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Konradsheim Limestone of the Gresten Klippen Zone (Austria): new insight into its stratigraphic and paleogeographic setting

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Abstract: Biostratigraphic investigations of pelitic intercalations and pebbles within the Konradsheim Limestone (Gresten Unit, "Gresten Klippen Zone") in the area of Konradsheim and Pechgraben — Maria Neustift (Lower and Upper Austria) imply that at least a part of that limestone is Cretaceous and not only Jurassic in age. In marly intercalations Foraminifera assemblages with *Caudammina ovulum* were found, in addition some pebbles in conglomeratic limestones contain Radiolaria of Early Cretaceous age. Therefore, the sedimentation of the Konradsheim Limestone lasted at least to the Early Cretaceous. The provenance of the Cretaceous Radiolaria bearing limestones is interesting, as north from the anticipated paleogeographical position of the Gresten Unit (European Platform) there are no similar deposits; they are only known from the Alpine realm. Implications for the Alpine and Carpathian geodynamic evolution are discussed.

Key words: Cretaceous, Eastern Alps, Gresten Unit, Foraminifera, Radiolaria, Konradsheim Limestone.

Introduction

Brecciated to conglomeratic whitish limestones from the "Gresten Klippen Zone" (Fig. 1) were described for the first time by Geyer (1909) in a comprehensive paper on the Geology of the Northern Calcareous Alps in Lower and Upper Austria. Trauth (1950, p. 166) named these brecciated and conglomeratic limestones "Konradsheimer Kalk" and assigned it to the Kimmeridgian–Early Tithonian. This stratigraphic view was held by all later authors (Aberer 1951; Schnabel 1970; Egger 1986; Widder 1988). Reinvestigation of the Konradsheim Limestone at the locus typicus in the village of Konradsheim and biostratigraphic researches based on Foraminifera indicate that at least a part of this limestone is younger than the Late Jurassic and represents Early Cretaceous. The further studies (Höck et al. 2003) within the Gresten Unit in the Pechgraben area have confirmed its Cretaceous age.

Geological setting

The Gresten Unit, often termed the Gresten Klippen Zone is one of the units situated today in front (Figs. 1, 2) of the Northern Calcareous Alps (NCA). It is regarded as a unit originally deposited north of the Rheno-Danubian Flysch along the southern margin of the Bohemian Massif (Oberhauser 1980; Schnabel 1992). It forms several klippen, built up of Jurassic and Lower Cretaceous deposits covered by variegated marls ("Buntmergelserie") ranging from Late Albian to Eocene (Widder 1988; Ruttner & Schnabel 1988). An extensive facies analysis about the Jurassic and Lower Cretaceous deposits has been made by Decker (1987) in a thesis with a facies and paleogeographical viewpoint.

The most characteristic lithofacies are the Gresten Beds of Early Jurassic age (Hettangian to Toarcian according to Prey 1980) with arkoses, sandstones and shales intercalated by coal in the lower part, and calcareous deposits in the upper part (Fig. 3). The Gresten Beds are covered by a sequence of marly and silty beds with some intercalations of sandy limestones (the Middle Jurassic Posidonia Marls) and by Oxfordian radi-

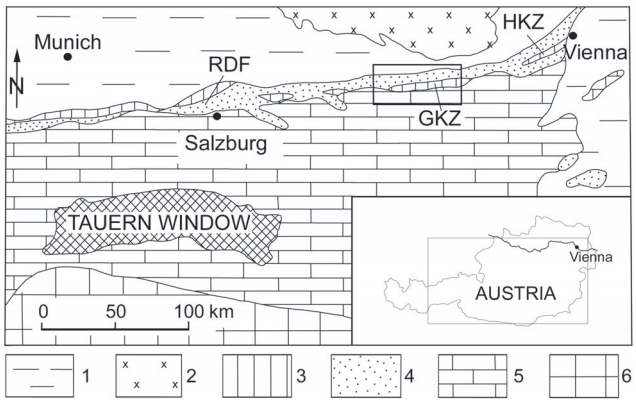


Fig. 1. Geological sketch map of the Eastern Alps with their foreland between Vienna and Munich. The small insert depicts the position of the research area shown in more detail in Fig. 2. **1** — Alpine Foredeep, **2** — Bohemian Massif, **3** — Helvetic zone including the Gresten Klippen Zone (GKZ) and the Hauptklippen Zone (HKZ), **4** — Rheno-Danubian Flysch (RDF), **5** — Austroalpine nappes, **6** — Southern Alps.

olarite (Lampelsberg Beds). The Late Jurassic and Early Cretaceous are represented by limestones and marls of various facies. These include turbiditic siliceous limestones (Scheibbsbach Beds), the red ammonite bearing nodular Arzberg limestone, which contains locally marly limestones, the dark grey micritic Arthof limestone and the Aptychus limestones (Lower Blassenstein Beds), which pass upwards into marls (Upper Blassenstein Beds). In the absence of formally determined lithostratigraphic formations we follow here the nomenclature used by Widder (1988), where the reader can find a more detailed lithological discussion. Within these sediments there are intercalations of conglomerates up to hundred meters in thickness, named Konradsheim Limestone (Konradsheimer Kalk by Trauth 1950).

This is schematically depicted in Fig. 3, which shows the general relationship of the Konradsheim Limestone with the Scheibbsbach Beds, Arthof/Arzberg limestones and Blassenstein Beds according to Widder (1988). The Konradsheim Limestone is usually developed as thick and very thick self- and matrix-supported conglomerates and sedimentary breccias, usually displaying gradation (comp. Faupl 1975). The clasts are generally represented by fragments of limestones, up to tens of centimeters in diameter. It is interpreted as a proximal channel-fill sediment along the southern margin of the European Platform (Decker 1987).

At the type locality in Konradsheim (Fig. 2) the Konradsheim Limestone is developed as a complex of massive conglomerates with thin intercalations of limestone and greenish marls. In the Pechgraben–Maria Neustift area (Fig. 2) the Konradsheim Limestone developed as intercalations of graded calcareous conglomerates within greenish marly limestones and marls (Upper Jurassic Scheibbsbach Beds) and/or within micritic limestones with *Saccocoma* and *Aptychus*, variegated marly limestones, and variegated nodular limestones (Arthofer Kalk), Kimmeridgian–Tithonian in age (Widder 1988; Schnabel 1970). The Konradsheim Limestone also occurs as separate blocks within variegated marls of Late Albian to Eocene age (Buntmergelserie), together with other blocks of various limestones and exotic blocks of granitoids (Widder 1988).

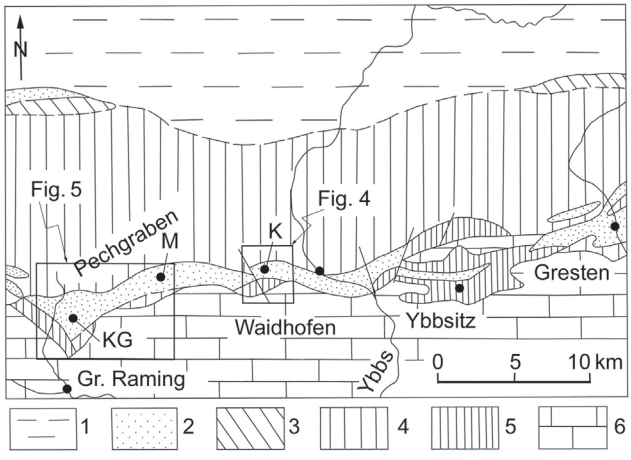


Fig. 2. Sketch map of the Gresten Unit (Gresten Klippen Zone) and adjacent units between Gresten and Pechgraben based on Schnabel (1992). The inserts show the areas displayed in Figs. 4 and 5. **1** — Alpine Foreland, **2** — Gresten Unit (Gresten Klippen Zone), **3** — Helvetic Zone, **4** — Rheno-Danubian Flysch Zone, **5** — Ybbsitz Klippen Zone, **6** — Northern Calcareous Alps, **K** — Konradsheim, **M** — Maria Neustift, **KG** — Kohlgraben.

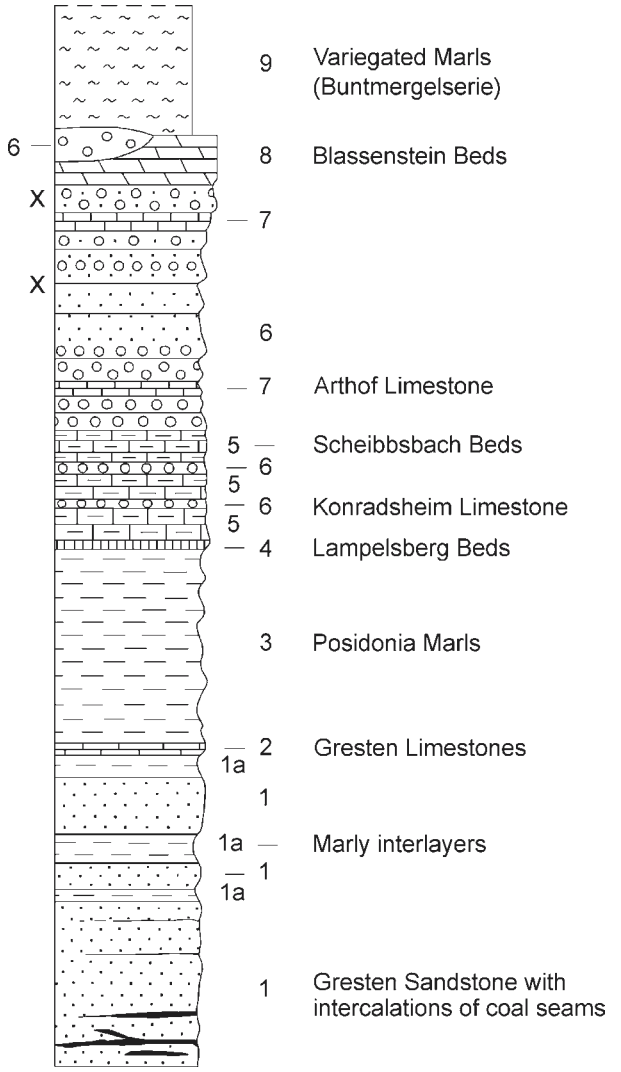


Fig. 3. Generalized lithostratigraphic column of the Gresten succession at the Höhenberg region (based on Widder 1988). × — marks the sample sites.

The age of the Konradsheim Limestone in the Konradsheim area was established by Trauth (1950) as "Malmian". This was based mainly on ammonites, which occur in the matrix of the limestone. The ammonite species found, indicate a stratigraphic range from Oxfordian to the Late Tithonian (Trauth 1950). According to various authors (Trauth 1950; Prey 1980; Tollmann 1985, Widder 1988) the age of the Konradsheim Limestone and the other limestones and marls is only poorly constrained, for example, according to Widder (1988), the Scheibbsbach Beds are the lowermost formation of all, just deposited on top of the Oxfordian Lampelsberg Beds, while Trauth (1950), Prey (1980) and Tollmann 1985) assign the former to the "Neocomian".

Generally, the Late Jurassic ("Malmian") age of the Konradsheim Limestone has been accepted (Oberhauser 1980), al-

though Schnabel (1970) mentioned the occurrence of the Cretaceous *Hormosina ovulum* (Grzybowski) in marly intercalations within the Konradsheim Limestone, which, after recent investigations, points to a Cretaceous age. In addition, Widder (1988) assumed a lowermost Neocomian age for the uppermost part of the Konradsheim Limestone.

Area of investigations

Our studies were carried out in three areas: at the Castle hill in Konradsheim village (Fig. 4), in the Finkengraben some 100 m west of this exposure and in the area between Pechgraben and the village of Maria Neustift (Fig. 5). Near Konradsheim several samples were collected from an intercalation of greenish marls between conglomerate layers of the Konradsheim Limestone, exposed at the lower bend of the road to the church (Figs. 6, 7). The Konradsheim Limestone forms here a big block within variegated marls (Buntmergelserie) more than 600 meters in length (Schnabel 1970). In the Finkengraben samples were taken from light pelitic limestones above red marls in the creek and from limestones at the southern slope of valley. In the area between Pechgraben and Maria Neustift (Fig. 5) two exposures were sampled (compare the map of Widder 1988 for the localities): several samples were taken from marly limestones and marls at the base of the Konradsheim Limestone, exposed in an abandoned quarry, situated in the area of "Höhenberg" along the road from the locality

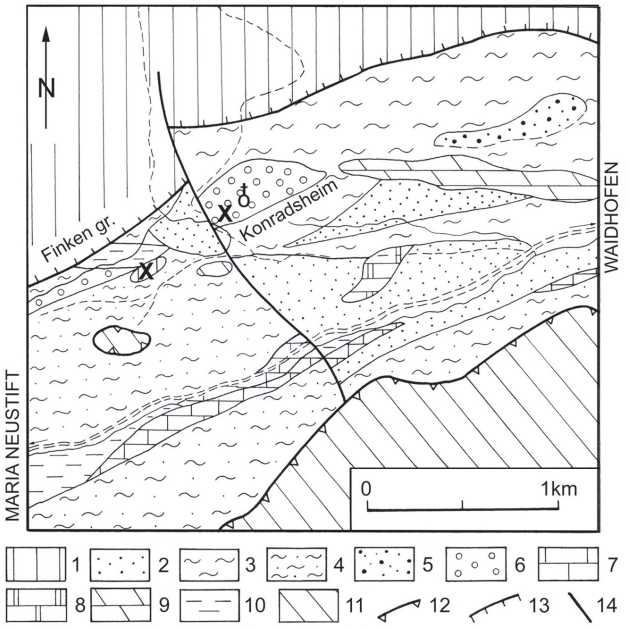


Fig. 4. Geological map of the Konradsheim area according to Schnabel (1970). **1** — Flysch Zone; **2** — Gaultflysch; **3** — Buntmergelserie; **4** — Early Cretaceous to Early Cenomanian Sandstone and Marls; **5** — Konradsheim Conglomerate; **6** — Konradsheim Limestone; **7** — Aptychus Limestone and Spotted Marl, Tithonian to Neocomian; **8** — Arzberg Limestone; **9** — Posidonia marls; **10** — Gresten Beds; **11** — Northern Calcareous Alps; **12** — Overthrust of the Northern Calcareous Alps; **13** — Overthrust of the Flysch Zone; **14** — Fault. × — sample locations of Finkengraben and Konradsheim.

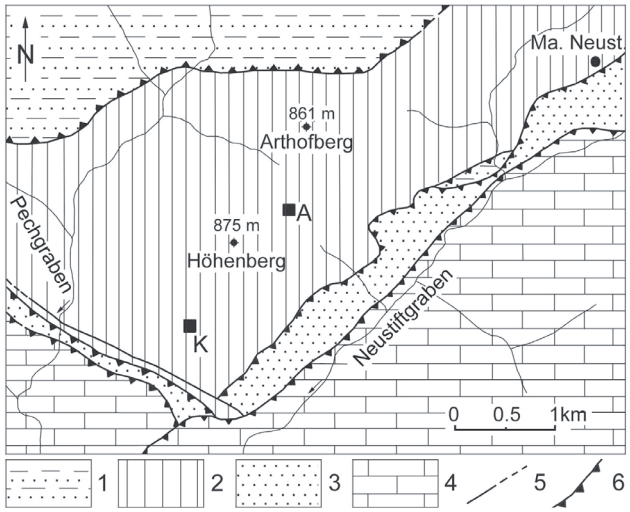


Fig. 5. Structural sketch map of the area between Pechgraben and Maria Neustift (based on Widder 1988). **1** — Rheno-Danubian Flysch Zone; **2** — Gresten Klippen Zone; **3** — Randcenoman; **4** — Northern Calcareous Alps; **5** — Faults; **6** — overthrust line. **K** — sampled site in Kohlgraben, **A** — sampled site along road towards Arthof.

Fig. 6. General view of the exposure in Konradsheim. The arrow indicates the area shown in Fig. 7.

Fig. 7. Detail of Fig. 6, Sampled site, on the bend of the road to Konradsheim. Samples 3A/2000, 4A/2000, 1A/2001, 2A/2001. The arrow shows the marly interlayers in the Konradsheim Limestone, which were sampled.

Fig. 8. Kohlgraben Quarry. At the left side medium bedded Arthof Limestone (A) according to Widder (1988) and on the right side thick bedded conglomerates of the Konradsheim Limestone (K). Arrow — sampled site: sample 19A/2000 and 6A/2001.

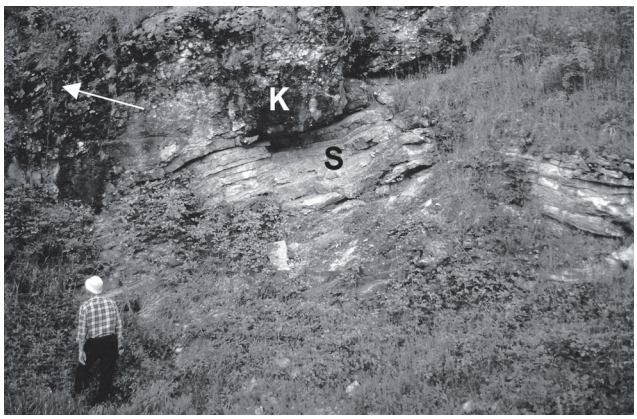


Fig. 9. Exposure along the road to Arthof. In the lower part, folded Scheibbsbach Beds (S) covered by the conglomerate of Konradsheim Limestones (K). The erosive contact between the conglomerate layer (Konradsheim Limestone) and Scheibbsbach Beds is clearly visible. Arrow — sampled site of pebbles within the conglomerate, sample 10A/2000.

"Stangl" to "Kohlgraben" (Fig. 8). Other samples were collected in the area near the locality "Arthofer" from a big exposure on a prominent bend of the road near the locality "Dichlberger" (Fig. 9). There is a complex of conglomeratic Konradsheim Limestone above the folded Scheibbsbach Beds. Samples were collected from the clasts of the conglomerates. In the Pechgraben–Maria Neustift area the Gresten sequence containing the Konradsheim Limestone forms huge separated blocks surrounded by the variegated marls of the Buntmergelserie (Widder 1988).

Micropaleontological analysis and results

Foraminifera

Standard processing methods (Glauber's salt, multiple heating and freezing) have been applied to isolate the Foraminifera. The dried residuum was sieved, with a final sieve size of 0.063 mm. Some samples have been analysed only in thin sections due to their hardness. The taxa were identified by using both, a stereoscope microscope and a SEM. In general, samples contain a scarce, badly preserved microfauna. However, the samples from the Konradsheim locality contain a relatively abundant and well-preserved microfauna.

Konradsheim locality: Foraminifera assemblages were identified in four samples. They are relatively abundant in sample 3A/2000 and contain taxa such as: *Ammodiscus/Glomospira* sp. sp. (about 90 % of the whole assemblage), *Neoflabellina* sp. (fragments), *Caudammina (Hormosina) ovulum* (Grzybowski) (Fig. 10.2,3), *Hormosina* sp., *Dorothia* cf. *oxycona* Reuss, *Rhabdammina* sp. (pyritized) and *Lenticulina* sp. Sample 4A/2000 contains a less rich assemblage than sample 3A with *Lenticulina* sp. (smooth-walled, unidentified, large specimens), *Marssonella (Dorothia) trochus* (Marsson) (Fig. 10.1), *Astacolus/Marginulina* sp. sp., *Caudammina (H.) ovulum*, *Hormosina* sp., *Pseudonodosinella troyeri* (Tappman) (Fig. 10.4), *Dentalina* sp., *Arenobulimina* indet., *Pleurostomella* sp., *Nodellum* sp., *Reophax* sp. Sample 1A/2001 and sample 2A/2001 contain an assemblage with *Lenticulina* sp. and a scarce macrofauna — *Inoceramus* prisms and redeposited shallow water elements such as corals and Bryozoa.

In this locality all Foraminifera assemblages are dominated by agglutinated taxa. For their biostratigraphical evaluation the standard zonation of agglutinated Foraminifera after Geroch & Nowak (1984) has been used. This zonation is widely applied, not only for the Polish part of the Outer Carpathians but also for the other areas (cf. Gradstein et al. 1994). Some taxa, such as *Caudammina ovulum, Marssonella trochus* and *Pseudonodosinella troyeri* are index species for the Cretaceous (Fig. 11). All three species are very characteristic, in particular *C. ovulum.* Its internal structure excludes any similarities with Jurassic taxa. However, the assemblages do not contain index calcareous benthic and planktonic Foraminifera, which would allow to determine the zones within the Cretaceous more precisely. The presence of *P. troyeri* gives a lower limit for the sedimentation of that part of the Konradsheim Limestone as Barremian. This is in agreement with the occurrence of *C. ovulum,* whose lower stratigraphic limit is Hauterivian. The upper limit is difficult to assess but the occurrences of *P. troyeri* implies that the sedimentation, not withstanding redeposition, cannot be younger than Turonian.

Finkengraben creek: sample 5A/2001 from white limestone contains: *Orbulina* sp., *Globotruncana* sp., *Tritaxia* sp., *Pleurostomella* sp., *Dorothia* sp., and prisms of *Inoceramus* sp. indicate a Late Cretaceous age.

Quarry Kohlgraben: samples 19A/2000 and 6A/2001 from marls within the Konradsheim Limestone contain Foraminifera assemblages with *Ammodiscus/Glomospira* sp. sp., *Caudammina* (*H.*) *ovulum* and also fragments of thick-walled *Inoceramus* sp. The age can be estimated as Cretaceous, not older than Barremian.

Road to Arthof: along the road**,** within the Konradsheim Limestone, sample 10A/2000 (thin section only) taken from a grey-black micrite pebble contains only fragments of foraminiferids tests: *Dorothia* sp., *Hedbergella* sp. (Cretaceous planktonic; Fig. 12.1–6) and rich Radiolaria (Spumellaria and Nas-

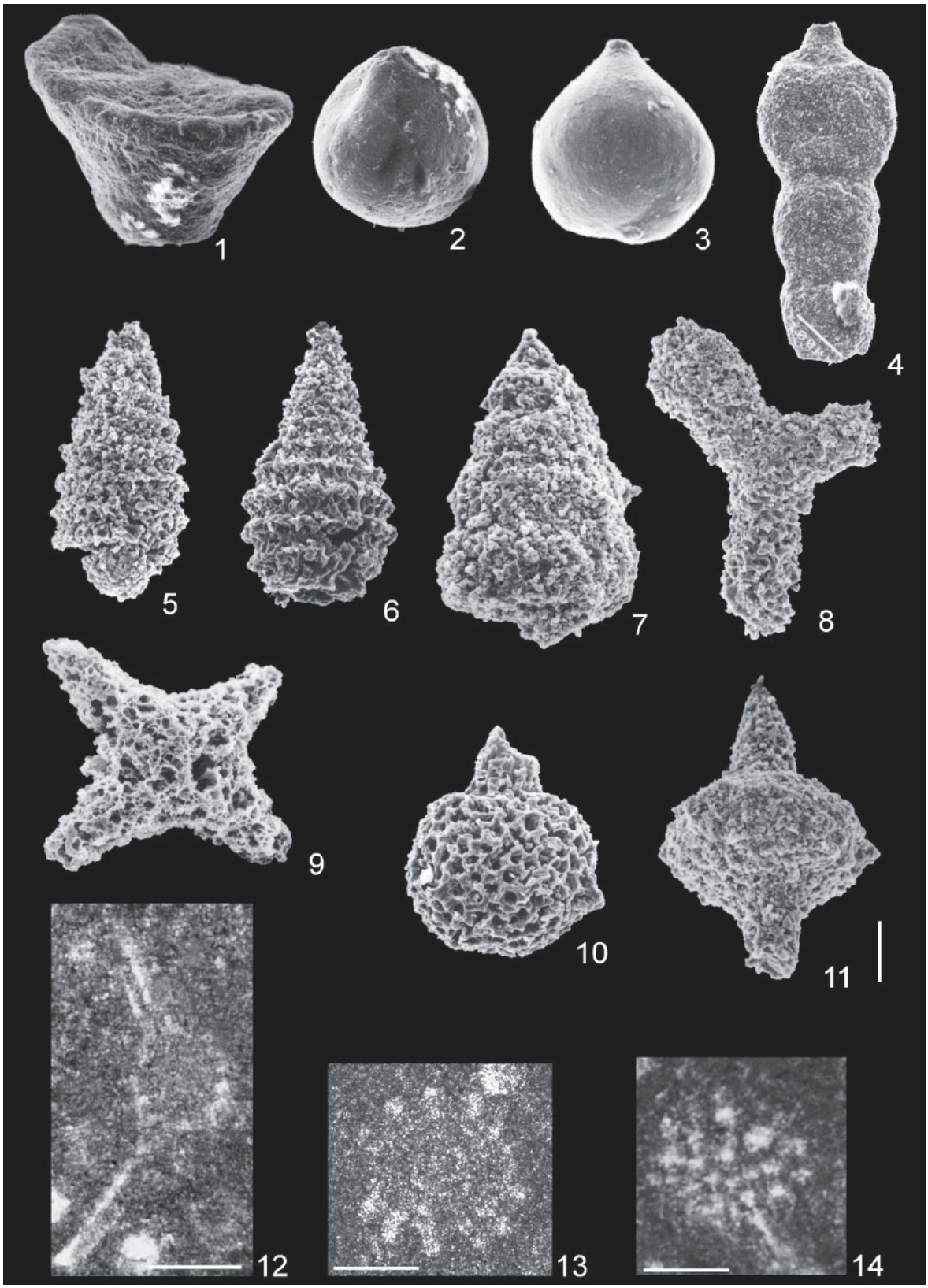
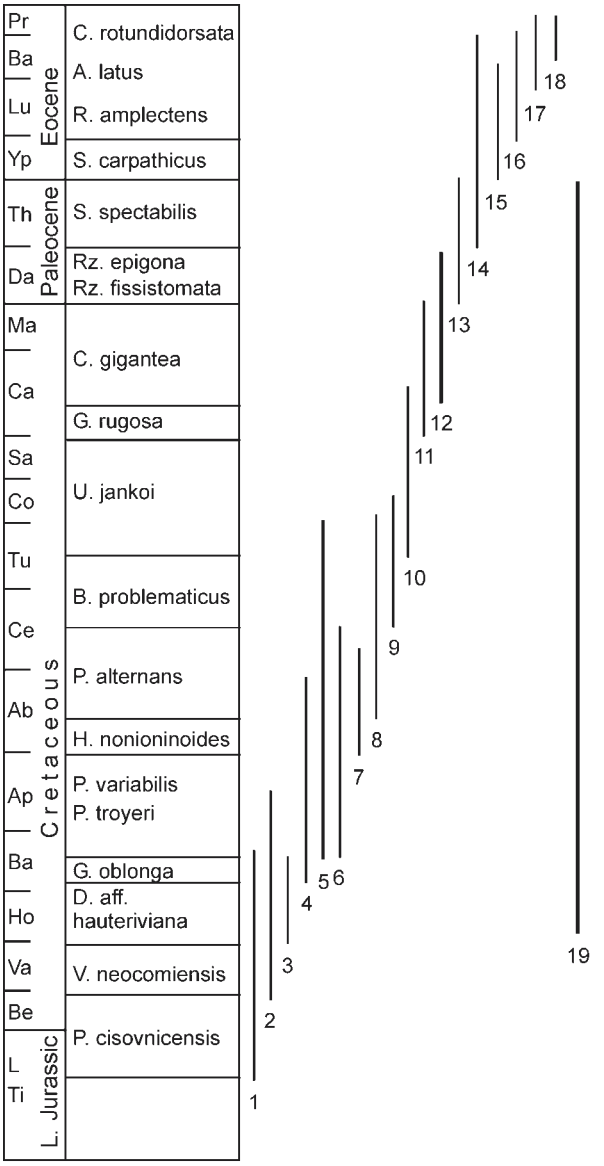


Fig. 10. Benthic Foraminifera: 1 — *Marssonella (D.) trochus*, 4A/2000; **2, 3** — *Caudammina* (*H.*) *ovulum*, 3A/2000, 4A/2000; **4** — *Pseudonodosinella troyeri*, 4A/2000. **Lower Cretaceous Radiolaria: 5, 6** — *Tethysetta mashitaensis* Mizutani, 10A/2000; **7** — *Stichomitra* aff. *asymbatos* Foreman, 10A/2000; **8** — *Paronaella* sp., 10A/2000; **9** — *Crucella* sp., 10A/2000; **10** — *Sethocapsa leiostraca* Foreman, 10A/2000; **11** — *Podobursa triacantha* (Fischli), 10A/2000; **12** — *Triactoma luciae* Jud, 10A/2000; **13** — *Pseudoaulophacus* (?) *florealis* Jud, 10A/2000; 14 — *Alievium helenae* Schaaf, 10A/2000. Scale bars = 100 μm.



1. Pseudoreophax cisovnicensis, 2. Verneuilinoides neocomiensis, 3. Dorothia aff. *hauteriviana, 4. Gaudryina oblonga, 5. Pseudonodosinella troyeri, 6. Pseudobolivina variabilis, 7. Haplophragmoides nonioninoides, 8. Plectorecurvoides alternans, 9.Bulbobaculites problematicus, 10. Uvigerinammina jankoi, 11. Goesella rugosa, 12. Caudammina gigantea, 13. Rzehakina fissistomata, 14. Spiroplectammina spectabilis, 15. Saccamminoides carpathicus, 16. Reticulophragmium amplectens, 17. Ammodiscus latus, 18. Cyclammina rotundidorsata, 19. Caudammina ovulum.*

Fig. 11. Foraminifera zonation after Geroch & Nowak 1984 (updated) and approximate ranges of index and important (bold lines) agglutinated taxa.

sellaria: see below) as well as echinoid spines. The age has been estimated as Cretaceous. A similar microfacies was found in other pebbles from this locality, but only poorly preserved.

Radiolaria

A Radiolaria microfauna is very abundant in grey, siliceous limestone pebbles (road to Arthof, Konradsheim Limestone).

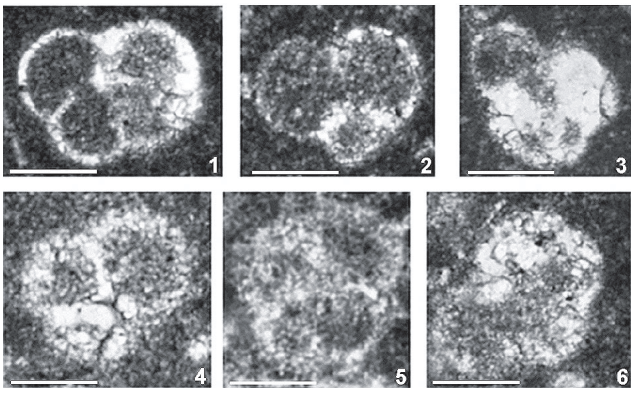


Fig. 12. Planktonic Foraminifera in thin sections: **1–6** — *Hedbergella* sp., 10A/2000. Scale bars = 100 μm.

For the biostratigraphic age determination the best preserved assemblages found in sample 10A/2000 were used. Assemblages of Radiolaria have been analysed, both in thin sections and after the extraction of skeletons from rock samples. Standard preparation methods have been used, including the treatment with diluted HF and sieving with a 0.063 mm sieve. Separated specimens are abundant, but generally poorly preserved with only a small amount of moderately to well preserved ones. In some cases a relatively intense recrystallization occurs. However, well preserved inner structures of the skeletons are visible in thin sections. The poor preservation does not allow a statistical evaluation of the microfauna, because the composition of the assemblages and their differences reflect the preservation rather than the primary faunal composition. Nevertheless, several specimens are sufficiently preserved for biostratigraphic analysis. The main component of the Radiolaria assemblage are spumellarians (about 60 % of all specimens) and nassellarians belonging to the family Sethocapsidae (Fig. 10.5–13). Multisegmented forms from the families such as: Archaeodictyomitridae, Theoperidae, Amphipyndacidae and Parvicingulidae are also present.

The composition of the radiolarian fauna in the deposits studied, and co-occurrence of *Pseudoaulophacus* (?) *florealis* Jud, *Triactoma luciae* Jud, *Pseudoeucyrtis* (?) *fusus* Jud, *Sethocapsa leiostraca* Foreman, *Podobursa triacantha* (Fischli) and *Tethysetta mashitaensis* Mizutani supports Early Valanginian age (Fig. 13), using age ranges determined from the Tethys (Baumgartner et al. 1995; Jud 1994) and North Pacific (Foreman 1975). The presence of *Tethysetta mashitaensis* Mizutani gives an upper age limit of Early Valanginian. Another taxon, *Pseudoaulophacus* (?) *florealis* Jud occurs in the Tethys for the first time in Early Valanginian and provides a lower age limit. It has to be emphasized that the described radiolarian assemblage represents a low latitude Tethyan fauna.

Discussion and conclusion

Biostratigraphic investigations of the pelitic intercalations within the Konradsheim Limestone in the areas of Konradsheim and Kohlgraben, explicitly show that those sediments are Cretaceous in age, not older than Barremian (Fig. 11).

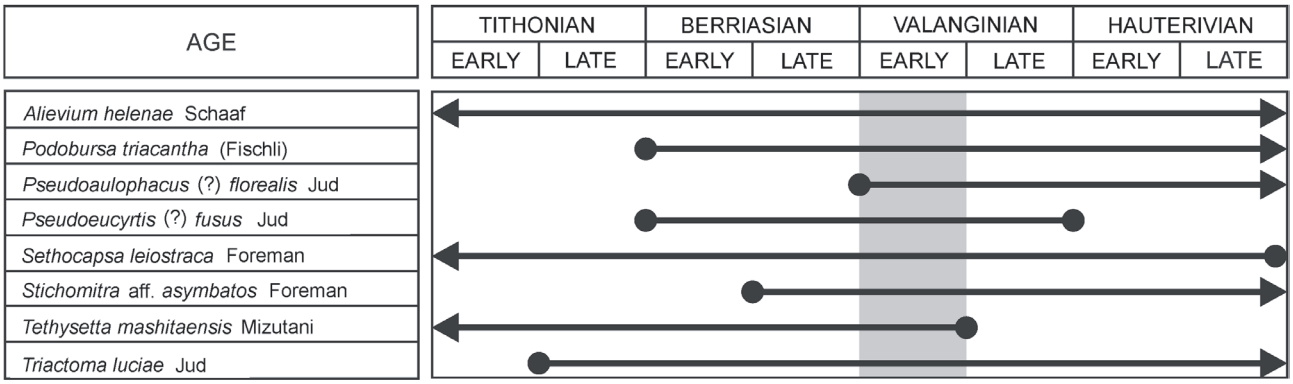


Fig. 13. Stratigraphic ranges of important Radiolaria after Baumgartner at al. (1995), Jud (1994) and Foreman (1975).

Near Arthof the occurrence of *Hedbergella* and Radiolaria in pebbles indicate that the age of the Konradsheim Limestone is younger than Early Valanginian. It should be stressed that already Schnabel (1970) mentioned the existence of a Foraminifera assemblage with *Caudammina (Hormosina) ovulum* obviously connected with the Konradsheim Limestone. The Cretaceous age of at least a part of the Konradsheim Limestones, younger than previously accepted is also supported by the occurrence of a Radiolaria assemblage of Early Cretaceous age in some of the conglomerate pebbles. The age of already rounded clasts is naturally older than the age of the host rocks. A similar co-existence of the Upper Jurassic and younger pebbles was described from conglomerates of the Gresten Unit near Scheibbs (Faupl & Schnabel 1987). The sedimentary structures of the conglomerates from the Konradsheim Limestone indicate deposits of high concentration turbidity currents and debris flows, that infilled submarine channels (Decker 1987). The occurrence of Konradsheim Limestones, and related blocks within Cretaceous–Paleogene marly deposits imply that, in some cases, they may represent resedimented bodies such as olistoliths. The provenance of the material is open to discussion, however the source area for at least a part of the pebbles of the Radiolaria-bearing limestones was most likely connected with the Tethyan realm to the South, which contradicts the paleogeographic picture accepted up to now. The similarity of the conglomerates of the Konradsheim Limestone from the Gresten Unit and a part of a sedimentary breccia — with mainly limestone clasts from the "Gruber quarry", which is a part of the Fusch Facies according to Frasl & Frank (1966); in the north-eastern part of the Tauern Window near Unterberg in the Grossarl Valley (Central Eastern Alps — Peer & Zimmer 1980; Slaczka & Höck 2000; Hoeck & Ślączka 2001) implies a possibility of a connection between both units.

The Cretaceous age of a part of the Konradsheim Limestone also creates some geotectonic questions namely: The question of the history and original position of the basin of the Gresten Unit and the position of the source area of the clastic material. It is generally accepted that this basin was situated on the southern margin of the Bohemian Massif, north of the Rheno-Danubian Flysch Zone and connected with Gresten Beds known from the basement of the Molasse Zone in the eastern part of Lower Austria (Janoschek & Matura 1980; Brix & Schulz (Eds.) 1993). However, at first their age is generally younger, Middle Jurassic (Wessely pers. com.). Secondly, in the late Middle Jurassic and in the Late Jurassic there is a significant difference between the sedimentary cover sequences of the Gresten Beds beneath the Molasse Zone and within the Gresten Unit. In the latter they are characterized by Oxfordian radiolarites, Late Jurassic red nodular and *Saccocoma*-bearing limestones as well as Late Jurassic to Early Cretaceous Aptychus limestones, which are lacking in the former area. On the other hand these Late Jurassic to Early Cretaceous facies are widespread in the Alps and in the Pieniny Klippen Belt of the Outer Carpathians. Therefore, it appears that younger deposits of the Gresten Unit and a part of the redeposited material shows more affiliation to the Tethyan realm rather than to the platform of the Bohemian Massif (see also Birkenmajer 1961). These changes of affinities with time imply that the Gresten realm was originally a part of the European Platform. During the Middle Jurassic the southern parts split off the platform and were later incorporated into the Tethyan realm as can be inferred from the appearance of the sediments from the Oxfordian radiolarites (Lampelsberg Beds) and Late Jurassic to Early Cretaceous calcareous deposits.

It needs to be stressed here that the occurrence of Gresten Beds are not only restricted to the European Platform. They are known also from the Inner Carpathians realm. Similar deposits were noted from Hungary (Mecsek Unit — Haas 2001) and from the Bihor Unit (Northern Apuseni Mts — Ianovici et al. 1976). However, it is not clear if they represent fragments split off the European Platform (Haas 2001) or represent a more local lithofacies.

The occurrence of coarse clastic deposits in the Early Cretaceous sequences of the Gresten Unit is in accordance with the Early Cretaceous appearance of similar deposits in other areas such as the north-eastern Tauern Window (Peer & Zimmer 1980; Hoeck & Ślączka 2001), the Haunsberg Wildflysch, N of Salzburg (Frasl 1987 with a contribution by E. Flügel) and the Lower Austroalpine nappes in the Hochfeind area (Schwarzeck breccia — Clar 1937; Tollmann 1977). It shows that uplifting movements during that time were more widespread within the outer part of the Tethys than was previously assumed. The position of the source rock-forming the breccias and conglomerates of the Konradsheim Limestone is not known yet. However, the facies of the pebbles point to an origin within the Tethyan realm. The source area was probably

situated on a uplifted platform between the margin of the European Platform and the Gresten Sedimentary Basin. The occurrence of olistholiths of Gresten Beds and their cover within the Late Cretaceous–Paleogene variegated marls (Buntmergelserie) shows that the uplifting movements prolonged to the Paleogene and also involved a part of the former Gresten Basin.

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