The late Middle to Late Jurassic Sedimentary Rocks of the Knallalm-Neualm Area north of Gosau (northwestern Dachstein Block, central Northern Calcareous Alps)

By

MATTHIAS AUER, HISASHI SUZUKI, FELIX SCHLAGINTWEIT & HANS-JÜRGEN GAWLICK

with 11 figures

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Address of the authors:
Montanuniversität Leoben
Department of Applied Geosciences and Geophysics
Chair of Prospection and Applied Sedimentology
Peter-Tunner-Straße 5
8700 Leoben
Austria

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Contents

Abstract

Recent mapping showed that the Knallalm-Neualm area of the northwestern Dachstein Block exhibits significantly more Jurassic rocks than previously assumed. The approximately 40 m thick siliceous succession of the Ruhpolding Radiolarite Group yielded a tremendous radiolarian fauna with 130 different species. The radiolarian association proves a Callovian to Middle Oxfordian depositional age. Two microbreccia horizons within the Ruhpolding Radiolarite Group contain Late Triassic to Middle/?Late Jurassic components of a source region similar to the local substratum. Above a thin enigmatic ?slide block horizon of yet uncertain age, only represented by loose blocks of semi-exotic Northern Calcareous Alps origin, follows an up to 150 m thick section of Plassen Formation shallow water limestones constituting the central part of the investigated area. This Plassen Limestone, formerly interpreted as Dachstein Limestone, was deposited in a Tithonian back-reef to open and closed lagoon environment. The lack of a transitional shallowing-upward sequence and the immediate start of back-reef to lagoonal sedimentation already in the lowermost Plassen Limestone part are an argument against a continuous Middle to Upper Jurassic stratigraphic succession. Considering the slide block horizon underneath, a syn- to post-Tithonian mega-slide emplacement of this Plassen Limestone occurrence has to be taken into account.

Zusammenfassung

Im Rahmen von geologischen Neuuntersuchungen im Knallalm-Neualmgebiet des nordwestlichen Dachstein Blockes konnte eine deutlich größere Verbreitung jurassischer Gesteine nachgewiesen werden, als bisher angenommen. Die circa 40 m mächtige kieselige Abfolge der Ruhpolding-Radiolarit-Gruppe lieferte eine reiche Radiolarienfauna mit 130 bestimmbaren Arten. Die Radiolarienassoziationen belegen einen Zeitraum der kieseligen Sedimentation vom Callovium bis Mittel-Oxfordium. Innerhalb der Ruhpolding-Radiolarit-Gruppe treten zwei Mikrobrekzien-Horizonte auf, deren Komponentbestand die Erosion und Umlagerung des lokalen Substrats widerspiegelt. Über der Ruhpolding-Radiolarit-Gruppe folgt ein geringmächtigen Horizont mit ortsfremdem kalkalpinem Blockmaterial, der von einem bis 150 m mächtigen Komplex von Flachwasserkalken der Plassen Formation überlagert wird, welcher das zentrale Arbeitsgebiet aufbaut. Die bisher als Dachsteinkalk gedeuteten tithonen Kalke wurden im Rückriff- bis offenen/geschlossenen Lagunen-Bereich abgelagert. Das Fehlen einer Übergangs-Sequenz, die von den radiolaritischen Beckenablagerungen zu den lagunären Seichtwasserkarbonaten überleitet, spricht gegen das Vorliegen einer vollständigen, kontinuierlichen stratigraphischen Abfolge und legt eine substantiellen Schichtausfall nahe. Für das Plassenkalk-Vorkommen des Knallalm-Neualmgebietes ist eine Platznahme im Rahmen großmaßstäblicher syn- oder post-tithoner Eingleitungvorgänge in Betracht zu ziehen.

1. Introduction

The Knallalm-Neualm area is situated on the northwestern Dachstein unit (Dachstein nappe of Tollmann 1976a, 1985; Dachstein Block of Frisch & Gawlick 2003; Fig. 1) north of the small town Gosau and east of the prominent Gamsfeld massif, and is part of the Upper Tirolic mega-unit sensu Frisch & Gawlick (2003). According to the official geological map of Austria (Sheet No. 95 St. Wolfgang; Plöchinger 1982a) the surface geology of the Knallalm-Neualm area is largely dominated by Norian to Rhaetian Dachstein Limestone with only minor occurrences of Early to Middle Jurassic red limestones and breccias, Late Jurassic siliceous rocks of the Tauglboden Formation and sparse outcrops at Gosau Group sediments of the northwesternmost rim of type-locality basin. Recent geological mapping revealed a considerably larger volume of late Middle to Late Jurassic rocks particularly in the form of a prominent occurrence of shallow water carbonates of the Plassen carbonate platform, previously assumed to be Dachstein Limestone (Friedel 1978; Plöchinger 1982a, 1982b), which occupies an area of about 0,5 km^2 (Fig. 2). This Plassen Limestone occurrence is mainly bordered by high angle faults. Only along the

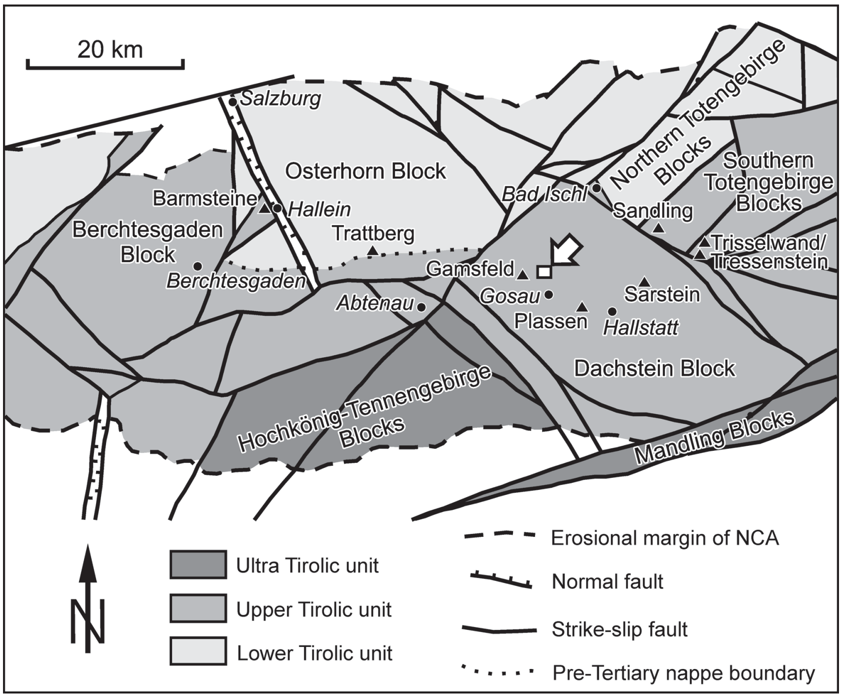


Fig. 1: Location of the Knallalm-Neualm area, indicated by a white rectangle, in the northwestern Dachstein Block (Upper Tirolic unit) of the block model of FRISCH & GAWLICK (2003).

northeastern side, in the region of the Hohe Knallam cottage, the stratigraphic succession seems to be a primary one with poorly exposed siliceous rocks of the Ruhpolding Radiolarite Group underneath, and thus adequate for the description of a local type-profile.

Apart from the correction and supplementation of the existing geological map of Austria (PLÖCHINGER 1982a) the main purpose of this article is the introduction and

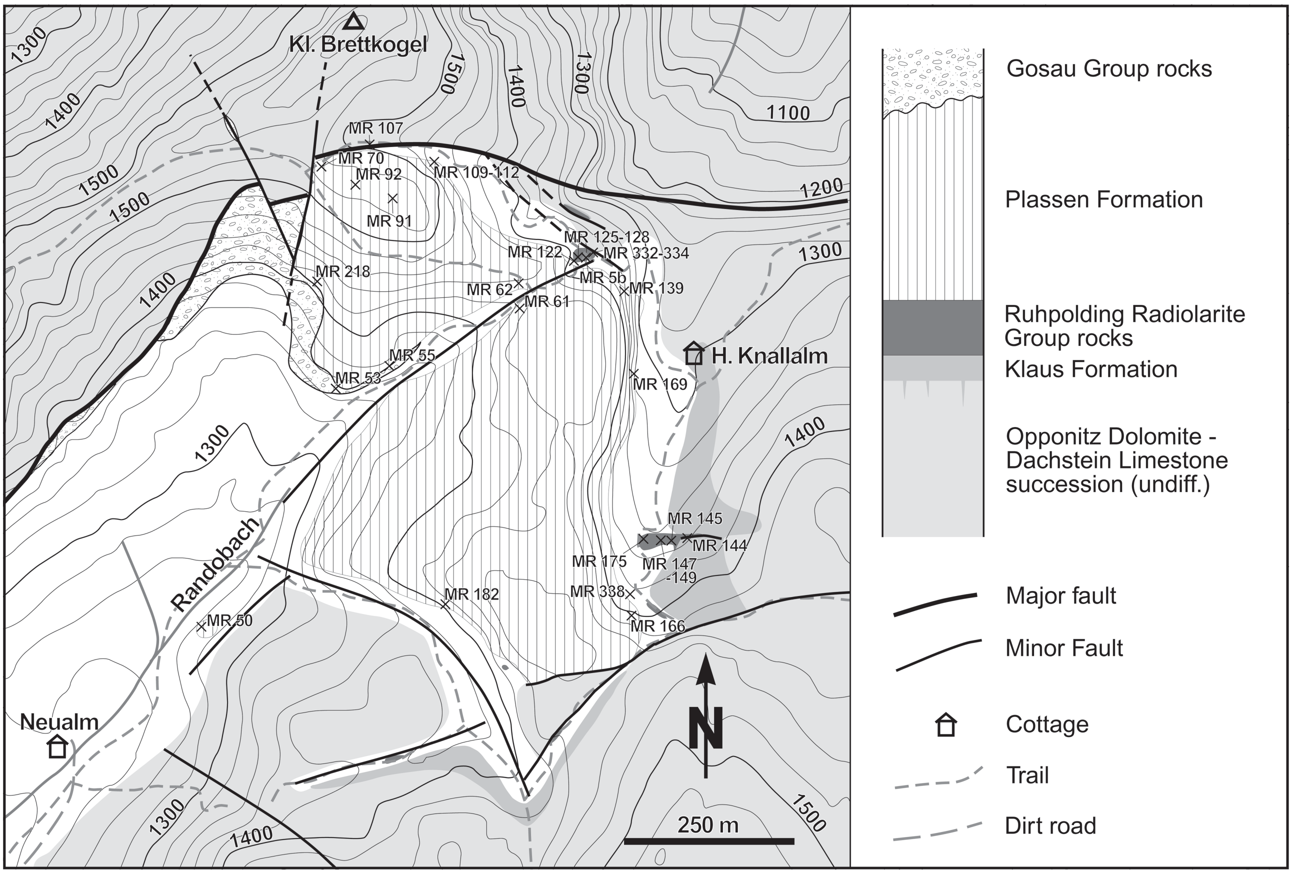


Fig. 2: Geological sketch map of the Knallalm-Neualm area including the relevant sample locations mentioned herein. Based on the official geological map of Austria (Sheet 95 St. Wolfgang; PLÖCHINGER 1982a) with major modifications. White: substratum unknown below a thick Quaternary cover.

documentation of this newly detected Plassen Formation succession with particular view on its microfacies and micropalaeontology. A second focus of concern is the analysis of the underlying sequence of the Ruhpolding Radiolarite Group which has been investigated neither lithostratigraphically nor biostratigraphically in detail yet. The siliceous, in parts marly limestones yielded a tremendous, excellently preserved late Middle to early Late Jurassic radiolarian fauna with more than hundred different species, which will be completely depicted by means of SEM photos. It will be shown and discussed that the situation of the apparently concordant and complete Middle to Late Jurassic succession is in fact more complicated.

2. Stratigraphic Framework

2.1. Stratigraphy of the central Northern Calcareous Alps

The Northern Calcareous Alps (NCA) form an E-W-elongated fold-and-thrust belt, stretching about 500 km from the Rhine valley to the Vienna Basin. They consist of a post-Variscan, Permian to Eocene sedimentary succession (TOLLMANN, 1976b). Up to the late Early Triassic mainly clastic sequences were deposited. In Middle to Late Triassic times, carbonate sedimentation prevailed with only minor intercalations of siliciclastic sediments. Dependent on their position at the passive northwestern margin of the Neotethys ocean, these carbonate successions show variable appearance and facies, with the pelagic Hallstatt zone rocks and the Hauptdolomite-Dachstein carbonate platform sediments as end members within the NCA realm (HAAS et al. 1995; GAWLICK, 2000). In the earliest Jurassic the carbonate platform drowned and a pelagic environment with far lower depositional rates and more variable, laterally rapidly changing sedimentary facies established, partially controlled by extensional tectonics (BÖHM 1992; EBLI 1997). In late Middle Jurassic time the sedimentation significantly changed with the regional deposition of radiolarian cherts (Ruhpolding Radiolarite Group; DIERSCHE 1980; GAWLICK & FRISCH 2003). In the southern to central NCA, radiolaritic carbonate clastic flysch sedimentation was strongly affected by active margin processes due to the closure of the Neotethys ocean (GAWLICK et al. 1999; GAWLICK & FRISCH, 2003). Shallow water carbonate deposition started around the Oxfordian-Kimmeridgian boundary with the Plassen carbonate platform, successively prograding over the former radiolarite basins and finally sealing them (GAWLICK & FRISCH 2003). Drowning of the Plassen carbonate platform took place in the Berriasian (GAWLICK & SCHLAGINTWEIT 2006) and was followed by turbiditic siliciclastic-rich basin sedimentation (Rossfeld Formation) generally assumed to be connected with „pre-Gosau" nappe stacking in late Early to mid-Cretaceous times (e.g. TOLLMANN 1976a; FAUPL & TOLLMANN 1979). The Gosau Group sediments (Turonian to Eocene) sealed the early Alpine structures, however, were themselves affected by intense syn- and post-Gosau deformation (e.g. SCHWEIGL & NEUBAUER 1997).

2.2. Stratigraphic Succession of the Knallalm-Neualm Area

The sedimentary succession of the investigated area

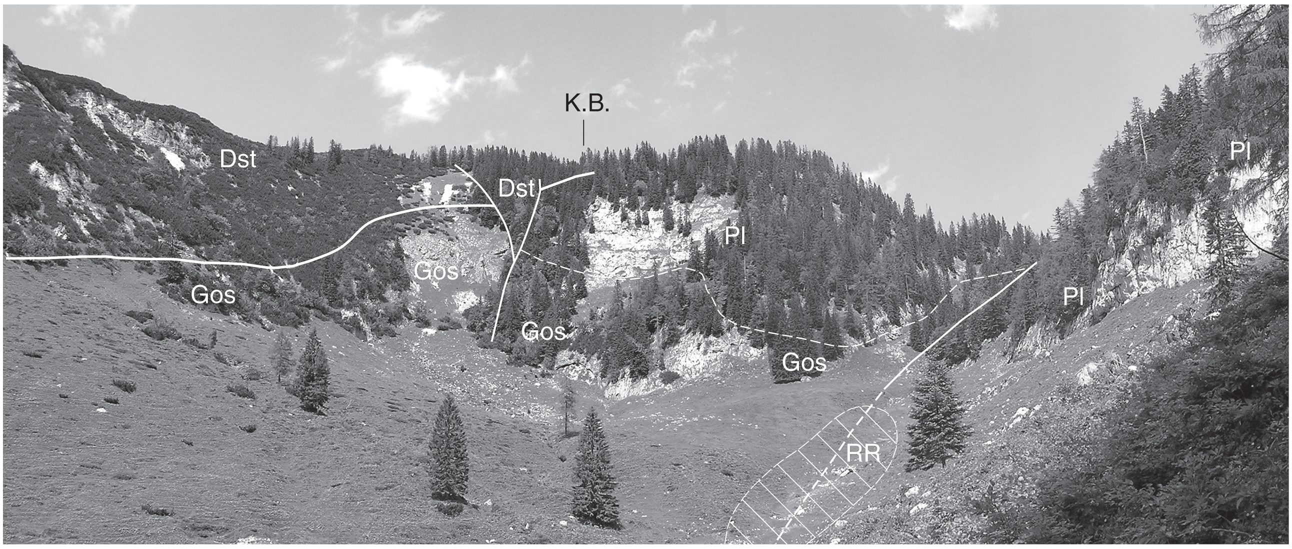


Fig. 3: Northward view from nearby the Neualm cottage (close to sample location MR 50 – Fig. 2) to the western Plassen Formation mountain ridge which borders along a prominent high-angle fault with several hundreds of metres of vertical offset (SE side down) against Norian lagoonal Dachstein Limestone. The Gosau Group is represented on the one hand by almost monomict basal breccias which rest primarily on Plassen Limestone along a strongly rugged surface cutting deeply into the substratum (right hand side), and on the other hand by polymict scarp breccias along the major fault bordering the Gamsfeld massif, which are strongly dominated by (Norian) Dachstein Limestone components. Abbreviations: Dst = Dachstein Limestone, RR = Ruhpolding Radiolarite Group (here only in the form of debris), Pl = Plassen Formation, Gos = Gosau Group rocks; K.B. = Kleiner Brettkogel.

comprises the range from the Norian Dachstein carbonate platform rocks to Late Cretaceous Gosau Group sediments (Fig. 2). Following above Carnian Opponitz Dolomites, the more than 1000 m thick Dachstein Limestone succession of the Knallalm-Neualm area senso lato (e.g. Gamsfeld massif) represents the lagoonal facies deposits of the Norian to Rhaetian carbonate platform with loferitic cyclic sedimentation. Despite rather limited thickness of less than 100 m fossil-rich wackestones to packstones of the Rhaetian Dachstein Limestone, e.g. with *Triasina hantkeni* and *Coptocampylodon rhaeticus*, strongly dominate the surface geology of the core area. The uppermost, often oolitic Dachstein Limestone is overlain by flat layered, mostly 10 to 20 m thick red limestones of the Klaus Formation rich in filaments, foraminifers, crinoids, nodosarides and protoglobigerines. Limestones of the Adnet Formation (Friedel 1978) are apparently missing. Cherty ribbons and layers mark the transition to the siliceous succession of the Ruhpolding Radiolarite Group with an overall thickness of about 40 m. On top of the calcareous radiolarites a thin ?slide mass horizon is only proven by semi-outcrops and debris. The overlying, up to about 150 m thick succession of the Plassen Formation makes up the central area of investigation and consists of bright whitish, mostly massive limestones. North of the Neualm cottage Gosau Group breccias not only border along steep syn-sedimentary faults against Dachstein Limestone and Plassen Formation (Wagreich & Faupl 2001), but also lay primarily along a karstified, erosional surface on Plassen Limestone (Fig. 3).

3. Stratigraphy and Facies

3.1. Ruhpolding Radiolarite Group

Siliceous rocks of the Ruhpolding Radiolarite Group are widespread in the Knallalm-Neualm area. However, whilst residual radiolarite debris is omnipresent in the grasslands around the Plassen Limestone massif, outcrops of noteworthy size and stratigraphic spread are rare and in fact restricted to two main locations (see Fig. 2): One about 300 m south of the Hohe Knallalm cottage exposing the lower to middle part of the stratigraphic unit and one about 250 m northwest of the latter, displaying the middle and upper parts of the section. However, also at these locations no complete profile across the Ruhpolding Radiolarite Group but only a few short partial sections exist.

3.1.1. Lithostratigraphy of the calcareous Radiolarites and the intercalated Microbreccias

The basal portion of the radiolaritic succession including the transition from the red limestones of the Klaus Formation can nicely be seen 300 m south of the Hohe Knallalm cottage. Some metres east of the trail in an up-side-down succession of a recumbent anticline´s forelimb the Ruhpolding Radiolarite Group starts with red irregular to well bedded siliceous limestones, about 2 m thick. After some metres of non-exposure the red colours change to this conspicuous ochre shade strongly predominating the higher parts of the stratigraphic unit. About 12 m above the formation basis an approximately 1 m thick polymict microbreccia-horizon is intercalated with up to 3-4 mm sized poorly to moderately rounded components mainly of the Klaus Formation. Above, another about 12 m of gradually more marly, ochre calcareous radiolarites are patchily documented (Fig. 4). Here, the younger part of the section is covered by debris from the Plassen Limestone cliff arising steeply some tens of metres farther to the west.

At the second outcrop location about 250 m northwest of the Hohe Knallalm cottage an overall stratigraphic spread of circa 30 metres of siliceous sediments is scarcly documented. The stratigraphically lowermost Ruhpolding Radiolarite Group rocks documented at this place are presented by a microbreccia (microbreccia horizon 1) and tectonically brecciated radiolarite. Again, the microbreccia is polymict with a strong predominance of Klaus Formation clasts. Above a large gap in exposure the upper 15 m of the stratigraphic unit are comparably well documented, often displaying ribbonchert and cherty layers of the section. Most important is another microbreccia occurrence (microbreccia horizon 2) near the very top of the radiolarite succession. It is about 70 cm thick and shows, compared to the other microbreccia horizon(s) already mentioned, a larger component spectrum and a more balanced polymict character (Fig. 5). Stratigraphic units recognised are: ?Carnian lagoonal dolomite and hypersaline clasts (?Opponitz dolomite), lagoonal Dachstein Limestone of Norian (?to Rhaetian) age, Rhaetian oolitic limestone (uppermost Dachstein Limestone), pelagic grey marly limestone (?Enzesfeld Formation, Liassic), crinoid limestone of the Hierlatz type (Liassic), *Bositra* filament limestone of the Klaus Formation (Dogger), calcareous radiolarites of the Ruhpolding Radiolarite Group and shallow water micrite and single yellowish brown ooids supposedly of Late Jurassic age. Except for the Liassic marly limestones and the Late Jurassic carbonates, all lithologies can be found in or nearby the Knallalm-Neualm area suggesting rather short distance transportation of the components. Above the microbreccia there are only some decimetres of calcareous radiolarites forming the highest exposed level of the Ruhpolding Radiolarite Group (Fig. 4). If this is the actual top of the stratigraphic unit, however, is unclear due to the cover of vegetation.

3.1.2. Radiolarian Biostratigraphy

Across the complete section samples have been taken for the investigation on radiolarians. The excellently preserved radiolarian fauna was age-assessed based on the radiolarian zonation for the NCA compiled by Suzuki & Gawlick (2003a). On this matter, considering the microfacies of the radiolarites (see Fig. 4), the danger of falsification due to mobilization and resedimentation processes must be kept in mind. However, regarding the fragility of the subjects and the only rough resolution of the radiolarian biostratigraphy, the probability of receiving radiolarians of substantial older stratigraphic levels seems to be negligible. Overall, 130 individual species have been determined. The

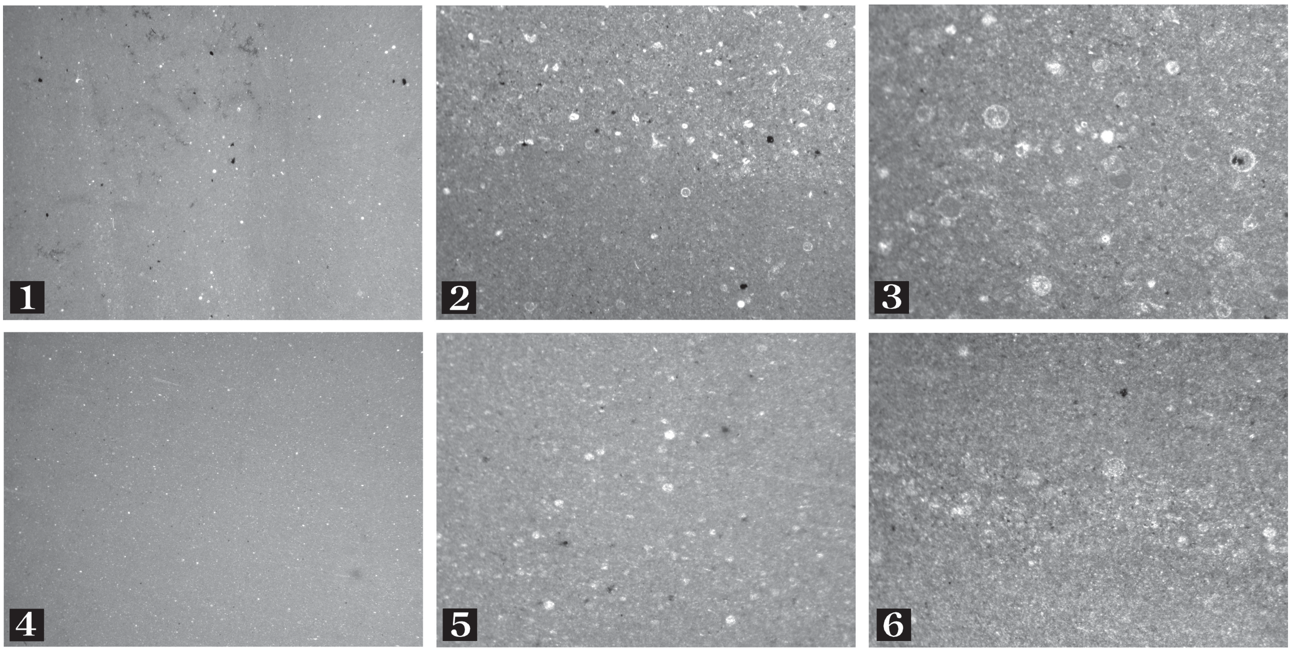


Fig. 4: Microfacies of the Callovian to Oxfordian calcareous radiolarites of the Knallalm-Neualm area (see Fig. 2 for location):
1. Ochre calcareous radiolarite of Early to Middle Oxfordian age, not bioturbated, with pyrite. Radiolarians, often recrystallized to calcite, occur in matrix supported texture. Size in width = 1.4 cm; sample MR 125.
2. Enlargement of (1). The radiolarians were enriched by low velocity – low density turbidites. Most radiolarian skeletons occur as calcite pseudomorphs, whilst they are quartz-preserved in some turbiditic layers. Size in width = 0.5 cm; sample MR 125.
3. Enlargement of (2). Radiolarian wacke- to packstone. In this layer many radiolarians are well-preserved and occur as quartz. Size in width = 0.25 cm; sample MR 125.
4. Thin-bedded to platy marly radiolarite, ochre, Callovium. The individual layers are mostly homogenous radiolarian wackestones. Size in width = 1.4 cm; sample MR 175.
5. Enlargement of (4). Radiolarian wackestone with pyrite. The radiolarians occurring in the matrix supported texture are often recrystallized to calcite. Size in width = 0.5 cm; sample MR 175.
6. Thin turbiditic layer with partly well preserved radiolarians. Size in width = 0.25 cm; sample MR 175.

mentioned samples yielded the following fauna (sample locations in numeric order; for SEM pictures of the complete Knallalm-Neualm radiolarian fauna see Fig. 6):

Sample **MR 5b** (250 m northwest of the Hohe Knallalm cottage) – ochre calcareous radiolarite with cherty ribbons and layers:
Archaeodictyomitra cf. *amabilis* AITA, 1987; *Archaeodictyomitra apiarium* (RÜST, 1885); *Archaeodictyomitra mitra* DUMITRICA, 1997 in DUMITRICA et al. 1997; *Archaeodictyomitra rigida* PESSAGNO, 1977; *Archaeodictyomitra sixi* YANG, 1993; *Archaeodictyomitra* sp. B sensu WEGERER et al., 2001; *Archaeospongoprunum* sp.; *Cinguloturris carpatica* DUMITRICA, 1982; *Dictyomitrella* cf. *kamoensis* MIZUTANI & KIDO, 1983; *Droltus galerus* SUZUKI, 1995; *Droltus hecatensis* PESSAGNO & WHALEN, 1982; *Eucyrtidiellum circumperforatum* CHIARI, MARCUCCI & PRELA, 2002; *Eucyrtidiellum nodosum* WAKITA, 1988; *Eucyrtidiellum unumaense pustulatum* BAUMGARTNER, 1984; *Eucyrtidiellum unumaense unumaense* (YAO, 1979); *Gongylothorax* aff. *favosus* DUMITRICA, 1970; *Gongylothorax* sp. C sensu SUZUKI & GAWLICK, 2003; *Gorgansium* cf. *morganense* PESSAGNO & BLOME, 1980; *Gorgansium* cf. *xigazeense* WU, 1993; *Hiscocapsa* cf. *hexagona* (HORI, 1999); *Hiscocapsa* cf. *magniglobosa* (AITA, 1987); *Hsuum baloghi* GRILL & KOZUR, 1986; *Hsuum brevicostatum* (OZVOLDOVA, 1975); *Hsuum maxwelli* PESSAGNO, 1977; *Loopus doliolum* DUMITRICA, 1997; *Parahsuum* aff. *simplum* YAO, 1982; *Parahsuum* sp. S sensu MATSUOKA, 1986; *Parvicingula cappa* CORTESE, 1993; *Parvicingula spinata* (VINASSA, 1899); *Parvifavus* sp. A; *Podobursa* aff. *nodosa* (CHIARI, MARCUCCI & PRELA, 2002); *Praewilliriedellum spinosum* KOZUR, 1984; *Pseudodictyomitra* sp. D sensu MATSUOKA & YAO, 1985; *Pseudodictyomitrella spinosa* GRILL & KOZUR, 1986; *Quarticella* sp. C sensu CHIARI et al., 2002; *Saitoum* cf. *levium* DE WEVER, 1981; *Sphaerostylus lanceola* (PARONA, 1890); *Spongotripus* sp.; *Stichocapsa naradaniensis* MATSUOKA, 1984; *Stichomitra annibill* KOCHER, 1981; *Stylocapsa catenarum* MATSUOKA, 1982; *Stylocapsa oblongula* KOCHER, 1981; *Tetracapsa* sp. A sensu SUZUKI & GAWLICK, 2003; *Tetracapsa* sp. B; *Theocapsomma costata* CHIARI, MARCUCCI & PRELA, 2002; *Tricolocapsa conexa* MATSUOKA, 1983; *Tricolocapsa* aff. *conexa* MATSUOKA, 1983; *Tricolocapsa fusiformis* YAO, 1979; *Tricolocapsa* cf. *parvipora* TAN, 1927; *Tricolocapsa undulata* (HEITZER, 1930); *Tricolocapsa* sp. A sensu OZVOLDOVA, 1992; *Tricolocapsa* sp. C; *Tricolocapsa* sp. M sensu BAUMGARTNER et al., 1995; *Tritrabs* cf. *casmaliaensis* (PESSAGNO, 1977); *Triversus hexagonatus* (HEITZER, 1930); *Triversus* cf. *hungaricus* (KOZUR, 1985); *Unuma* cf. *gorda* HULL, 1997; *Williriedellum carpathicum* DUMITRICA, 1970; *Williriedellum dierschei* SUZUKI & GAWLICK, 2004 in GAWLICK et al. 2004; *Williriedellum marcucciae* CORTESE, 1993; *Williriedellum sujkowskii* WIDZ & DE WEVER, 1993; *Wrangellium* sp.; *Zhamoidellum exquisitum* HULL, 1997; *Zhamoidellum ovum* DUMITRICA, 1970; *Zhamoidellum* cf. *ventricosum* DUMITRICA, 1970.
Biostratigraphic interpretation of MR 5b: The maximum age range is given by the occurrence of *Zhamoidellum ovum*

(Early Callovian to Early Tithonian; Suzuki & Gawlick 2003a), the minimum age by *Eucyrtidiellum unumaense* and *Williriedellum marcucciae* (Middle Oxfordian, Beccaro 2004). Overall, the radiolarian fauna has to be assigned to the lower to middle parts of the *Zhamoidellum ovum*-zone (Callovian to Middle Oxfordian) of Suzuki & Gawlick (2003a; modified according to Beccaro 2004, Suzuki et al. 2004), and herein, due to the absence of *Protonuma lanosus* and to the presence of *Stylocapsa catenarum*, probably to the *Williriedellum dierschei* subzone (Early to Middle Oxfordian).

Sample **MR 125** (250 m northwest of the Hohe Knallalm cottage, approx. 10 m higher in the succession than MR 5b) – ochre calcareous radiolarite, directly overlying the upper microbreccia horizon; at the same time the uppermost occurrence of Ruhpolding Radiolarite Group rocks: *Amphipyndax durisaeptum* Aita, 1987; *Angulobracchia* sp.; *Archaeodictyomitra minoensis* (Mizutani, 1981); *Archaeodictyomitra rigida* Pessagno, 1977; *Archaeodictyomitra sixi* Yang, 1993; *Cinguloturris* cf. *carpatica* Dumitrica, 1982; *Dictyomitrella kamoensis* Mizutani & Kido, 1983; *Droltus* aff. *hecatensis* Pessagno & Whalen, 1982; *Emiluvia premyogii* Baumgartner, 1984; *Eucyrtidiellum circumperforatum* Chiari, Marcucci & Prela, 2002; *Eucyrtidiellum nodosum* Wakita, 1988; *Eucyrtidiellum ptyctum* (Riedel & Sanfilippo, 1974); *Eucyrtidiellum semifactum* Nagai & Mizutani, 1990; *Eucyrtidiellum unumaense pustulatum* Baumgartner, 1984; *Eucyrtidiellum unumaense* ssp. (Yao, 1979); *Gongylothorax favosus* Dumitrica, 1970; *Gongylothorax* aff. *favosus* Dumitrica, 1970; *Gongylothorax* sp. C sensu Suzuki & Gawlick, 2003; *Hsuum brevicostatum* (Ozvoldova, 1975); *Hsuum maxwelli* Pessagno, 1977; *Loopus doliolum* Dumitrica, 1997; *Parvicingula cappa* Cortese, 1993; *Parvicingula mashitaensis* Mizutani, 1981;

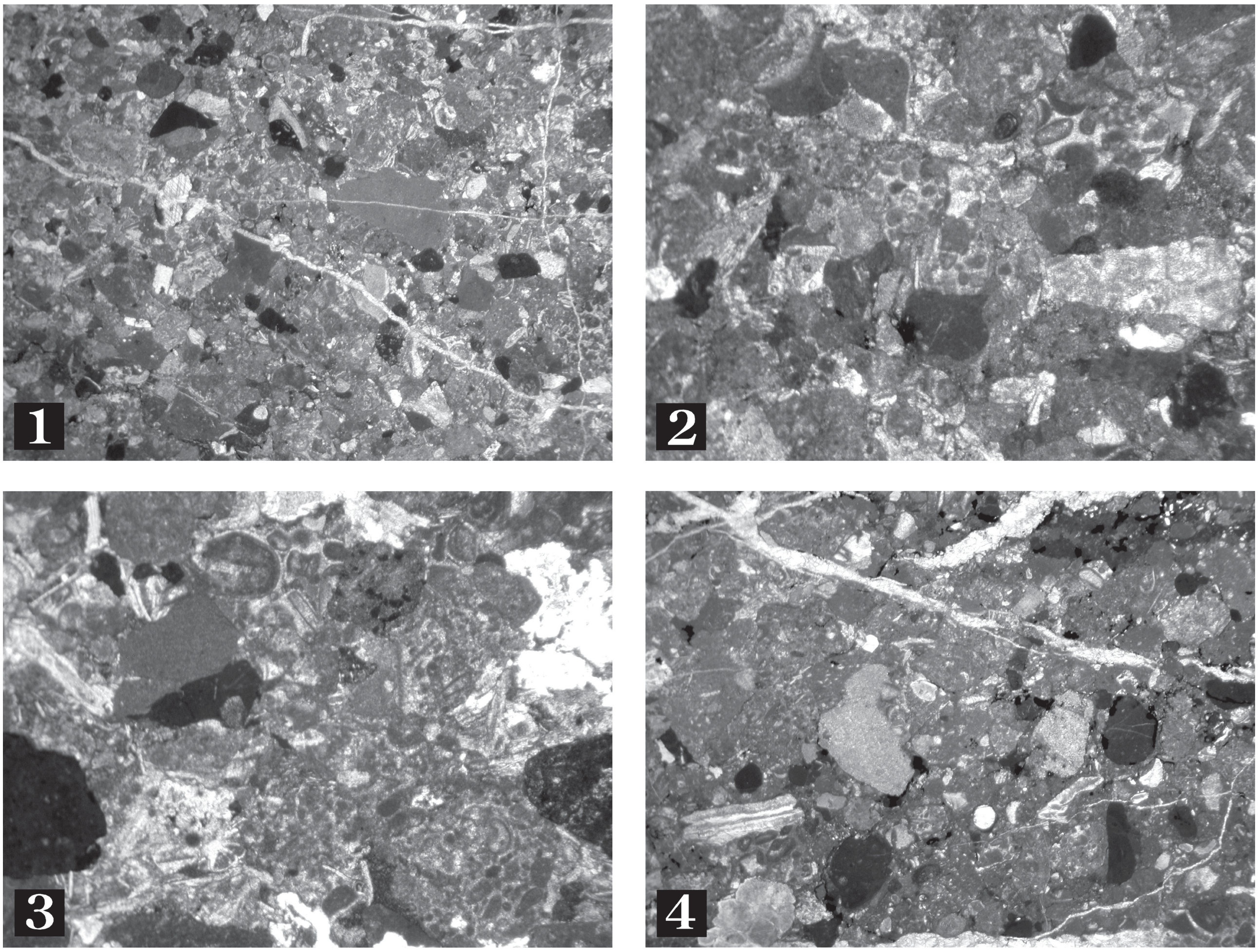


Fig. 5: Images from microbreccia horizon 2 which shows a larger component spectrum than microbreccia horizon 1 (see Fig. 2 for location):

1. Polymict carbonate breccia with Triassic to Jurassic clasts of a mobilized sequence typical for the northern Upper Tirolic unit, e.g. with Norian to Rhaetian lagoonal Dachstein Limestone, ?Middle Jurassic Bositra limestones and ?Late Jurassic ooids. Size in width = 1.4 cm; sample MR 126.
2. Enlargement of (1). Polymict carbonate breccia with Rhaetian oolitic limestone, dolomites and different Late Jurassic shallow water material. Size in width = 0.5 cm; sample MR 126.
3. Different Triassic and Jurassic clasts, e.g. Norian Dachstein Limestone, Klaus Limestone and different Late Jurassic shallow water material. Size in width = 0.5 cm; sample MR 127.
4. MR 128. Polymict breccia with clasts made up e.g. of Dachstein Limestone, pseudomorphs after gypsym, radiolarite, and different Middle Jurassic wackestones. Size in width = 1.4 cm; sample MR 128.

Parvicingula spinata (VINASSA, 1899); *Praewilliriedellum spinosum* KOZUR, 1984; *Protunuma* cf. *multicostatus* (HEITZER, 1930); *Pseudodictyomitra* sp. D sensu MATSUOKA & YAO, 1985; *Pseudoeucyrtis* sp. J sensu BAUMGARTNER et al., 1995; *Quarticella ovalis* TAKEMURA, 1986; *Saitoum levium* DE WEVER, 1981; *Sphaerostylus lanceola* (PARONA, 1890); *Spongocapsula* sp.; *Spongotripus* sp.; *Stichocapsa cicciona* CHIARI, MARCUCCI & PRELA, 2002; *Stichocapsa convexa* YAO, 1979; *Stichocapsa naradaniensis* MATSUOKA, 1984; *Stichocapsa robusta* MATSUOKA, 1984; *Stichocapsa* sp. E sensu BAUMGARTNER et al., 1995; *Stichomitra* cf. *annibill* KOCHER, 1981; *Stylocapsa catenarum* MATSUOKA, 1982; *Stylocapsa oblongula* KOCHER, 1981; *Stylocapsa spiralis* MATSUOKA, 1982; *Tetracapsa himedaruma* (AITA, 1987); *Tetracapsa* sp. A sensu SUZUKI & GAWLICK, 2003; *Theocapsomma cordis* KOCHER, 1981; *Theocapsomma costata* CHIARI, MARCUCCI & PRELA, 2002; *Theocapsomma cucurbiformis* BAUMGARTNER, 1995; *Tricolocampe magnipora* (CHIARI, MARCUCCI & PRELA, 2002); *Tricolocapsa conexa* MATSUOKA, 1983; *Tricolocapsa plicarum* YAO, 1979; *Tricolocapsa undulata* (HEITZER, 1930); *Tricolocapsium* sp. A; *Triversus hexagonatus* (HEITZER, 1930); *Triversus hungaricus* (KOZUR, 1985); *Unuma* sp.; *Williriedellum carpathicum* DUMITRICA, 1970; *Williriedellum crystallinum* DUMITRICA, 1970; *Williriedellum dierschei* SUZUKI & GAWLICK, 2004 in GAWLICK et al. 2004; *Williriedellum glomerulus* (CHIARI, MARCUCCI & PRELA, 2002); *Williriedellum marcucciae* CORTESE, 1993; *Wrangellium* aff. *hsuei* (PESSAGNO, 1977); *Zhamoidellum ovum* DUMITRICA, 1970; *Zhamoidellum ventricosum* DUMITRICA, 1970.

The occurrences of *Eucyrtidiellum unumaense* and *Williriedellum marcucciae* set the upper limit to Middle Oxfordian (BECCARO 2004). *Stylocapsa spiralis*, *Stylocapsa catenarum*, *Williriedellum dierschei*, *Stichocapsa robusta*, *Pseudodictyomitra* sp. D and *Zhamoidellum ovum* and the absence of *Protonuma lanosus* determine sample MR 125 into the *Williriedellum dierschei* subzone of the *Zhamoidellum ovum* zone (Early to Middle Oxfordian; SUZUKI & GAWLICK 2003a modified according to BECCARO 2004, SUZUKI et al. 2004).

Sample **MR 144** (300 m south of the Hohe Knallalm cottage) – red calcareous radiolarite stratigraphically about 1 m above the top of the Klaus Formation-type red limestones (in fact appearing 1 m below the top Klaus Formation as the sequence is upside-down):

Archaeodictyomitra minoensis (MIZUTANI, 1981); *Archaeodictyomitra rigida* PESSAGNO, 1977; *Eucyrtidiellum* cf. *unumaense* (YAO, 1979); *Gongylothorax favosus* DUMITRICA, 1970; *Loopus doliolum* DUMITRICA, 1997; *Pseudodictyomitra* sp.; *Triversus hexagonatus* (HEITZER, 1930).

The less well-preserved, only sparse radiolarian fauna can be allocated the *Protunuma lanosus* to *Williriedellum dierschei* subzone of the *Zhamoidellum ovum* zone (Callovian to Middle-Oxfordian; SUZUKI & GAWLICK 2003a, modified according to BECCARO 2004, SUZUKI et al. 2004).

Sample **MR 149** (300 m south of the Hohe Knallalm cottage, approx. 10 m higher in stratigraphy higher than MR 144) – marly ochre calcareous radiolarite directly above the microbreccia horizon:

Acanthocircus cf. *suboblongus* (YAO, 1972); *Alievium* sp.; *Archaeodictyomitra amabilis* AITA, 1987; *Archaeodictyomitra apiarium* (RÜST, 1885); *Archaeodictyomitra* cf. *minoensis* (MIZUTANI, 1981); *Archaeodictyomitra mitra* DUMITRICA, 1997 in DUMITRICA et al. 1997; *Archaeodictyomitra rigida* PESSAGNO, 1977; *Archaeospongoprunum* sp.; *Cinguloturris carpatica* DUMITRICA, 1982; *Dictyomitrella kamoensis* MIZUTANI & KIDO, 1983; *Emiluvia* cf. *bisellea* DANELIAN, 1995; *Eucyrtidiellum* cf. *circumperforatum* CHIARI, MARCUCCI & PRELA, 2002; *Eucyrtidiellum nodosum* WAKITA, 1988; *Eucyrtidiellum ptyctum* (RIEDEL & SANFILIPPO, 1974); *Eucyrtidiellum unumaense pustulatum* BAUMGARTNER, 1984; *Eucyrtidiellum unumaense* ssp. (YAO, 1979); *Gongylothorax favosus* DUMITRICA, 1970; *Gongylothorax* aff. *favosus* DUMITRICA, 1970; *Gorgansium* sp.; *Homoeoparonaella* sp.; *Hsuum brevicostatum* (OZVOLDOVA, 1975); *Hsuum hisuikyoense* ISOZAKI & MATSUDA, 1985; *Hsuum maxwelli* PESSAGNO, 1977; *Lithocampium* sp. C; *Loopus doliolum* DUMITRICA, 1997; *Neorelumbra skenderbegi* CHIARI, MARCUCCI & PRELA, 2002; *Napora* sp.; *Paronaella* sp.; *Parvicingula cappa* CORTESE, 1993; *Parvifavus* sp.; *Podobursa triacantha* (FISCHLI, 1916); *Praewilliriedellum spinosum* KOZUR, 1984; *Protunuma lanosus* OZVOLDOVA, 1996 in SYKORA & OZVOLDOVA 1996; *Pseudodictyomitra primitiva* MATSUOKA & YAO, 1985; *Sphaerostylus lanceola* (PARONA, 1890); *Spongocapsula krahsteinensis* SUZUKI & GAWLICK, 2004 in GAWLICK et al. 2004; *Stichocapsa convexa* YAO, 1979; *Stichocapsa robusta* MATSUOKA, 1984; *Stichomitra* sp.; *Stylocapsa oblongula* KOCHER, 1981; *Syringocapsa lata* YANG, 1993; *Syringocapsa suavis* YANG, 1993; *Tetracapsa* sp. A sensu SUZUKI & GAWLICK, 2003; *Tetraditryma* sp.; *Theocapsomma bicornis* BAUMGARTNER, 1995; *Theocapsomma cordis* KOCHER, 1981; *Theocapsomma costata* CHIARI, MARCUCCI & PRELA, 2002; *Tricolocapsa conexa* MATSUOKA, 1983; *Tricolocapsa leiostraca* (FOREMAN, 1973); *Tricolocapsa* cf. *parvipora* TAN, 1927; *Tricolocapsa plicarum* YAO, 1979; *Tricolocapsa undulata* (HEITZER 1930); *Tricolocapsium* sp. A; *Tricolocapsium* sp. B; *Tritrabs* cf. *casmaliaensis* (PESSAGNO, 1977); *Tritrabs rhododactylus* BAUMGARTNER, 1980; *Triversus hexagonatus* (HEITZER, 1930); *Triversus hungaricus* (KOZUR, 1985); *Unuma gorda* HULL, 1997; *Williriedellum carpathicum* DUMITRICA, 1970; *Williriedellum dierschei* SUZUKI & GAWLICK, 2004 in GAWLICK et al. 2004; *Williriedellum marcucciae* CORTESE, 1993; *Xitus magnus* BAUMGARTNER, 1995 in BAUMGARTNER et al. 1995; *Zhamoidellum ovum* DUMITRICA, 1970.

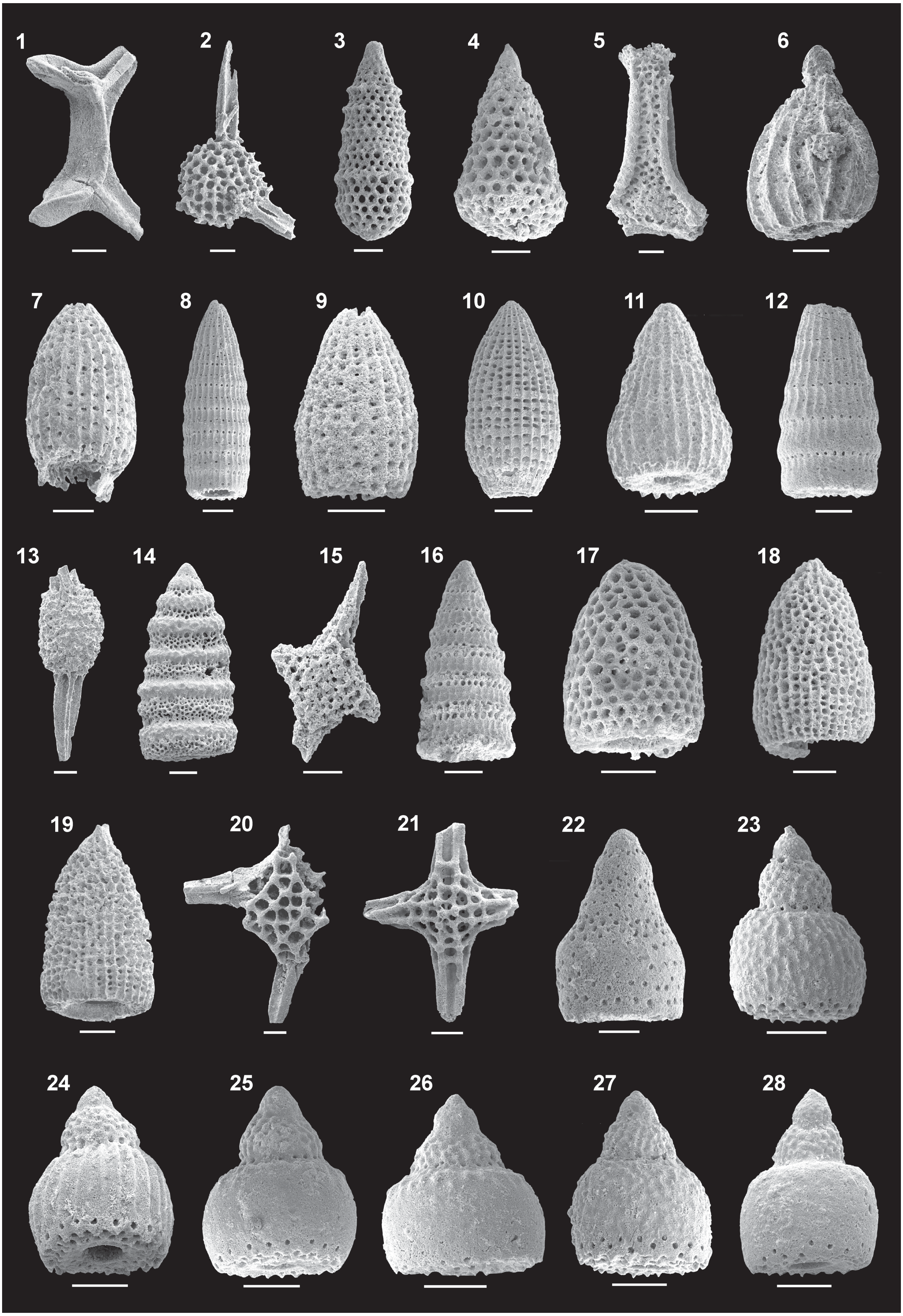
The occurrence of *Eucyrtidiellum unumaense* and *Williriedellum marcucciae* set the upper limit to Middle Oxfordian (BECCARO 2004). *Protonuma lanosus*, *Zhamoidellum ovum*, *Gongylothorax favosus* and *Williriedellum dierschei* allocate sample MR 149 to the *Protonuma lanosus* subzone of the *Zhamoidellum ovum* zone (Callovium; SUZUKI & GAWLICK 2003a).

Sample MR 175 (300 m south of the Hohe Knallalm cottage, approx. 10 m stratigraphically higher than MR 149) – thin-bedded to platy marly radiolarite, ochre:

Amphipyndax cf. *tsunoensis* AITA, 1987; *Archaeodictyomitra* cf. *apiarium* (RÜST, 1885); *Archaeodictyomitra minoensis* (MIZUTANI, 1981); *Archaeodictyomitra mitra* DUMITRICA, 1997 in DUMITRICA et al. 1997; *Archaeodictyomitra rigida* PESSAGNO, 1977; *Archaeodictyomitra* cf. *sixi* YANG, 1993; *Cinguloturris carpatica* DUMITRICA, 1982; *Crucella* sp.; *Droltus galerus* SUZUKI, 1995; *Eucyrtidiellum nodosum* WAKITA, 1988; *Eucyrtidiellum ptyctum* (RIEDEL & SANFILIPPO, 1974); *Eucyrtidiellum semifactum* NAGAI & MIZUTANI, 1990; *Eucyrtidiellum unumaense dentatum* BAUMGARTNER, 1995; *Eucyrtidiellum unumaense pustulatum* BAUMGARTNER, 1984; *Eucyrtidiellum unumaense unumaense* (YAO, 1979); *Gongylothorax* aff. *favosus* DUMITRICA, 1970; *Gongylothorax* aff. *siphonofer* DUMITRICA, 1970; *Gorgansium* cf. *morganense* PESSAGNO & BLOME, 1980; *Helvetocapsa matsuokai* (SASHIDA, 1999) in SASHIDA et al. 1999; *Hiscocapsa* cf. *hexagona* (HORI, 1999); *Homoeoparonaella* cf. *elegans* (PESSAGNO, 1977); *Hsuum brevicostatum* (OZVOLDOVA, 1975); *Hsuum* cf. *exiguum* YEH & CHENG, 1996; *Hsuum maxwelli* PESSAGNO, 1977; *Lithocampium matsuokai* (HULL, 1997); *Loopus doliolum* DUMITRICA, 1997; *Neorelumbra skenderbegi* (CHIARI, MARCUCCI & PRELA, 2002); *Parahsuum levicostatum* TAKEMURA, 1986;

Parahsuum aff. *simplum* YAO, 1982; *Parahsuum* sp. S sensu MATSUOKA, 1986; *Parvicingula cappa* CORTESE, 1993; *Parvicingula spinata* (VINASSA, 1899); *Parvicingula dhimenaensis* BAUMGARTNER, 1984; *Parvifavus wallacheri* (GRILL & KOZUR, 1986); *Parvifavus* sp. A; *Praewilliriedellum spinosum* KOZUR, 1984; *Protunuma lanosus* OZVOLDOVA, 1996 in SYKORA & OZVOLDOVA 1996; *Protunuma ochiensis* MATSUOKA, 1983; *Pseudodictyomitrella spinosa* GRILL & KOZUR, 1986; *Pseudodictyomitra* sp. D sensu MATSUOKA & YAO, 1985; *Pseudoeucyrtis* sp. J sensu BAUMGARTNER, et al. 1995; *Quarticella levis* TAKEMURA, 1986; *Quarticella ovalis* TAKEMURA, 1986; *Saitoum* cf. *pagei* PESSAGNO, 1977; *Sphaerostylus lanceola* (PARONA, 1890); *Spongotripus* sp. E; *Stichocapsa* aff. *biconica* MATSUOKA, 1991; *Stichocapsa naradaniensis* MATSUOKA, 1984; *Stichomitra* cf. *annibill* KOCHER, 1981; *Stichomitra takanoensis* AITA, 1987; *Stylocapsa tecta* MATSUOKA, 1983; *Tetracapsa* sp. A sensu SUZUKI & GAWLICK, 2003; *Tetracapsa* sp. C; *Theocapsomma cordis* KOCHER, 1981; *Theocapsomma* cf. *cucurbiformis* BAUMGARTNER, 1995;

Fig. 6: Radiolarian fauna of the Knallalm-Neualm area (in alphabetic order; scale bar = 30 µm):
1. *Acanthocircus* cf. *suboblongus* (YAO, 1972); **2.** *Alievium* sp.; **3.** *Amphipyndax durisaeptum* AITA, 1987; **4.** *Amphipyndax* cf. *tsunoensis* AITA, 1987; **5.** *Angulobracchia* sp.; **6.** *Archaeodictyomitra* cf. *amabilis* AITA, 1987; **7.** *Archaeodictyomitra apiarium* (RÜST, 1885); **8.** *Archaeodictyomitra minoensis* (MIZUTANI, 1981); **9.** *Archaeodictyomitra mitra* DUMITRICA, 1997 in DUMITRICA et al. 1997; **10.** *Archaeodictyomitra rigida* PESSAGNO, 1977; **11.** *Archaeodictyomitra sixi* YANG, 1993; **12.** *Archaeodictyomitra* sp. B sensu WEGERER et al., 2001; **13.** *Archaeospongoprunum* sp.; **14.** *Cinguloturris carpatica* DUMITRICA, 1982; **15.** *Crucella* sp.; **16.** *Dictyomitrella kamoensis* MIZUTANI & KIDO, 1983; **17.** *Droltus galerus* SUZUKI, 1995; **18.** *Droltus* aff. *galerus* SUZUKI, 1995; **19.** *Droltus hecatensis* PESSAGNO & WHALEN, 1982; **20.** *Emiluvia* cf. *bisellea* DANELIAN, 1995; **21.** *Emiluvia premyogii* BAUMGARTNER, 1984; **22.** *Eucyrtidiellum circumperforatum* CHIARI, MARCUCCI & PRELA, 2002; **23.** *Eucyrtidiellum nodosum* WAKITA, 1988; **24.** *Eucyrtidiellum ptyctum* (RIEDEL & SANFILIPPO, 1974); **25.** *Eucyrtidiellum semifactum* NAGAI & MIZUTANI, 1990; **26.** *Eucyrtidiellum unumaense dentatum* BAUMGARTNER, 1995; **27.** *Eucyrtidiellum unumaense pustulatum* BAUMGARTNER, 1984; **28.** *Eucyrtidiellum unumaense unumaense* (YAO, 1979); **29.** *Gongylothorax favosus* DUMITRICA, 1970; **30.** *Gongylothorax* aff. *favosus* DUMITRICA, 1970; **31.** *Gongylothorax* aff. *siphonofer* DUMITRICA, 1970; **32.** *Gongylothorax* sp. C sensu SUZUKI & GAWLICK, 2003; **33.** *Gorgansium* cf. *morganense* PESSAGNO & BLOME, 1980; **34.** *Gorgansium* cf. *xigazeense* WU, 1993; **35.** *Helvetocapsa matsuokai* (SASHIDA, 1999) in SASHIDA et al. 1999; **36.** *Hiscocapsa* cf. *hexagona* (HORI, 1999); **37.** *Hiscocapsa* cf. *magniglobosa* (AITA, 1987); **38.** *Homoeoparonaella* cf. *elegans* (PESSAGNO, 1977); **39.** *Hsuum baloghi* GRILL & KOZUR, 1986; **40.** *Hsuum brevicostatum* (OZVOLDOVA, 1975); **41.** *Hsuum* cf. *exiguum* YEH & CHENG, 1996; **42.** *Hsuum hisuikyoense* ISOZAKI & MATSUDA, 1985; **43.** *Hsuum maxwelli* PESSAGNO, 1977; **44.** *Lithocampium matsuokai* (HULL, 1997); **45.** *Lithocampium* sp. C; **46.** *Loopus doliolum* DUMITRICA, 1997; **47.** *Napora* sp. **48.** *Neorelumbra skenderbegi* (CHIARI, MARCUCCI & PRELA, 2002); **49.** *Parahsuum levicostatum* TAKEMURA, 1986; **50.** *Parahsuum* aff. *simplum* YAO, 1982; **51.** *Parahsuum* sp. S sensu MATSUOKA, 1986; **52.** *Paronaella* sp.; **53.** *Parvicingula cappa* CORTESE, 1993; **54.** *Parvicingula dhimenaensis* BAUMGARTNER, 1984; **55.** *Parvicingula mashitaensis* MIZUTANI, 1981; **56.** *Parvicingula spinata* (VINASSA, 1899); **57.** *Parvifavus wallacheri* (GRILL & KOZUR, 1986; **58.** *Parvifavus* sp. A; **59.** *Podobursa* aff. *nodosa* (CHIARI, MARCUCCI & PRELA, 2002); **60.** *Podobursa triacantha* (FISCHLI, 1916); **61.** *Praewilliriedellum spinosum* KOZUR, 1984; **62.** *Protunuma lanosus* OZVOLDOVA, 1996 in SYKORA & OZVOLDOVA, 1996; **63.** *Protunuma* cf. *multicostatus* (HEITZER, 1930); **64.** *Protunuma ochiensis* MATSUOKA, 1983; **65.** *Pseudodictyomitra primitiva* MATSUOKA & YAO, 1985 **66.** *Pseudodictyomitra* sp. D sensu MATSUOKA & YAO, 1985; **67.** *Pseudodictyomitrella spinosa* GRILL & KOZUR, 1986; **68.** *Pseudoeucyrtis* sp. J sensu BAUMGARTNER et al., 1995; **69.** *Quarticella levis* TAKEMURA, 1986; **70.** *Quarticella ovalis* TAKEMURA, 1986; **71.** *Quarticella* sp. C sensu CHIARI et al., 2002; **72.** *Saitoum levium* DE WEVER, 1981; **73.** *Saitoum* cf. *pagei* PESSAGNO, 1977; **74.** *Sphaerostylus lanceola* (PARONA, 1890); **75.** *Spongocapsula krahsteinensis* SUZUKI & GAWLICK, 2004 in GAWLICK et al. 2004; **76.** *Spongotripus* sp. E; **77.** *Stichocapsa* aff. *biconica* MATSUOKA, 1991; **78.** *Stichocapsa cicciona* CHIARI, MARCUCCI & PRELA, 2002; **79.** *Stichocapsa convexa* YAO, 1979; **80.** *Stichocapsa naradaniensis* MATSUOKA, 1984; **81.** *Stichocapsa robusta* MATSUOKA, 1984; **82.** *Stichocapsa* sp. E sensu BAUMGARTNER et al., 1995; **83.** *Stichomitra* cf. *annibill* KOCHER, 1981; **84.** *Stichomitra takanoensis* AITA, 1987; **85.** *Stylocapsa catenarum* MATSUOKA, 1982; **86.** *Stylocapsa oblongula* KOCHER, 1981; **87.** *Stylocapsa spiralis* MATSUOKA, 1982; **88.** *Stylocapsa tecta* MATSUOKA, 1983; **89.** *Syringocapsa lata* YANG, 1993; **90.** *Syringocapsa suavis* YANG, 1993; **91.** *Tetracapsa himedaruma* (AITA, 1987); **92.** *Tetracapsa* sp. A sensu SUZUKI & GAWLICK, 2003; **93.** *Tetracapsa* sp. B; **94.** *Tetracapsa* sp. C; **95.** *Tetraditryma* sp.; **96.** *Theocapsomma bicornis* BAUMGARTNER, 1995; **97.** *Theocapsomma cordis* KOCHER, 1981; **98.** *Theocapsomma costata* CHIARI, MARCUCCI & PRELA, 2002; **99.** *Theocapsomma cucurbiformis* BAUMGARTNER, 1995; **100.** *Tricolocampe magnipora* (CHIARI, MARCUCCI & PRELA, 2002); **101.** *Tricolocapsa conexa* MATSUOKA, 1983; **102.** *Tricolocapsa* aff. *conexa* MATSUOKA, 1983; **103.** *Tricolocapsa fusiformis* YAO, 1979; **104.** *Tricolocapsa leiostraca* (FOREMAN, 1973); **105.** *Tricolocapsa* cf. *parvipora* TAN, 1927; **106.** *Tricolocapsa plicarum* YAO, 1979; **107.** *Tricolocapsa undulata* (HEITZER, 1930); **108.** *Tricolocapsa* sp. A sensu GORICAN, 1994; **109.** *Tricolocapsa* sp. A sensu OZVOLDOVA, 1992; **110.** *Tricolocapsa* sp. C; **111.** *Tricolocapsa* sp. M sensu BAUMGARTNER et al., 1995; **112.** *Tricolocapsium* sp. A; **113.** *Tricolocapsium* sp. B; **114.** *Tritrabs* cf. *casmaliaensis* (PESSAGNO, 1977); **115.** *Tritrabs rhododactylus* BAUMGARTNER, 1980; **116.** *Tritrabs simplex* KITO & DE WEVER, 1992; **117.** *Triversus hexagonatus* (HEITZER, 1930); **118.** *Triversus hungaricus* (KOZUR, 1985); **119.** *Unuma gorda* HULL, 1997; **120.** *Williriedellum carpathicum* DUMITRICA, 1970; **121.** *Williriedellum dierschei* SUZUKI & GAWLICK, 2004 in GAWLICK et al. 2004; **122.** *Williriedellum glomerulus* (CHIARI, MARCUCCI & PRELA 2002); **123.** *Williriedellum sujkowskii* WIDZ & DE WEVER, 1993; **124.** *Williriedellum marcucciae* CORTESE, 1993; **125.** *Wrangellium* aff. *hsuei* (Pessagno 1977); **126.** *Xitus magnus* BAUMGARTNER, 1995 in BAUMGARTNER et al. 1995; **127.** *Zhamoidellum exquisitum* HULL, 1997; **128.** *Zhamoidellum kozuri* (HULL, 1997); **129.** *Zhamoidellum ovum* DUMITRICA, 1970; **130.** *Zhamoidellum ventricosum* DUMITRICA, 1970.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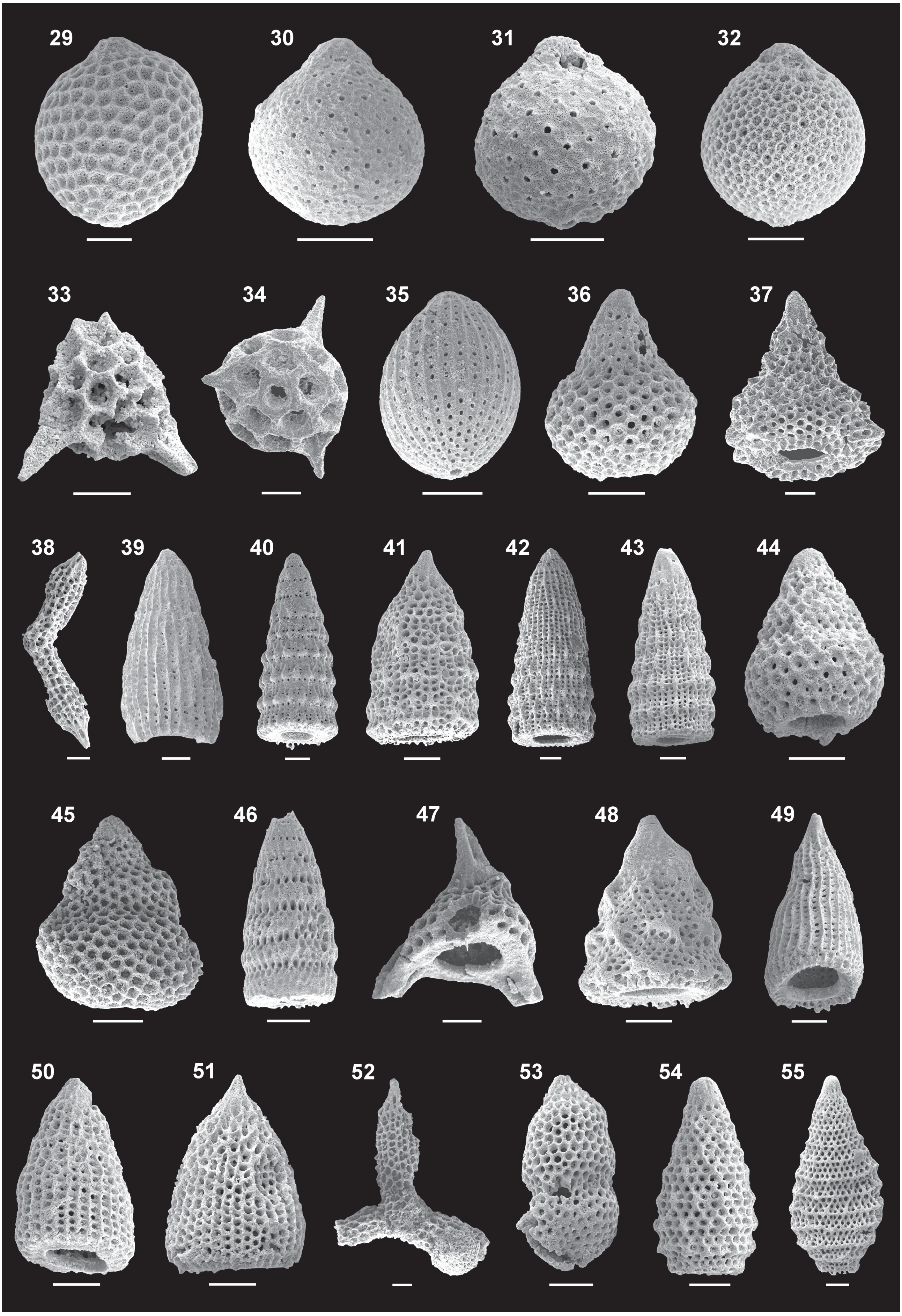
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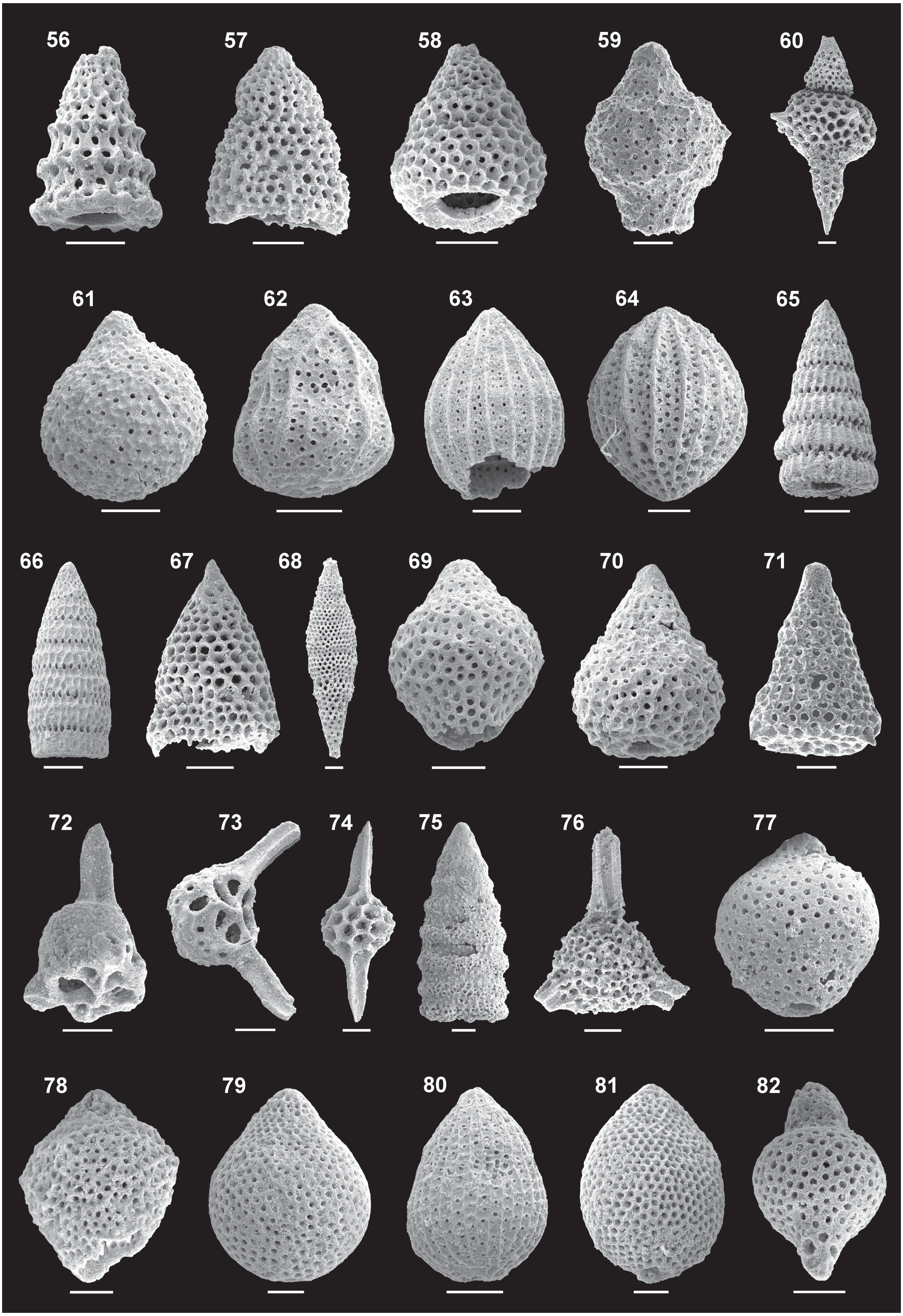
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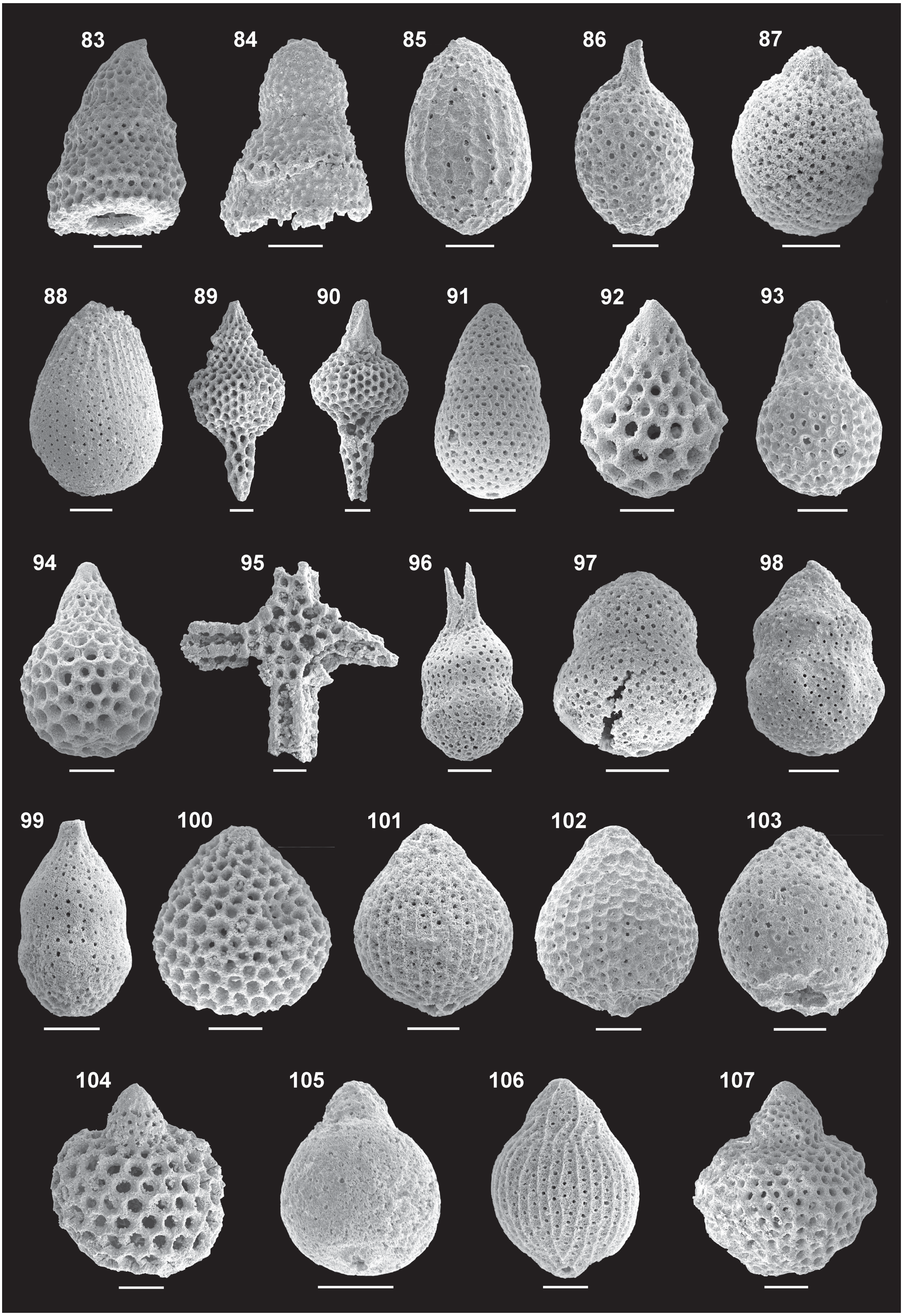
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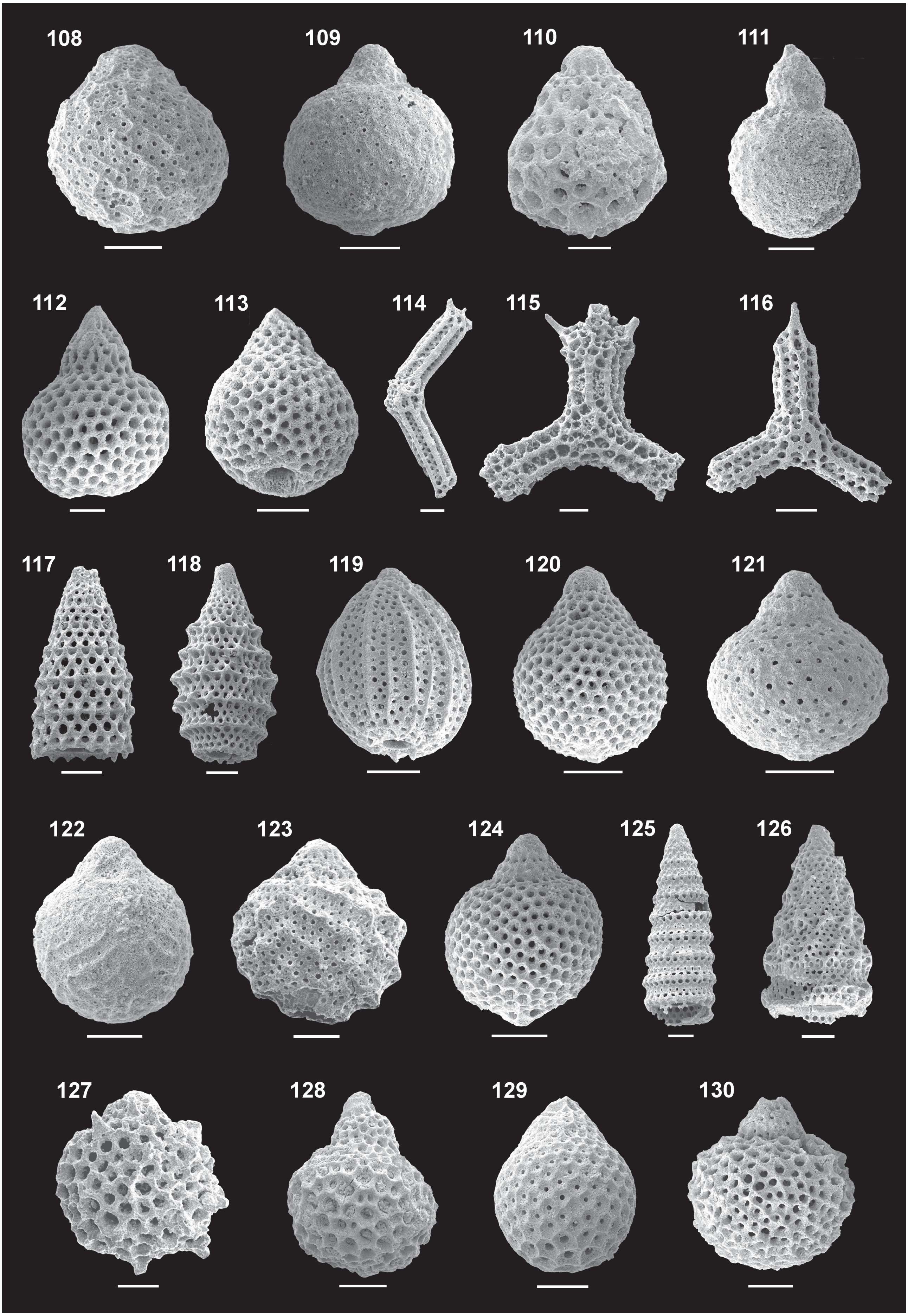
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Tricolocapsa cf. *conexa* Matsuoka, 1983; *Tricolocapsa leiostraca* (Foreman, 1973); *Tricolocapsa undulata* (Heitzer, 1930); *Tricolocapsa* sp. A sensu Ozvoldova, 1992; *Tricolocapsa* sp. A sensu Gorican, 1994; *Tricolocapsa* sp. C; *Tritrabs* cf. *casmaliaensis* (Pessagno, 1977); *Tritrabs simplex* Kito & De Wever, 1992; *Triversus hexagonatus* (Heitzer, 1930); *Triversus hungaricus* (Kozur, 1985); *Unuma gorda* Hull, 1997; *Williriedellum carpathicum* Dumitrica, 1970; *Williriedellum dierschei* Suzuki & Gawlick, 2004 in Gawlick et al. 2004; *Williriedellum marcucciae* Cortese, 1993; *Xitus magnus* Baumgartner, 1995 in Baumgartner et al. 1995; *Zhamoidellum kozuri* (Hull, 1997); *Zhamoidellum ovum* Dumitrica, 1970; *Zhamoidellum ventricosum* Dumitrica, 1970.

Biostratigraphic interpretation of MR 175: The maximum age is constrained by the occurrence of *Zhamoidellum ovum* (Early Callovium to Early Tithonium; Suzuki & Gawlick 2003a), the minimum age by *Eucyrtidiellum unumaense* and *Williriedellum marcucciae*, whose last occurrence was in the Middle Oxfordian (Suzuki & Gawlick 2003a, modified according to Beccaro 2004, Suzuki et al. 2004). Due to the occurrence of *Protonuma lanosus* sample MR 175 must be accounted to the *Protonuma lanosus* subzone of the *Zhamoidellum ovum* zone (Callovian; Suzuki & Gawlick 2003a) probably close to the transition to the *Williriedellum dierschei* subzone.

Summarizing, all Ruhpolding Radiolarite Group samples yielded radiolarian fauna which can be assigned to the lower to middle parts of the *Zhamoidellum ovum* zone (Callovian to Middle Oxfordian; Suzuki & Gawlick 2003a, upper limit modified according to Beccaro 2004). Differences in the radiolarian associations allow a vague refinement of the zone assignment which is in line with the conclusions drawn from field observation and thin section analysis: Microbreccia horizon 1 at the outcrop area northwest of the Hohe Knallalm cottage shows similar lithological characteristics like the microbreccia horizon at the location south of the Hohe Knallalm cottage and is therefore correlated with the latter. Emanating from rather small thickness variations in the radiolarites, MR 5b can be regarded to be some metres above MR 175, resulting in the synthetic stratigraphic profile illustrated in Fig. 7. The concluded positions of the partial sections relative to each other are supported by the occurrences of *Protonuma lanosus* which is found only in samples MR 149 and MR 175 and is absent in samples MR 5b and MR 125, respectively. However, the exact upper limit of *Protonuma lanosus* is to be tested.

3.2. ?Slide Block Horizon above the Ruhpolding Radiolarite Group

In two places there is evidence for the existence of a thin ?slide block horizon overlying the Ruhpolding Radiolarite Group: at the location 250 m northwest of the Hohe Knallalm cottage and 100 m south of the second above-mentioned Ruhpolding Radiolarite Group outcrop, almost 400 m south of the Hohe Knallalm cottage. At the main location northwest of the Hohe Knallalm extraclast blocks up to decimetres in size can be found in the 20 metres of grassland area between the uppermost Ruhpolding Radiolarite Group and the lowermost Plassen Formation outcrops. No matrix could be proven between the blocks – hence there is no direct information on the depositional age of this horizon.

The blocks are made up mainly of two lithologies: dark bituminous dolomites and limestones and dark spiculitic, slightly siliceous limestones. The dolomites sometimes show micro-bedding and brecciation and were apparently deposited in a tidal flat environment whilst the limestones are simply dull and micritic. Both dolomites and limestones are fossil-free – according to the facies/lithology and observation outside the investigated area (see below) a Middle Triassic primary stratigraphic age (?Gutenstein For-

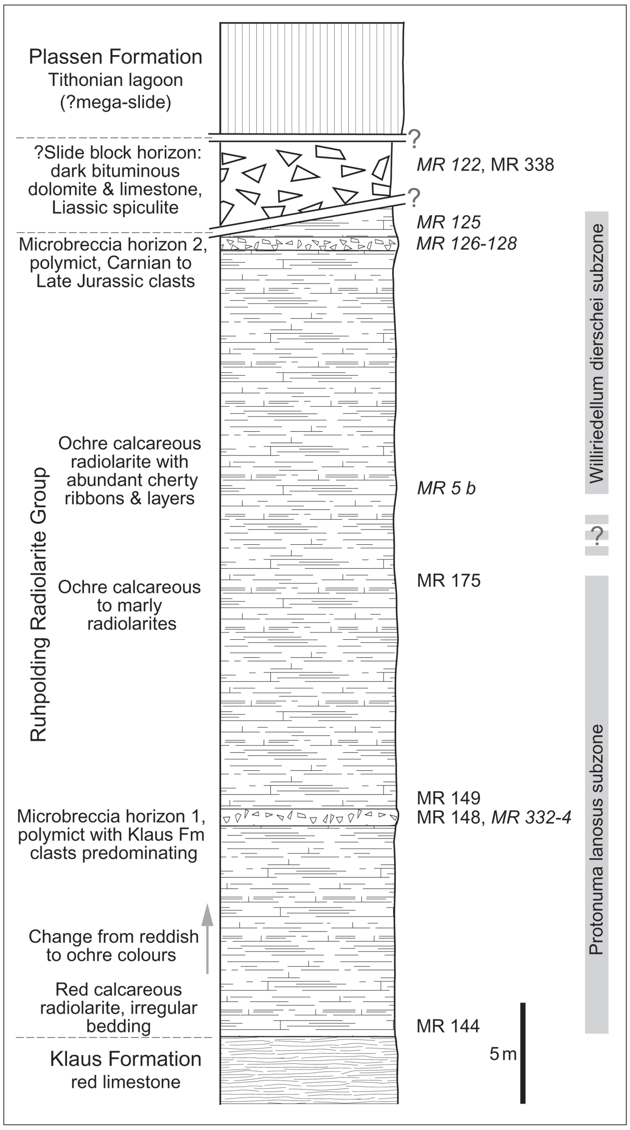


Fig. 7: Synthetic tentative sedimentary column of the Middle to Late Jurassic succession of the Knallalm-Neualm area, including the inferred positions of the radiolarian samples within the profile. In the column the border between the *Protonuma lanosus* subzone and the *Williriedellum dierschei* subzone is supposed to be somewhere between samples MR 175 and MR 5b. Based on the situation at the two outcrop areas northwest and south of the Hohe Knallalm cottage (see text and Fig. 2) – samples from the locality northwest of the Hohe Knallalm are indicated by *italics*.

mation) seems most likely, but a Late Triassic (Carnian) age cannot be excluded.

The grey spiculitic limestones (Fig. 8), which have also been found 400 m south of the Hohe Knallalm cottage, are of higher statigraphic value as they bear radiolarians: although less frequent and mostly broken into small pieces, some radiolarian species could be determined, e.g. *Canoptum* cf. *rugosum* PESSAGNO & POISSON, 1981, *Parahsuum ovale* HORI & YAO, 1988 and *Gorgansium* sp. H. (Fig. 9), proving a Liassic depositional age. Neither the bituminous (?Middle to Late Triassic) carbonates nor the Liassic spiculites occur in the closer vicinity of the Knallalm-Neualm area at topographic heights suitable for erosion and redeposition. Therefore a fairly high relief energy and a more far-distance transport must be assumed for these comparably large blocks which are exotic in relation to the Knallalm-Neualm region.

3.3. Microfacies and Micropalaeontology of the newly detected Plassen Formation Occurrence

The Plassen Limestone occurrence of the Knallalm-Neualm forms basically one single, continuous complex stretching about 850 m in north-south and 500 m in east-west direction. In addition, there is one isolated small outcrop about 200 m to the southwest, at half-way to the Neualm cottage (MR 50; Fig. 2). Almost everywhere the Plassen Limestone occurrence ends at high-angle faults of variable orientation. Solely in the northeast/east in the closer vicinity of the Hohe Knallalm cottage the sequence seems to be part of a primary stratigraphic succession, overlying siliceous rocks of the Ruhpolding Radiolarite Group. However, instead of a continuous transitional sequence above the deep water radiolaritic basin succession merely this poorly exposed enigmatic ?slide block horizon is intercalated. The lowermost

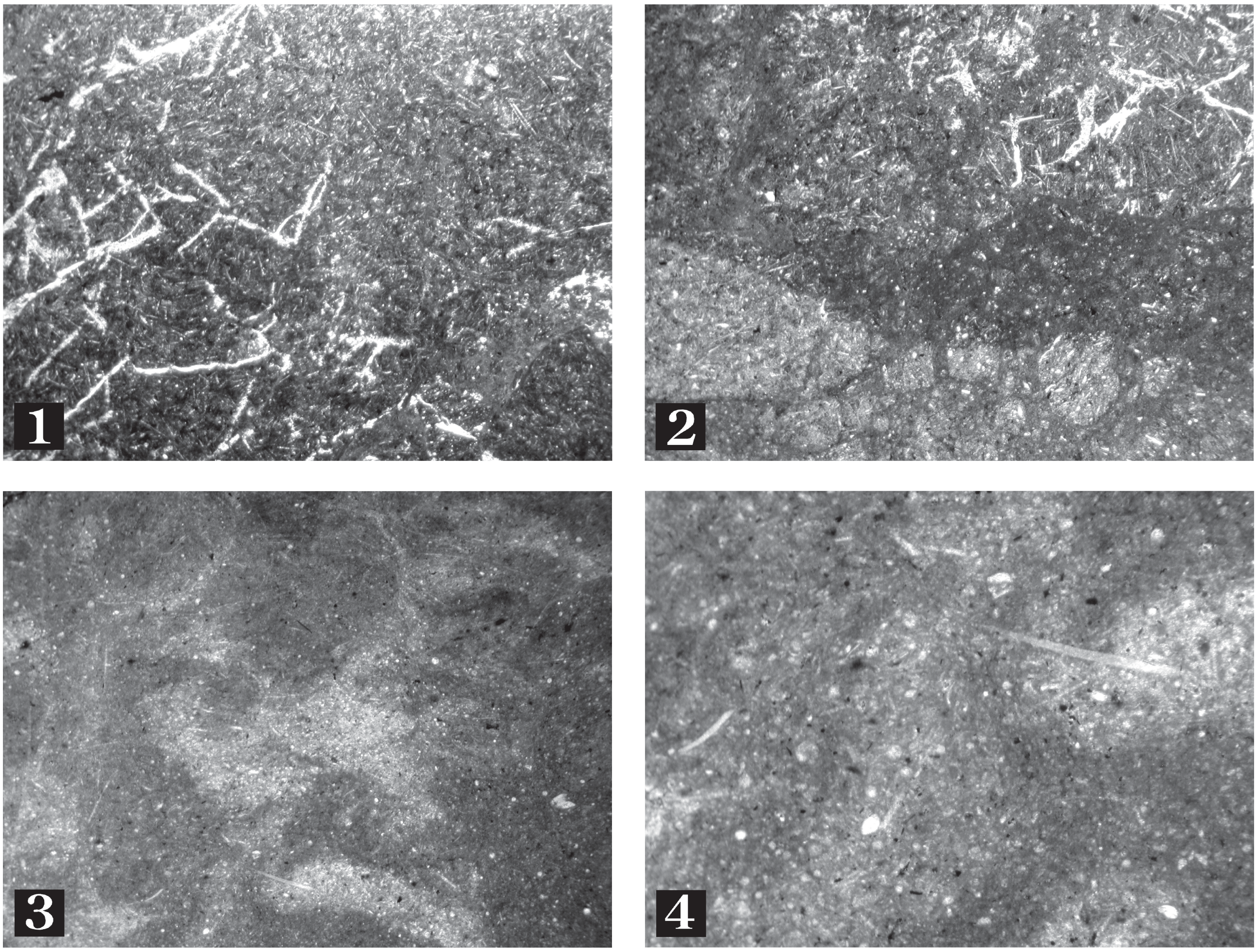


Fig. 8: Microfacies of the radiolarian-bearing dark spiculitic limestones of Liassic age:
1. Bioturbated, dark-grey spicula-rich wacke- to packstone, partly with radiolarians, fractured. Sample MR 122; width of photo 1.4 cm.
2. Upper part of the photo: Bioturbated, dark-grey spicula-rich wacke- to packstone, partly with radiolarians, fractured. Lower part of the photo: monomict breccia with spicula-rich components in a cherty-marly matrix indicating relief in the deposition area. Sample MR 122c; width of photo 1.4 cm.
3. Bioturbated and partly silicified spicula- and radiolarian-rich dark grey limestone with crinoids. Sample MR 338; width of photo 1.4 cm.
4. Enlargement of (3): Spicula and radiolarian-rich bioturbated wackestone, rich in pyrite. Sample MR 338; width of photo 0.25 cm.

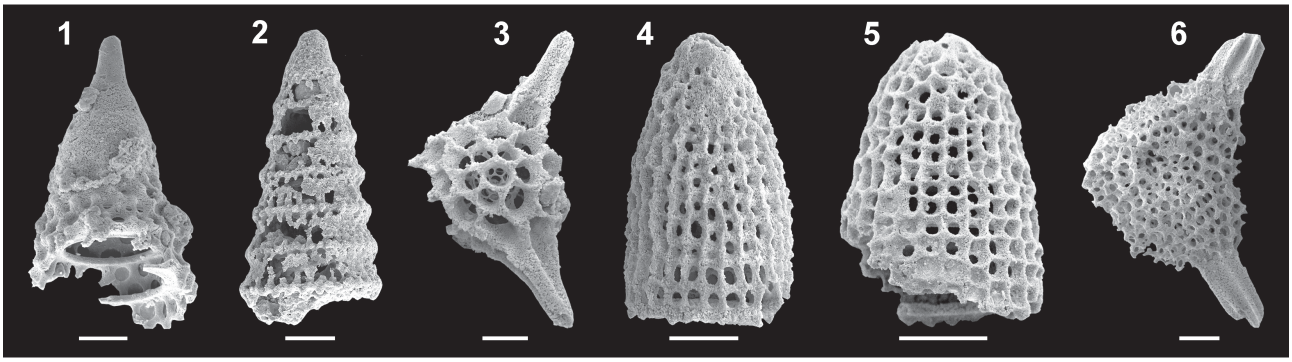


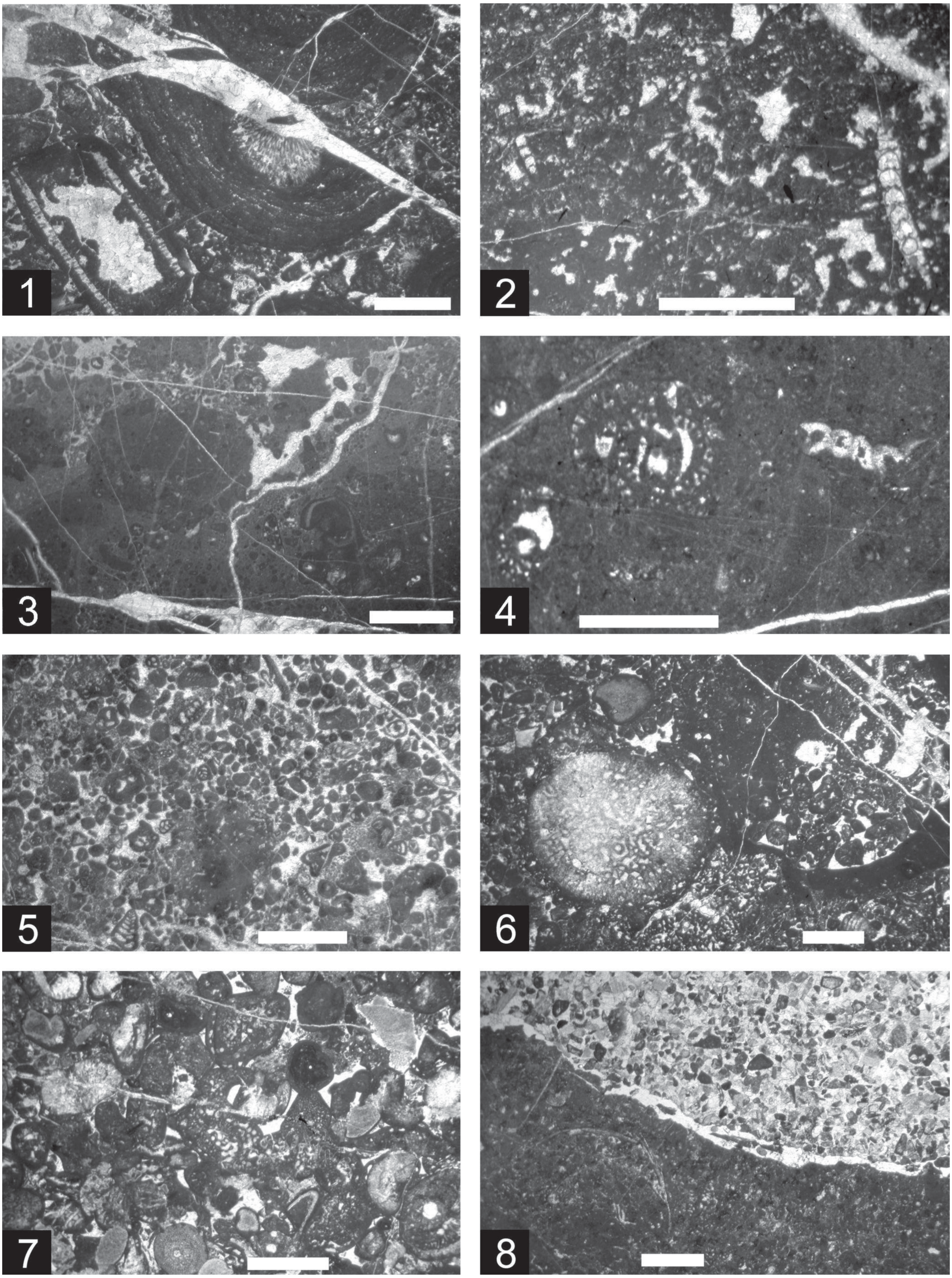
Fig. 9: Radiolarians isolated from different samples of dark the Liassic spiculitic limestone blocks (in alphabetic order; scale bar = 30 µm):
1. *Atalanta* sp. (Sample MR 122a); **2.** *Canoptum* cf. *rugosum* Pessagno & Poisson, 1981 (MR 338); **3.** *Gorgansium* sp. H (MR 122a); **4.** *Parahsuum* cf. *simplum* Yao, 1982 (MR 122c); **5.** *Parahsuum ovale* Hori & Yao, 1988 (MR 122b); 6. *Spongotripus* sp. (MR 122b).

part of the Plassen Formation was already deposited under shallow water conditions, and an initial shallowing-upward succession in the form of slope and reefal platform margin deposits, observable at other places and generally assigned to the Kimmeridgian (Schlagintweit et al. 2004), is here missing.

The Plassen Formation depositional setting and facies development does not show significant variations across the complete Knallalm-Neualm sequence which is up to estimated 150 m thick: the bright whitish massive limestones were all exclusively deposited in a back-reef to open and closed lagoon environment. Typical algal elements of the predominating wacke- and packstones are the dasycladales *Salpingoporella annulata* Carozzi, 1953, *Clypeina*? cf. *solkani* Conrad & Radoièiæ, 1972 (Fig. 11.5) or *Clypeina sulcata* (Alth, 1882) (Fig. 10.4, 11.3). Benthic foraminifera are represented by *Andersenolina* cf. *elongata* (Leupold, 1935 in Leupold & Bigler 1935) (Fig. 11.1) or *Pseudocyclammina lituus* (Yokoyama, 1890). *Andersenolina alpina* (Leupold, 1935 in Leupold & Bigler 1935), *Mohlerina basiliensis* (Mohler, 1938) (Fig. 11.4) and protopeneroplids (Fig. 11.6) occur in packstones and indicate a more agitated, open lagoonal to back-reef depositional environment. Here, also oncoids and rivulariacean algae are present (Fig. 10.1). The dasycladalean algae *Neoteutloporella obsoleta* (Carozzi, 1954) (Fig. 11.8) and *Neoteutloporella socialis* (Praturlon, 1963) (Fig. 11.10), typical reefal inhabitants (Carozzi 1954, Dragastan et al. 1987, Bodeur 1995) were detected only at the northern rim of the Plassen carbonate platform occurrence (samples MR 70, MR 111). Together with the appearance of the dasycladales *Salpingoporella pygmaea* (Gümbel, 1891) (sample MR 92), *Linoporella* aff. *gigantea* (Carozzi, 1955) or the benthic foraminifer *Coscinophragma* aff. *cribrosa* (Reuss, 1846) (sample MR 111), which are all typical reef to near-reef elements (e.g. Bucur et al. 1996, Senowbari Daryan et al. 1994), a back-reef environment in near-reef position can be assumed for the northernmost part of the Knallalm-Neualm Plassen platform carbonates. This interpretation is also substantiated by the rather wide distribution of *Bacinella* bindstones in this part of the sequence, often containing the foraminifer *Troglotella incrustans* Wernli & Fookes, 1992 (Fig. 10.2).

The occurrences of *Anchispirocyclina lusitanica* (Egger, 1902) (single finding in the small isolated outcrop, sample MR 50; see Fig. 2), *Protopeneroplis* aff. *ultragranulata* (Gorbatchik, 1971) (Fig. 11.6) and *Neoteutloporella socialis* (Praturlon, 1963) indicate a Tithonian age for the complete succession (Schlagintweit et al. 2005 for further details). *Neoteutloporella socialis* (Praturlon, 1963) has as yet not been reported from the first, Late Kimmeridgian reefal interval of the Plassen carbonate platform but only from the second one in the Late Tithonian (e.g. Schlagintweit et al. 2003; Gawlick et al. 2004; Schlagintweit & Gawlick unpubl. data). Therefore, these sediments at the northern margin of the occurrence seem to be the youngest strata of the Knall-

Fig. 10: Microfacies of the Plassen carbonate platform rocks of the Knallalm-Neualm area:
1. Oncoidal rudstone with rivulariacean algae and dasycladales. Facies interpretation: Back-reef to open lagoon. Sample MR 182; scale bar = 2 mm.
2. *Bacinella*-bindstone with *Troglotella incrustans* Wernli & Fookes, 1992. Facies interpretation: Back-reef. Sample MR 112; scale bar = 1 mm.
3. Wacke- to packstone with irregular mud cracks. Facies interpretation: Tidal Flat. Sample MR 166; scale bar = 1 mm.
4. Wackestone with *Pseudocyclammina* cf. *lituus* (Yokoyama, 1890) and fragment of *Clypeina sulcata* (Alth, 1882). Sample MR 139; scale bar = 0.5 mm.
5. Packstone with numerous small benthic foraminifera (textulariids, miliolids). Facies interpretation: Open lagoon. Sample MR 218; scale bar = 2 mm.
6. Packstone with „stromatoporoids“ and *Bacinella irregularis* Radoicic, 1959. Facies interpretation: Open to closed lagoon. Sample MR 107; scale bar = 2 mm.



7. Bioclastic packstone with *Pinnatiporidium* sp., remains of echinoids, „*Tubiphytes*“ *morronensis* CRESCENTI, 1969. Sample MR 109. Facies interpretation: Back-reef; scale bar = 2 mm.
8. Sedimentary contact between Late Jurassic Plassen carbonate platform (below) and Late Cretaceous Gosau Group (above). Sample MR 62; scale bar = 2 mm.

alm-Neualm Plassen platform carbonates. As some microfacies types (e.g. Fig. 10.3), unfortunately without diagnostic microfossils, are directly comparable to the Early Tithonian transgressive-regressive cycles exposed at Mount Plassen (SCHLAGINTWEIT et al. 2003, 2005), it seems likely that in the Knallalm-Neualm area Plassen Limestone of both Early and Late Tithonian age occur.

Neoteutloporella socialis (PRATURLON, 1963) represents a dasycladale of rather confined abundance within the Alpine Plassen carbonate platform and has as yet been reported only from Mount Trisselwand (SCHLAGINTWEIT & EBLI 1999), Mount Tressenstein (FENNINGER & HÖTZL 1967) and the Barmstein Limestones at the Trattberg of the Osterhorn mountain range (FENNINGER 1972). At the Barmstein Limestone type-locality near Hallein, however, both *Neoteutloporella socialis* (PRATURLON, 1963) and *Neoteutloporella obsoleta* (CAROZZI, 1954) are missing (GAWLICK et al. 2005). In contrast, other characteristic microfacies types mentioned such as lagoonal wackestones with *Clypeina* div. sp., *Pseudocyclammina lituus* (YOKOYAMA, 1890) or *Andersenolina elongata* (LEUPOLD, 1935 in LEUPOLD & BIGLER 1935) are widespread in various Barmstein Limestone occurrences.

With respect to the Plassen carbonate platform at the type-locality Mount Plassen (SCHLAGINTWEIT et al. 2003, 2005 for details), the exposed sequence of the Knallalm can be interpreted as an incomplete section, because both the Kimmeridgian slope and platform margin successions, particularly the shallowing-upward sequence passing over from radiolaritic basin sediments, and the final drowning succession (GAWLICK & SCHLAGINTWEIT 2006 for details) are missing here. Nevertheless, apart from the above-mentioned occurrence of *Neoteutloporella socialis*, the microfacies and micropalaeontology of the Plassen Formation succession of the Knallalm-Neualm area are in good accordance with that of the coeval part of the type-locality sequence.

4. Discussion of the Sedimentary Profile

At first view, the Middle to Late Jurassic succession of the Knallalm-Neualm area seems to be a rather normal, complete NCA sequence with the Plassen Formation following above Ruhpolding Radiolarite Group strata. However, on closer inspection the transition between these two stratigraphic units displays some peculiarities: firstly, locally this thin, only poorly preserved horizon with semi-exotic NCA material occurs. Secondly, there is no transitional sequence mediating from deep water to shallow water deposition, observable in many places with continuous sedimentation (e.g. Mount Plassen type-locality: SCHLAGINTWEIT et al. 2003; Mount Krahstein: GAWLICK et al. 2004). Thirdly, there are is no real evidence for Kimmeridgian sedimentation.

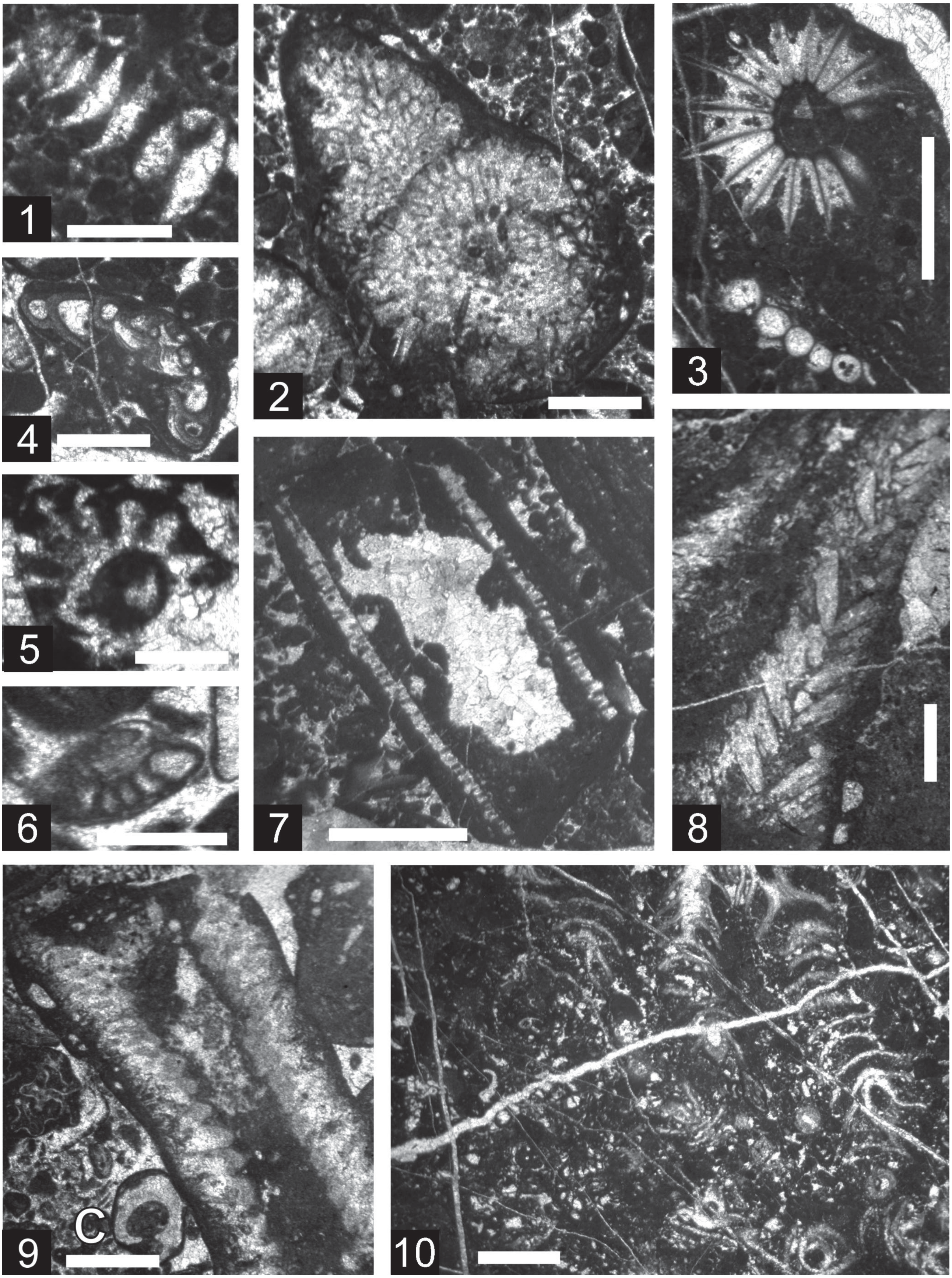
In the Knallalm-Neualm area the basal Plassen Formation immediately starts with back-reef limestones, overlain by and laterally interfingering with lagoonal sediments. A transition sequence (slope facies and margin facies), which is generally expected in a prograding carbonate platform system, does not exist. There are two main possibilities to explain this situation: The first is the existence of a more or less bedding-parallel fault above the Ruhpolding Radiolarite Group strata. In this case the ?slide block horizon should be rather regarded as a kind of fault-related tectonic melange zone. However, as a portion of the section is missing, crustal thinning/normal faulting is a more likely mechanism than crustal thickening/reverse faulting. Furthermore the origin and emplacement of these semi-exotic blocks is difficult to explain with this tectonic approach. The second, seemingly more favourable interpretation is that the Plassen Formation complex came as a mega-slide into its present position and is thus best regarded as a part of the ?slide block horizon.

The slide mass interpretation is corroborated by the patchy local, but nevertheless widespread distribution of similar rock associations above the Ruhpolding Radiolarite Group in the surrounding of the Knallalm-Neualm area:

- About 500 m west of the Neualm cottage there are m^3-sized occurrences of Gutenstein-type dark bituminous limestones and Liassic radiolarian-bearing marly limestones.
- Approximately 2 km southeast of the Hohe Knallalm cottage (locality „Wiesalm") outcrops of bituminous dark limestones/dolomites extend some tens of metres. There, residues of Werfen Formation clastics support the interpretation of the bituminous carbonates as Gutenstein Formation.
- In the Sarsteinalm region another 10 km farther to the east bituminous rauhwacke occurs.

Moreover in the Sarsteinalm area on top of the Ruhpolding Radiolarite Group slices of ?Late Kimmeridgian-Tithonian Plassen Limestone have been described and interpreted as slide blocks (GAWLICK et al. 2006). Similar to the Knallalm-Neualm area, a part of the Late Jurassic profile is missing; however, there the Plassen Formation is represented particularly by the initial, Kimmeridgian shallowing-upward sequence with slope and platform margin deposits, whilst lagoonal limestones are only of minor importance. Thus it is rather the situation of the Sarsteinalm Plassen Limestone occurrence strongly resembling the one of the Knallalm-

Fig. 11: Microfossils from the Plassen Limestone (Tithonian) of the Knallalm-Neualm area:
1. Benthic foraminifera *Andersenolina* cf. *elongata* (LEUPOLD in LEUPOLD & BIGLER, 1935). Sample MR 91. Scale bar = 0.5 mm.
2. Protohalimedacean alga *Pinnatiporidium* sp. Sample MR 110; scale bar = 0.5 mm.
3. Dasycladale *Clypeina sulcata* (ALTH, 1882). Sample MR 169; scale bar = 1 mm.
4: Benthic foraminifera *Mohlerina basiliensis* (MOHLER, 1938). Sample MR 53; scale bar = 0.5 mm.
5. Dasycladale *Clypeina*? cf. *solkani* CONRAD & RADOICIC, 1972. Sample MR 55; scale bar = 0.5 mm.
6. Benthic foraminifera *Protopeneroplis* aff. *ultragranulata* (GORBATCHIK, 1971). Sample MR 61; scale bar = 0.5 mm.
7. Dasycladale indet. Sample MR 182; scale bar = 1 mm.



8. Dasycladale *Neoteutloporella obsoleta* (CAROZZI, 1954). Sample MR 111; scale bar = 1 mm.
9. Dasycladale *Linoporella* aff. *gigantea* (CAROZZI, 1955). Note fragment of *Carpathocancer*? *plassenensis* (SCHLAGINTWEIT & GAWLICK, 2002) ((C), see SCHLAGINTWEIT et al., this volume). Sample MR 109; scale bar = 1 mm.
10. Dasycladale *Neoteutloporella socialis* (PRATURLON, 1963). Sample MR 70; scale bar = 2 mm.

Neualm area than its lithology, microfacies and micropalaeontology since all Plassen Limestone microfacies types and their micropalaeontological assemblages are different. On the other hand, considering the substantial distance between the locations, differences in the composition of the mobilized masses are not completely surprising.

Due to the lack of matrix rocks, the age of the suggested mass movements cannot directly be inferred. However, the Tithonian age of the Plassen Limestone mega-slide and the ?Coniacian-Santonian age of the Gosau Group sediments (PLÖCHINGER, 1982a) transgressing on the Plassen Limestone define a maximum time-frame. Integrating the observations from other locations of the central NCA, an emplacement at the beginning of this period constrained seems most probable. There are hints on increasing instabilities in the former carbonate platform regions in the Latest Jurassic, reflected in the mobilization and resedimentation of enormous masses of shallow water debris in the Tithonian (SCHLAGINTWEIT & GAWLICK 2007), and the erosion cutting down as deep as the Early Tithonian lagoonal deposits of the Plassen carbonate platform s. str. (SCHLAGINTWEIT & GAWLICK 2007). So, a Late Tithonian age seems most likely for the mobilisation and redeposition processes, however, a Cretaceous age can neither be excluded.

Accepting the mass movement origin of the Knallalm-Neualm succession above the Ruhpolding Radiolarite Group, still the question rises about the gap in sedimentary record in the Kimmeridgian. On the on hand, mass movements of this size might also accompanied by basal erosion. On the other hand, Kimmeridgian sediments in nearby regions of similar palaeogeographic situation has been very low as well, e.g. in the Tauglboden area (Osterhorn Block; GAWLICK, unpubl. data) and in the Salzkammergut area (Höherstein-Plateau north of Mount Sandling; GAWLICK et al. 2007). Apparently, there were significant changes in the geodynamic setting in the Oxfordian to Tithonian/Beriassian period which are as yet only fragmentarily understood. However, the Middle to Late Jurassic (or even Early Cretaceous?) succession of the Knallalm-Neualm area definitely yields an important contribution for a better understanding of the still poorly known early orogenic cycle of the NCA, whose original stratigraphic witnesses have widely been eroded.

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