

MORPHOMETRIC APPROACH TO DETERMINATION OF LOWER JURASSIC SIPHOVALVULINID FORAMINIFERA

LUKA GALE^{1,2}, FILIPPO BARATTOLO³ & ROBERTO RETTORI⁴

¹University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geology, Aškerčeva 12, SI-1000 Ljubljana, Slovenia. E-mail: luka.gale@ntf.uni-lj.si

²Geological Survey of Slovenia, Dimičeva 14, SI-1000 Ljubljana, Slovenia. E-mail: luka.gale@geo-zs.si

³Università degli Studi di Napoli Federico II, Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Largo S. Marcellino 10, I-80138 Napoli, Italy. E-mail: filippo.barattolo@unina.it

⁴Università degli Studi di Perugia, Dipartimento di Fisica e Geologia, I-06123 Perugia, Italy. E-mail: roberto.rettori@unipg.it

To cite this article: Gale L., Barattolo F. & Rettori R. (2018) - Morphometric approach to determination of Lower Jurassic siphovalvulinid foraminifera. *Riv. It. Paleontol. Strat.*, 124(2): 265-282.

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., 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.

Received: September 13, 2017; accepted: February 13, 2018

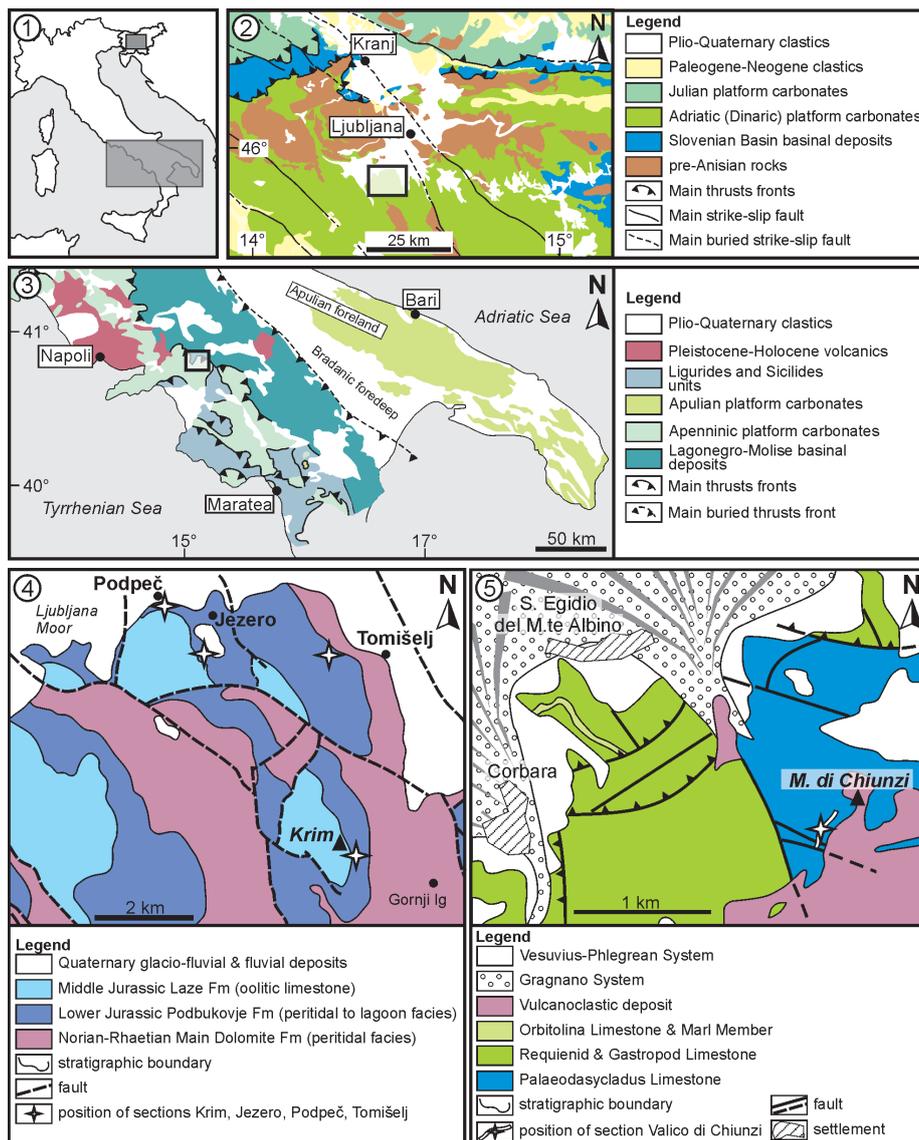


Fig. 1 - Geological setting and position of the sampled sections. 1.1) Position of Figures 1.2 and 1.3. 1.2) Present distribution of palaeogeographic units in central Slovenia and position of Figure 1.4 (transparent rectangle). Map redrawn and simplified after Bavec et al. (2013) and Rožič (2016). 1.3) Present distribution of palaeogeographic units in Southern Apennines and position of Figure 1.5 (transparent rectangle). Modified after Di Lucia et al. (2012). 1.4) Geological map with position of the Mt. Krim, Jezero, Podpeč and Tomišelj sections, northern Dinarides, Slovenia. Modified after Buser et al. (1967) and Buser (1968). 1.5) Geological map with position of the Chiunzi Pass section, Southern Apennines, Italy. Modified after Geological Map of Italy 1:50.000, sheets 466-485 "Sorrento-Termini" (ISPRA, 2016).

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-thrusted 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 intra-clastic 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 lithotid limestone, locally capped by red claystone surfaces (emersion horizons in Martinuš et al. 2012); the uppermost part

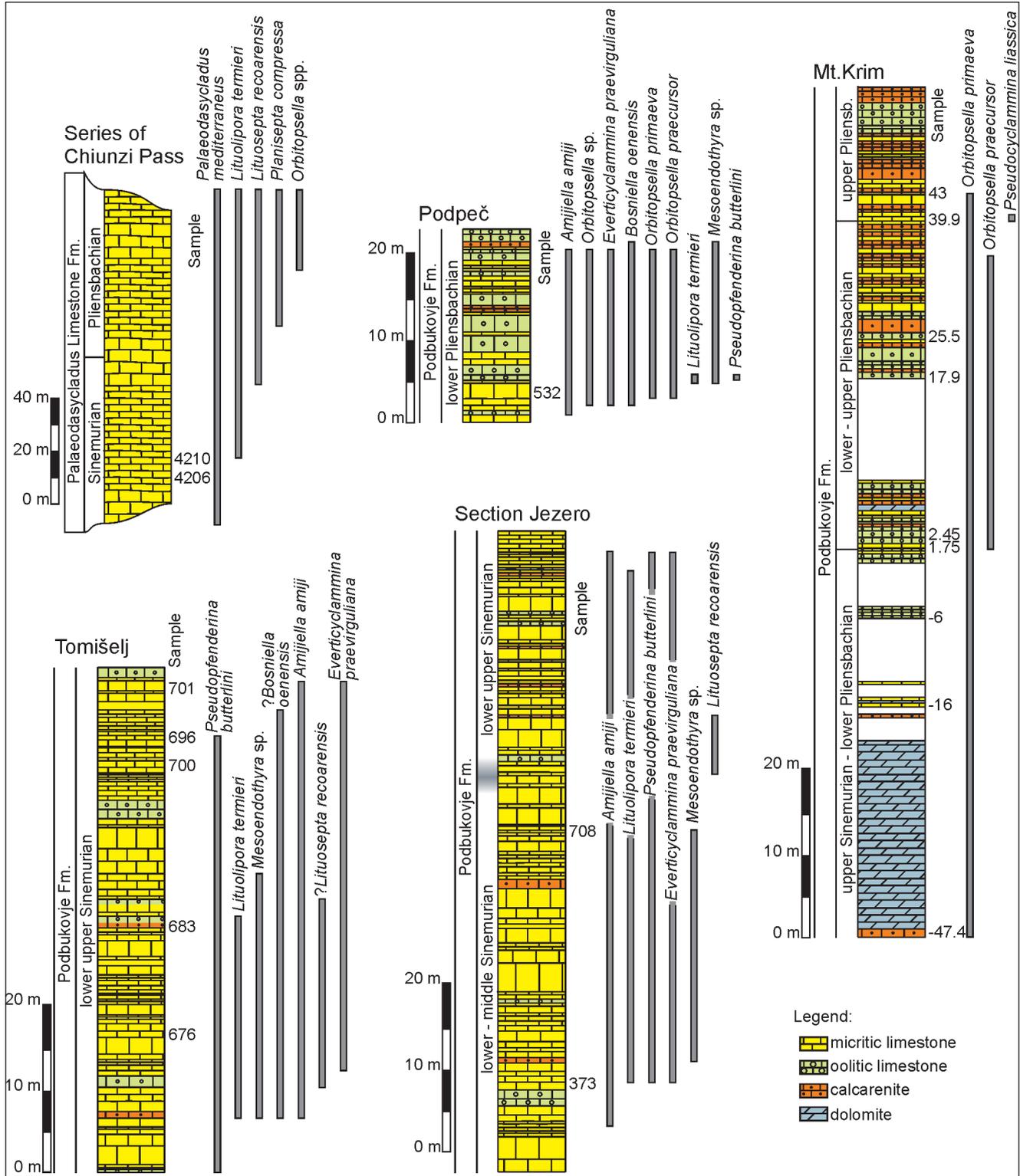


Fig. 2 - Schematic presentation of sampled sections and positions of the samples.

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 Calcarei a

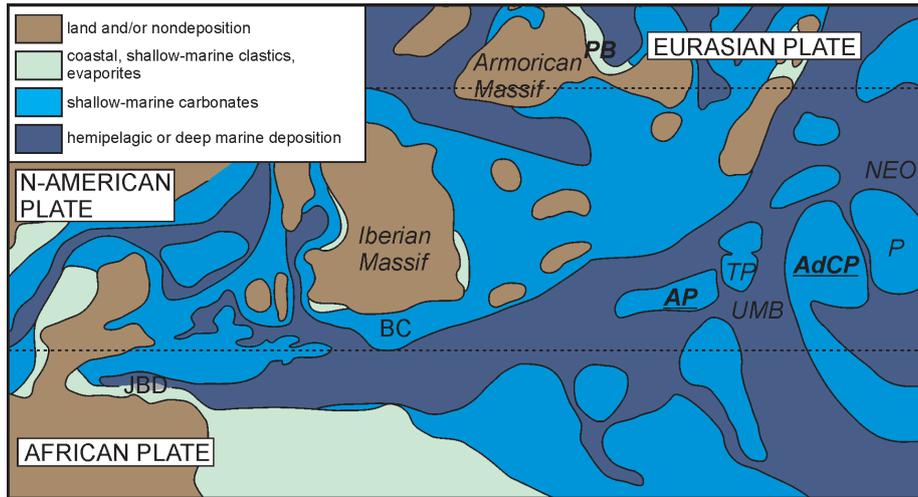


Fig. 3 - Palaeogeographic map of the present peri-Mediterranean area for late Sinemurian. AdCP: Adriatic carbonate platform; AP: Apenninic carbonate platform; BC: Betic Cordillera platform; JBD: Jbel Bou Dahar platform; Pelagonia; PB: Paris Basin; UMB: Umbria Marche Basin; TP: Trento platform. Modified after Thierry (2000) and Bosence et al. (2009).

Paleodasycladus (Paleodasycladus 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 siphonvulvinids 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 *Siphonvulvina* 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. gibraltarenensis* 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).

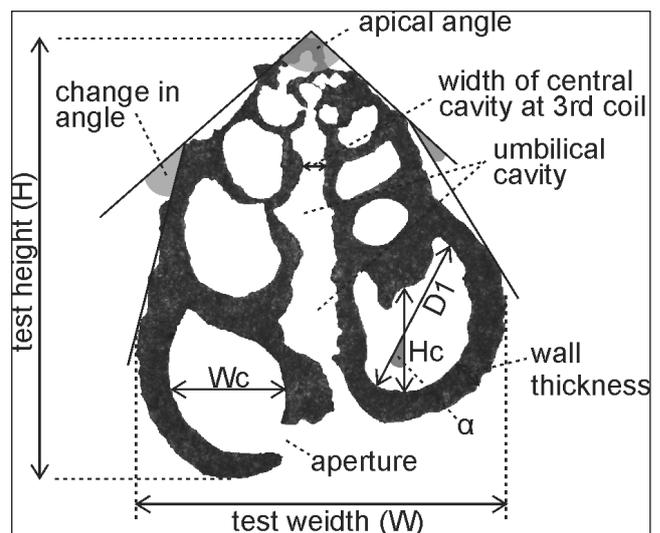


Fig. 4 - Measured parameters. Note how the outline of test is difficult to draw in places due to recrystallization of the test wall. Hc (chamber height), Wc (chamber width) and D1 (length of lumen from proximal outer edge of the last chamber to the distal inner edge of the same chamber) were all measured in the same chamber (possibly the last one), but are here shown separately for reasons of image legibility. α : angle between Hc and D1.

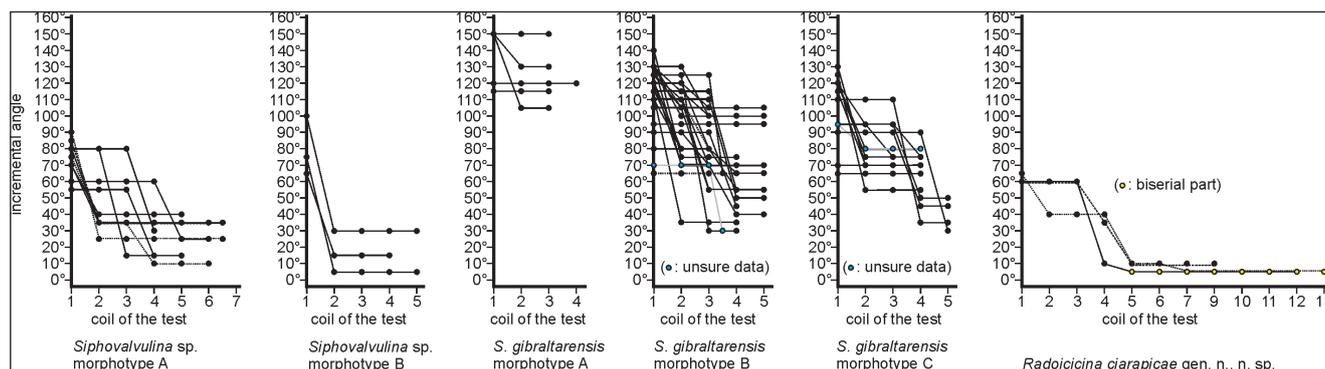


Fig. 5 - Size of the incremental angle through the ontogeny of different morphotypes of *Siphovalvulina*. Dots indicate the size of the angle at each coil of the test. If the test with the next coil becomes narrower, the line that connects two successive dots “steps down”. If the test became flaring, then the line would “step up”. If the angle remains the same (the test maintains the same shape), then the line is horizontal. For example, the shape of each of the three specimens in *Siphovalvulina* morphotype B is represented by a series of dots, connected by a line. The uppermost line shows that one of these specimens starts with an apical angle of 100°. In the next (second) coil, the test becomes more parallel-sided, i.e. the angle between the sides of the test is now only 30°. The test then retains this angle until its final coil.

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, *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).

Phylum **FORAMINIFERA** d’Orbigny, 1826

Class **GLOBOTHALAMEA** Pawlowski,

Holzmann & Tyszka, 2013

Order “**Textulariida**” Delage & Hérouard, 1896
(sensu Pawlowski, Holzmann & Tyszka, 2013, incl.

Textulariida Delage & Hérouard, 1896
emend. Kaminski, 2004)

Suborder **Textulariina** Delage & Hérouard, 1896

Superfamily Eggerelloidea Cushman, 1937

Remarks. Septfontaine (1988) grouped *Siphovalvulina* together with *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 columella. 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 *Siphovalvulina* with *Pseudopfenderina* was adopted also by Kaminski

(2004), who placed Pfenderinidae in the suborder Orbitolinina of the order Loftusiida. On the basis of *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 Eggerelloidea within the order Textulariida (sensu Kaminski 2004). Alternatively, BouDagher-Fadel et al. (2001) placed *Siphovalvulina* into the family Verneulinidae of the superfamily Verneulinacea which was placed by Kaminski (2004) under Verneulinina belonging to the order Lituolida. According to Kaminski (2004), Lituolida consists of “noncanaliculate” agglutinated groups. In a distinct classification by Mikhalevich (2014), *Siphovalvulina* is left as *incertae sedis* among Verneulinida, 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 *Siphovalvulina* and *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.

Section	Coordinates	Lithological description	Age	Depositional environment
Jezero	45°57'30" N, 14°26'00" E	Medium-thick to massive (up to 335 cm thick) beds predominate in the lower 39 m of the section. Dark grey to almost black micritic limestone covers the lower 6 m of the section. Bioturbations, parallel lamination, lenses of ooid grainstone and one possible stromatolitic horizon are locally present. Wackestone contains small ooids, bivalves, gastropods and oncoids. Some beds are covered by thin red claystone. Ooid grainstone follows from the 6th to 10th metre, locally passing upwards into micritic limestone, which itself contains horizons with accumulated bivalves, gastropods and ooids. Mudstone and wackestone then predominate again. A level of pronounced emersion is present around the 14th metre, with red claystone surfaces permeating black micritic limestone. Beds or levels of ooid grainstone are subordinate. Cross laminations and grading are commonly seen within oolites. Troughs between ripples are locally filled with accumulated bivalve and gastropod shells. Fine-grained flat-pebble breccia is present at the 28th metre. At the 30th metre, the mudstone becomes increasingly black and has the smell of bitumen. Black bioclastic floatstone is present between the 32nd and 37th metre. A bed one meter 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, ooid packstone and grainstone, bioclast floatstone and rudstone. Bed thickness is very inconsistent, ranging from platy to more than 2 m-thick beds. Micritic limestone is often black or dark grey. The section ends with medium-bedded bivalve floatstone. Shells are concentrated in the upper or in the lower part of the beds, or dispersed through the entire bed.	lower – middle Sinemurian and lower upper Sinemurian	Open lagoon (ramp?)
Tomiselj	45°57'51" N, 14°28'06" E	Beds are medium to very thick. Limestone is the predominating lithology; few beds are topped by a few millimetres of brown or reddish claystone. The section starts with gray mudstone and wackestone in beds up to 135 cm thick. Bioturbation and parallel lamination are locally present. Wackestone contains disarticulated valves of small bivalves, peloids and intraclasts. Small lenses of ooid grainstone are present. Fine-grained oolite is more common between 12.5 and 19 m of the section. The wackestone in this part contains bivalves, ooids and intraclasts; mudstone is locally laminated. Micritic limestone again predominates between the 19th and 30th meter. Horizons of ooid grainstone are locally present within the micritic limestone. Ooid grainstone covers the interval between 30th and 35th metre. Few massive beds are inversely graded. Rare oncoids are locally present, as well as levels of bivalve floatstone. Ooid grainstone 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 ooid packstone and grainstone start to become more common.	lower upper Sinemurian	Open lagoon (ramp?); more restricted conditions at the top of the section
Mt. Krim (*material and log available courtesy of D. Emeršič and A. Šmuc)	45°55'33" N, 14°25'33" E	Beds are predominantly medium-thick, oolitic 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 (stromatolites?) are locally visible. A short interval of thin to medium-thick beds of ooid grainstone follows, and then the section continues with interchanging ooid grainstone, bioclast-peloid wackestone, packstone and mudstone. The most common bioclasts are bivalves, gastropods, in some thin sections foraminifera, calcimicrobes and green algae are visible; corals are also occasionally present. Lithotid bivalves appear 50 m from the base of the section and are present in several levels up until the top, also in their original position (perpendicular to bedding). Small-scale Neptunian dykes filled with red micritic limestone are present especially in the upper part of the section.	upper Sinemurian - Pliensbachian	Lagoon, partially restricted by ooid bars and aggregations of lithotid bivalves
Podpeč	45°58'22" N, 14°25'16" E	Most beds are medium-thick to massive, and of highly variable lithology. Dominant are ooid grainstone and bioclast-ooid grainstone. Also common are peloid wackestone to packstone, oncoid and bioclast floatstone. The most frequent bioclasts are fragmented bivalves; common are terebratulid brachiopods, foraminifera, gastropods and dasycladaceans. Lithotid bivalves are present in several levels, most commonly accumulated within red claystone, rarely embedded in limestone beds, with valves oriented concordant with bedding. Only one level with lithotids in a life position is present; these were buried by ooid bar. Thin to medium-thick beds of wackestone and mudstone are subordinate. Irregular bedding planes, red clayey surfaces, parallel lamination and grading are common, cross lamination was also found lateral to the sampled section.	lower Pliensbachian	Lagoon, partially restricted by ooid bars and aggregations of lithotid bivalves
Valico di Chiunzi / Chiunzi Pass	40°43'09" N, 14°37'09" E	The interval with the new taxon encompasses the first occurrence of <i>Lituolipora termieri</i> . It consists of 10 to 40 cm thick bedded mud supported limestone (wackestone), episodically intercalated with bioclast packstone and grainstone. Ooid grainstone is very rare. Micritic sediment is crossed by fenestral fabric. Pendant cements are observed attached on the roof of cavities and the floor is filled by geopetal calcareous silt. The rest of cavities are filled by blocky cement. Bioclasts are dominant, mainly by algae (<i>Palaodasycladus mediterraneus</i> (Pia), <i>Palaodasycladus gracilis</i> Cros & Lemoine, <i>Thaumatoporella parvovesiculifera</i> (Raineri), <i>Cayeuxia</i> -like thalli). Foraminifera are well represented. Recrystallized gastropods and calcareous sponges occasionally occur. In addition to bioclasts, peloids and oncoids (microbial- <i>Thaumatoporella</i> consortium) are recorded.	lower Sinemurian – lower-middle Pliensbachian	Shallow, low energy, subtidal lagoon

Tab.1 - Short description of sampled sections.

	<i>Siphovalvulina</i> morphotype A	<i>Siphovalvulina</i> morphotype B	<i>Siphovalvulina gibraltarensis</i> morphotype A	<i>Siphovalvulina gibraltarensis</i> morphotype B	<i>Siphovalvulina gibraltarensis</i> morphotype C	<i>Radoicicina ciarapicae</i> gen. n., n. sp.
Number of measurements	10	3	6	33	16	3
Test height, H (mm)	0.45-0.88 (a 0.62; sd 0.13)	0.23-0.32	0.12-0.26 (a 0.19; sd 0.05)	0.16-0.56 (a 0.30; sd 0.08)	0.47-0.69 (a 0.57; sd 0.06)	*0.39-0.72 **0.72-1.47
Test width, W (mm)	0.20-0.51 (a 0.34; sd 0.08)	0.11-0.14	0.2-0.37 (a 0.30; sd 0.05)	0.19-0.49 (a 0.32; sd 0.08)	0.39-0.65 (a 0.51; sd: 0.07)	0.30-0.35
H/W	1.49-2.29 (a 1.85; sd 0.26)	2.13-2.53	0.57-0.70 (a 0.62; sd 0.05)	0.64-1.52 (a 1.11; sd 0.20)	0.71-1.07 (a 0.89; sd: 0.11)	*1.13-2.38 **2.38-4.91
No. coils	4-6.5	4-5.5	3	3-5	3.5-5	*4-8 **8-13 ***0-7
Apical angle (°)	55-90	65-100	115-150	60-120	65-130	60-65
Last chamber height, Hc (mm)	0.08-0.26 (a 0.15; sd 0.05)	0.04-0.05	0.05-0.12 (a 0.08; sd 0.03)	0.06-0.16 (a 0.10; sd 0.03)	0.14-0.22 (a 0.18; sd 0.03)	*0.09-0.15 **0.10-0.18
Last chamber width, Wc (mm)	0.09-0.18 (a 0.13; sd 0.03)	0.03-0.04	0.06-0.12 (a 0.10; sd 0.03)	0.06-0.16 (a 0.11; sd 0.03)	0.15-0.23 (a 0.18; sd 0.02)	*0.10-0.12 **0.24-0.31
Hc/Wc	0.87-1.47 (a 1.21; sd 0.23)	0.91-1.66	0.54-1.00 (a 0.80; sd 0.15)	0.66-1.23 (a 0.93; sd 0.16)	0.86-1.07 (a 0.96; sd 0.06)	*0.71-1.50 **0.40-0.58
Angle between Hc and D1 (°)	0-45 (a 30; sd 13)	32-45	0-63 (a 27; sd 23)	20-47 (a 34; sd 7)	22-42 (a 35, sd 6)	*30-40
Hc/D1	0.71-0.97 (a 0.85; sd 0.08)	0.62-0.91	0.54-0.98 (a 0.74; sd 0.14)	0.63-1.00 (a 0.78; sd 0.10)	0.67-0.92 (a 0.78; sd 0.08)	*0.46-0.73
Proloculus of A generation (mm)	0.02-0.05 (n=7)	0.03 (n=1)	0.03 (n=1)	0.02-0.07 (n=10)	0.02-0.05 (n=6)	0.03-0.04
Wall thickness (mm)	0.02-0.04	0.01	0.01-0.02	0.01-0.05	0.02-0.08	0.02-0.04
Width of umbilical cavity at 3rd coil (tightest part)	0.01-0.02 (a 0.015; sd 0.002)	Too narrow (lumen not visible)	0.03-0.07 (a 0.05; sd 0.02)	0.02-0.07 (a 0.04; sd. 0.02)	0.03-0.10 (a 0.04; sd 0.02)	*0.02 ***0.03

Tab. 2 - Measured parameters in siphovalvulinids 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.

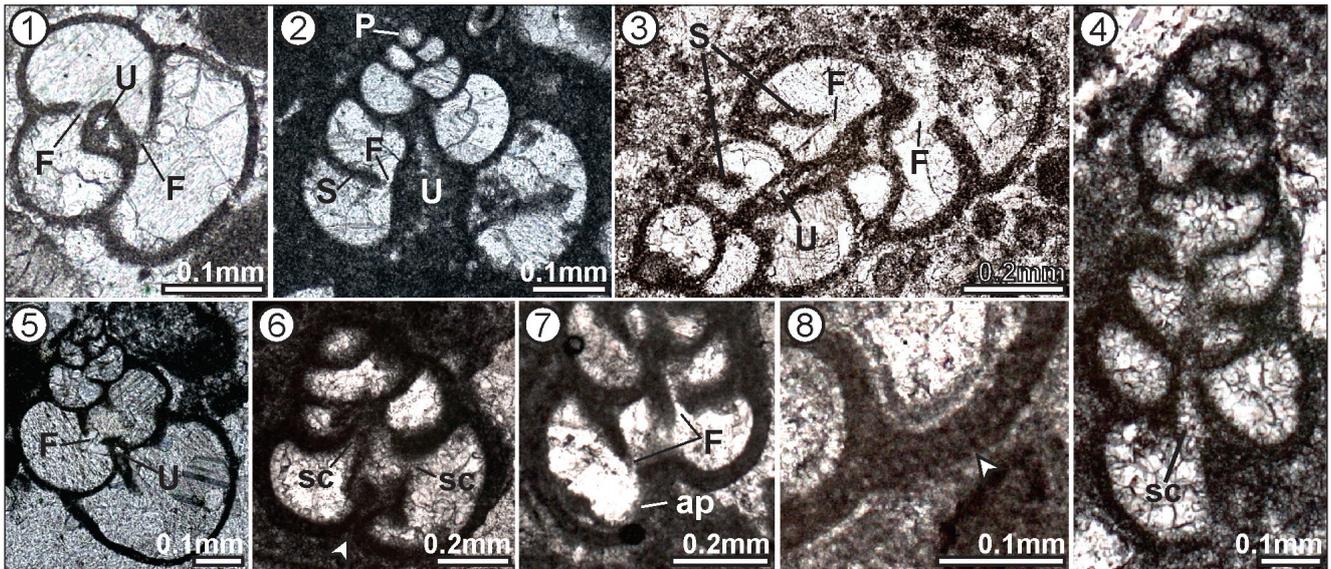


Fig. 6 - Morphology of *Siphovalvulina*. 6.1) Transverse section. Note that the umbilical cavity (previous interpreted as a siphonal canal) is not a special structure, but simply a cavity defined by the inner walls of the chambers and that the primary connection between the chambers is through protruding foramina. Sample Podpeč 525. 6.2-6.5) Sections slightly oblique to the axis of coiling. Note the opening in the “roof” of the last chamber in Fig. 6.4, seemingly connecting it with the narrow umbilical cavity. Samples Mt. Krim 1.75, Tomišelj 701 and Chiunzi Pass BA.4206. 6.6) Slightly tangential section where connections between the chambers and the umbilical cavity are visible. Note that the latter is open to the exterior of the test (arrowhead). Sample Chiunzi Pass BA.4206. 6.7) Slightly tangential section. Note a wide aperture at the base of the chamber, interiorly directed. Sample Chiunzi Pass BA.4206. 6.8) Detail of the wall. Note parapores (“canaliculi”) indicated by arrowhead. Sample Chiunzi Pass BA.4206

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, interior marginal; 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 cham-

ber wall and thus completely bypass it. The aperture is rather interior marginal (Fig. 6.5). Similarly, we cannot confirm the aperture becoming cribrate in the last part of the test, but it apparently remains a simple, interior marginal 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 *Radoicicina* 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

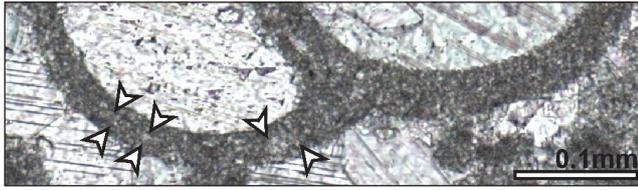


Fig. 7 - Possible laminae within the wall of the *Siphovalvulina*. Sample Chiunzi Pass BA.4210.

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).

Siphovalvulina morphotype A

Figs 6.4, 6.7, 6.8, 9.1-9.11.

(?) 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, 2, 3A, 4, 5B, 6C.

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

2016 *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).

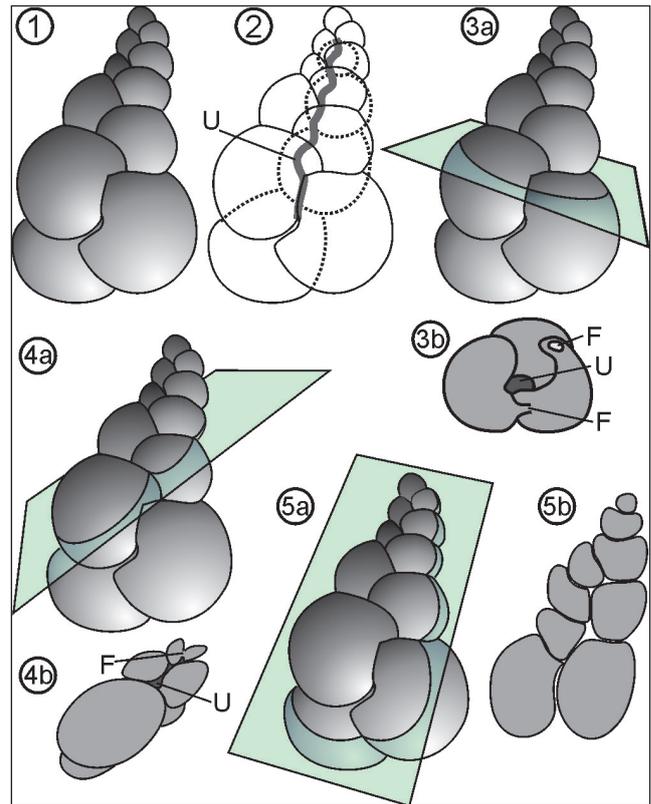
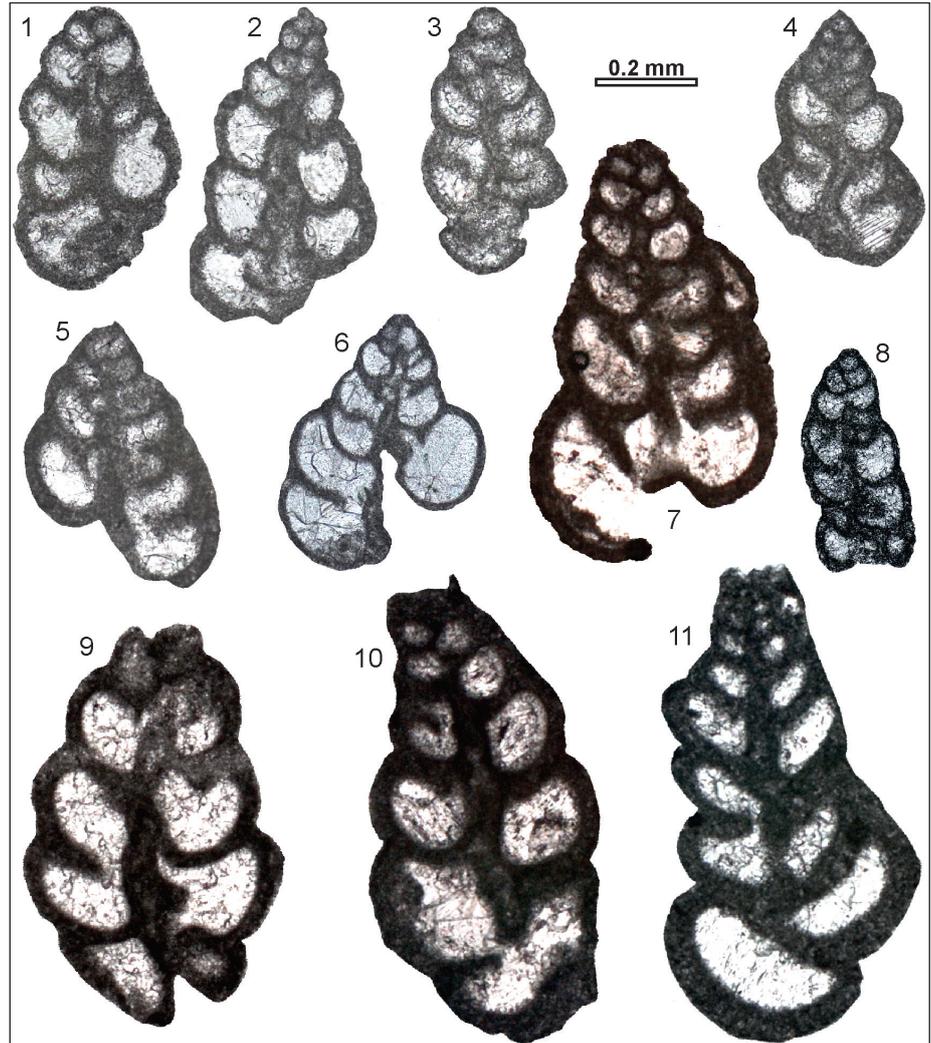


Fig. 8 - Model of *Siphovalvulina*. 8.1) External view. 8.2) Wire-frame model with position of the umbilical cavity (U). 8.3) Basal section. 8.4) Oblique section. 8.5) Tangential section. Abbreviations: F- foramen; U- umbilical cavity.

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 microagglutinated, 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.

Fig. 9 - *Siphovalvulina* morphotype A. 9.1-9.5) Sample Chiunzi Pass BA.4210 (lower Sinemurian). 9.6) Sample Mt. Krim 1.75 (Pliensbachian). 9.7) Sample Chiunzi Pass BA.4206. 9.8) Sample Mt. Krim (Pliensbachian) 47.4. 9.9-9.10) Sample Chiunzi Pass BA.4206 (lower Sinemurian). 9.11) Sample Chiunzi Pass BA.4210 (lower Sinemurian).



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.

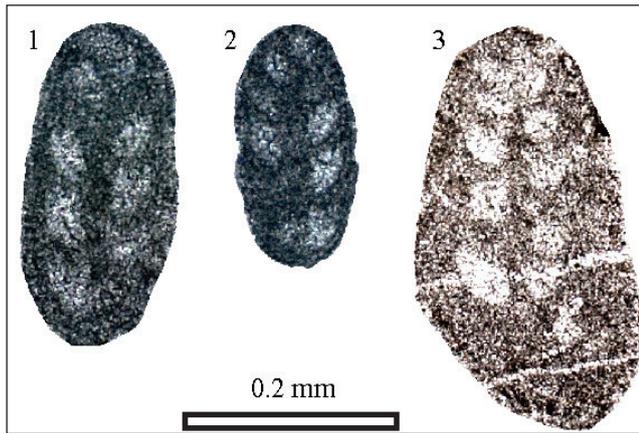


Fig. 10 - *Siphovalvulina* morphotype B. 10.1) Sample and thin section Tomišelj 683 (lower upper Sinemurian). Note the narrow umbilical cavity (visible as slightly twisted dark line) seemingly extending into the last chamber. 10.2) Sample Tomišelj 683 (lower upper Sinemurian). 10.3) Sample Jezero 708 (lower - middle Sinemurian).

Siphovalvulina morphotype B

Figs 10.1-10.3

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.

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 para-pores 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).

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

Figs 11.4-11.13, 11.15

1966 *Trochamminidés* – Radoičić, 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.

pars 1998 *Siphovalvulina variabilis* Septfontaine, 1988 – Fugagnoli & Loriga Broglio, p. 60, fig. 9.2.

2013 *Trochammina* sp. – Haas et al., fig. 13a.

Material: Specimens from lower to middle Sinemurian

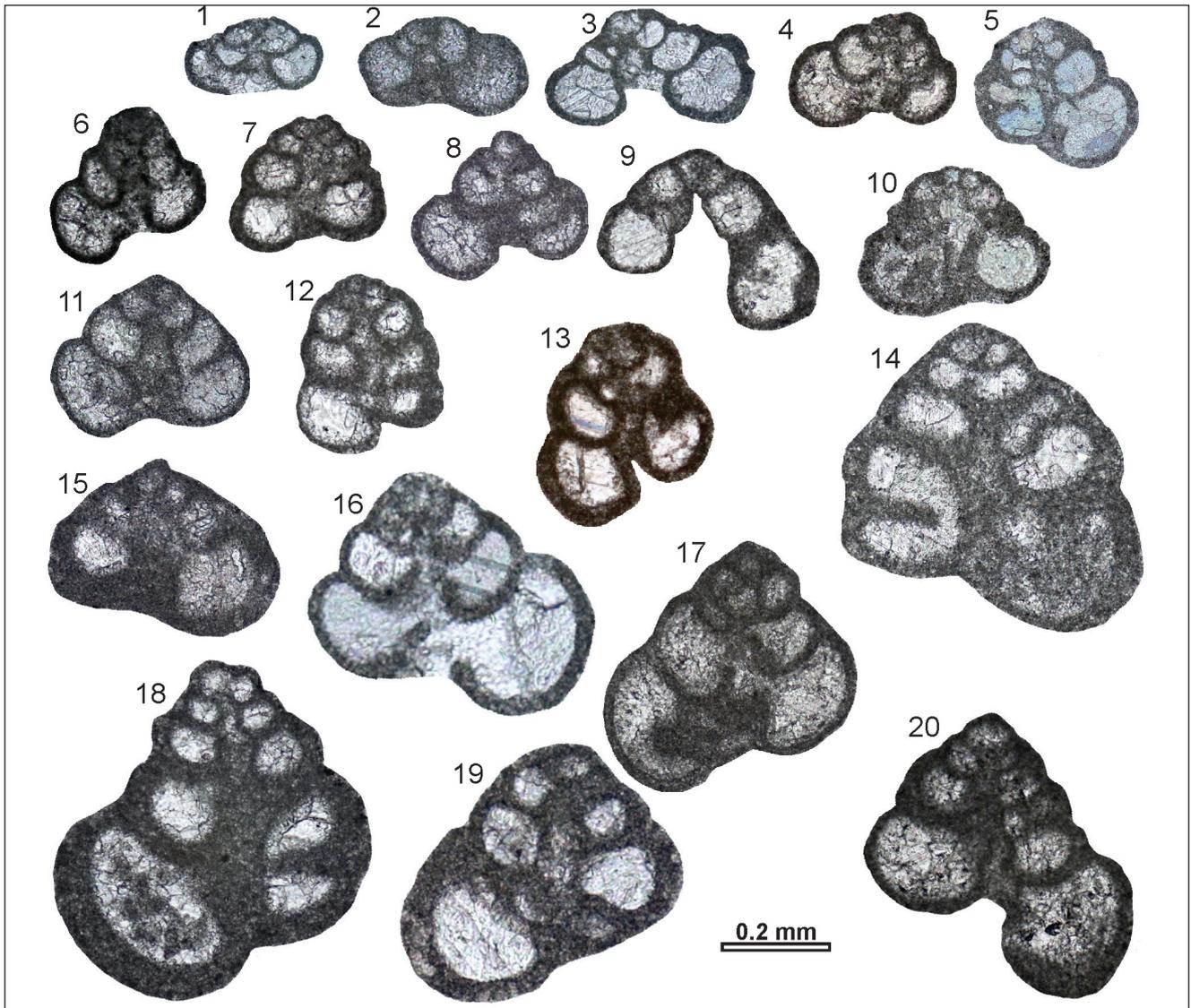


Fig. 11 - *Siphovalvulina* ex gr. *gibraltarensis*. 11.1-11.3) *S. gibraltarensis* morphotype A. 11.1 - Sample Mt. Krim 6 (Pliensbachian). 11.2 - Sample Mt. Krim 25.5 (Pliensbachian). 11.3 - Sample Mt. Krim 1.75 (Pliensbachian). 11.4-11.13, 11.15) *S. gibraltarensis* morphotype B. 11.4 - Sample Chiunzi Pass BA.4210 (lower Sinemurian). 11.5 - Sample Mt. Krim 1.75 (Pliensbachian). 11.6-11.7 - Sample Chiunzi Pass BA.4210 (lower Sinemurian). 11.8 - Sample Podpeč 532 (lower Pliensbachian). 11.9-11.10 - Sample Chiunzi Pass BA.4210 (lower Sinemurian). 11.11 - Sample Tomišelj 700 (lower upper Sinemurian). 11.12 - Sample Chiunzi Pass BA.4210 (lower Sinemurian). 11.13 - Sample Chiunzi Pass BA.4206 (lower Sinemurian). 11.15 - Sample Jezero 373 (lower - middle Sinemurian). 11.14, 11.16-11.20) *S. gibraltarensis* morphotype C. 11.14 - Sample Chiunzi Pass BA.4210 (lower Sinemurian). 11.16 - Sample Mt. Krim 1.75 (Pliensbachian). 11.17-11.18 - Sample Chiunzi Pass BA.4210 (lower Sinemurian). 11.19 - Sample Mt. Krim 39.9 (Pliensbachian). 11.20 - Sample Chiunzi Pass BA.4210 (lower Sinemurian).

(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 in-

cremental 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 (Radoičić 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 Tomišelj 701) and Pliensbachian (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 Rajka Radoićić for her contribution to micropalaeontology.

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, interior marginal; 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 *Belorussiella* sp. – Chiocchini et al., pl. 7, fig. 1-2.
2005 Valvulinidi – 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.

Material: Samples BA.4206 and BA.4210 (locality Chiunzi Pass, lower Sinemurian). Sample Chiunzi Pass BA.4210, thin section BA.4210-10 (lower Sinemurian). 12.2-12.13: *Radoicicina ciarapicae* gen. n., n. sp., paratypes. 12.2-12.4, 12.7-12.9, 12.12- Sample Chiunzi Pass BA.4210 (lower Sinemurian). 12.5-12.6, 12.10-12.11, 12.13- Sample Chiunzi Pass BA.4206 (lower Sinemurian).

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: Palaeodasycladus Limestone Formation. Decimetric, well-bedded limestone. Heterogenous vuggy wackestone to peloid-bioclastic packstone with benthic foraminifera, peloids, dasycladalean algae, gastropods and thaumatoporellid microproblematica.

Association: In sample BA.4206: Textulariida, *Textularia* sp., *Valvulina* sp., *Duotaxis metula* Kristan, *Siphovalvulina* ex gr. *gibraltarensis*, *S.* cf. *variabilis*, *Everticyclammina praevirguliana* Fugagnoli, ?*Mesoendothyra* sp., quinqueloculine Miliolida; thaumatoporellids, *Cayeuxia* sp.; gastropod. In sample BA.4210: *Valvulina* sp., ?*Pseudopfenderina butterlini* (Brun), *Lituolipora termieri* (Hottinger), *Siphovalvulina* ex gr. *gibraltarensis*, *S.* cf. *variabilis*, *E. praevirguliana*, *Earlandia tintinniformis* (Mišik), *Agathammina*-like small miliolid, Involutinidae; *Cayeuxia* 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-

Fig. 12 - *Radoicicina* gen. n. 12.1) *Radoicicina ciarapicae* gen. n., n. sp., holotype. Sample Chiunzi Pass BA.4210, thin section BA.4210-10 (lower Sinemurian). 12.2-12.13) *Radoicicina ciarapicae* gen. n., n. sp., paratypes. 12.2 -12.4, 12.7 -12.9, 12.12 - Sample Chiunzi Pass BA.4210 (lower Sinemurian). 12.5 -12.6, 12.10-12.11, 12.13 - Sample Chiunzi Pass BA.4206 (lower Sinemurian). 12.14) *Radoicicina* sp. Sample Chiunzi Pass BA.4206 (lower Sinemurian).



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 *Siphovalulina* 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 *Siphovalulina* 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 open-

ings in near morphologically identical *Velleditsiella* 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 re-determined. 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*

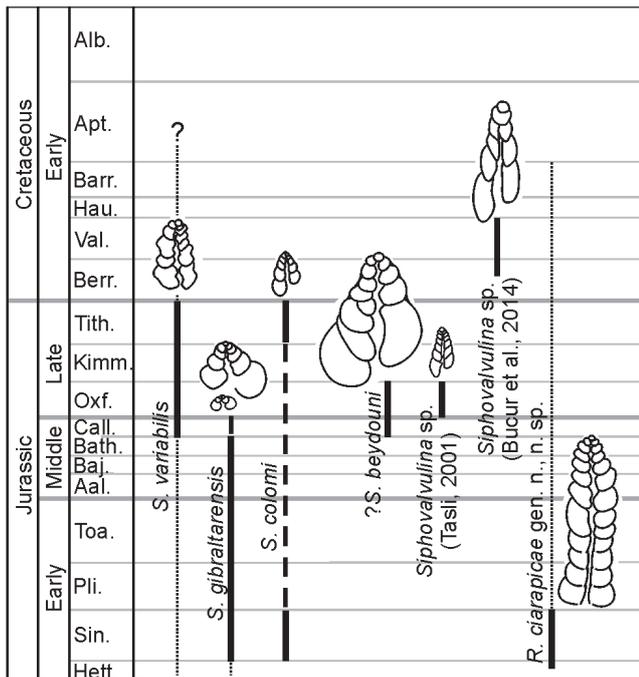


Fig. 13 - Currently known stratigraphic range of *Siphovalvulina* species and *Radoicicina* gen. n. The range of *S. variabilis* and *S. beydouni* is drawn solely on the basis of specimens figured in the literature. Note that *Siphovalvulina* morphotype A (this paper) was not assigned to either of them.

(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* (as Valvulinidi in Barattolo & Romano 2005). These are closely followed by *S. colomi*, which, however, may also appear already in the late Hettangian. Thus the emerging image is that of a fast radiation of forms and a filling of vacant ecological niches following the end-Triassic crisis in carbonate-secreting organisms and not of a slow, steady evolution. This view, however, could change with the more detailed stratigraphic studies of Hettangian – Sinemurian successions.

CONCLUSIONS

Morphometric analysis and visual comparison have led us to distinguish five morphotypes of *Siphovalvulina* in Sinemurian and Pliensbachian shallow marine carbonates. Morphological variability and size range are generally high for each morphotype, emphasizing the need for species-level determinations to be performed on a reasonably large number of specimens. One of the morphotypes

could belong to *S. variabilis* or *S. beydouni*, extending the stratigraphic range of one of these species to Sinemurian or possibly Hettangian. Three of the morphotypes have been assigned to *S. ex gr. gibraltarensis*. They differ in the width of their apical angle and in their final test size. The differences between these morphotypes could be genetic, phenotypic, or related to di- or trimorphism. A 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.

REFERENCES

- Barattolo F. & Romano R. (2005) - Shallow carbonate platform bioevents during the Upper Triassic-Lower Jurassic: an evolutive interpretation. *Boll. Soc. Geol. Ital.*, 124: 123-142.
- Bavec M., Novak M. & Poljak M. (2013) - Geological map of Slovenia 1:1.000.000. Geological Survey of Slovenia, Ljubljana.
- Bosence D., Procter E., Aurell M., Bel Kahla A., BouDagher-Fadel M., Casaglia F., Cirilli S., Mehdie M., Nieto L., Rey J., Scherreiks R., Soussi M. & Waltham D. (2009) - A dominant tectonic signal in high-frequency, peritidal carbonate cycles? A regional analysis of Liassic platforms from western Tethys. *J. Sed. Res.*, 79: 389-415.
- BouDagher-Fadel M.K. (2008) - Evolution and geological significance of larger benthic foraminifera. In: Wignall P.B. (Ed.) - *Developments in Palaeontology and Stratigraphy*: 1-540. Elsevier, Amsterdam.
- BouDagher-Fadel M.K. & Bosence D.W.J. (2007) - Early Jurassic benthic foraminiferal diversification and biozones in shallow-marine carbonates of western Tethys. *Senckenberg. Letbaea*, 87: 1-39.
- BouDagher-Fadel M.K., Rose E.P.F., Bosence D.W.J. & Lord A.R. (2001) - Lower Jurassic foraminifera and calcified microflora from Gibraltar, western Mediterranean. *Palaeontology*, 44: 601-621.
- Bucur I.I., Păcurariu A., Săsăran E., Filipescu S. & Filipescu R. (2014) - First record of lowermost Cretaceous shallow-water limestones in the basement of the Transylvanian Depression (Romania). *Carnets Géol.*, 14: 199-209.
- Buser S. (1968) - Basic Geological Map SFRY 1 : 100.000,

- Sheet Ribnica, L 33-78. Federal Geological Survey, Beograd.
- Buser S., Grad K. & Pleničar M. (1967) - Basic Geological Map SFRY 1 : 100.000, Sheet Postojna, L 33-77. Federal Geological Survey, Beograd.
- Chiocchini M., Farinacci A., Mancinella A., Molinari V. & Potetti M. (1994) - Biostratigrafia a foraminiferi, dasicladali e calpionelle delle successioni carbonatiche Mesozoiche dell'Appennino Centrale (Italia). In: Biostratigrafia dell'Italia centrale. *Studi Geol. Camerti*, 9: 9-130.
- Colom G. (1980) - Estudios sobre las lithofacies y micropaleontología del Lias inferior de la Isla de Cabrera. (Balears). *Rev. Esp. Micropal.*, 12: 47-64.
- Corliss B.H. & Chen C. (1988) - Morphotype patterns of Norwegian Sea deep-sea benthic foraminifera and ecological implications. *Geology*, 16: 716-719.
- Cushman J.A. (1937) - A monograph of the foraminiferal family Verneuilinidae. *Contributions of Cushman Laboratory of Foraminifera Research*, Spec. Publ. 7: 1-157.
- Dager Z. (1978) - Les foraminifères du Trias de la Péninsule de Kocaeli – Turquie. *Notes Labor. Paleont. Univ. Geneve*, 3: 23-71.
- Darga R. & Schlagintweit F. (1991) - Mikrofazies, Paläontologie und Stratigraphie der Lerchkogelkalke (Tithon-Berrias) des Dietrichshorns (Salzburger Land, Nördliche Kalkalpen). *Jb. Geol. B.-A.*, 134: 205-226.
- Delage Y. & Hérouard E. (1896) - Traité de Zoologie Concrète, Volume 1, La Cellule et les Protozoaires. Schleicher Frères, Paris, 584 pp.
- Di Lucia M., Trecalli A., Mutti M. & Parente M. (2012) - Biochemostratigraphy of the Barremian-Aptian shallow-water carbonates of the southern Apennines (Italy): pinpointing the OAE1a in a Tethyan carbonate platform. *Solid Earth*, 3: 1-28.
- Dozet S. (2009) - Lower Jurassic carbonate succession between Predole and Mlačevo, Central Slovenia. *Mining Metall. Quat.*, 56: 164-193.
- Dozet S. & Strohmenger C. (2000) - Podbukovje Formation, central Slovenia. *Geologija*, 43: 197-212.
- Ekmekci E. & Altiner D. (2008) - *Timidonella? primitiva* n. sp. (Foraminiferida) from the Middle Jurassic of the Eastern Taurides (Southern Turkey): Remarks on evolutionary steps of hauraniids. *Turkish J. Earth Sci.*, 17: 73-84.
- Fugagnoli A. (2004) - Trophic regimes of benthic foraminiferal assemblages in Lower Jurassic shallow water carbonates from northeastern Italy (Calcarei Grigi, Trento Platform, Venetia Prealps). *Palaeogeogr., Palaeoclimatol., Palaeoecol.* 205, 111-130.
- Fugagnoli A. & Loriga Broglio C. (1998) - Revised biostratigraphy of Lower Jurassic shallow water carbonates from the Venetian Prealps (Calcarei Grigi, Trento Platform, Northern Italy). *Studi Trentini Sci. Natur. – Acta Geol. (Trento)*, 73: 35-73.
- Gale L. (2015) - Microfacies characteristics of the Lower Jurassic lithotid limestone from northern Adriatic Carbonate Platform (central Slovenia). *Geologija*, 58: 121-138.
- Gale L. & Kelemen M. (2017) - Early Jurassic foraminiferal assemblages in platform carbonates of Mt. Krim, central Slovenia. *Geologija*, 60: 99-115.
- Gale L., Kolar-Jurkovšek T., Šmuc A. & Rožič B. (2012) - Integrated Rhaetian foraminiferal and conodont biostratigraphy from the Slovenian Basin, eastern Southern Alps. *Swiss J. Geosci.*, 105: 435-462.
- Grădinaru M., Lazar I., Bucur I.I., Grădinaru E., Săsăran E., Ducea M.N. & Andrașanu A. (2016) - The Valanginian history of the eastern part of the Getic Carbonate Platform (Southern Carpathians, Romania): Evidence for emergence and drowning of the platform. *Cretaceous Res.*, 66: 11-42.
- Granier B., Toland C., Gèze R., Azar D. & Maksoud S. (2016) - Some steps toward a new story for the Jurassic – Cretaceous transition in Mount Lebanon. *Carnets Geol.*, 16: 247-269.
- Haas J., Pelikán P., Görög Á., Józsa S. & Ozsvárt P. (2013) - Stratigraphy, facies and geodynamic settings of Jurassic formations in the Bükk Mountains, North Hungary: its relations with the other areas of the Neotethyan realm. *Geol. Mag.*, 150: 18-49.
- Haig D.W., McCartney E., Barber L. & Backhouse J. (2007) - Triassic-Lower Jurassic foraminiferal indices for Bahamian-type carbonate-bank limestones, Cablac Mountain, East Timor. *J. Foram. Res.*, 37: 248-264.
- Hautmann M., Benton M.J. & Tomašových A. (2008) - Catastrophic ocean acidification at the Triassic-Jurassic boundary. *N. Jb. Geol. Paläont. Abh. (Stuttgart)*, 249: 119-127.
- Hottinger L. (2006) - Illustrated glossary of terms used in foraminiferal research. *Carnets Géol.*, Mem. 2006/02 (CG2006_M02): 1-43.
- Iannace A., Merola D., Perrone V., Amato A., Cinque A., Santacroce R., Sbrana A., Sulpizio R., Zanchetta G., Budillon F., Conforti A. & D'Argenio B.D. (2016) - Note illustrative della Carta Geologica d'Italia alla scala 1:50.000, fogli 466-485 "Sorrento- Termini", 204 pp. http://www.isprambiente.gov.it/Media/carg/note_illustrative/466_485_Sorrento_Termini.pdf
- ISPRA (2016) - Carta Geologica d'Italia alla scala 1:50.000, fogli 466-485 "Sorrento- Termini". http://www.isprambiente.gov.it/Media/carg/466_485_SORRENTO_TERMINI/Foglio.html
- Ivanova D. & Kolodziej B. (2010) - Late Jurassic-Early Cretaceous foraminifera from Štramberg-type limestones, Polish Outer Carpathians. *Stud. Uni. Babeş-Bolyai, Geologia*, 55: 3-31.
- Kabal Y. & Tasli K. (2003) - Biostratigraphy of the Lower Jurassic carbonates from the Aydinick area (Central Taurides, S. Turkey) and morphological analysis of *Lituolipora termieri* (Hottinger, 1967). *J. Foram. Res.*, 33: 338-351.
- Kaminski M.A. (2004) - The year 2000 classification of the agglutinated foraminifera. In: Bubík M. & Kaminski M.A. (Eds.) - Proceedings of the Sixth international workshop on agglutinated foraminifera 8: 237-255. Gryzbowski Foundation Spec. Publ., Kraków.
- Koehn-Zaninetti L. (1969) - Les Foraminifères du Trias de la

- region de l'Almtal (Haute-Autriche). *Jb. Geol. B.-A.*, spec. vol. 14: 1-155.
- Krajewski M. & Olszewska B. (2007) - Foraminifera from the Late Jurassic and Early Cretaceous carbonate platform facies of the southern part of the Crimea Mountains; southern Ukraine. *Ann. Soc. Geol. Poloniae*, 77: 291-311.
- Loeblich A.R. & Tappan H. (1988) - Foraminiferal genera and their classification. Van Nostrand Reinhold Company, New York, 970 pp.
- Mancinelli A., Chiocchini M., Chiocchini R.A. & Romano A. (2005) - Biostratigraphy of Upper Triassic-Lower Jurassic carbonate platform sediments of the central-southern Apennines (Italy). *Riv. It. Paleont. Strat.*, 111: 271-283.
- Martinuš M., Bucković D. & Kukoć D. (2012) - Discontinuity surfaces recorded in shallow-marine platform carbonates: an example from the Early Jurassic of the Velebit Mt. (Croatia). *Facies*, 58: 649-669.
- Matthews S.C. (1973) - Notes on open nomenclature and on synonymy lists. *Palaeontology*, 16: 713-719.
- Miler M. & Pavšič J. (2008) - Triassic and Jurassic beds in Krim Mountain area (Slovenija). *Geologija*, 51: 87-99.
- Mikhalevich V.I. (2014) - Post-Cambrian testate foraminifera as a system in its evolution. Nova Sci. Publ., New York, 426 pp.
- Motahari A., Aghanabati A., Ahmadi V. & Meisami A. (2014) - Biostratigraphy of Jurassic sediments in High Zagros Belt (northeast of Shiraz-Iran). *MAGHT Res. Report*, spec. vol. 2: 286-294.
- Noujaim Clark G. & BouDagher-Fadel M.K. (2004) - Larger benthic foraminifera and calcareous algae of the Upper Kesrouane Limestone Formation (Middle/Upper Jurassic) in Central Lebanon: Stratigraphy, sedimentology and regional synopsis. *Rev. Paléob.*, 23: 477-504.
- Pawłowski J., Holzmann M. & Tyszka J. (2013) - New supraordinal classification of Foraminifera: Molecules meet morphology. *Marine Micropaleontol.*, 100: 1-10.
- Placer L. (1999) - Contribution to the macrotectonic subdivision of the border region between Southern Alps and External Dinarides. *Geologija*, 41: 223-255.
- Radoičić R. (1966) - Microfacies du jurassiques des Dinarides externes de la Yougoslavie. *Geologija*, 9: 5-337.
- Reolid M., Rodríguez-Tovar F.J., Nagy J. & Olóriz F. (2008) - Benthic foraminiferal morphogroups of mid to outer shelf environments of the Late Jurassic (Prebetic Zone, southern Spain): Characterization of biofacies and environmental significance. *Palaeogeogr., Palaeoclim., Palaeoecol.*, 261: 280-299.
- Rigaud S. & Blau J. (2016) - New robertinid foraminifers from the Early Jurassic of Adnet, Austria and their evolutionary importance. *Acta Palaeont. Pol.*, 61: 721-734.
- Rožič B. (2016) - Paleogeographic units. In: Novak M. & Rman N. (Eds) - Geological atlas of Slovenia: 14-15. Geological Survey of Slovenia, Ljubljana.
- Schlagintweit F., Gawlick H.-J. & Lein R. (2005) - Micropaläontologie und Biostratigraphie der Plassen-Karbonatplattform der Typlokalität (Ober-Jura bis Unter-Kreide, Salzkammergut, Österreich). *J. Alp. Geol. (Mitt. Ges. Geol. Bergbaustud. Österr.)*, 47: 11-102.
- Septfontaine M. (1980) - Les Foraminifères imperforés des milieux de plate-forme au Mésozoïque: détermination pratique, interprétation phylogénétique et utilisation biostratigraphique. *Rev. Micropaléont.*, 23: 169-203.
- Septfontaine M. (1986) - Milieux de dépôt et foraminifères (Lituolidés) de la plate-forme carbonatée du Lias moyen du Maroc. *Rev. Micropaléontol.*, 28: 265-289.
- Septfontaine M. (1988) - Ver sunne classification évolutive des Lituolides (Foraminifères) Jurassiques en milieu de plate-forme carbonate. *Rev. Paléob.*, vol. spec. 2 (Benthos '86): 229-256.
- Tasli K. (2001) - Benthic foraminifera of the Upper Jurassic platform carbonate sequence in the Aydıncik (Icel) Area, Central Taurides, S Turkey. *Geol. Croatica*, 54: 1-13.
- Thierry J. (2000) - Late Sinemurian (193-191 Ma). In: Dercout J., Gaetani M., Vrielynck B., Barrier E., Biju-Duval B., Brunet M.F., Cadet J.P., Crasquin S. & Sandulescu M. (Eds.) - Peri-tethys paleogeographical atlas: 49-59. CCGM/GGMW, Paris.
- Trifonova E. (1992) - Taxonomy of Bulgarian Triassic foraminifera. I. Families Psammosphaeridae to Nodosinellidae. *Geol. Balcanica*, 22: 3-50.
- Velić I. (2007) - Stratigraphy and palaeobiogeography of Mesozoic benthic Foraminifera of the Karst Dinarides (SE Europe). *Geol. Croatica*, 60: 1-113.
- Vlahović I., Tišljarić J., Velić I. & Matičec D. (2005) - Evolution of the Adriatic Carbonate Platform: Palaeogeography, main events and depositional dynamics. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 220: 333-360.

