone Laze Formation. The middle part of the Podbukovje Formation was sampled in the Jezero, Tomišelj, Mt. Krim and Podpeč sections. The material from the Dinarides was supplemented with two samples of lower Sinemurian from the Chiunzi Pass section from the Southern Apennines (Figs 1-2). This section includes the Calcari a
Paleodasycladus (Palaeodasycladus Limestone) of the former Apenninic Carbonate Platform. The Calcari a Paleodasycladus is underlain by Dolomia Superiore. In turn, the Calcari a Paleodasycladus is followed by Calcari Oolitici ed Oncolitici (Iannace et al. 2016). The palaeogeographic relationship between the Adriatic and the Apenninic carbonate platforms is presented in Figure 3. A short description of the sections is provided in Table 1. Sections from the Dinarides are further described in more detail in Gale (2015), and Gale & Kelemen (2017).

Methods

Specimens were sought for in non-oriented thin sections prepared from well-lithified limestones from the studied sections (positions of samples with figured siphovalvulinds are indicated in Fig. 2). From the total of 250 photographed specimens, 71 in axial or near-axial section were quantitatively assessed. Height (H) was measured along the axis of growth (Fig. 4). Perpendicular to this is the width (W), taken at the widest part of the test. The ratio between H and W was then calculated in order to avoid descriptive terms for the test shape (e.g., low or high trochospiral, bell-shaped etc.). Because descriptions of known species of Siphovalvulina refer to shapes of chambers, shapes of septa and their position relative to the main axis of the test (see BouDagher-Fadel et al. 2001), we also tried to quantify these differences. Thus, the height (Hc) and the width (Wc) of the chamber lumen were measured, preferably for the last, largest chamber. Hc was measured from the most distal part of the chamber parallel to the test axis, and Wc was measured perpendicular to Hc. Besides Hc, the largest diameter (D1) of the same (last) chamber was measured diagonally, from the proximal outer margin of the chamber towards the distal internal margin (see Fig. 4). The angle between Hc and D1, which could potentially reflect the different shapes of the chambers, was subsequently measured to check for possible differences between the species. The width of the umbilical cavity (previous called a siphonal canal; see remarks in description of the genus) was measured at the narrowest part of the third coil of the test. Wall thickness and the size of the proloculus, when visible, were also measured. Finally, we measured the incremental angle of the test, starting with the apical angle, and then measuring the change in the angle between the sides of the test (e.g., diagnosis of S. colomi states that the test becomes more parallel-sided with later growth, whereas S. gibraltarrensis retains a widely flaring test; BouDagher-Fadel et al. 2001). The angle between the sides of the test at successive coils is graphically represented in Fig. 5. The measured specimens were then compared side by side at the same scale in order that the morphologic variability would be recognisable. Basic statistic parameters were calculated using Microsoft Excel (Microsoft Office Professional Plus 2010; © Microsoft Corporation). The terminology employed follows Hottinger (2006), while the synonymy list is prepared according to Matthews (1973).
On the basis of the side by side comparison of the 71 specimens, six morphogroups were established. One of these was subsequently moved to a new genus, \textit{Radoicicina} gen. n. Wide morphological variations are observed in nearly all of the groups. Quantitative analysis helped in confirming the differences between the recognized morphogroups (Table 2).

**Results**

On the basis of the side by side comparison of the 71 specimens, six morphogroups were established. One of these was subsequently moved to a new genus, \textit{Radoicicina} gen. n. Wide morphological variations are observed in nearly all of the groups. Quantitative analysis helped in confirming the differences between the recognized morphogroups (Table 2).

**Remarks.** Septfontaine (1988) grouped \textit{Siphovalvulina} together with \textit{Pseudopfenderina} Hottinger into the subfamily Pseudopfenderininae of the family Pfenderinidae, even though the first genus has a “siphonal canal” (here referred to as an axial cavity), and the latter a central columnella. According to Loeblich and Tappan (1988), the Pfenderinidae contains trochospiral Early Jurassic to Late Cretaceous forms with an imperforate wall of “microgranular calcite with some agglutinated material” (Loeblich & Tappan 1988: 151). The grouping of \textit{Siphovalvulina} with \textit{Pseudopfenderina} was adopted also by Kaminski (2004), who placed Pfenderinidae in the suborder Orbitolinina of the order Loftusiida. On the basis of \textit{Siphovalvulina} having simple parapores (“canaliculate wall”), we suggest it would be more appropriate to place this genus into a new family Siphovalvulinidae of the initially trochospiral or triserial superfamily Eggerellacea within the order Textulariida (sensu Kaminski 2004). Alternatively, BouDagher-Fadel et al. (2001) placed \textit{Siphovalvulina} into the family Verneuilinidae of the superfamily Verneuilinacea which was placed by Kaminski (2004) under Verneuilinina belonging to the order Lituolida. According to Kaminski (2004), Lituolida consists of “noncanaliculate” agglutinated groups. In a distinct classification by Mikhailevich (2014), \textit{Siphovalvulina} is left as \textit{incertae sedis} among Verneuilinida, but with consideration that this group has a “noncanaliculate” wall.

**Siphovalvulinidae fam. n.**

**Diagnosis:** Test free, triserial, may later become biserial; high or low conical in shape; proloculus simple; possessing simple umbilical cavity; aperture simple, interiomarginal; chambers connected by protrusion of the wall of the previous chamber into the next; possible secondary connections between chamber and umbilical cavity; wall finely agglutinated, with simple parapores.

**Remarks.** The Siphovalvulinidae fam. n. currently comprises genera \textit{Siphovalvulina} and \textit{Radoicicina} gen. n. The stratigraphic range of the family is thus from Hettangian to Lower (possibly also Upper) Cretaceous. The parapores may be obscured by diagenesis.
Tab. 2 - Measured parameters in siphovalvulinds from Lower Jurassic of Dinarides and Southern Apennines. a: average (arithmetic mean); sd: standard deviation; D1: length of lumen from proximal outer edge of the last chamber to the distal inner edge of the same chamber; n: number of measurements; *: for triserial part; **: total; ***: for biserial part.

<table>
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<tr>
<th>Section</th>
<th>Coordinates</th>
<th>Lithological description</th>
<th>Age</th>
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<tr>
<td>Krezio</td>
<td>45°37'30&quot; N, 14°26'30&quot; E</td>
<td>Medium-thick to massive (up to 335 cm thick) beds predominate in the lower 19 m of the section. Dark grey to almost black medium to thick limestone covers the lower 6 m of the section. Biostromes, parallel laminations, lenses of void granitoid and one possible ortholitholitic horizon are locally present. Wackestone contains small ooids, bioclasts, peloidal packstone and ooids. Some beds are covered by thin red claystone. Ooidal granitoid follows from the 6th to 10th metre, locally passing upwards into micritic limestone, which itself contains horizons with accumulated brachiopods, gastropods and ooids. Mudstone and wackestone then predominate again. A level of pronounced erosion is present around the 14th metre, with red claysalt surfaces permeating black micritic limestone. Beds or levels of void granitoid are subordinate. Cross laminations and grading are commonly seen within oolites. Troughs between ripple sets are locally filled with accumulated brachiopods and gastropod shells. Fine-grained flat pebble breccia is present at the 26th metre. At the 30th metre, the mudstone becomes increasingly grey and has the smell of bitumen. Black bioclastic floatstone is present between the 32nd and 37th metre. A bed one metre thick at the 33rd metre resembles shatter breccia – micritic limestone is cracked and filled with gastropod and mollusc debris in an oolitic matrix. For the next 30 m, the lithology quickly shifts between mudstone, wackestone, oolitic packstone and grainstone, bioclast-peloidal wackstone and mudstone. Bed thickness is very inconsistent, ranging from 2 to more than 2 m-thick beds. Micritic limestone is often black or dark grey. The section ends with medium-beded bioclast floatstone breccia. Shells are concentrated in the upper part of the bed, or dispersed through the entire bed.</td>
<td>lower – middle Sinemurian</td>
<td>Open lagoon (tramp?)</td>
</tr>
<tr>
<td>Tomilič</td>
<td>45°37'51&quot; N, 14°28'06&quot; E</td>
<td>Beds are medium to very thin. The lithology is predominantly limestones; few beds are topped by a few millimetres of brown or reddish claystone. The section starts with grey mudstone and wackestone in beds up to 15 cm thick. Biostromation and parallel lamination are locally present. Wackestone contains discontinual valves of small brachiopods, peloids and intraclasts. Small lenses of void granitoid are present. Fine-grained ooidal limestone is more common between 12.5 and 19 m of the section. The wackestone in this part contains brachiopods, ooids and intraclasts. Mudstone is locally laminated. Micritic limestone again predominates between the 19th and 30th metre. Horizons of void granitoid are locally present within the micritic limestone. Ooidal granitoid covers the interval between 30th and 35th metre. Few massive beds are irregularly graded. Rare oncolites are locally present, as well as levels of brachiopod floatstone. Ooidal granitoid also forms the upper part of some micritic beds. Some 52 m from the base of the section black mudstone appears for the first time, and fine-grained ool packstone and granitoid start to become more common.</td>
<td>lower upper Sinemurian</td>
<td>Open lagoon (tramp?), restricted conditions at the top of the section</td>
</tr>
<tr>
<td>Mt. Korn</td>
<td>45°55'33&quot; N, 14°25'33&quot; E</td>
<td>Beds are predominately medium-thick, oolidic limestone up to 1.8 m thick. The lower part of the section is mostly dolomitized, with few micritic limestone beds, rarely with the texture of packstone. The dolomite is mostly coarse-grained, but laminations (stromatolities) are locally visible. A short interval of thin to medium-thick beds of ooidal granitoid follows, and then the section continues with interchanging ooidal granitoid, brachiopod-peloidal wackstone, packstone and mudstone. The most common bioclasts are brachiopods, gastropods, and in some thin-sections foraminifera, calcareous forams and algae are visible; corals are also occasionally present. Lithiotid bivalves occur up 30 m from the base of the section and are present in several levels until the top of the section. They are also in their original position (perpendicular to pebble bedding). Small-scale Neptunian dykes filled with red micritic limestone are present especially in the upper part of the section.</td>
<td>upper Sinemurian – Pliensbachian</td>
<td>Lapwings, partially restricted by ool bands and aggregations of lithiotid brachiopods</td>
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<tr>
<td>Podpeč</td>
<td>45°54'22&quot; N, 14°25'16&quot; E</td>
<td>Most beds are medium-thick to massive, and of highly variable lithology. Dominant are ooidal granitoid and bioclast-oolitic granitoid. Also common are peloidal wackstone to packstone, oncoid and bioclast floatstone. The most frequent bioclasts are fragmented brachiopods; common are lithiotids, brachiopods, gastropods and dactyliaridar. Lithiotids are present in several levels, mostly in the central part of the section. Bedded limestone is present at several levels, in most cases the micritic limestone is rich in brachiopods, rarely included in bedded limestones, with oncoloites oriented concordant with bedding. Only one level with lithiotids in a life position is present; these were buried by oolitic bar. Thin to medium-thick beds of wackestone and micrite are subordinate. Irregular bedding planes, red clayey surfaces, parallel lamination and grading are common, cross lamination is also common lateral to the sampled section.</td>
<td>lower Pliensbachian</td>
<td>Lapwings, partially restricted by ool bands and aggregations of lithiotid brachiopods</td>
</tr>
<tr>
<td>Valico di Chimenti / Chiunzi Pass</td>
<td>40°43'30&quot;N, 14°37'30&quot;E</td>
<td>The interval with the new taxon encompasses the first occurrence of Lithotiidae, Lagoon. It consists of 10 to 40 cm thick bedded mud supported limestone (wackestone), eustatically intercalated with brachiopod packstone and graniotone. Ooidal granitoid is very rare. Micritic sediment is crossed by faint bedding planes. Pendent cement crystals are observed attached to the roof of cavities and the floor is filled by a small cavity silt. The rest of cavities are filled by blocky cement. Bioclasts are dominant, mainly by algae (Palaeodasycladus taxiformes (Pia), Palaeodasycladus gracilis (Pia)), bivalves (Cryoecia sp., Hastus sp., Paramechinella sp. (Raimondi), Cepicephalia sp. (Raimondi)), foraminifera (Cros &amp; Lemoine, 1988). Foraminifera are well represented. Recrystallized gastropods and calcareous sponges occasionally occur. In addition to bioclasts, peloids and oncolites (microbial–Hastus sp. associations) are recorded.</td>
<td>lower Sinemurian – lower-middle Pliensbachian</td>
<td>Shallow low energy, subtidal lagoon</td>
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Tab. 1 - Short description of sampled sections.
Genus *Siphovalvulina* Septfontaine, 1988, emend.

*Type species:* *Siphovalvulina variabilis* Septfontaine, 1988

**Emended diagnosis:** Test free, triserial, high or low conical in shape; proloculus simple; chambers subglobular; simple axial cavity, extending along the entire test length; aperture simple, interiomarginal; chambers connected by protrusion of the wall of the previous chamber into the next; possible secondary connections between chamber and simple umbilical cavity; wall finely agglutinated, with simple parapores.

**Remarks.** The previous descriptions of *Siphovalvulina* (Septfontaine 1988; BouDagher-Fadel et al. 2001) suggested the presence of a twisted “siphonal canal” (corresponding to the entosolenian tube in Hottinger 2006), connecting successive apertures. We interpret the presumed “siphonal canal” to be a narrow umbilical cavity extending from the umbilical side of the test towards the proloculus. The umbilical cavity is restricted (shaped or formed) only by the inner chamber walls (i.e., it is not restricted by additional wall; Figs 6.1-6.4), and remains unfilled throughout the ontogeny. It may be narrow and remain roughly the same width (as in *S. variabilis*), or may be flaring (as in *S. ex gr. gibraltarensis*). It also appears that the umbilical cavity is not the primary connection between successive chambers. Instead, foramina are separated from it by the inner chamber wall and thus completely bypass it. The aperture is rather interiomarginal (Fig. 6.5). Similarly, we cannot confirm the aperture becoming cribrate in the last part of the test, but it apparently remains a simple, interiomarginal opening. In some specimens, it appears that chamber lumina are secondarily connected with the umbilical cavity (Figs 6.4, 6.6). As has been observed (Septfontaine 1988; BouDagher-Fadel et al. 2001), the wall in some specimens appears to bear parapores (Fig. 6.8). Very rarely, poorly visible layers may be seen inside the wall (Fig. 7), but this remains to be confirmed. On the basis of different cross sections a model of *Siphovalvulina* is shown in Fig. 8.

**Comparison.** *Siphovalvulina* differs from *Radoiciicina* gen. n. in its being triserial throughout the ontogeny and in its more twisted umbilical cavity. It is morphologically very similar to *Velleditsiella* Rigaud & Blau from Hettangian to Sinemurian of Austria, but the latter genus is presumed to have a lamellar aragonitic wall and has hook-like extensions of the inner wall (Rigaud & Blau 2016). Furthermore, the umbilical cavity in *Velleditsiella* is lined by umbilical laminar extensions of the chambers (perhaps hinting at the existence of an umbilical canal system), while no such structure has been reported for *Siphovalvulina*. Triassic low
to medium-high trochospiral foraminifera with microagglutinated walls, usually referred to as “Trochammina” Parker & Jones, are morphologically very similar to *S. gibraltarensis* and Haig et al. (2007) even suggest that they belong to the same genus. However, species of “Trochammina” have four to five chambers in the last whorl (descriptions in Koehn-Zaninetti 1969; Dager 1978; Trifonova 1992; see also Haig et al. 2007), and parapores have never been reported. Furthermore, the aperture in *Trochammina* is an umbilical-extraumbilical arch, in true (i.e., recent) *Trochammina* bordered by a narrow lip (Loeblich & Tappan 1988).

**Remarks.** The origin of *Siphovalvulina* remains unresolved. Septfontaine (1988) suggested that it originates from Triassic forms described as “Trochammina”. This is certainly an attractive proposition, since both have a twisted umbilical cavity. The evolution, however, would have to involve a reduction in the number of chambers per coil and the attribution of parapores in the wall. The two genera could rather be viewed as convergent, and not successive, forms.

**Stratigraphic range.** Hettangian to Lower (Upper?) Cretaceous (Septfontaine 1988).

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*Siphovalvulina* morphotype A

Figs 6.4, 6.7, 6.8, 9.1-9.11.

(7) 1980 “*Siphovalvulina*” – Septfontaine, pl. 2, fig. 10.

2003 *Siphovalvulina* sp. – Kabal & Tasli, pl. 4, fig. 9.

2004 *Siphovalvulina beydouni* BouDagher-Fadel & Noujaim-Clark (n. sp.) – Noujaim-Clark & BouDagher-Fadel, p. 489, pl. 4, fig. 1, 2A, 3, 4, 5B, A, B.

2005 *Siphovalvulina variabilis* Septfontaine, 1988 – Schlagintweit et al., p. 42, fig. 26c.

2006 *Siphovalvulina beydouni* BouDagher-Fadel & Noujaim-Clark in Noujaim-Clark & BouDagher-Fadel, 2004 – Granier et al., pl. 1, fig. 7.

**Material:** Measured specimens come from the upper Sinemurian – Pliensbachian of Slovenia (samples Mt. Krim -47.4, 1.75) and from the lower Sinemurian of the Southern Apennines (samples Chiunzi Pass BA.4206, BA.4210).

**Description.** The test is high conical in shape, with four to almost seven coils. The apical angle is relatively narrow (55–90°; *n* = 10) and in the final stage the sides of the tests diverge below 10–35°. Sutures are very clear and the outline of the test is very irregular. The umbilical cavity is narrow (up to 0.02 mm wide at 3rd coil), and only slowly increasing in width as it grows. The wall is micro-agglutinated, with rarely visible parapores.

**Remarks.** This morphotype differs from morphotypes *S. ex gr. gibraltarensis* in having a generally smaller apical angle, a narrower test, a higher number of coils, and especially in its having a far narrower umbilical cavity. At the third coil, the incremental angle is below 80°, while it is generally between 60 and 130° in *S. ex gr. gibraltarensis*. At the fourth coil, the incremental angle is less than 60°, compared to the angle of 35–110° in *S. ex gr. gibraltarensis*. *Siphovalvulina* morphotype B becomes almost parallel-sided already between the second and third coils and is distinctively smaller in size. The umbilical cavity of the latter species is probably narrower.
The high conical test, the undulating surface and the size of the test roughly correspond to the Middle Jurassic specimen in Septfontaine (1980), which was later designated as the holotype of species *Siphovalvulina variabilis* (Septfontaine 1988: 245), and to the Kimmeridgian-Tithonian specimen figured in Schlagintweit et al. (2005) under the same name. The specimen pictured herein on Figure 9.6, on the other hand, closely matches *Siphovalvulina beydouni* in Noujaim Clark & BouDagher-Fadel (2004) and Granier et al. (2016), with a similar stratigraphic position as the type material of *S. variabilis*, as both specimens are from the Callovian to Oxfordian. Due to the lack of comparative types of material for *S. variabilis*, we are unable to assign our morphotype to either of the two species. Another specimen similar to that pictured on Figure 9.6 and also from the Lower Jurassic is shown in Kabal and Tasli (2003) as *Siphovalvulina sp.*

**Stratigraphic range and geographic distribution.** Due to nomenclature-related problems, the stratigraphic range of this species is uncertain. The specimen figured by Kabal & Tasli (2003) is, like material from the Dinarides and the Apennines, from Sinemurian-Pliensbachian strata of the Central Taurides. The specimens in Noujaim Clark & BouDagher-Fadel (2004) and Granier et al. (2016), which closely match the specimen figured here in Figure 9.6, on the other hand, come from Callovian to Oxfordian strata of Lebanon. Furthermore, *Siphovalvulina variabilis* was reported from the Callovian of Zuckerspitz in Switzerland (Septfontaine 1980) and from the Kimmeridgian-Tithonian of Salzkammergut, Austria (Schlagintweit et al. 2005). If we consider the possibility that these specimens belong to the same species, its stratigraphic range would be from the Sinemurian to the Tithonian.
**Siphovalvulina** morphotype B

*Material:* Specimens from the lower upper Sinemurian (sample Tomišelj 683) and lower-middle Sinemurian (sample Jezero 708) of Slovenia.

**Description.** The test is relatively small (up to 0.32 mm long), high conical in shape and nearly parallel-sided (incremental angle between 5 and 30°, except between the first and the second coil). The number of coils ranges from four to five-and-a-half. The chambers are relatively constant in shape, reniform, with the highest part on the innermost side of the chamber, and very slowly increasing in size or maintaining a constant size during the last stages of growth. The umbilical cavity is very narrow and of constant width throughout the growth. The wall is microagglutinated, recrystallized.

**Remarks.** *Siphovalvulina* morphotype B has a far narrower umbilical cavity than other species of this genus and has chambers of nearly constant size, resulting in far smaller chambers in the final stages of growth. It further differs from *S. variabilis* and *Siphovalvulina gibraltarensis* morphotype C in the smaller test size and from *S. colomi* in its greater number of coils. *Siphovalvulina* ex gr. *gibraltarensis* also has a far lower H/W value. It is possible that this is a new, unnamed species of *Siphovalvulina*. However, the low number of specimens is at the moment insufficient to describe a new species.

**Geographic distribution and stratigraphic range.** Sinemurian of the Dinarides.

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**Siphovalvulina ex gr. gibraltarensis**

BouDagher-Fadel, Rose, Bosence & Lord, 2001

**Siphovalvulina gibraltarensis** BouDagher-Fadel, Rose, Bosence & Lord, 2001 morphotype A

Figs 11.1-11.3

1994 *Trochammina* sp. – Chiocchini et al., Pl. 2, fig. 18.
*2001 Siphovalvulina gibraltarensis* sp. nov. BouDagher-Fadel et al., p. 605, pl. 1, fig. 6-11. [cum syn.]
pars 2007 *Siphovalvulina gibraltarensis* BouDagher-Fadel, Rose, Bosence & Lord 2001 - BouDagher-Fadel & Bosence, p. 9, pl. 11, fig. 1, 7.
2007 *Siphovalvulina gibraltarensis* – Velić.

*Material:* The measured specimens come from the lower upper Sinemurian (samples Tomišelj 676) and the upper Sinemurian - Pliensbachian (samples Mt. Krim -6, 1.75, 25.5) of Slovenia.

**Description.** The test is low conical in shape, starting with a wide apical angle (115-150°) and retaining a wide incremental angle throughout the ontogeny. The number of coils is low, with three commonly visible. The outline of the test is smooth to gently undulating, with weakly depressed sutures. Chambers are globular in shape. The umbilical cavity increases in size up until the third coil. The wall is microagglutinated. No parapores can be distinguished.

**Remarks.** This group of siphovalvulinids corresponds in size and shape to the holotype of *S. gibraltarensis* in BouDagher-Fadel et al. (2001). It differs from the other species of this genus in its wider umbilical cavity, smaller H/W rate, and the low conical shape of the test.

**Stratigraphic range and geographic distribution.** Known from the Lower Jurassic of the peri-Mediterranean area (see BouDagher-Fadel & Bosence 2007) and the lower Middle Jurassic of the Apennines (Chiocchini et al. 1994).

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**Siphovalvulina gibraltarensis** BouDagher-Fadel, Rose, Bosence & Lord, 2001 morphotype B

Figs 11.4-11.13, 11.15

1966 *Trochamminidés* – Radoićić, pl. 98, fig. 1.
pars 1980 *Eggerellina* sp. – Colom, fig. 4.64-4.68, 4.73-4.77, 4.79-4.80.
pars 1980 *Marssonella angulata* n. sp. – Colom, p. 58, fig. 5.9.
2013 *Trochammina* sp. – Haas et al., fig. 13a.

*Material:* Specimens from lower to middle Sinemurian...
Lower Jurassic sipholavulinid foraminifera

(sample Jezero 373), lower upper Sinemurian (samples Tomišelj 693, 696, 700, 701), upper Sinemurian and Pliensbachian (samples Mt. Krim -16, -6, 1.75, 17.9, 39.9, 43) and lower Pliensbachian (sample Podpeč 532) of Slovenia, lower Sinemurian of Southern Apennines (locality Chiunzi Pass, samples BA.4206 and BA.4210).

Description. Relatively small specimens of *Siphovalvulina* (average height 0.3 mm), possibly differing from *S. gibraltarensis* morphotype A in its higher number of coils and decreasing incremental angle, resulting in a low to moderately conical, bell-shaped test.

Stratigraphic range and geographic distribution. Specimens listed in the synonymy are from the lowermost Jurassic of Cabrera, Balearic Islands (Colom 1980), Pliensbachian of Venetian Prealps (Fugagnoli & Loriga Broglio 1998), Bathonian of Bükk Mountains (Haas et al. 2013) and from upper Middle Jurassic of Dinarides (Radoićić 1966).
**Siphovalvulina gibraltarensis** BouDagher-Fadel, Rose, Bosence & Lord, 2001 morphotype C
Figs 11.14, 11.16-11.20

pars 2007 *Siphovalvulina gibraltarensis* BouDagher-Fadel, Rose, Bosence & Lord 2001 - BouDagher-Fadel & Bosence, p. 9, pl. 2, fig. 1, 2; pl. 4, fig. 2B; pl. 6, fig. 3-5; pl. 9, fig. 6.

**Material:** Specimens from lower upper Sinemurian (sample Tomić) and Plinschbachtal (sample Mt. Krim 2.45) of Slovenia, lower Sinemurian of Southern Apennines (samples Chiunzi Pass, samples BA.4206 and BA.4210).

**Description.** This group includes moderately high conical specimens of *Siphovalvulina* ex gr. *gibraltarensis* with a relatively large (average height 0.57 mm) test with up to five coils.

**Remarks.** The group differs from morphotype A in its markedly larger test. The distinction between morphotypes A and B is not so clear, but the size distribution of the two morphotypes shows a bimodal distribution with a dividing value at 0.45 mm.

**Stratigraphic range and geographic distribution.** Lower Jurassic of the peri-Mediterranean area (BouDagher-Fadel & Bosence 2007).

**Radoicicina gen. n.**

**Type species:** *Radoicicina ciarapicae* gen. n., n. sp.

**Derivation of name:** In honour of the late Gloria Ciarapica for her contribution to geology and palaeontology of the Apennines.

**Diagnosis:** Test free, triserial, later becoming biserial, conical in shape; proloculus simple; chambers subglobular; simple umbilical cavity extending along the entire test length; aperture simple, interiomarginal; chambers connected by short protrusions of the wall of the previous chamber into the next; possible secondary connections between chambers and axial cavity; wall finely agglutinated, with simple parapores.

**Remarks.** *Radoicicina* differs from *Siphovalvulina*, *Velleditsiella* and “Trochammina” in its having a biserial final stage of growth. It is further distinguished from *Siphovalvulina* with its less twisted umbilical cavity, and from *Velleditsiella* and “Trochammina” with its microagglutinated wall with parapores.

**Composition of the genus.** At the moment the genus is represented only by the type species *Radoicicina ciarapicae* n. sp.

**Stratigraphic range and geographic distribution.** As for type species (see below).

**Radoicicina ciarapicae** gen. n., n. sp.
Figs 12.1-12.13

(©) 1994 Bolognesiia sp. – Chiocchini et al., pl. 7, fig. 1-2. 2005 Valvunlidi – Barattolo & Romano, fig. 5.3.

**Derivation of name:** In honour of the late Gloria Ciarapica for her contribution to geology and palaeontology of the Apennines.


**Repository:** Department of Earth Science, Environment and Resources of the University of Naples Federico II, Naples.

**Holotype:** the specimen in Fig. 12.1 (thin section BA.4210-10).

**Paratypes:** the specimens in Figs 12.2-12.13 (Thin sections BA.4206-3, BA.4206-5, BA.4206-10, BA.4206-11, BA.4210-7, BA.4210-9, BA.4210-13, BA.4210-15, BA.4210-17, BA.4210-18).

**Type locality:** Chiunzi Pass (Southern Apennines, Italy).

**Type level:** Palaeocycladus Limestone Formation. Decimetric, well-bedded limestone. Heterogenous vuggy wackestone to peloid-hioblastic packstone with benthic foraminifera, peloids, dasycladalean algae, gastropods and thaumatoporelloid microproblematica.

**Association:** In sample BA.4206: Textulariida, Textulariida sp., Valvulina sp., Duntaxis metula Kristan, Siphovalvulina ex gr. gibraltarensis, S. cf. variabilis, Everticyclammina praevirguliana Fugagnoli, ?Mesendothyra sp., quinqueloculina Milolidia; thaumatoporellids, Caycemia sp.; gastropod. In sample BA.4210: Valvulina sp., Pseudopfenderina buterlini (Brun), Linolipora termieri (Hottinger), Siphovalvulina ex gr. gibraltarensis, S. cf. variabilis, E. praevirguliana, Earlandia tintinniformis (Mišik), Agathammina-like small milolid, Involutinididae; Caycemia sp., thaumatoporellids.

**Diagnosis:** *Radoicicina* with up to eight coils in triserial part of the test, followed by up to seven series of biserial chambers. The test is highly conical, up to 1.5 mm long, with nearly parallel sides in the biserial part.

**Description.** The test is very elongated and relatively large. The triserial part of the test is highly conical, with sides diverging at 40-65°, but steadily becoming more parallel during the growth. In the biserial part, the sides are almost parallel, with an incremental angle of approximately 5°. Sutures are clearly visible and moderately depressed. Chambers of the triserial part are kidney-shaped, rounded and fairly constant in shape. Chambers of the biserial part are semicircular, well rounded, almost constant in height through the ontogeny, and only slightly wider than the test in its triserial part. The umbilical cavity is narrow and parallel-sided, making wide meanders along the axis of growth.

**Remarks.** *Radoicicina ciarapicae* gen. n., n. sp. differs from species of the genus *Siphovalvulina* in the final biserial part of the test. Its triserial part dif-
fers from *S. cf. variabilis* in being more parallel-sided (10° or less at 5th coil) and in having a smaller Hc to D1 ratio. *Radoicicina ciarapicae* is significantly wider than *Siphovalvulina* morphotype B. It has larger final chambers of the triserial part, a wider umbilical cavity and a thicker test wall. As a result, we dismiss the possibility that *R. ciarapicae* simply represents a more advanced ontogenetic stage than any of the *Siphovalvulina* species. Chiocchini et al. (1994) identified specimens from the upper Barremian of Monti Aurunci as *Belorussiella*. However, *Belorussiella*’s aperture is an elongated slit (after Loeblich & Tappan 1988), whereas it appears that the specimen shown by Chiocchini et al. (1994) may have an umbilical cavity (see their pl. 7, fig. 2).

**Geographic distribution and stratigraphic range.** Outside its type locality, *Radoicicina ciarapicae* is currently also known from the Hettangian of the Venetian Prealps (Barattolo & Romano 2005), and the Sinemurian of the Dinarides (pers. data). Its range may extend up to the upper Barremian (cf. Chiocchini et al. 1994).

*Radoicicina* sp.

Fig. 12.14

**Material:** One specimen from sample Chiunzi Pass, samples BA.4206 (lower Sinemurian).
Description. A relatively small *Radoicicina*, with five coils of chambers in a triserial arrangement, followed by six pairs of biserial chambers. The entire test is 0.59 mm long; the triserial part is 0.11 mm wide and the biserial 0.17 mm wide. The wall is thin (0.01 mm).

Remarks. This specimen differs from *Radoicicina ciarapicae* in its smaller test.

**DISCUSSION**

**Morphological variability in *Siphovalvulina***

As shown above, several morphotypes of *Siphovalvulina* could be distinguished on the basis of the gathered material. Interestingly, we did not distinguish a distinct morphotype, which would correspond to *S. colomi*, which is also commonly present in the Lower Jurassic carbonates (e.g., BouDagher-Fadel et al. 2001; Motaharian et al. 2014; see also specimens on pl. 2, figs. 1-5, 9-11, 16 in Chiocchini et al. 1994, and on pl. 3, fig. m in Mancinelli et al. 2005), but ranges to the Upper Jurassic (Fig. 6A in Krajewski & Olszewska 2007). Four species of *Siphovalvulina* are thus known so far. In addition to these, Bucur et al. (2014) show an unnamed *Siphovalvulina* from the Lower Cretaceous of Transylvania, which has very high chambers, elongated parallel to the umbilical cavity, and Tasli (2001) another unnamed *Siphovalvulina* from the Upper Jurassic of the Central Taurides, which resembles *S. colomi*, but has a narrower test, smaller trapezoidal chambers and a higher number of coils. Both may represent an undescribed species.

The early appearance soon after the end-Triassic extinction, the high morphologic variability and the widespread occurrence in different facies types and associations mark *Siphovalvulina* as a probable opportunist of the Early Jurassic assemblages (e.g., Fugagnoli 2004; BouDagher-Fadel & Bosence 2007; Gale & Kelemen 2017). The morphological variability of *Siphovalvulina* could be related to exploiting different microhabitats. Plano-convex forms such as *S. ex gr. gibraltarensis* could belong to epifauna, living on the sea bottom or crawling on macroalgae, while more elongated forms could reflect an infaunal life tendency (cf. Corliss & Chen 1988; Reolid et al. 2008). The role of the openings from chambers to umbilical cavity is also not yet explained. Rigaud and Blau (2016) suggest that openings in near morphologically identical *Velleditiella* shortened the connection between chambers and the surrounding environment. We suggest that they could also aid in the exchange of gas, as might the thinned wall over the parapores.

**Biostratigraphic value and phylogeny**

*Siphovalvulina* is often among the first microfossils that appear in lowermost Jurassic shallow marine carbonates (e.g., Chiocchini et al. 1994; Mancinelli et al. 2005; Gale et al. 2012). Septfontaine (1986) took the first occurrence of *Siphovalvulina* as the base of the lower – middle Sinemurian *Siphovalvulina-Mesoendothyra* zone. BouDagher-Fadel and Bosence (2007) later introduced the *Siphovalvulina gibraltarensis* biozone for the Hettangian, characterized by *Siphovalvulina* spp. (unnamed species), simple *Textularia* spp., the absence of more advanced textularids and the first appearance of *Involutina liassica* (Jones). *Siphovalvulina gibraltarensis* and *S. colomi* appear in the lower to middle Sinemurian *Siphovalvulina colomi* zone, characterized by the presence of *I. liassica*, *Pseudopfenderina* cf. *butterlini* (Brun) and some other, simple agglutinated forms. A biostratigraphic value of *Siphovalvulina* is also indicated in Velić (2007), who suggests that *S. variabilis* is the first to appear in the Dinarides during the Hettangian, and is joined by *S. gibraltarensis* and *S. colomi* in the early Sinemurian.

As discussed, the main obstacle in defining some sort of biostratigraphic zones and also in discussing the phylogeny of *Siphovalvulina* lays in the often mentioned but poorly recorded variability of its species. For example, many attributions to *S. variabilis* are present in the literature, with specimens coming from the Lower Jurassic (e.g., Fugagnoli & Loriga Broglio 1998; Mancinelli et al. 2005; Gale & Kelemen 2017), the Middle Jurassic (e.g., Ekmekci & Altiner 2008) as well as from the Upper Jurassic to Lower Cretaceous beds (e.g., Darga & Schlagintweit 1991; Krajewski & Olszewska 2007; Ivanova & Kołodziej 2010; Grădinaru et al. 2016). However, all of these specimens differ from the holotype of *S. variabilis* and some should be redefined. With this in mind, Figure 13 shows the stratigraphic ranges of all of the known species of *Siphovalvulina*, which differ somewhat from those presented by Velić (2007) and by BouDagher-Fadel and Bosence (2007). The earliest species that appear in the Hettangian seem to be *S. gibraltarensis*
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(As “Trochammina” almtalensis in Gale & Kelemen 2017) and Siphovalvulina morphotype A (as S. variabilis in Kabal & Tasli 2003, and in Gale & Kelemen 2017), possibly along with the new genus and species, Radoicicina ciarapicae, differs from Siphovalvulina in its having a biserial final part of the test and a less twisted umbilical cavity. The two genera constitute Siphovalvulinidae fam. n., which we presume underwent rapid speciation in the lowermost Jurassic.

Acknowledgements: This work was financially supported by the Slovenian Research Agency (Programme Number P1-0011) and by the Erasmus+ 2016/17 programme (contract STA-2016-2017-643). We sincerely thank Dejan Emeršič and Andrej Šmuc (Faculty of Natural Sciences and Engineering, Ljubljana), who provided thin sections from the Krim section, and Mladen Štumergar (Geological Survey of Slovenia) for technical support. Finally, we thank the reviewers and editor for their suggestions and constructive remarks on the manuscript.

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