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Spiraloconulus suprajurassicus n. sp. – a New Benthic Foraminifer from the Late Jurassic of the Northern Calcareous Alps of Austria

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Spiraloconulus suprajurassicus n. sp., eine neue Benthosforaminifere aus dem Oberjura der Nördlichen Kalkalpen von Österreich

Zusammenfassung

Spiraloconulus suprajurassicus n. sp., eine neue großwüchsige Foraminifere, wird aus dem Kimmeridgium–Tithonium der Nördlichen Kalkalpen von Österreich beschrieben. Ein weiteres Vorkommen stammt aus dem Ober-Tithonium–Unter-Berriasium von Rumänien. Sie repräsentiert die dritte Art der Gattung *Spiraloconulus* Allemann & Schroeder, 1980, bisher bekannt aus dem Intervall Ober-Aalenium–Bathonium (?Unter-Callovium). Die ammobaculitoide Gehäusemorphologie, der grob-agglutinierende Habitus und das Vorkommen in höher energetischen Paläoenvironments gestatten einen Vergleich mit *Spiraloconulus giganteus* Cherchi & Schroeder. Eine mittel- bis oberjurassische phylogenetische Reihe von *S. perconigi* über *S. giganteus* und schließlich zu *S. suprajurassicus* wird postuliert, einhergehend mit einer zunehmenden Komplexität der Marginalzone. *Spiraloconulus suprajurassicus* ist eine im Oberjura der Nördlichen Kalkalpen sehr seltene Art und findet sich vorwiegend in Resedimenten, bevorzugt vom Typus der Barmsteinkalke.

Abstract

A new large-sized foraminifer is described as *Spiraloconulus suprajurassicus* n. sp. from the Kimmeridgian–Tithonian of the Northern Calcareous Alps of Austria. A further occurrence is from the Late Tithonian–Early Berriasian of Romania. It represents the third species of the genus *Spiraloconulus* Allemann & Schroeder, 1980 known so far from the interval Late Aalenian–Bathonian (Early Callovian?). Given its ammobaculitoid morphology, its coarsely agglutinated habitus and the preference for well-agitated external platform settings, *S. suprajurassicus* can be compared with *S. giganteus* Cherchi & Schroeder. A Middle–Late Jurassic phylogenetic lineage from *S. perconigi* to *S. giganteus* and finally *S. suprajurassicus* is postulated attended by an increase of complexity of the marginal zone. *Spiraloconulus suprajurassicus* represents a rare foraminifer in the Late Jurassic of the Northern Calcareous Alps, mostly occurring in resediments, e.g., the Barmstein Limestone.

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Introduction

Larger benthic foraminifera are important constituents in Jurassic shallow-water carbonates of the Tethyan realm. They also have biostratigraphic relevance (e.g., HOTTINGER, 1967, 1971; BASSOULLET & FOURCADE, 1979; SEPTFONTAINE, 1980, 1988; SEPTFONTAINE et al., 1991; BASSOULLET, 1997; VELIĆ, 2007). The appearance ("origination event") of these agglutinating forms, often with complex inner structures, followed the end-Triassic mass extinction in Sinemurian–Pliensbachian times (KAMINSKI et al., 2010).

In the Northern Calcareous Alps of Austria, shallow-water carbonates with larger benthic foraminifera are known from the uppermost Oxfordian–Tithonian interval of the Plassen Carbonate Platform and associated resedimented deposits within basinal series, e.g., the Barmstein Limestone (e.g., FENNINGER & HÖTZL, 1967; STEIGER & WURM, 1980; STEIGER, 1981; DARGA & SCHLAGINTWEIT, 1991; SCHLAGINTWEIT & EBLI, 1999; SCHLAGINTWEIT et al., 2005). A large agglutinating taxon, already recorded by SCHLAGINTWEIT & EBLI (1999) in open nomenclature as "lituolidae gen. et sp. indet." from Mount Trisselwand (Text-Fig. 1) and meanwhile detected from several other locations (Text-Fig. 2), is described as a new species of the genus *Spiraloconulus* ALLEMANN & SCHROEDER, 1980.

Geological Setting and Material

About 20 specimens of *Spiraloconulus suprajurassicus* n. sp. were detected in 16 thin-sections of various localities of the Plassen Carbonate Platform *sensu stricto*, Barmstein Limestone and basal resedimented deposits of the Wolfgangsee Carbonate Platform:

Plassen Carbonate Platform *s. str.*

Mount Trisselwand: thin-sections TK 21, TK 24, TK 35 (see Text-Fig. 1a), ÖK no. 96 Bad Ischl. For geological setting see SCHLAGINTWEIT & EBLI (1999).

Barmstein Limestone

Mount Barmsteine: thin-section B 74, ÖK no. 94 Hallein. For geological setting see STEIGER (1981) and GAWLICK et al. (2005).

Mount Ewige Wand: thin-section E 314, ÖK no. 96 Bad Ischl. For geological setting see GAWLICK et al. (2010).

Mount Höherstein: thin-section D 66, ÖK no. 96 Bad Ischl. For geological setting see GAWLICK et al. (2003).

Mount Tressenstein: thin-sections D 222, 469, 470, 471 (see Text-Fig. 1a), ÖK no. 96 Bad Ischl. For geological setting see GAWLICK & SCHLAGINTWEIT (2009).

Mount Trisselwand: thin-sections MT 344, 347a, T 8, ÖK no. 96 Bad Ischl. For geological setting see SCHLAGINTWEIT & EBLI (1999).

Mount Jochwand: thin-section B 51-2, ÖK no. 96 Bad Ischl. For geological setting see GAWLICK et al. (2010).

Mount Zwerchwand: thin-section E 83, ÖK no. 96 Bad Ischl. For geological setting see GAWLICK et al. (2010).

Basal resedimented deposits of the Wolfgangsee Carbonate Platform

Mount Lugberg: thin-section E 764 ÖK no. 66 Gmunden. For geological setting see GAWLICK et al. (2007).

Systematic Description

The systematic follows the "year 2000 classification" of KAMINSKI (2004).

Class Foraminifera D' ORBIGNY

Subclass Textulariia MIKHALEVICH

Order Loftusiida KAMINSKI & MIKHALEVICH, 2004 in KAMINSKI, 2004

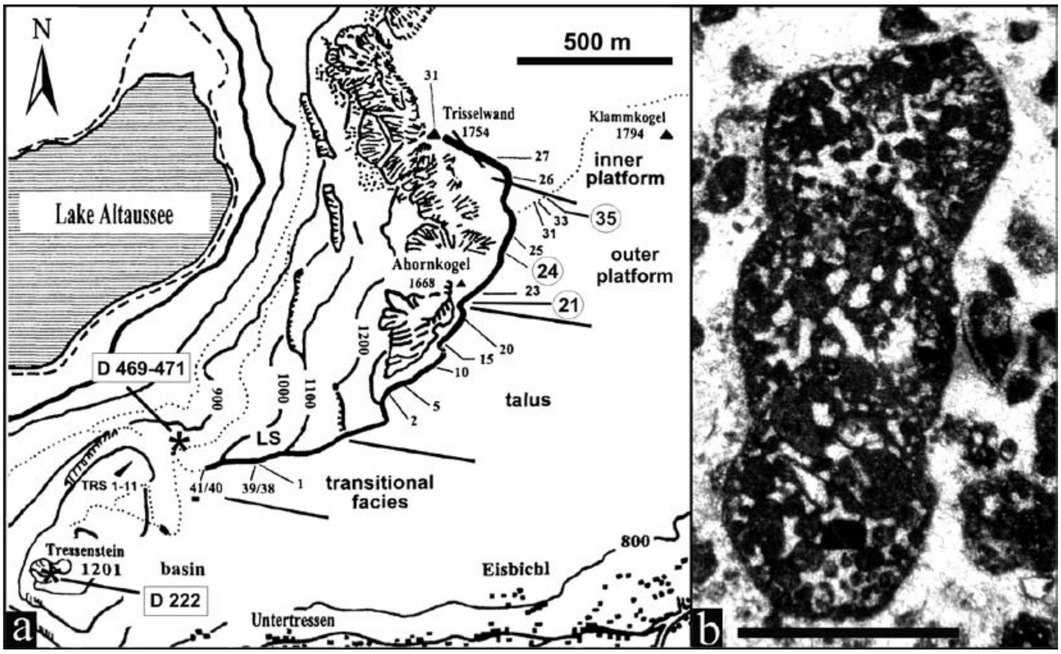
Suborder Orbitolinina KAMINSKI, 2004

Superfamily Pfenderinacea SMOUT & SUGDEN, 1962

Family Hauraniidae SEPTFONTAINE, 1980

Subfamily Amijellinae SEPTFONTAINE, 1980

Genus *Spiraloconulus* ALLEMANN & SCHROEDER, 1980



Text-Fig. 1.
a: Occurrences of *Spiraloconulus suprajurassicus* n. sp. in the Plassen Carbonate Platform of Mount Trisselwand (samples TW 21, TW 24, TW 35) (from SCHLAGINTWEIT & EBLI, 1999) and Barmstein Limestone (samples D 469-D 471 containing the holotype specimen) (from GAWLICK & SCHLAGINTWEIT, 2009) (see also Text-Fig. 2).
b: *Spiraloconulus suprajurassicus* n. sp., shallow longitudinal section (= *Lituolidae* gen. et sp. indet. in SCHLAGINTWEIT & EBLI, 1999, Pl. 5, Fig. 8, sample TW 21). Scale bar 1 mm.

Diagnosis (from LOEBLICH & TAPPAN, 1987): "Test large, conical to cylindrical, enrolled to rectilinear, early enrolled stage producing a flattened test apex, distinctly coiled microspheric specimens up to 2 mm in breadth and up to 1.6 mm in height, megalospheric tests smaller, with maximum height of 1.5 mm and diameter of 1.1 mm, conical to almost cylindrical, with more strongly developed rectilinear stage; wall microgranular, calcareous, coarsely agglutinated, and may include very large calcareous grains, imperforate epidermis, with septulae (beams and rafters) forming an irregular subepidermal network or marginal zone, the central part of the chambers with pillar-like growths from the septa interspersed between the apertural pores, the pillars rarely completely crossing the chamber lumen but leave a narrow open space adjacent to the succeeding septum, septa of the rectilinear stage strongly convex toward the apertural face; aperture cribrate on the terminal face."

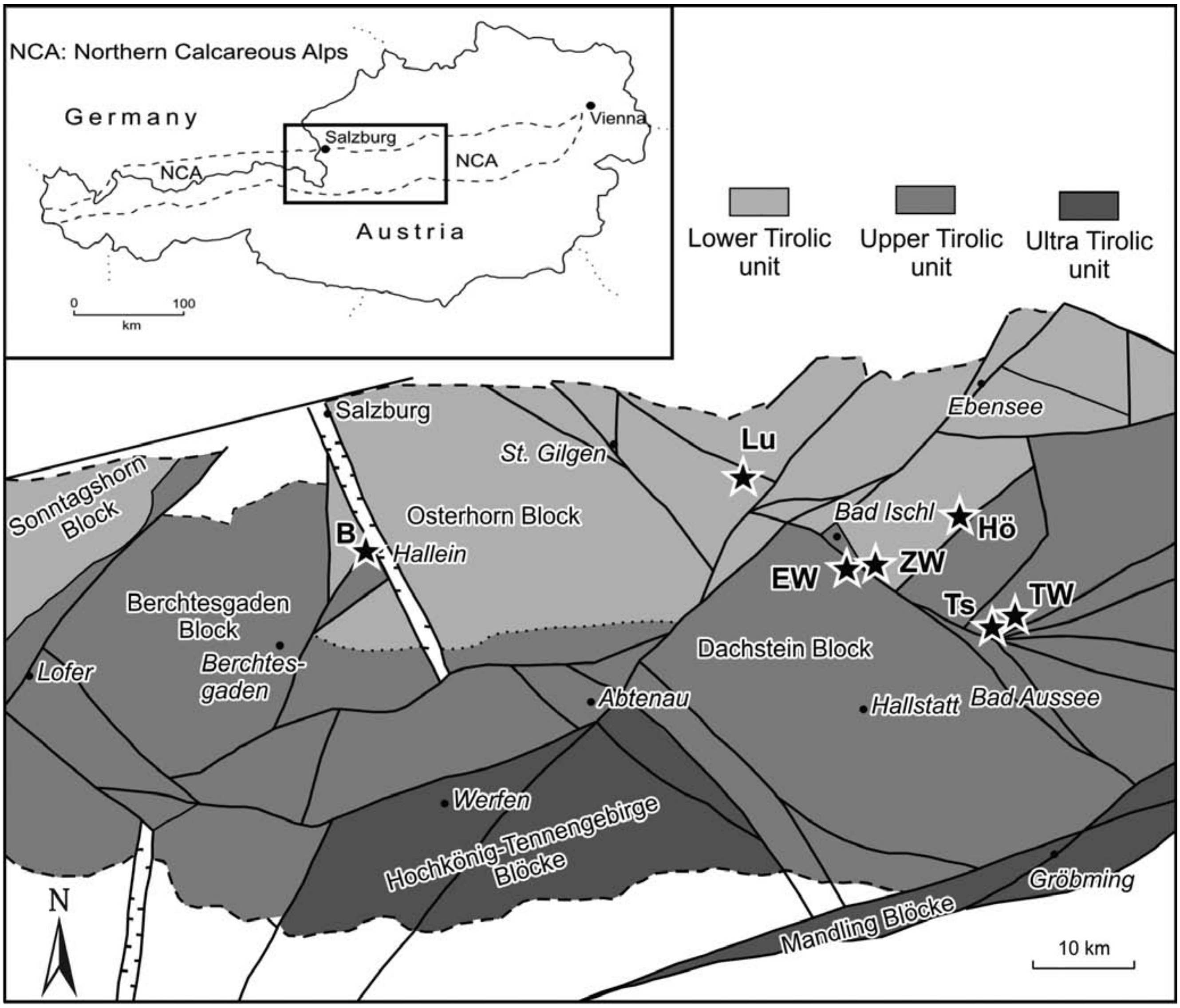
Remarks: In the description of the type-species *Spiraloconulus perconigi*, ALLEMANN & SCHROEDER (1972, p. 208) stated that there are abundant grains incorporated into the chamber interior, which are so big that they "touch the chamber floor of the earlier camper" and that these could erroneously be mistaken for pillars. This characteristic is also included in the genus diagnosis provided by LOEBLICH & TAPPAN (1987). Concerning this matter, it cannot be comprehended why BOUDAGHER-FADEL (2008, p. 179) characterized the genus *Spiraloconulus* as possessing "thin septa, linked by thick heavy pillars" ... notably a central zone with "endoskeletons of pillars from septum to septum". Interseptal columnar pillars are part of the foraminiferan endoskeleton stretching between consecutive septa (e.g., HOTTINGER, 2006).

Spiraloconulus suprajurassicus n. sp.

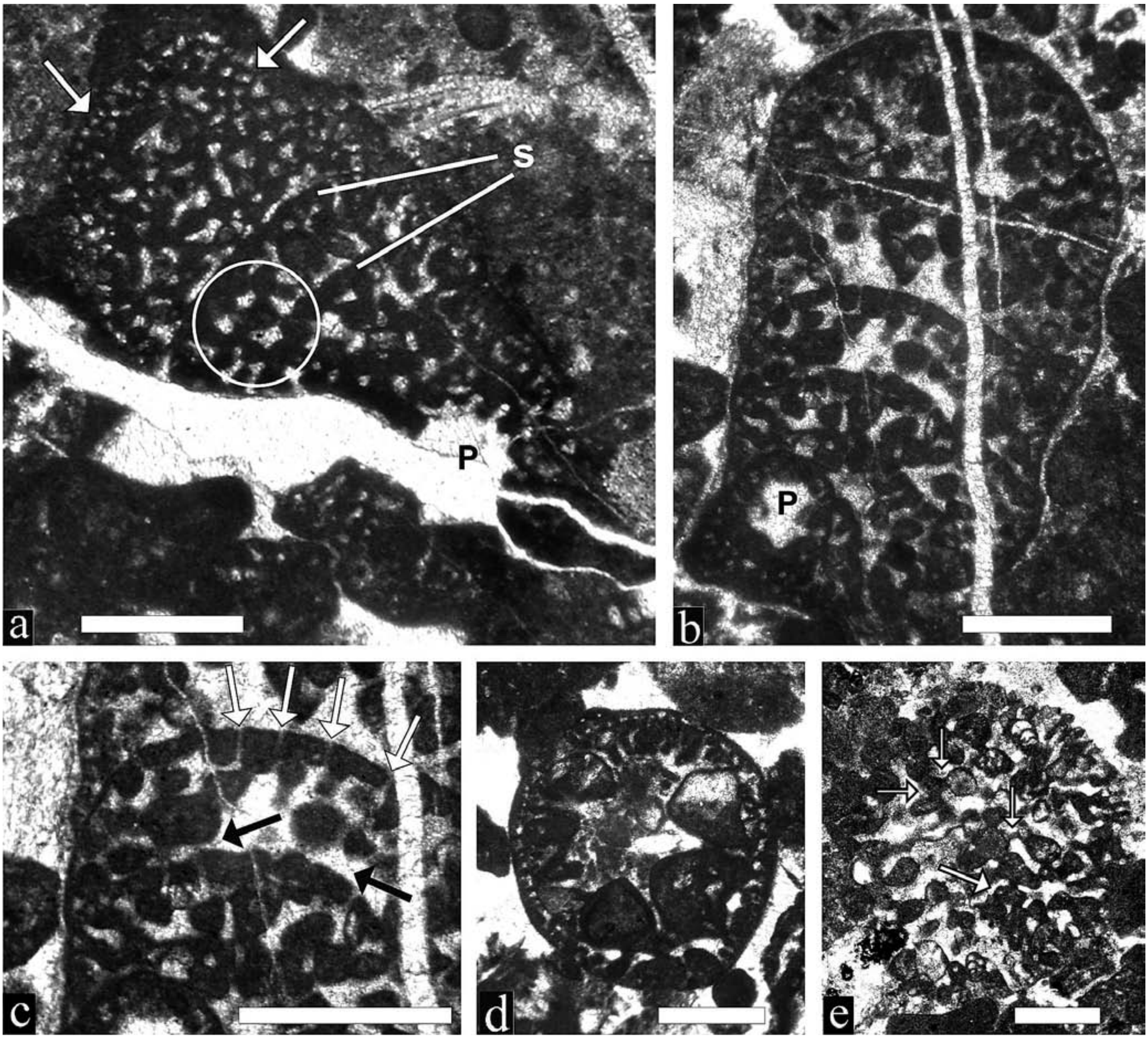
(Text-Fig. 1b, Text-Figs. 3a–e, Text-Figs. 4a–f, Text-Fig. 5, Text-Figs. 7a–d)

1999 Lituolidae gen. et sp. indet. – SCHLAGINTWEIT & EBLI, p. 398, Pl. 5, Fig. 8; Pl. 7, Figs. 2–3.

2011 Foraminifera X – DRAGASTAN, p. 101, Pl. 6, Figs. 1–2 (macrospheric specimens).



Text-Fig. 2.
Geographic and tectonic position (recent block configuration) of the localities where *Spiraloconulus suprajurassicus* n. sp. has been detected (slightly modified after FRISCH & GAWLICK, 2003).
Abbreviations: B: Barmsteine; Lu: Lugberg; EW: Ewige Wand; ZW: Zwerchwand; Hö: Höherstein; Ts: Tressenstein; TW: Trisselwand.



Text-Fig. 3.
Spiraloconulus suprajurassicus n. sp. from the Barmstein Limestone.

a: Holotype specimens, oblique equatorial section (tangential in the upper part) with ~5 chambers forming the rectilinear part. p = proloculus, s = septa, white arrows = subepidermal network of horizontal and vertical partitions. The white circle shows a part of the central zone with glued agglutinated particles. Thin-section D 471, Mount Tressenstein. Scale bar 0.5 mm.

b: Equatorial section; 5 chambers form the rectilinear enrolled part of the test. Note the pillar-like connected agglutinated particles in the interior of the chambers. p = proloculus. Thin-section D 470, Mount Tressenstein. Scale bar 0.5 mm.

c: Detail of b showing the multiple chamber connections (white arrows) and the connected agglutinated particles that do not completely cross the chamber lumina so that a narrow open space adjacent to the succeeding septum is left (black arrows). Scale bar 0.5 mm.

d: Transverse section showing rather large agglutinated particles and the narrow marginal zone. Thin-section D 469, Mount Tressenstein. Scale bar 0.5 mm.

e: Transverse section showing the agglutinated rounded particles such as peloids (including also some tiny benthic foraminifera) interconnected by micritic walls (arrows). Thin-section B 51-2, Mount Zwerchwand. Scale bar 0.5 mm.

2011 Otaina magna RAMALHO – BUCUR et al., Pl. 1, Fig. 1 (microspheric specimen).

Derivatio nominis: The species name refers to the occurrence in the Late Jurassic, given that the genus was so far only known from Middle Jurassic strata.

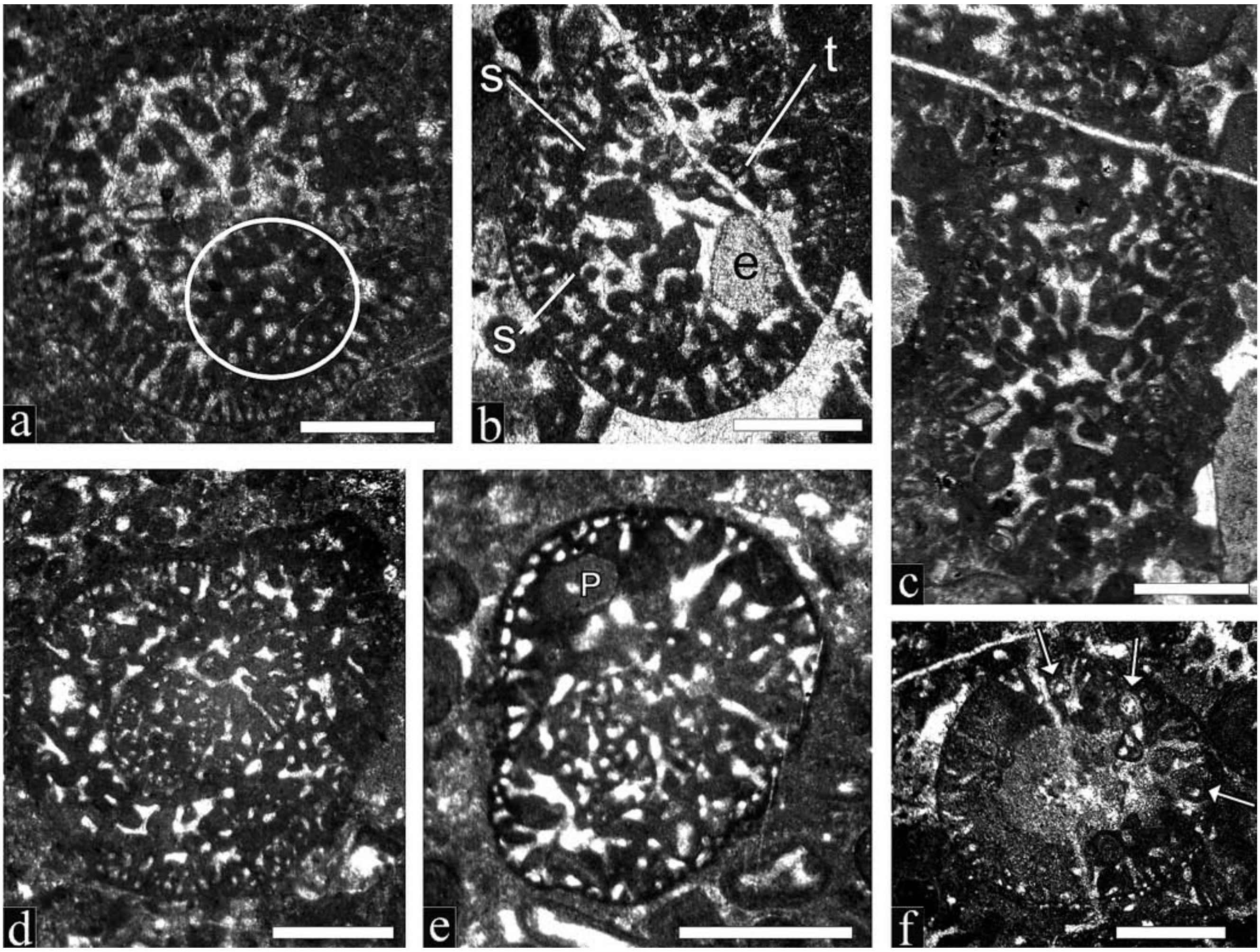
Holotype: Specimen in oblique equatorial section figured in Text-Fig. 3a. Thin section D 471.

Depository: The holotype and the material from Mounts Trisselwand, Tressenstein, Höherstein Plateau, Ewige Wand, Zwerchwand and Lugberg are stored in the collection of Hans-Jürgen Gawlick, University of Leoben, Austria.

Locus typicus: Between Mount Tressenstein and Mount Trisselwand, ÖK 1:50.000 sheet no. 96 Bad Ischl (Text-Fig. 1a). The samples were collected in the framework of geological and micropalaeontological investigations of the Upper Jurassic series cropping out at Mount Tressenstein (for details see GAWLICK & SCHLAGINTWEIT, 2009).

Stratum typicum: Barmstein Limestone of presumably Late Tithonian age as deduced from calpionellids obtained from the near-by Mount Tressenstein (SCHLAGINTWEIT & EBLI, 1999; GAWLICK & SCHLAGINTWEIT, 2009).

Diagnosis: Test dimorphic with macrospheric and microspheric generation. Macrospheric forms consisting of a



Text-Fig. 4
Spiraloconulus suprajurassicus n. sp. from the Barmstein Limestone (a, c–f) and basal resedimented deposits of the Wolfgangsee Carbonate Platform (b)

a: Transverse section. The white circle marks an area where the septum with multiple foramina is cut. Detail see Text-Fig. 5. Thin-section D 66, Mount Höherstein. Scale bar 0.5 mm.

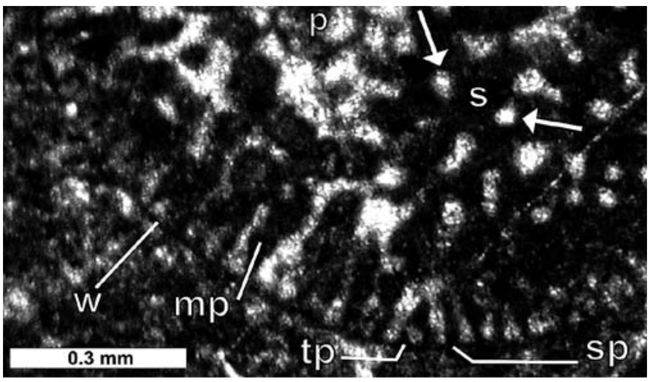
b: Transverse section cutting two successive chambers. S = septum of the younger chamber. Note the large agglutinated echinoid fragment (e) and the textulariid foraminifer (t). Thin-section E 764, Mount Lugberg. Scale bar 0.5 mm.

c: Oblique section. Thin-section MT 344, Mount Trisselwand. Scale bar 0.5 mm.

d–e: Slightly oblique equatorial sections, interpreted as microspheric specimens. Note the large agglutinated particle (p) in e. Thin-sections T 8, Mount Trisselwand (d) and B 74, Mount Barmsteine (e). Scale bars 0.5 mm.

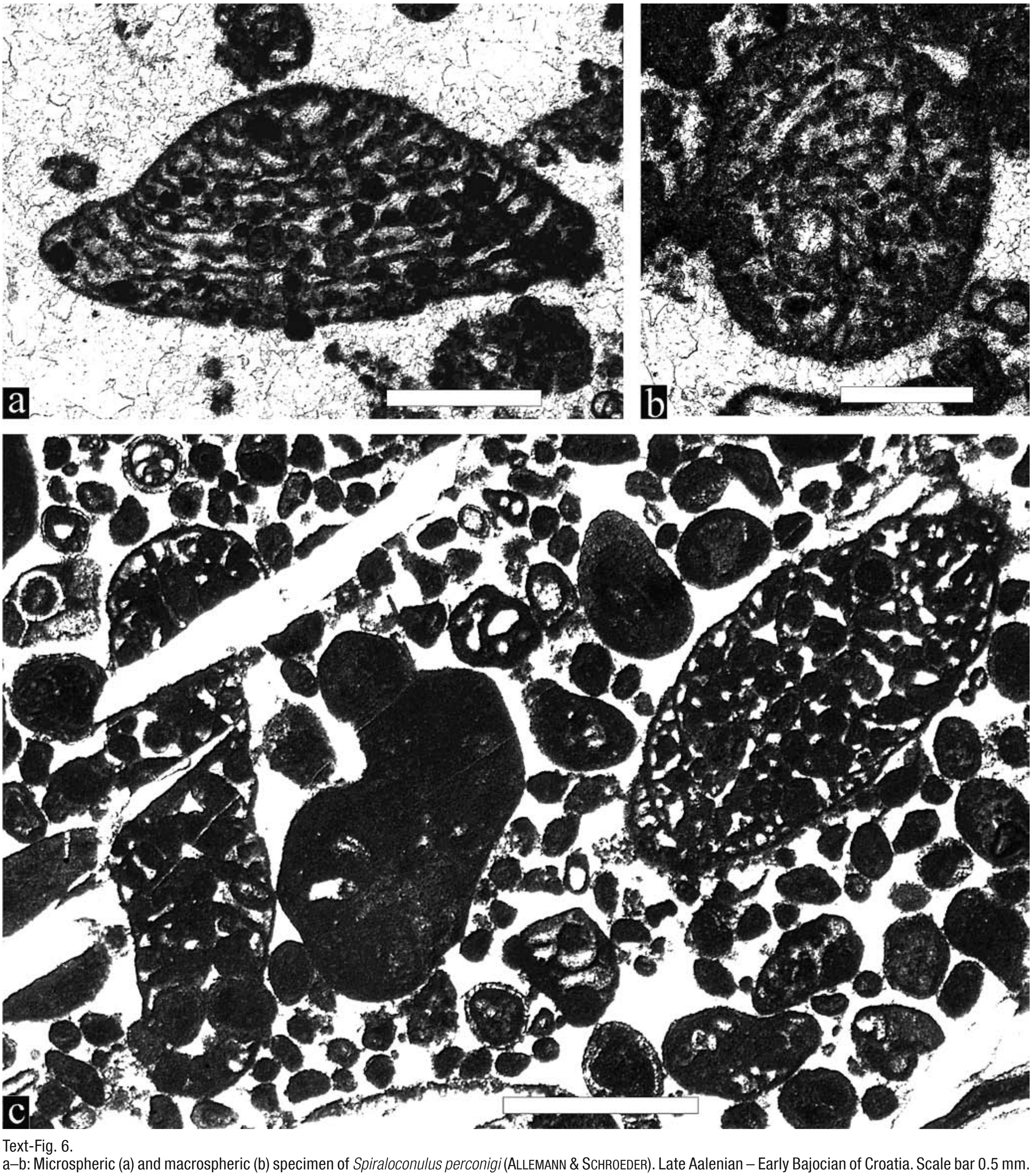
f: Transverse section. The three arrows show large agglutinated particles at the transition of the marginal zone to the central zone. Thin-section E 314, Mount Ewige Wand. Scale bar 0.5 mm.

globular proloculus within a short initial spire followed by a cylindrical to cylindroconical-enrolled stage. Wall and septa coarsely agglutinating; marginal zone of chambers with exoskeleton formed by numerous horizontal and vertical partitions. Central zone of chambers with agglutinated particles that may be arranged like a string of pearls. These structures do not connect two subsequent septa in a pillar-like manner, but leave a narrow open space towards the preceding septum. Septa with multiple small foramina. The microspheric generation displays a distinct initial spire without observable proloculus and has larger test dimensions.



Text-Fig. 5.
Detail of the internal structure (marginal and central zone) of *Spiraloconulus suprajurassicus* n. sp. in transverse section (detail from Text-Fig. 4a). mp = main partition (or septulum; Hottinger, 2006), sp and tp = secondary and tertiary vertical partition of the marginal zone, w = thin test wall, white arrows: foramina perforating the septum (s), p = large agglutinated particle in the central zone. Note that the aspect of the marginal zone recalls an orbitolinid foraminifer (Henson, 1948; Hottinger, 2006, Fig. 19).

Description: Test dimorphic, with micro- and macrospheric generations. Macrospheric specimens consist of a small initial spire (trocho- or planispiral?) followed by a uniserial cylindrical to slightly cylindroconical part (type ammobaculitoid). The initial part of the macrospheric specimens consists of a subspherical proloculus (diameter 0.15–0.25 mm) followed by a short spire (trocho- or planspiral?) (Text-Figs. 3a–b). Whether the protoconch of the new species is bilocular (with deuteroconch as in *S. perconigi)* is unknown; the section shown in Text-Fig. 3b could correspond to a subdivided embryonic apparatus. Macrospheric specimens display a test height of 1.92 mm (specimen in Text-Fig. 3a) and 2.25 mm (specimen in Text-Fig. 3b) (Dragastan, 2011: up to 4.6 mm). The initial spire is followed by an uniserial cylindrical to slightly cylindroconical part of 4 to 6 chambers. The chamber height is 0.2 to 0.38 mm. The number of chambers in the coiled part is unknown, in the uncoiled part it is up to 6. Septa curved (thickness 0.04 to 0.045 mm), convex towards growth direction, pierced by numerous irregularly distributed foramina (diameter ~0.015 to 0.025 mm) that are distributed within the whole of the central zone (Text-Fig. 3c). The amount of agglutinated particles within the septa is impossible to elucidate since often tiny completely micritized and structurless peloids are incorporated and cannot be distinguished from the homogeneous micr具granular appearance of the septa. The chambers consist of a thin marginal zone

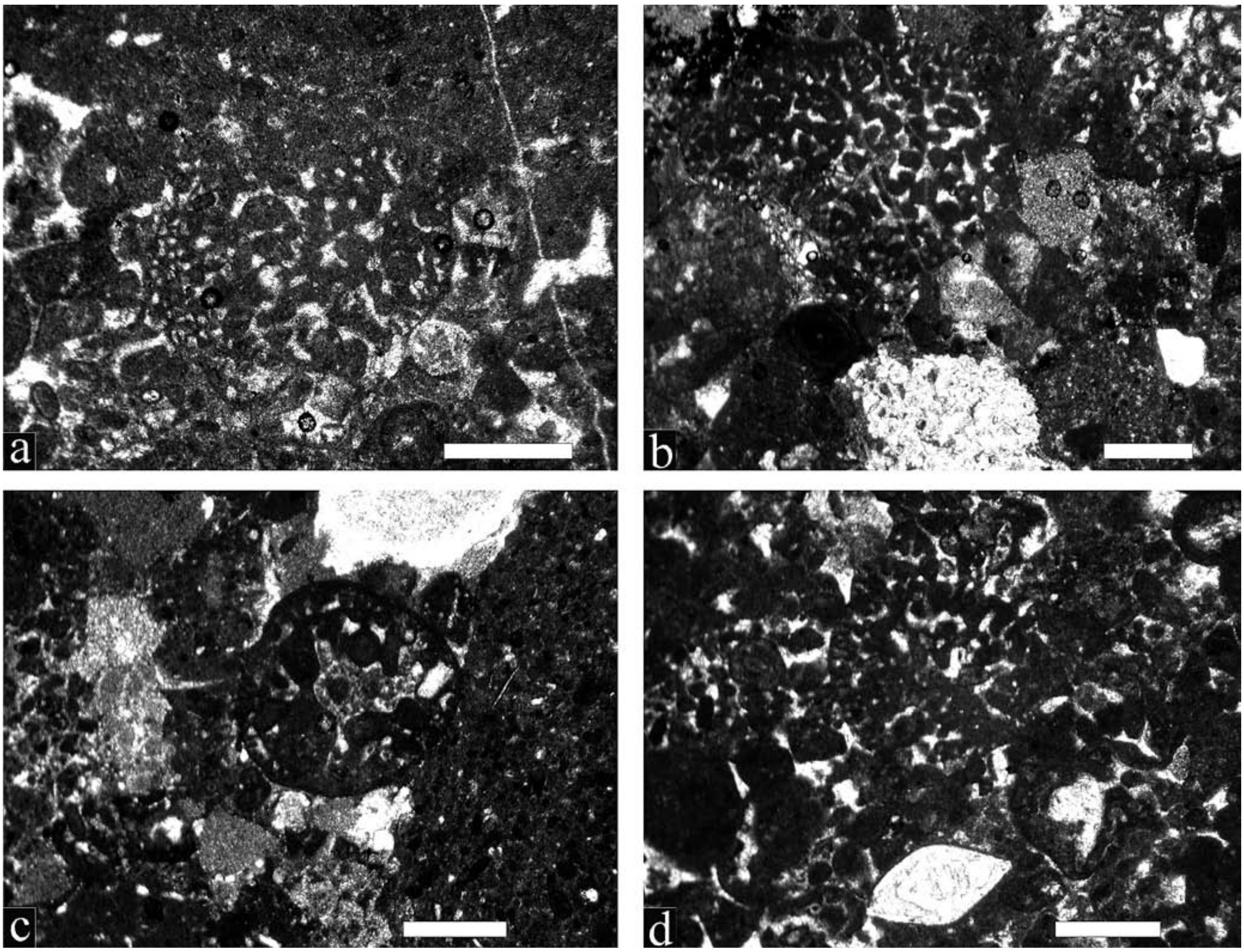


Text-Fig. 6.
a–b: Microspheric (a) and macrospheric (b) specimen of *Spiraloconulus perconigi* (Allemann & Schroeder). Late Aalenian – Early Bajocian of Croatia. Scale bar 0.5 mm.
c: Two microspheric specimens of *Spiraloconulus giganteus* Cherchi & Schroeder. Bajocian of Croatia. Scale bar 1 mm.

accounting for ~15 % to max. 20 % of the test diameter. In tangential sections, this zone is subdivided, forming a subepidermal network of cellules (width 0.03 to 0.07 mm) exhibiting a polygonal outline (Text-Fig. 3a). This network is produced by series of horizontal and vertical partitions. The vertical radial plates with longer main partitions and shorter secondary plates (often 2–3 per chamberlet) are best discernible in transverse sections of the assumed microspheric specimens (Text-Figs. 4a–b). The incorporation of larger particles can be observed near the transition from the marginal to the central zone (Fig. 4f). The latter occupies the major part (>80 %) of the chambers. It consists of many agglutinated grains/particles (up to 0.45 mm in diameter, e.g., Text-Fig. 3d). These grains are connected to each other and to the septa by micritic walls sometimes arranged in lines like a string of pearls (Text-Fig. 3a, Text-Fig. 4c). They occupy a large space of the chamber interior but always leave a free passage at the chamber base not forming structures connecting two consecutive septa. The micritic connection can be seen in both transverse (e.g., Text-Fig. 3e) and axial sections (Text-Fig. 3a) forming a three-dimensional network.

Two specimens show a pronounced coiled part without an observable proloculus (Text-Figs. 4d–e); these are interpreted as microspheric generation. The presumably planispiral coiled tests consist of about 2 whorls. The number of chambers of the coiled part cannot be indicated, but seems to be distinctly higher than in the macrospheric specimens (Text-Figs. 3a–b). Test diameter of the two equatorial sections is 1.15 mm and 1.8 mm. Given that the test diameter of the microspheric generation of the other two *Spiraloconulus* species (*S. perconigi* and *S. giganteus)* is always larger in the microspheric specimens, the transverse sections (more or less always circular in section) of the uncoiled part with diameters of 1.35 to 1.85 mm should belong to this generation (Text-Figs. Fig. 3d–e, Text-Figs. 4a–b, f). The internal structure of the microspheric and macrospheric generation is roughly identical. Foramina transversing the septa seem to have a slightly greater diameter (~0.05 to 0.08 mm).

Remarks: *Spiraloconulus suprajurassicus* represents the third species of the genus *Spiraloconulus* Allemann & Schroeder comprising the type-species *S. perconigi* (Allemann & Schroeder, 1972, 1980) (Text-Figs. 6a–b) and *S. giganteus*



Text-Fig. 7.
Tests of *Spiraloconulus suprajurassicus* n. sp. as individual bioclasts in calciturbiditic deposits of the Barmstein Limestone.
a: Thin-section D 222, Mount Tressenstein.
b–c: Thin-section MT 347a, Mount Trisselwand.
d: Thin-section E 83, Mount Zwerchwand.
Scale bars 0.5 mm.

Cherchi & Schroeder, 1981 (Text-Fig. 6c). The former is known from the Aalenian–Bajocian, the latter from the Late Aalenian – Bathonian with possible occurrence in the Lower Callovian (Bassoullet, 1997; Velić, 2007; Chiocchini et al., 2008).

As *Spiraloconulus perconigi* has an orbitoliniform test morphology, it is clearly different from *Spiraloconulus suprajurassicus* and therefore there is no need to go into detail about other differences. *Spiraloconulus giganteus* with its cylindrical enrolled test portion is similar; the differences to *Spiraloconulus suprajurassicus* can be summarized as follows:

- In *S. giganteus*, the enrolled part is irregular cylindrical resulting from bending of the test (e.g., Pl. 1, Fig. 5 in Cherchi & Schroeder, 1981); in *S. suprajurassicus* n. sp., the enrolled part is rather regular.
- Septa and the beams and rafters of the subepidermal network are more robust, thicker in *S. suprajurassicus*. Moreover, it seems that the marginal zone of *S. suprajurassicus* with horizontal partitions and several orders of vertical partitions is higher evolved than the one of *S. giganteus*. Such a phylogenetic evolution towards more complexity in the marginal zone is a well known phenomenon in other foraminiferan groups such as the orbitolinids (e.g., Schroeder et al., 2002). Concerning the genus *Spiralonulus*, a possible Middle to Late Jurassic phylogenetic lineage from *S. perconigi* (only vertical partitions) to *S. giganteus* (simple system of horizontal and vertical partitions?) and *S. suprajurassicus* (complex system of partitions in the marginal zone) is postulated.
- Overall dimensions are different, e.g., the test diameter (enrolled part) of macrospheric specimens of *S. giganteus* is 0.7-0.8 (max. 0.9 mm) versus 1.0 to 1.3 mm (or even larger referring to transverse sections that cannot be transferred to one or the other generation) in *S. suprajurassicus*. Another example is the chamber height in the cylindrical test part (macrospheric specimens): 0.12 to 0.2 mm in *S. giganteus* versus 0.2 to 0.38 mm in *S. suprajurassicus*. The enrolled portion shows a reduced number of chambers in *S. suprajurassicus* (4–6 *versus* 20–30, max. 37 in *S. giganteus*).
- Last but not least, according to the present knowledge, both taxa are stratigraphically clearly separated from each other.

Microfossil association and palaeoenvironment: In the Barmstein Limestone, the tests of *Spiraloconulus suprajurassicus* occur as individual bioclasts in the calciturbiditic layers, not within clasts of the mass-flow breccias, meaning a more or less contemporaneous resedimentation (Text-Figs. 7a–d). In grain to packstone limestones, *Spiraloconulus suprajurassicus* is associated with debris of dasycladalean algae such as *Clypeina jurassica* Favre & Richards, *Selliporella neocomiensis* (Radoičić), other green algae such as *Thaumatoporella parvovesiculifera* (Raineri) and *Pinnatiporidium* sp., benthic foraminifera such as *Mohlerina basiliensis* (Mohler), *Protopeneroplis ultragranulata* (Gorbatchik), *Andersenolina alpina* (Leupold), *Pseudocyclammina lituus* (Yokoyama), *Lenticulina* sp. and small textulariids. The microencruster incertae sedis *Crescentiella morronensis* (Crescenti) is also present. The microfossils often display a micritic coating. For the calciturbidites, a platform margin source area can be assumed. For the autochthonous platform carbonates, an outer platform palaeoenvironment was deduced by Schlagintweit & Ebli (1999) (see Text-Fig. 1a). Here, *Spiraloconulus suprajurassicus* occurs in biosparitic limestones indicating a well-agitated palaeoenvironment. Here, peloids, tiny benthic foraminifera, and debris of other organisms (e.g., echinoids) were incorporated into the test.

Concerning *S. giganteus*, it is striking that from the Middle Jurassic of Sardinia, ooids were characteristically agglutinated into the test. The same accounts for specimens from the Middle Jurassic (Bajocian, see Velić, 2007) of Croatia (Text-Fig. 6). Both examples come from distant and palaeogeographically different areas. This observation indicates a very special palaeohabitat preference of *S. giganteus* for high-energy ooid shoals, and represents another example for great selectivity for test building material known also from other foraminifera (e.g., Schlagintweit et al., 2007).

Stratigraphy: At Mount Lugberg, *Spiraloconulus suprajurassicus* is associated with sediments containing *Labyrinthina mirabilis* Weynschenk and *Kilianina*? *rahonensis* Foury & Vincent, indicating a Kimmeridgian age (Bassoullet, 1997). Biostratigraphic data obtained from calpionellid wackestones associated with the Barmstein Limestone at the localities Mount Ewige Wand and Mount Jochwand indicate an Upper Tithonian age (*intermedia* zone, see Gawlick et al., 2010). Based on benthic foraminifera and dasycladalean algae, an Upper Tithonian to Earliest Berriasian? age was assumed by Schlagintweit & Ebli (1999) for the occurrences at Mount Trisselwand. From the Eastern Carpathians of Romania, the species is recorded from the Late Tithonian–Early Berriasian (Bucur et al., 2011; Dragastan, 2011). Summarizing, *Spiraloconulus suprajurassicus* was observed in deposits that can be ascribed to the Kimmeridgian–Tithonian (Early Berriasian?) interval.

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