Austrian Journal of Earth Sciences | Volume 101 | 17 - 26 | Vienna | 2008

Tetrataxiella? *floriforma* n. sp. and other benthic foraminifera from the Gosau Group of the Northern Calcareous Alps, Austria

Felix SCHLAGINTWEIT[1)*)] & Diethard SANDERS[2)]

KEYWORDS

Northern Calcareous Alps
Benthic foraminifera
Upper Cretaceous
Systematics
Gosau Group
Austria

[1)] Lerchenauerstr. 167, D-80935 München, Germany; e-mail: EF.Schlagintweit@t-online.de

[2)] Institute of Geology and Palaeontology, University of Innsbruck, Innrain 52, A-6020 Innsbruck, Austria;

[*)] Corresponding author, diethard.g.sanders@uibk.ac.at

Abstract

Some benthic foraminifera that are rarely mentioned in the literature are described here from shallow-water limestones of the Upper Cretaceous Lower Gosau Subgroup (LGS, Austria). The new species *Tetrataxiella*? *floriforma* n. sp. was found in great abundances in association with cuneolinids, miliolids and calcareous green algae (dasycladaceans, halimedaceans). The fine-grained agglutinated test of *Tetrataxiella*? *floriforma* n. sp. typically displays a quadriserial chamber arrangement. Its tentative attribution to the previously monospecific taxon *Tetrataxiella* Seiglie, 1964 (type-species *T. ayalai*), known only from modern environments, is discussed. Within the Lower Gosau Subgroup, the stratigraphic range of *T.*? *floriforma* n. sp. documented so far is Upper Turonian to Santonian, whereas in the Dinarides, it is reported from the Turonian. Other taxa described are *Gendrotella rugoretis* (Gendrot), *Ammobaculites* sp. and *Reticulinella fleuryi* Cvetko, Gušić and Schroeder. This is the first documented occurrences of *Gendrotella* and *Reticulinella* in the LGS.

Einige, in der Literatur nur selten erwähnte benthonische Foraminiferen werden aus Flachwasserkalken der oberkretazischen unteren Gosau-Subgruppe von Österreich beschrieben. Die neue Art *Tetrataxiella*? *floriforma* n. sp. wurde in großen Mengen in Assoziation mit Cuneolinen, Milioliden und kalkigen Grünalgen (Dasycladales, Halimedaceae) vorgefunden. Die fein-agglutinierenden Gehäuse von *Tetrataxiella*? *floriforma* n. sp. weisen eine typische quadriseriale Kammeranordnung auf. Die vorläufige Zuordnung zur Gattung *Tetrataxiella* Seiglie, 1964 (Typusart *T. ayala*), bisher nur von heutigen Ablagerungsräumen bekannt, wird diskutiert. Die bisher bekannte stratigraphische Reichweite von *T.*? *floriforma* n. sp. innerhalb der unteren Gosau Subgruppe ist Ober-Turonium bis Santonium, während sie aus den Dinariden aus dem Ober-Turonium bekannt ist. Andere in dieser Arbeit beschriebene Taxa sind *Gendrotella rugoretis* (Gendrot), *Ammobaculites* sp. und *Reticulinella fleuryi* Cvetko, Gušić und Schroeder. Es sind dies die ersten Nachweise von *Gendrotella* und *Reticulinella* in der unteren Gosau Subgruppe.

1. Introduction

The Upper Cretaceous Lower Gosau Subgroup (LGS) of the Northern Calcareous Alps has a long-established reputation for its wealth of well-preserved fossils and hosts several 'classic' localities of invertebrate palaeontology (e. g. Felix, 1903). The succession is rich in marls of shallow to deep neritic environments that have provided well-preserved and diverse (micro)fossil assemblages (e. g. Wagreich, 1992). By contrast to the marls, which can be sampled for microfossils by washing and sieving, the foraminiferal assemblages of shallow-water limestones of the LGS are still in need of further documentation (e.g. Höfling, 1985; Schlagintweit, 1992, 2008). Most of these shallow-water limestones accumulated in the Late Turonian to Santonian interval, wherein larger benthic foraminifers are generally very scarce. Smaller benthic forms are more difficult to identify from thin-sections and may have escaped recognition. In the present paper, we describe taxa of smaller benthic foraminifera that to date were not or only scarcely known from the LGS. In addition, a new species, *Tetrataxiella*? *floriforma* n. sp. is introduced and discussed.

2. Geological Setting

Late Jurassic to Early Cretaceous convergence and nappe stacking in the are of the future Northern Calcareous Alps were followed by exhumation and subaerial exposure of large parts of the orogen (e.g. Ratschbacher et al., 1989). Subsequent marine transgression started during the Turonian. From then to Campanian times, a variegated, mixed siliciclastic-carbonate succession of more than 2000 metres thickness accumulated in terrestrial to deep neritic environments (Lower Gosau Subgroup; Wagreich and Faupl, 1994). From Santonian to Campanian times, deposition of the Lower Gosau Subgroup was followed by deepening to bathyal and abyssal depths (Wagreich and Faupl, 1994).

During the Late Cretaceous, both, the diversity and composition of macro- and microfossil assemblages indicate that the area of the Northern Calcareous Alps was part of a transitional belt between the Tethyan (mesogean) and the 'temperate' biogeographic realm, respectively (Sanders et al., 1997; Summesberger et al., 1999; Hradecka et al., 1999 a, b). The transitional marine-biogeographic character may be related to the intermittent prevalence of warmer versus cooler oceanic waters along the northern fringe of Tethys (e.g. Sanders et al., 1997). In addition, a physiognomic analysis of fossil land plant leaves indicates a seasonal, subtropical to marine mesother-

mal low-altitude land climate during the deposition of at least a part of the Gosau Group (Herman and Kvacek, 2002).

During deposition of the LGS, two distinct shelf types existed, with different prevalent sediments and different morphology, as a result of the localized input of siliciclastic sediments and syndepositional tectonism (Sanders, 1998; Sanders and Höfling, 2000). Type A shelves were characterized by a paralic to neritic facies belt with variegated mixed siliciclastic-carbonate facies associations. On the inner shelf to shore zone belt of type A shelves, coral-rudist limestones, rudist limestones and bioclastic limestones accumulated in areas of reduced siliciclastic input (Sanders and Pons, 1999). During intervals of persistent low clastic input, small carbonate shelves locally developed in depositional sequences interpreted as highstand systems tract (Sanders et al., 1997). Accumulation of thicker packages of biogenic limestones remained confined to the inner shelf (Sanders and Höfling, 2000). Type B shelves, by contrast, had a narrow paralic to neritic facies tract ahead of a deep, muddy shelf. Type B shelves characterized the rapid transgression that was followed by deposition of the deep-water succession of the Upper Gosau Subgroup (Sanders, 1998). The taxa of benthic foraminifers described in the present paper all derive from type A shelf successions, in most cases from shallow-water limestones deposited from the above-mentioned inner-shelf carbonate depositional systems.

3. Material and sample localities

All the taxa described herein derive from thin-sections. The samples were collected from several localities in the LGS (in alphabetical order):

Brandenberg, Tyrol: The benthic foraminifers reported from the Brandenberg area occur in the Upper Turonian to Coniacian carbonate successions of the Haidach Section (see Sanders and Baron-Szabo, 1997, Sanders and Pons, 1999, fig. 6, for lithological column), the Unterberg Section (Sanders, 1998, fig. 7A), Atzl Section (Sanders, 1998, fig. 11) and the Prinzkopf-Krumbachalm Section (Sanders, 1998, fig. 7C).

Gams, Styria: This locality covers the succession of Noth-Klamm documented by Sanders and Pons (1999, fig. 14) (= Upper Turonian Noth Formation of Siegl-Farkas and Wagreich, 1997).

Pletzachalm, Tyrol: The Pletzachalm Section near Kramsach (see Fig. 1) was first described lithologically in detail by Leiss (1988). The micropalaeontological content (benthic foraminifers, calcareous algae) was studied by Schlagintweit (1991a, b, 1992) and Schlagintweit and Ebli (1995, 1998), revealing several new taxa, mainly calcareous algae. The benthic foraminifers treated here, *Ammobaculites* sp., *Gendrotella rugoretis* (Gendrot) and *Tetrataxiella*? *floriforma* n. sp. are from the lower part of the section (Middle?, Upper Turonian), below the rudist limestones that were dated as Lower-Middle Coniacian on the basis of nannofloras from strata below and above (pers. comm. M. Wagreich in Schlagintweit, 1992). These rudist limestones are time-equivalent to those from Weisswasser.

Weisswasser, Lower Austria: The Weisswasser section was studied and illustrated by Sanders and Pons (1999, fig. 17), following Ruttner and Woletz (1955) and Faupl et al. (1987). Here, *Reticulinella fleuryi* Cvetko, Gušić and Schroeder and *Tetrataxiella*? *floriforma* n. sp. were found in foraminiferal wacke-/packstones within the rudist limestone interval. Additional data about the microfauna from this locality were provided by Schlagintweit (1992). The rudist limestones were dated biostratigraphically as Lower-Middle Coniacian (e.g. Wagreich, 1990) and on the basis of strontium isotope stratigraphy (Steuber, 2001).

Wegscheidgraben at Pass Gschütt: This locality belongs to the type-region of the Gosau Group, the area around Gosau (Upper Austria), Rußbach and Abtenau (Salzburg). Lithostratigraphically, it is part of the middle to upper Santonian Hochmoos Formation (see Höfling, 1985 and Wagreich 1988, for details).

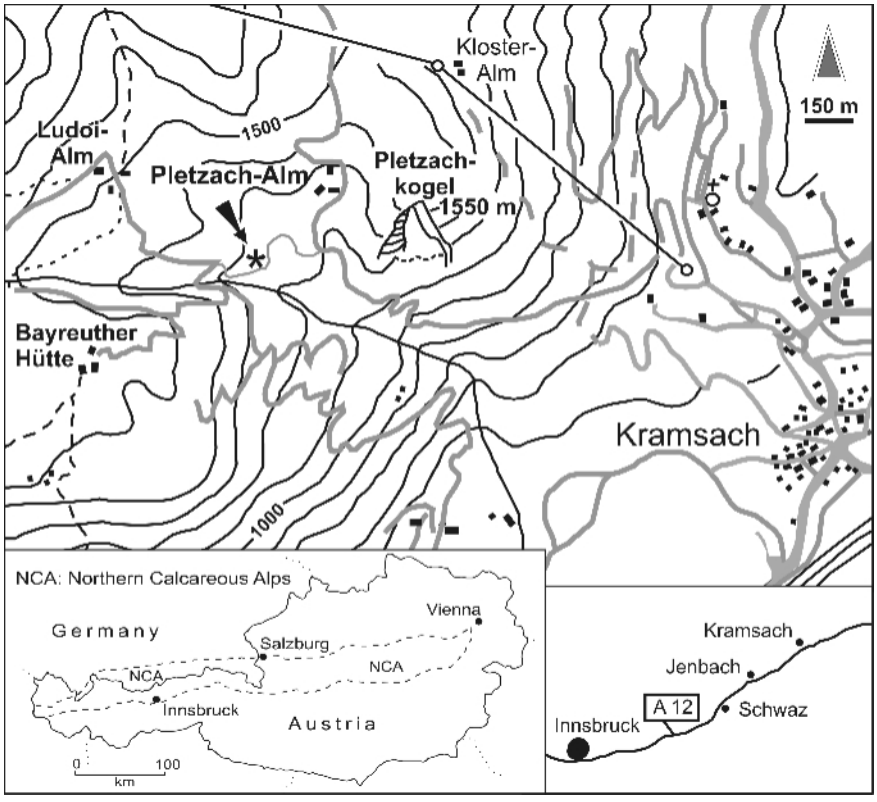


Figure 1: Locality map of the Pletzachalm section of the Lower Gosau Subgroup, the type-locality of the benthic foraminifer *Tetrataxiella? floriforma* n. sp.

4. Systematic Palaeontology

Genus Gendrotella Maync, 1972

Gendrotella rugoretis (Gendrot, 1968)

(Fig. 3/1-6)

1968 *Choffatella rugoretis* n. sp. – Gendrot: 675, pl. 4/6-13.

1972 *Gendrotella rugoretis* (Gendrot) nov. comb. – Maync: 356, pl. 1/1-5.

1984 Lituolidé indéterminé – Bilotte: pl. 13/3.

Description: Test flat discoidal, often slightly curved, enrolled planispiral (test length: 0.52-0.64 mm). Chambers numerous recurved and narrow. Wall microgranular homogeneous. In (sub)axial sections (test thickness: 0.12-0.18 mm), the latest chamber is only cut randomly due to the chamber curving (Fig. 3/3, 3/5-6).

Remarks: The species was originally described as a representative of the genus *Choffatella* Schlumberger by Gendrot (1968) from the Santonian of southern France. Maync (1972) recognized that the test wall lacks any choffatellid subepidermal layer, and introduced the new genus *Gendrotella*, so far this being monospecific. The Alpine Turonian specimens are distinctly smaller than those from the Santonian type-locality (length 1.2-1.28 mm, thickness 0.19-0.36 mm), but the poor data set (two values for each parameter) does not represent the total morphometric range. The phenomenon that in (sub)-axial sections the last chamber is mostly cut randomly and discernible only as a small subsphaerical lumen is also well known from other planspiral taxa with falciform chambers. For example, Laug and Pybernes (1979) interpreted this observation with the assumption of a spiral channel along the external test margin in *Daxia minima*. However, Cherchi and Schroeder (1980) convincingly demonstrated that this is an effect of sectioning of two subsequent chambers, one only in a random manner.

Facies: In the lower Gosau Subgroup *Gendrotella rugoretis* was found in marly lagoonal limestones (floatstones) with abundant gastropod shells and an overall low microfaunistic diversity. Rare specimens are reported from foraminiferal-algal wacke- to packstones with cuneolinids, *Nezzazatinella picardi* (Henson), *Tetrataxiella*? *floriforma* n. sp., *Permocalculus nikolapantici* Radoičić, *Milanovicella hammudai* (Radoičić), *Terquemella* sp. and *Clypeina* sp.

Occurrences: Pletzachalm, Brandenberg.

Stratigraphy: Late Santonian age at the type-locality in S France (Gendrot, 1968); Latest Coniacian-Santonian in the Provence region, S France (Tronchetti, 1981); Late Santonian in the French-Spanish Pyrenees (Bilotte, 1984). Late Turonian-Coniacian age in the Northern Calcareous Alps (Pletzachalm, Brandenberg).

Genus *Ammobaculites* Cushman, 1910

Ammobaculites sp.

(Fig. 3/7-9)

2007 *Reophax* sp. – Schlagintweit et al.: fig. 3/2.

2007 *Reophax* sp. – Radoičić and Schlagintweit: pl. 3/3.

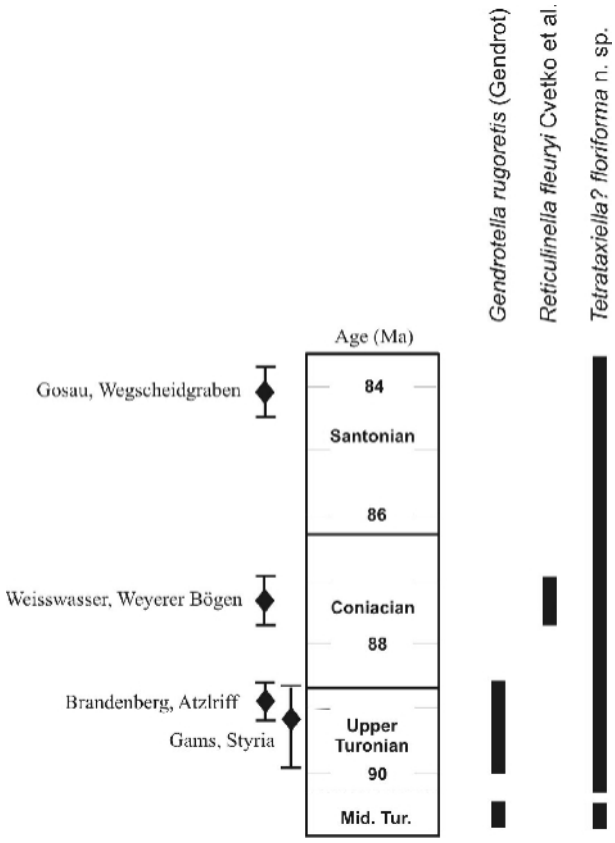


Figure 2: Strontium isotope stratigraphic ages (mean values, upper and lower age limits) of selected localties with hippuritids of the Lower Gosau Subgroup (adopted from Steuber, 2001: time scale of Obradovitch, 1993) and occurrences of benthic foraminifers *Gendrotella rugoretis* (Gendrot), *Reticulinella fleuryi* Cvetko, Gušić and Schroeder and *Tetrataxiella*? *floriforma* n. sp.

Remarks: The specimen from the LGS correspond exactly to the generic diagnosis provided by Loeblich and Tappan (1988: p. 74). Gosauian specimens of *Ammobaculites* sp. without showing the small initial spire were previously illustrated as *Reophax* sp. (see synonymy). In our material, there are two complete specimens in thin-sections, shown in fig. 3/7 (length 2.8 mm, maximum thickness 0.56 mm, 6 chambers in the rectilinear part) and fig. 3/8 (length 1.95 mm, maximum thickness 0.4 mm, 5 chambers in the rectilinear part). Both show a relatively small initial spire, followed by a large elongate rectilinear part. Transverse sections in the same thin-section attain diameters of up to 0.85 mm, pointing to specimens of larger size. We desist from a specific attribution, as many representatives of *Ammobaculites* lack adequate descriptions based on abundant material, preferably of both free specimens together with thin-sections.

Facies: The Late Cretaceous specimens seemed to prefer siliciclastic influenced marginal marine palaeoenvironments, where they occur together with gastropods, miliolids (*Quinqueloculina* sp., *Vidalina hispanica* Schlumberger), occasionally associated with *Tetrataxiella*? *floriforma* n. sp. and *Gendrotella rugoretis* (Gendrot). Microfacies are dark-grey, marly limestones (wackestones) with variable amounts of quartz grains. Typically, *Ammobaculites* sp. occurs together with the

dasycladalean alga *Neomeris mokragorensis* Radoičić and Schlagintweit (Fig. 3/7), with dispersed fertile ampullae incorporated into the test wall of *Ammobaculites* sp. as building material (Fig. 3/9).

Occurrences: Pletzachalm, Brandenberg.

Stratigraphy: Late Turonian-Coniacian.

Genus *Reticulinella* Bonnefous, Hamaoui and Tixier, 1970

Reticulinella fleuryi Cvetko, Gušić and Schroeder, 1997

(Fig. 3/10-17)

*1997 Reticulinella fleuryi n. sp. - Cvetko, Gušić and Schroeder: 133, pl. 1-2.

2001 *Reticulinella fleuryi* Cvetko, Gušić and Schroeder – Cvetko Tešović, Gušić, Jelaska and Bucković: 607, fig. 7J-L.

2004 *Reticulinella fleuryi* Cvetko, Gušić and Schroeder – Sanders, Pons and Caus: pl. 4, fig. 3-6, 9.

Description: Test free, globular coiled planspirally, involute. Exoskeleton consisting of subepidermal partitions protruding into the chamber lumina (e.g., Fig. 3 1/10, 13). The network of transverse and parallel partitions can be seen in tangential sections (Fig. 3/15, 17). Diameters of axial sections vary between 0.3 and 0.4 mm (mean 0.35 mm, n = 11), equatorial diameters up to 0.57 mm (Fig. 3/14) (Cvetko et al., 1997: up to 0.46 mm).

Remarks: *R. fleuryi* was reported by Sanders et al. (2004) from the Campanian of the Central Alps of Krappfeld, Austria; further occurrences are from Southern Italy, Croatia (type-area) and Greece. It has not yet been reported from the Pyrenees or Southern France. The Alpine specimens from Weisswasser fit perfectly with the original description; rare specimens slightly exceed the maximum equatorial diameters observed at the type-locality.

Facies: At its type-locality, *R. fleuryi* occurs frequently in foraminiferal wacke- to packstones, a microfacies equivalent to that of the LGS. The accompanying microfauna, however, is comparable with respect to major groups (cuneolinids, miliolids) but differs in species due to the different stratigraphic levels of both occurrences. At the Weisswasser locality *R. fleuryi* is associated with cuneolinids, some *Tetrataxiella*? *floriforma* n. sp. and equally large representatives of *Quinqueloculina* sp. Calcareous algae are represented by *Terquemella* sp.

Occcurrences: Weisswasser.

Stratigraphy: At the Croatian type-locality, *R. fleuryi* was reported from the Lower-Middle Campanian of the so-called Rasotica Unit (Cvetko et al., 1997; Cvetko Tešović et al., 2001). Although the base of the Rasotica Unit was shown to also include parts of the Upper Santonian, based on strontium isotope stratigraphy (Steuber et al., 2005) these new data did not change the total stratigraphic range (Upper Santonian to Middle Campanian, Cvetko et al., 1997). The discovery of *R. fleuryi* just beneath the rudist limestones at Weisswasser, dated biostratigraphically to the Middle Coniacian, and by means of Sr-data (Wagreich and Faupl, 1994; Steuber, 2001), widens its stratigraphic range.

Family Globotextulariidae Cushman, 1927

Genus *Tetrataxiella* Seiglie, 1964

Tetrataxiella? *floriforma* n. sp.

(Fig. 4/1-32)

Derivatio nominis: (latin flos, floris = flower) because of the transverse sections resembling a flower.

Type-locality: Pletzachalm, Tyrol (see Fig. 1).

Type strata: Marly limestones (wacke- to packstones) of the Lower Gosau Subgroup. *Tetrataxiella*? *floriforma* n. sp. occurs together with *Vidalina hispanica* Schlumberger, *Quinqueloculina* sp., *Cuneolina compressa* Schlagintweit, *Nezzazatinella picardi* (Henson) and the calcareous algae *Halimeda paucimedullaris* Schlagintweit and Ebli, *Dissocladella*? *pyriformis* Schlagintweit, *Neomeris mokragorensis* Radoičić and Schlagintweit, *Oroseina pletzachensis* Schlagintweit and Ebli and *Acicularia*? *antiqua* Pia. The macrofauna consists of gastropods.

Holotype: Transverse section shown in figure 4/1. Holotype and paratypes occurring in the same thin-section (fig. 4/2, 4/4-15) are deposited at the Bayerische Staatssammlung für Paläontologie und Historische Geologie, Munich, with the number BSPG 5120a 93. This thin-section is stored among the material deposited for the description of *Neomeris circularis* (= *Neomeris mokragorensis* Radoičić and Schlagintweit) provided by Schlagintweit and Ebli (1995).

Figure 3: Benthic foraminifers from the Lower Gosau Subgroup of the Northern Calcareous Alps

1: *Gendrotella rugoretis* (Gendrot). Brandenberg, sample 19995-26, oblique equatorial section, scale bar = 0.3 mm.

2: *Gendrotella rugoretis* (Gendrot). Brandenberg, sample 19995-26, oblique section, scale bar = 0.3 mm.

3: *Gendrotella rugoretis* (Gendrot). Brandenberg, sample 16795-9, subaxial section, scale bar = 0.3 mm.

4-6: *Gendrotella rugoretis* (Gendrot). Brandenberg, sample 19995-26, subaxial sections; note slightly S-shaped test curving and random sectioning of last chamber resulting in a small visible marginal lumen (arrows), scale bar = 0.3 mm.

7: *Ammobaculites* sp. Pletzachalm, sample BSPG 5212a 93, equatorial section, note debris of dasycladalean alga *Neomeris mokragorensis* Radoičić and Schlagintweit, scale bar = 0.5 mm.

8: *Ammobaculites* sp. Pletzachalm, sample BSPG 5212a 93, equatorial section, scale bar = 0.5 mm.

9: Detail from 8 showing the usage of the fertile ampullae of *Neomeris mokragorensis* Radoičić and Schlagintweit as test building material, scale bar = 0.2 mm.

10: *Reticulinella fleuryi* Cvetko, Gušić and Schroeder, oblique section. Weisswasser, sample 1833, scale bar = 0.1 mm.

11: *Reticulinella fleuryi* Cvetko, Gušić and Schroeder, oblique section. Weisswasser, sample 1834, scale bar = 0.1 mm.

12: *Reticulinella fleuryi* Cvetko, Gušić and Schroeder, oblique section cutting the proloculus. Weisswasser, sample 1833, scale bar = 0.1 mm.

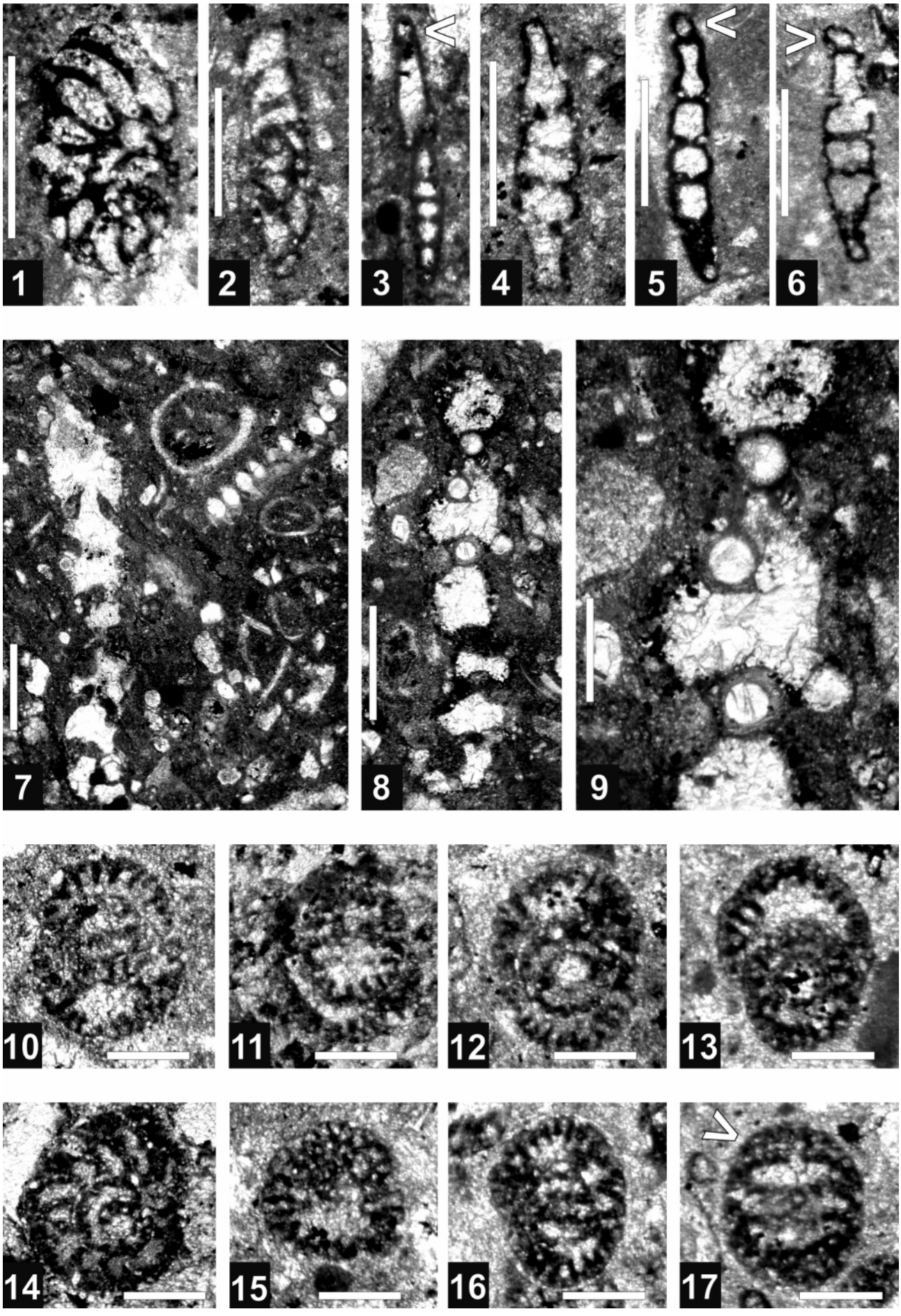
13: *Reticulinella fleuryi* Cvetko, Gušić and Schroeder, axial section showing well vertical partitions. Weisswasser, sample 1833, scale bar = 0.1 mm.

14: *Reticulinella fleuryi* Cvetko, Gušić and Schroeder, equatorial section. Weisswasser, sample 1834, scale bar = 0.1 mm.

15: *Reticulinella fleuryi* Cvetko, Gušić and Schroeder, tangential section. Weisswasser, sample 1834, scale bar = 0.1 mm.

16: *Reticulinella fleuryi* Cvetko, Gušić and Schroeder, subaxial section slightly oblique. Weisswasser, sample 1833, scale bar = 0.1 mm.

17: *Reticulinella fleuryi* Cvetko, Gušić and Schroeder, subaxial section showing subepidermal network. Weisswasser, sample 1833, scale bar = 0.1 mm.

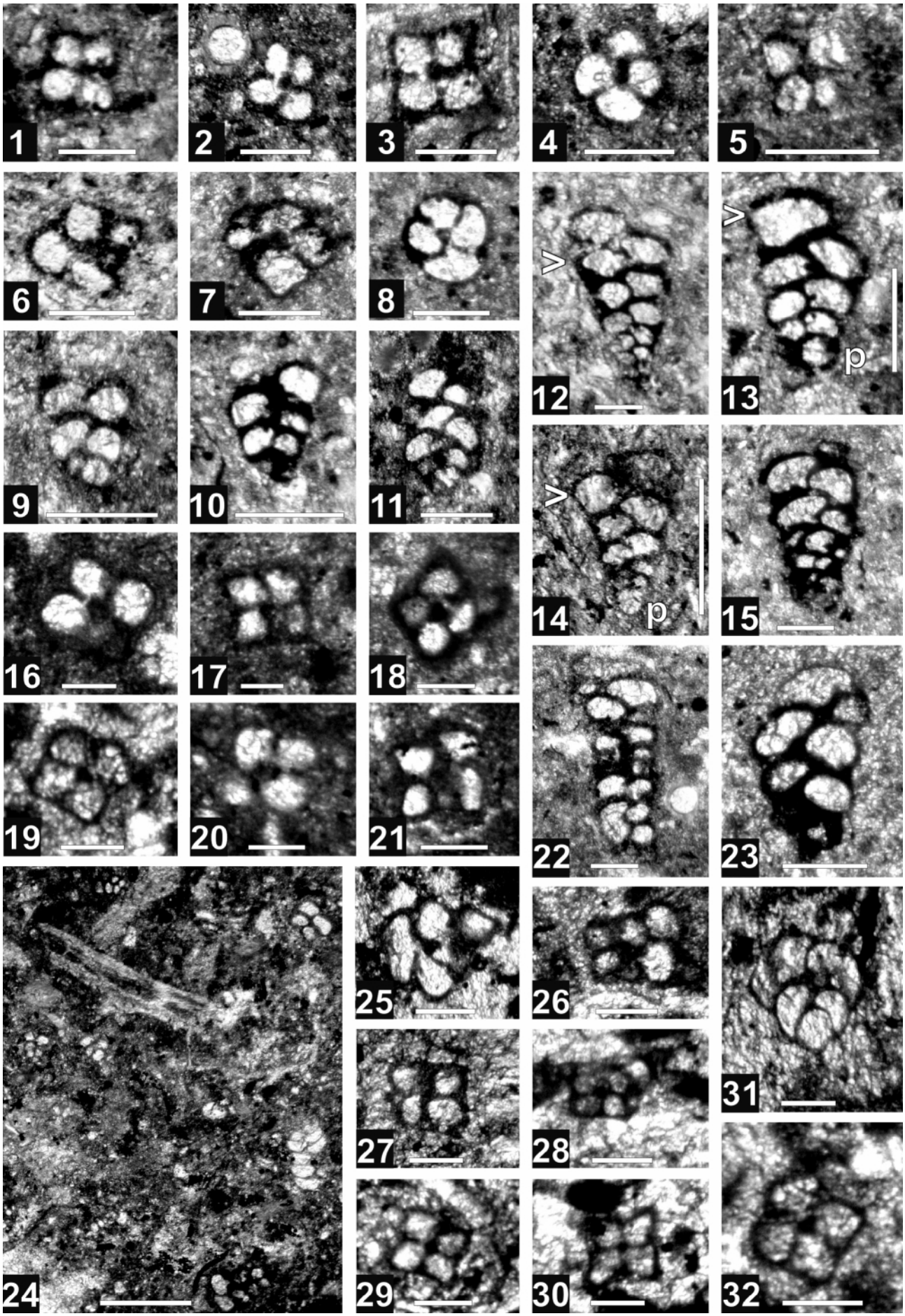

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

Diagnosis: Test free, small, elongate high-conical with quadriserial arranged inflated chambers giving rise to a flower-shaped outline in transverse sections. Chamber interior simple, wall finely agglutinated. Aperture an interio-marginal slit, umbilical in position.

Description: Test free, small, elongate high-conical (e.g. Fig. 4/14). The length of the test measured from longitudinal sections ranges from 0.11 to 0.35 mm (usually 0.15 to 0.2 mm). The width is 0.08 to 0.19 mm in transverse sections. The width/length ratio of the test varies between 0.5 and 0.68, in very small specimens up to 0.83, documenting the reduced chambers size increase during ontogeny. The umbilical side is rounded, terminal end convex, often with elevation of the ultimate and enlarged chamber above one half of the test (Fig. 4/12-13). Wall thin (except the sutural region), finely agglutinated, solid, rather loosely cemented. In the sutural region, the test wall thickens, producing only a moderate depression of sutures (Fig. 4/12-13, 15, 23). Dark appearance of wall is observable in other foraminifers co-occurring (see Fig. 4/2-5 for comparison), possibly caused by pyritized organic material. Initial chamber (proloculus) in central position, subglobular with diameters from 0.015 to 0.04 mm (Fig. 4/13-14). As there are only four chambers per whorl visible, the test seems to be quadriserial throughout; a differing chamber arrangement in the juvenile part has not been seen so far. In the latter part, chambers are ovoidal to sublobular, later becoming inflated with convex terminal faces. Chambers increase rather constantly in size as added, only the latest chambers broaden more significantly with respect to previous chambers. In the adult stage, chamber periphery likely carinate (e.g. Fig. 4/12-13). The resemblance to a four-leaved flower results from the symmetric carinate chamber periphery (~ 90 degree between two edges) (e.g. Fig. 4/1, 3, 17). Rounded chamber periphery is seldom (Fig. 4/4, 8) and presumably represents transverse sections through juvenile parts. There are no internal structures dividing the chambers. The solid umbilicus appears rounded in transverse sections (diameter 0.015 to 0.032 mm) generally occupying about 10 % of test diameter (maximum 20 %). Chambers are connected by small interiomarginal openings.

Remarks: The genus *Tetraminouxia* (type-species *T. gibbosa*), which was established in the Santonian of S France (Gendrot 1963), is an exclusively Late Cretaceous genus with quadriserial tests. Later, another species was described as *Tetraminouxia salentina* (Luperto Sinni and Reina 1991), from the Campanian of S Italy. This is quadriserial throughout the whole test and has a comparable wide umbilical area with cribrose aperture well visible in transverse sections, thus differing markedly from our specimens. Other genera with quadriserial tests (partly or throughout) occurs within the family Globotextulariidae Cushman with mostly recent representatives. Amongst these, the genus *Tetrataxiella* Seiglie, 1964 seems to be closest to

Figure 4: *Tetrataxiella*? *floriforma* n. sp. from the Lower Gosau Subgroup of the Northern Calcareous Alps
1: Transverse section, holotype. Pletzachalm, sample BSPG 5120a 93, scale bar 0.1 mm.
2: Transverse section, note the isolated ampulla of the dasycladalean alga *Neomeris mokragorensis* Radoičić and Schlagintweit (left above). Pletzachalm, sample BSPG 5120a 93, scale bar = 0.1 mm.
3: Transverse section. Pletzachalm, sample P 7, scale bar = 0.1 mm.
4: Transverse section, note rounded chamber periphery. Pletzachalm, sample BSPG 5120a 93, scale bar = 0.1 mm.
5: Transverse section. Pletzachalm, sample BSPG 5120a 93, scale bar = 0.1 mm.
6: Oblique transverse section, note finely agglutinated test (see also Fig. 11-12). Pletzachalm, sample BSPG 5120a 93, scale bar = 0.1 mm.
7: Oblique transverse section. Pletzachalm, sample BSPG 5120a 93, scale bar = 0.1 mm.
8: Transverse section, note rounded chamber periphery. Pletzachalm, BSPG 5120a 93, scale bar = 0.1 mm.
9: Oblique longitudinal section. Pletzachalm, sample BSPG 5116a 93, scale bar = 0.1 mm.
10: Oblique longitudinal section. Pletzachalm, sample BSPG 5120a 93, scale bar = 0.1 mm.
11: Oblique longitudinal section. Pletzachalm, sample BSPG 5120a 93, scale bar = 0.1 mm.
12: Longitudinal section, note angular chamber periphery in adult part (arrow). Pletzachalm, sample BSPG 5120a 93, scale bar = 0.1 mm.
13: Longitudinal section, note globular proloculus (p) and angular chamber periphery in adult part (arrow). Pletzachalm, sample BSPG 5120a 93, scale bar = 0.1 mm.
14: Longitudinal section, note globular proloculus (p) and angular chamber periphery (arrow). Pletzachalm, sample BSPG 5120a 93, scale bar = 0.1 mm.
15: Longitudinal section. Pletzachalm, sample BSPG 5120a 93, scale bar = 0.1 mm.
16: Oblique transverse section. Brandenberg, sample 19996-22, scale bar = 0.1 mm.
17: Transverse section, note acute chamber periphery.Brandenberg, sample 19956-22, scale bar = 0.1 mm.
18: Oblique transverse section. Brandenberg, sample 17995-2, scale bar = 0.1 mm.
19: Transverse section. Brandenberg, sample 241295-4A, scale bar = 0.1 mm.
20: Oblique transverse section. Brandenberg, sample 549512, scale bar = 0.1 mm.
21: Oblique transverse section. Brandenberg, sample 549512, scale bar = 0.1 mm.
22: Longitudinal section. Pletzachalm, sample P 7, scale bar = 0.1 mm.
23: Oblique longitudinal section. Brandenberg, sample 19995-26, scale bar = 0.1 mm.
24: Microfacies (wacke- to packstone) with abundant tests of *Tetrataxiella*? *floriforma* n. sp. Pletzachalm, sample BSPG 5120a 93, scale bar = 0.5 mm.
25: Oblique section. Brandenberg, sample 2499-1, scale bar = 0.1 mm.
26: Oblique section. Brandenberg, sample 2499-1, scale bar = 0.1 mm.
27: Oblique transverse section. Brandenberg, sample 2499-1, scale bar = 0.1 mm.
28: Oblique transverse section. Brandenberg, sample Atz 4, scale bar = 0.1 mm.
29: Transverse section, not acute chamber periphery. Brandenberg, sample 241295-4A, scale bar = 0.1 mm.
30: Transverse section, note acute chamber periphery. Brandenberg, sample 2499-1, scale bar = 0.1 mm.
31: Oblique section, note globular proloculus. Brandenberg, sample 2499-1, scale bar = 0.1 mm.
32: Transverse section. Brandenberg, sample 241295-4A, scale bar = 0.1 mm.


1
2
3
4
5
6
7
8
v
v
p
9
10
11
12
13
v
p
16
17
18
v
p
14
15
19
20
21
22
23
24
25
26
31
27
28
29
30
32

our specimens. Its generic diagnosis is given by Loeblich and Tappan (1988, p. 144) as follows: "*Test free, elongate conical, quadriserial, chambers inflated and strongly overlapping, so that the final whorl occupies one-half the test lenth, interior simple; wall agglutinated, surface smoothly finished except for frequent large grains of quartz or shell fragments; aperture a low interiomarginal arch, opening into the umbilicus*". Although our specimens seem to correspond to this diagnosis, we nonetheless put a question mark to this assignment as *Tetrataxiella* is described only from free specimens (our material is from thin-sections). There is also a stratigraphic gap of more than 80 million years between both occurrences. The test length of *T. ayalai* varies from 0.21 to 0.31 mm. *T.*? *floriforma* n. sp. shows similar test sizes. The material of the type-species *T. ayalai* from the Holocene of Venezuela was sampled in water depths from 70-84 m. Due to the common co-occurrences with dasycladalean algae, a more shallow water depth is deduced for *T.*? *floriforma* n. sp.

Occurrences: Pletzachalm, Brandenberg, Weisswasser, Atzlreef Brandenberg.

Facies: *Tetrataxiella*? *floriforma* n. sp. was found in bioturbated bioclastic floatstones, packstones and fine-grained grainestones in close vertical association with coral-sponge-rudist limestones and/or with rudist biostromes. *T.*? *floriforma* n. sp. was also found in marly bioclastic wackestones grading into microbioclastic packstones, rich in miliolids and diverse textulariaceans. These marly bioclastic limestones probably accumulated in shallow subtidal environments of low to moderate water energy at some distance away from rudist biostromes and coral-sponge-rudist bioconstructions. *Tetrataxiella*? *floriforma* n. sp. commonly occurs in great abundance, together with numerous other smaller benthic foraminifera. As with most agglutinated shallow-water, vagile benthic foraminifera, the new taxon thus probably preferred fine-sandy to muddy substrates in areas of low to moderate water energy, irrespective of their relative position to organic buildups.

Stratigraphy: The age of strata containing *Tetrataxiella*? *floriforma* n. sp. ranges from Late Turonian (Nothklamm at Gams), ?Late Turonian to Coniacian (Brandenberg, Theresienstein), Coniacian (Weisswasser) to Late Santonian (Wegscheidgraben-Section in Hochmoos Formation at Gosau). In the literature, a slightly oblique cross-section of *Tetrataxiella*? *floriforma* n. sp. displaying the typical quadriserial test arrangement is visible on plate III, figure 3 of Radoičić (1994) left of *Montcharmontia apenninica* De Castro from the Lower Turonian of the Pastrik Mountain/Yugoslavia.

5. Conclusions

The LGS comprises various lithologies that contain abundant benthic foraminifera, namely marls, marly and pure limestones, and mixed siliciclastic limestones. The microfauna of the carbonates described from thin-section material is relatively well known. However, further poorly known taxa and taxa not yet described were discovered recently. Many taxa from marls were reported as isolated specimens from washed samples. To assess the total inventory of these carbonates, investigations by oriented sections are still necessary.

The discovery of the tiny, new foraminifera *Tetrataxiella*? *floriforma* n. sp., is of special interest, tentatively refered to the genus *Tetrataxiella* Seiglie, currently only known from modern environments. The new taxon was overlooked by previous workers not only in the area of the Northern Calcareous Alps but also elsewhere, and speculatively this might be the reason for the long stratigraphic gap between *Tetrataxiella*? *floriforma* n. sp. and the modern Venezuelan type-species. Further investigations on Cenozoic strata may deliver further findings. A wider distribution within the Adriatic carbonate platform can be expected for *Tetrataxiella*? *floriforma* n. sp. based on illustrations in the literature on the Dinarides.

Another important result is the extension of the stratigraphic range of *Reticulinella fleuryi* Cvetko, Gušić and Schroeder, previously known from the Upper Santonian to Middle Campanian, but now extending to the Middle Coniacian. The occurrence of this taxon in the Northern Calcareous Alps clearly documents the southern Tethyan influence during the Late Cretaceous.

Acknowledgements

We thank Michael Wagreich (Vienna) for critically reading the manuscript. Rolf Schroeder, Frankfurt a. Main, and Holger Gebhardt, Wien, are thanked for careful reviews of the manuscript. Our english was kindly revised by Hugh Rice (Vienna).

References

Bilotte, M., 1984. Les grands Foraminifères benthiques du Crétacé Supérieur Pyrénéen. Biostratigraphie. Réflexion sur les corrélations mésogéennes. Benthos ´83, 2nd International Symposium Benthic Foraminifera (Pau, April 1983), 61-67.

Bilotte, M., 1984. Le Crétacé supérieur des plates-formes Est-pyrénéennes. Actes du Laboratoire de Géologie Sédimentaire et Paléontologie, sér. 2, 1 (plates) and 5 (text, 1985), 1-438.

Cherchi, A. and Schroeder, R., 1980. A propos de la présence d´un « canal spiral » chez *Daxia* Cuvillier & Szakall (Foraminifera Lituolidae). Géobios, 13, 259-261.

Cvetko, B., Gušić, I. and Schroeder, R., 1997. *Reticulinella fleuryi* n. sp. (Foraminiferida) from the Upper Cretaceous (Upper Santonian-Middle Campanian) of the Island of Brač, Croatie. Revue de Micropaléontologie, 40, 131-139.

Cvetko Tešović, B., Gušić, I., Jelaska, V. and Bucković, 2001. Stratigraphy and microfacies of the Upper Cretaceous Pučišća Formation, Island of Brač, Croatia. Cretaceous Research, 22, 591-613.

Faupl, P., Pober, E. and Wagreich, M., 1987. Facies development of the Gosau Group of the eastern part of the Northern Calcareous Alps during the Cretaceous and the Paleogene. In; Flügel, H.W. and Faupl, P. (eds), Geodynamics of the Eastern Alps, 142-155. Springer, Berlin.

Felix, J. P., 1903. Studien über die korallenführenden Schichten der oberen Kreideformation in den Alpen und in den Mediterrangebieten. Palaeontographica, 49, 163-359, Stuttgart (Schweizerbart).

Gendrot, C., 1963. Quelques Foraminifères nouveaux du Sénonien inférieur des Martigues (Bouches du Rhone). Revue de Micropaléontologie, 6, 67-72.

Gendrot, C., 1968. Stratigraphie et micropaléontologie du Sénonien de la région des Martigues près Marseille (Bouches-du-Rhône). Eclogae geologicae Helvetiae, 61, 657-694.

Herman, A. and Kvacek, J., 2002. Campanian Grünbach flora of Lower Austria: preliminary floristics and palaeoclimatology. Annalen des Naturhistorischen Museums Wien, 103A, 1-21.

Hradecká, L., Lobitzer, H., Ottner, F., Sachsenhofer, R.F., Siegl-Farkas, A., Svábenická, L. and Zorn, I., 1996a. Biostratigraphy and palaeoenvironment of the marly marine transgression of Weißenbachalm Lower Gosau Subgroup (Upper Turonian-Lower Santonian Grabenbach Formation, Northern Calcareous Alps, Styria). Abhandlungen der Geologischen Bundesanstalt, 56, 475-517.

Hradecká, L., Lobitzer, H., Ottner, F., Sachsenhofer, R.F., Siegl-Farkas, A., Svábenická, L. and Zorn, I., 1996b. Biostratigraphy and facies of selected exposures in the Grünbach-Neue Welt Gosau Group (Coal-bearing series, Inoceramus-Marl and Zweiersdorf-Formation, Late Cretaceous and Paleocene, Lower Austria). Abhandlungen der Geologischen Bundesanstalt, 56, 519-551.

Höfling, R., 1985. Faziesverteilung und Fossilvergesellschaftungen im karbonatischen Flachwasser-Milieu der alpinen Oberkreide (Gosau-Formation). Münchner geowissenschaftliche Abhandlungen, 3, 1-240.

Kaminski, M.A., 2004. The year 2000 classification of agglutinated Foraminifera. In: Bubik, M. and Kaminski, M.A. (eds.): Proc. 6th Int. Workshop Agglutinated Foraminifera. Grzybowski Foundation Special Publication, 8, 237-255.

Laug, B. and Peybernès, B., 1979. *Daxia minima* nov. sp., Lituolidé nouveau de l`Aptien Basco-Bearnais. Géobios, 12, 717-723.

Leiss, O., 1988. Die Kontrolle des Sedimentationsgeschehens und der Biofazies durch evolutive orogenetische Prozesse in den Nördlichen Kalkalpen am Beispiel von Gosauvorkommen. Documenta naturae, 43, 1-95.

Loeblich, A.R., Jr. and Tappan, H., 1985. Some new and redefined genera and families of agglutinated foraminifera II. Journal of Foraminiferal Research, 15, 175-217.

Loeblich, A.R., Jr. and Tappan, H., 1988. Foraminiferal genera and their classification. - 2 volumes: 1-970, (Van Nostrand Reinhold) New York.

Luperto-Sinni, E. and Reina, A., 1991. *Tetraminouxia salentina* nuova specie di Foraminifero dei calcari Campaniani del Salento (Puglia, Italia Meridionale). Paleopelagos, 1, 39-45.

Maync, W., 1972. *Gendrotella* n. gen. and *Choffatella caronae* n. sp. from the Lower Senonian of Southern France. Eclogae geologicae Helvetiae, 65, 355-359.

Ratschbacher, L., Frisch, W., Neubauer, F., Schmid, S.M. and Neugebauer, J. 1989. Extension in compressional orogenic belts: The Eastern Alps. Geology, 17, 404-407.

Radoičić, R., 1994. On some Cenomanian-Turonian successions of the Pastrik Mountain (Kukes Cretaceous Unit; Mirdita). Annales Géologiques de la Péninsule Balkanique, 58, 1-16.

Radoičić, R. and Schlagintweit, F. 2007. *Neomeris mokragorensis* sp. nov. (Calcareous alga, Dasycladales) from the Cretaceous of Serbia, Montenegro and the Northern Calcareous Alps (Gosau Group, Austria). Annales Géologiques de la Péninsule Balkanique, 68, 39-51.

Ruttner, A. and Woletz, G., 1955. Die Gosau von Weisswasser bei Unterlaussa. Mitteilungen der geologischen Gesellschaft Wien, 48, 221-256.

Sanders, D., 1998. Tectonically controlled Late Cretaceous terrestrial to neritic deposition, Gosau Group, Northern Calcareous Alps (Tyrol, Austria). Facies, 39, 139-178.

Sanders, D. and Baron-Szabo, R., 1997. Coral-rudist bioconstructions in the Upper Cretaceous Haidach section (Northern Calcareous Alps, Austria). Facies, 36, 69-90.

Sanders, D. and Höfling, R., 2000. Carbonate deposition in mixed siliciclastic-carbonate environments on top of an orogenic wedge (Late Cretaceous, Northern Calcareous Alps, Austria). Sedimentary Geology, 137, 127-146.

Sanders, D., Kollmann, H. and Wagreich, M., 1997. Sequence development and biotic assemblages on an active continental margin: The Turonian-Campanian of the Northern Calcareous Alps. Bulletin de la Societé géologique de France, 168, 351-372.

Sanders, D. and Pons, J. M., 1999. Rudist formations in mixed siliciclastic-carbonate depositional environments, Upper Cretaceous, Austria: Stratigraphy, sedimentology, and models of development. Palaeogeography, Palaeoclimatology, Palaeoecology, 148, 249-284.

Sanders, D., Pons, J.M. and Caus, E., 2004. Shallow-water limestone clasts in a Campanian deep-water debrite (Krappfeld, Central Alps, Austria): implications for carbonate platform history. Annalen des Naturhistorischen Museums in Wien, 106 A, 139-165.

Schlagintweit, F., 1991a. On the occurrence of the genus *Permocalculus* Elliott, 1955 (Calcareous algae, Gymnocodiaceae) in the Upper Cretaceous of the Northern Calcareous Alps (Branderfleck Formation, Gosau Formation) with the description of *Permocalculus gosaviense* n. sp. Revue de Paléobiologie, 10, 37-46.

Schlagintweit, F., 1991b. *Dissocladella*? *pyriformis* n. sp., new chlorophycean alga from the Upper Cretaceous of the Northern Calcareous Alps (Gosau Formation/Branderfleck Formation). Revue de Micropaléontologie, 34, 191-200.

Schlagintweit, F., 1992. Benthonische Foraminiferen aus Flachwasserkarbonaten der Oberkreide der Nördlichen Kalkalpen (Gosauschichtgruppe, Österreich). Mitteilungen der Österreichischen Geologischen Gesellschaft, 84, 327-353.

Schlagintweit, F., 2008. Reassessment of "*Nummoloculina*" regularis Philippson, 1887, benthic foraminifer from the Late Cretaceous of the Northern Calcareous Alps, Austria. Neues Jahrbuch für Geologie und Paläontologie, 248, 115-122.

Schlagintweit, F., Auer, M. and Gawlick, H.-J., 2007. *Reophax*? *rhaxelloides* n. sp., a new benthic foraminifer from Late Jurassic reefal limestones of the Northern Calcareous Alps (Austria). Journal of Alpine Geology, 48, 57-69.

Schlagintweit, F. and Ebli, O., 1995. Remarks on *Neomeris circularis* Badve & Nayak, 1983 (Calcareous alga, *Dasycladales*). Jahrbuch der Geologischen Bundesanstalt, 138, 715-724.

Schlagintweit, F. and Ebli, O., 1998. *Halimeda paucimedullaris* n. sp. and *Oroseina pletzachensis* n. sp., two new calcareous algae from the Upper Cretaceous of the Northern Calcareous Alps (Gosau Group, Austria) followed by remarks on *Dissocladella*? *pyriformis* Schlagintweit, 1991. Revue de Paléobiologie, 17, 361-371.

Seiglie, G.A., 1964. Algunos foraminíferos arenáceos recientes de Venezuela. Boletín del Instituto Oceanográfico, Universidad de Oriente, Cumana, 3, 5-14.

Siegl-Farkas, A. and Wagreich, M., 1997. Correlation of palyno- (spores, pollen, dinoflagellates) and calcareous nannofossil zones in the Late Cretaceous of the Northern Calcareous Alps (Austria) and Transdanubian Central Range (Hungary). Advances in Austrian-Hungarian Joint Geological Research: 127-135.

Steuber, T., 2001. Strontium isotope stratigraphy of Turonian-Campanian Gosau-type rudist formations in the Northern Calcareous Alps (Austria and Germany). Cretaceous Research, 22, 429-441.

Steuber, T., Korbar, T., Jelaska, V. and Gušić, I. (2005). Strontium-isotope stratigraphy of Upper Cretaceous platform carbonates of the island of Brač (Adriatic Sea, Croatia): implications for global correlation of platform evolution and biostratigraphy. Cretaceous Research, 26, 741-756.

Tronchetti, G., 1981. Les foraminifères crétacés de Provence (Aptien à Santonien). Travaux du Laboratoire de Géologie Historique et Paléontologie Marseille, 12, 1-559.

Tronchetti, G., 1984. Influence du substrat et de la salinité dans la répartition des Foraminifères benthiques: example du Crétacé Moyen et Supérieur de Provence (SE France). Benthos ´83, 2nd International Symposium Benthic Foraminifera (Pau, April 1983), 567-571.

Tronchetti, G. and Zijlstra-Bessais, H., 2002. *Minouxia inflata* nov. sp., nouveau foraminifère benthique du Cénomanien de Tunisie. Réflexion sur les genres *Minouxia* Marie, 1854 et *Tetraminouxia* Gendrot, 1963. Revue de Paléobiologie, 21, 539-551.

Wagreich, M., 1988. Sedimentologie und Beckenentwicklung des tieferen Abschnittes (Santon-Untercampan) der Gosauschichtgruppe von Gosau und Rußbach (Oberösterreich-Salzburg). Jahrbuch der Geologischen Bundesanstalt, 131, 663-685.

Wagreich, M., 1990. Bericht 1989 über geologische Aufnahmen in der kalkalpinen Oberkreide auf Blatt 69 Großraming. Jahrbuch der Geologischen Bundesanstalt, 133, 423-433.

Wagreich, M., 1992. Correlation of Late Cretaceous calcareous nannofossil zones with ammonite zones and planktonic Foraminifera: the Austrian Gosau sections. Cretaceous Research, 13, 505-516.

Wagreich, M. and Faupl, P., 1994. Palaeogeography and geodynamic evolution of the Gosau Group of the Northern Calcareous Alps (Late Cretaceous, Eastern Alps, Austria). Palaeogeography, Palaeoclimatology, Palaeoecology, 110, 235-254.

Received: 27. March 2008
Accepted: 28. May 2008

Felix SCHLAGINTWEIT[1)*)] & Diethard SANDERS[2)]

[1)] Lerchenauerstr. 167, D-80935 München, Germany;
e-mail: ef.schlagintweit@t-online.de

[2)] Institute of Geology and Palaeontology, University of Innsbruck, Innrain 52, A-6020 Innsbruck, Austria;

[*)] Corresponding author, diethard.g.sanders@uibk.ac.at