©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

Ann. Naturhist. Mus. Wien	106 A	139–165	Wien, November 2004

Shallow-water limestone clasts in a Campanian deep-water debrite (Krappfeld, Central Alps, Austria): implications for carbonate platform history

by DIETHARD SANDERS[1], JOSEP MARIA PONS[2] & ESMERALDA CAUS[2]

(With 6 plates, 5 text-figures and 5 tables)

Manuscript submitted on 17 December 2003,
the revised manuscript on 23 February 2004

Abstract

In a debrite intercalated into a succession of Campanian deep-water marls quarried at Wietersdorf (Krappfeld, Central Alps, Austria), limestone clasts record lowstand erosion of a carbonate shelf. The debrite interval is about 3 m thick, and consists mainly of limestone clasts with rudists, intra-plasticlasts of deep-water marls, and of bioclasts from neritic areas (including isolated rudists). The planktic foraminiferal assemblage in the matrix of the debrite suggests a late Campanian age. The limestones of the clasts record erosion of an outer platform succession subject to subaerial exposure and karstification, followed by rounding and bioerosion of clasts along a rocky to gravelly shore, before ultimate deposition in the debrite. The benthic foraminiferal assemblage of the clasts is dominated by textulariines and miliolines, and contains a few taxa to date not reported from the Upper Cretaceous of the Northern Calcareous Alps. The rudist fauna is dominated by hippuritids and radiolitids. The hippuritid fauna of *Vaccinites vesiculosus*, *V. ultimus*, *Hippurites colliciatus* and *H. heritischi* appears to be characteristic of the lower to middle Campanian. For rudist shells, strontium isotope ratios produced by previous authors indicate an early middle Campanian age, suggesting an age difference of a few millions of years between the rudists and late Campanian debrite deposition.

Key words: Upper Cretaceous, Eastern Alps, Central Alps, carbonate platform

Introduction

At Wietersdorf in the Upper Cretaceous of Krappfeld, a debrite layer intercalated into a succession of deep-water marls is exposed. Because of its content in both isolated rudists and limestone clasts derived from a carbonate shelf, and because the Upper Cretaceous of Krappfeld is very scarce in rudists (cf. VAN HINTE 1963), this debrite has long attracted the attention of rudist palaeontologists. The rudist fauna of the debrite was previously investigated by KÜHN (1960) and LUPU (1977). THIEDIG (1975) also figured some rudists of the debrite, and was first who recognized that the debrite was deposited as an event bed. STEUBER (2001) had produced strontium isotope data of the shells of rudists of the debrite layer. The microfacies and micropalaeontology, and the diagenetic

[1] Dr. Diethard SANDERS, Institut für Geologie und Paläontologie, Universität Innsbruck, A-6020 Innsbruck. – Austria.

[2] Dr. Josep Maria PONS, Dr. Esmeralda CAUS, Departament de Geologia, Universitat Autònoma de Barcelona, E-08193 Bellaterra (Barcelona). – Espanya.

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

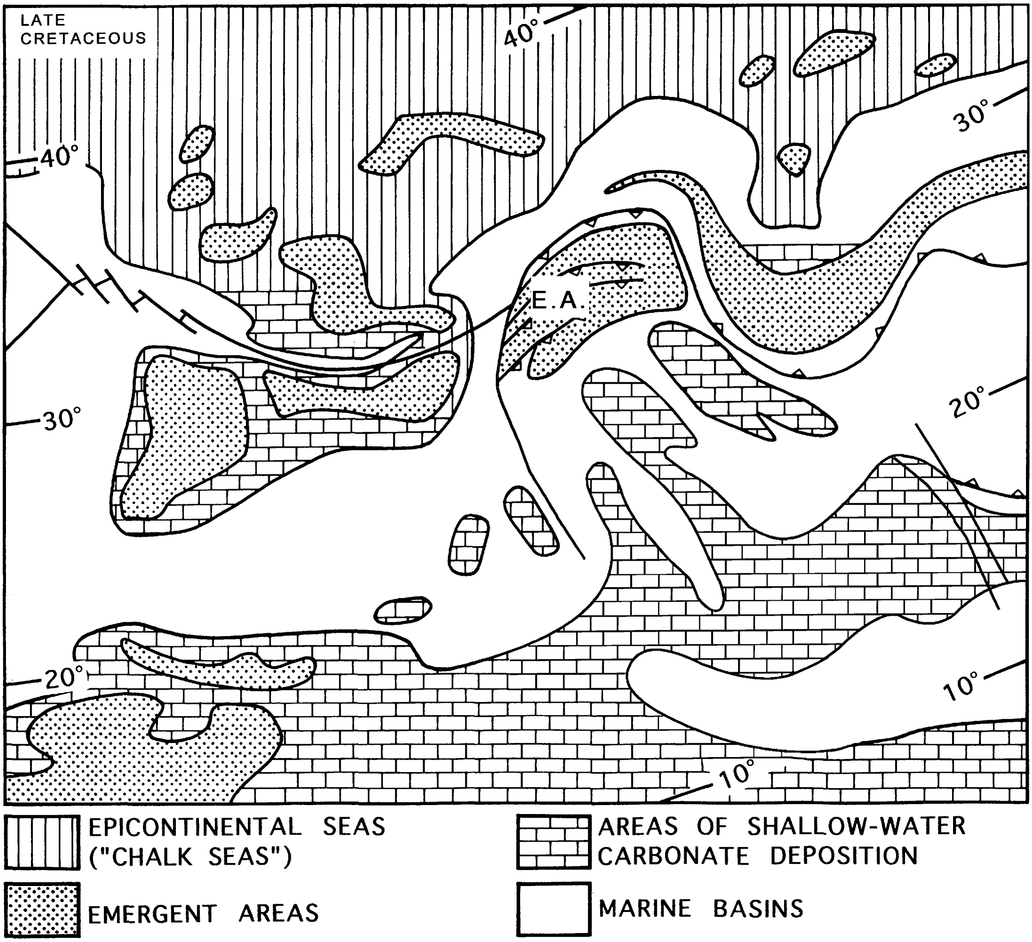


Fig. 1: Late Cretaceous palaeogeography of the central and western Tethys (modified after BOSELLINI 2002). E. A.: Alpine orogenic wedge.

pathways of the platform clasts, however, still were unclear. For the present study, we selected twenty-three limestone clasts for documentation of biotic assemblages, microfacies and diagenesis. Seventy polished slabs and 49 thin sections were investigated. Results indicate erosion of a subaerially exposed carbonate shelf, along a rocky to gravelly shore, followed by redeposition of shore zone clasts within the deep-water debrite.

Geological Setting

The present Central Alps are part of the Austroalpine structural unit, a continental domain that was situated between the Penninic seaway in the north and the Tethys in the south (fig. 1) (e. g. FAUPL & WAGREICH 2000). During latest Jurassic to early Cretaceous orogenic convergence, the area of the Central Alps was overridden by Austroalpine

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

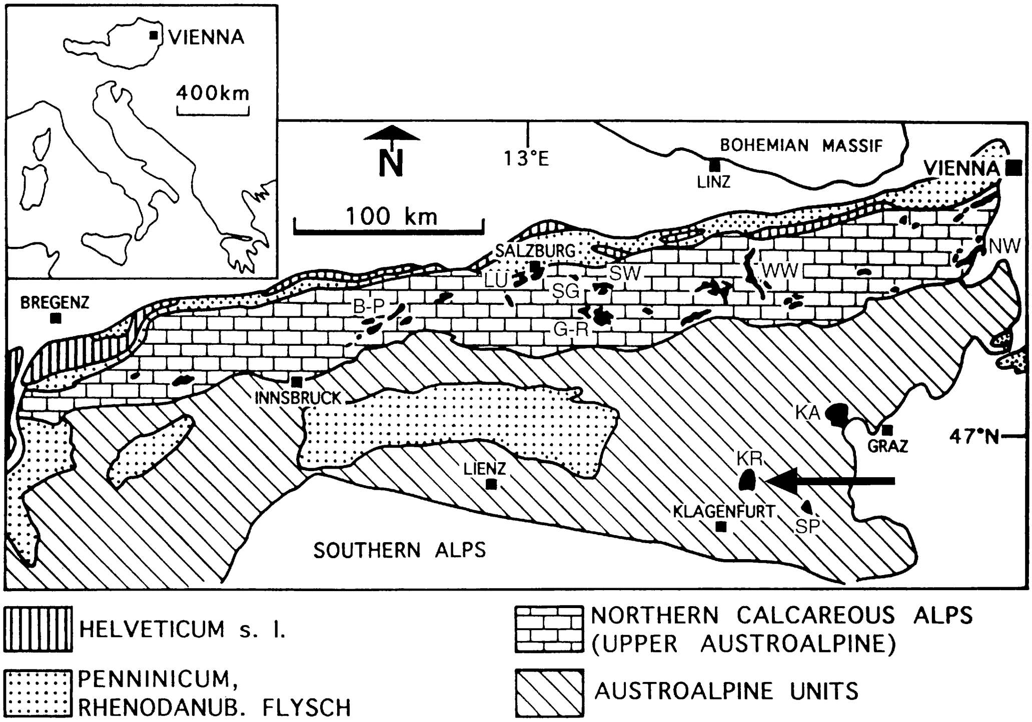


Fig. 2: Larger outcrops of Upper Cretaceous deposits (black) in the Eastern Alps. Upper Cretaceous of the Northern Calcareous Alps: B-P: Brandenberg-Pendling; G-R: Gosau-Rigaus; LU: Lattenberg, Untersberg; NW: Neue Welt; SG: Sankt Gilgen; SW: Sankt Wolfgang area; WW: Weisswasser. Upper Cretaceous of the Central Alps; KA: Kainach. KR: Krappfeld (marked by arrow); SP: Sankt Paul in Lavanttal.

thrust nappes that today include the Northern Calcareous Alps (fig. 2) (e. g. OBERHAUSER 1995). Subsequent to nappe thrusting, large parts of the orogen were uplifted and subaerially eroded (e. g. RATSCHBACHER et al. 1989). From Turonian to Campanian times, as a result of deep-seated detachments in the orogen (e. g. RATSCHBACHER et al. 1989), a large part of the emergent areas was transgressed by the sea, and a mixed clastic-carbonate succession (Gosau Group) accumulated (e. g. WAGREICH & FAUPL 1994). As a consequence of oblique orogenic convergence, Late Cretaceous basin development was mainly controlled by strike slip and extension (e. g. FAUPL & WAGREICH 2000). In the Central Alps, the succession of Kainach (fig. 2) records strike slip as main process of basin development (NEUBAUER et al. 1995). During the Late Cretaceous, one or a few islands probably existed between the Central Alps and, northward thereof, the Northern Calcareous Alps (OBERHAUSER 1995). Because of later erosion, however, the persistence in space and time of these islands is hardly to reconstruct.

In the area of Krappfeld (figs. 2, 3), a Santonian to Campanian succession (Krappfeld Group; VAN HINTE 1963) overlies a substrate of metamorphics and of Triassic dolomites and clastics. The few preserved stratigraphic transitions (cf. THIEDIG 1975) from the substrate into the Krappfeld Group record an overall rapid deepening from a transgres-

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

sive, rocky to gravelly shore zone via neritic environments to bathyal depths (VAN HINTE 1963). Such a deepening, combined with a thickness of the Krappfeld Group of more than 2000 meters suggest that this depocenter, too, was controlled by strike-slip (WAGREICH & SIEGL-FARKAS 1999, WILLINGSHOFER et al. 1999). Only during Early Tertiary time, perhaps as a result of surface uplift and/or because strike-slip related subsidence ceased (cf. WAGREICH & SIEGL-FARKAS 1999), terrestrial and neritic deposits accumulated (cf. VAN HINTE 1963).

Age of debrite

THIEDIG (1975: 509) summarized and discussed the biochronostratigraphic evidence from the Krappfeld Group and stated that the debrite layer may be of late Campanian age. Immediately above the debrite, however, unnamed "new determinations" (THIEDIG 1975: 509) marked a late Campanian to Maastrichtian age range. For the debrite, our data (tab. 1) indicate a co-occurrence of *Globotruncanita stuarti*, *Globotruncana bulloides* and *G. ventricosa*. This suggests that the assemblage pertains to the falsostuarti zone, which can be correlated to within the late Campanian (SCHÖNFELD & BURNETT 1991, WAGREICH & KRENMAYR 1993, see also WAGREICH & SIEGL-FARKAS 1999). Strontium isotope ratios in shells of rudists of the debrite indicate an age of about 80 Ma (80.9-79.3 Ma), corresponding to the lower middle Campanian in the time scale of GRADSTEIN et al. (1995) (STEUBER 2001, his fig. 4). This indicates that an age difference of a few millions of years exists between the rudists and the marl matrix of the debrite (cf. GRADSTEIN et al. 1995, their Fig. 8).

Tab. 1: Alphabetic list of planktic foraminifera identified in the matrix of the Knödelbrekzie debrite. n. d. = not determined. Not determined at genus level: hedbergellids (sample K10) and heterohelicids (samples K10, K14).

Genus	**Species**	**Range**	**Sample**
Globigerinelloides	n. d.	Aptian to Maastrichtian	K4, K10, K14,
Globotruncana	*arca*	late Santonian-late Maastrichtian	K1, K14,
Globotruncana	*bulloides*	latest Santonian-early Maastrichtian	K1,
Globotruncana	*falsostuarti*	late Campanian-top Maastrichtian	K2,
Globotruncana	*?linneiana*	-	K9
Globotruncana	*ventricosa*	middle Campanian-early Maastrichtian	K12
Globotruncanita	*stuarti*	base to top Maastrichtian	K15
Rosita	*fornicata*	early Santonian-late Maastrichtian	K1, K2,

Debrite interval

The debrite sampled by us is exposed in quarry no. V of the Wietersdorfer Zementwerke AG. This quarry is abandoned since about 45 years (cf. THIEDIG 1975: 502), and is cut into a succession that consists mainly of beds of lithoclastic calcirudites to calcarenites, and of marly limestones to marls with planktic foraminifera. The calcirudites to calcarenites are arranged in sharp-based, normally graded beds a few decimeters to a few meters thick. The base of some graded beds may show a few flute casts and load casts

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

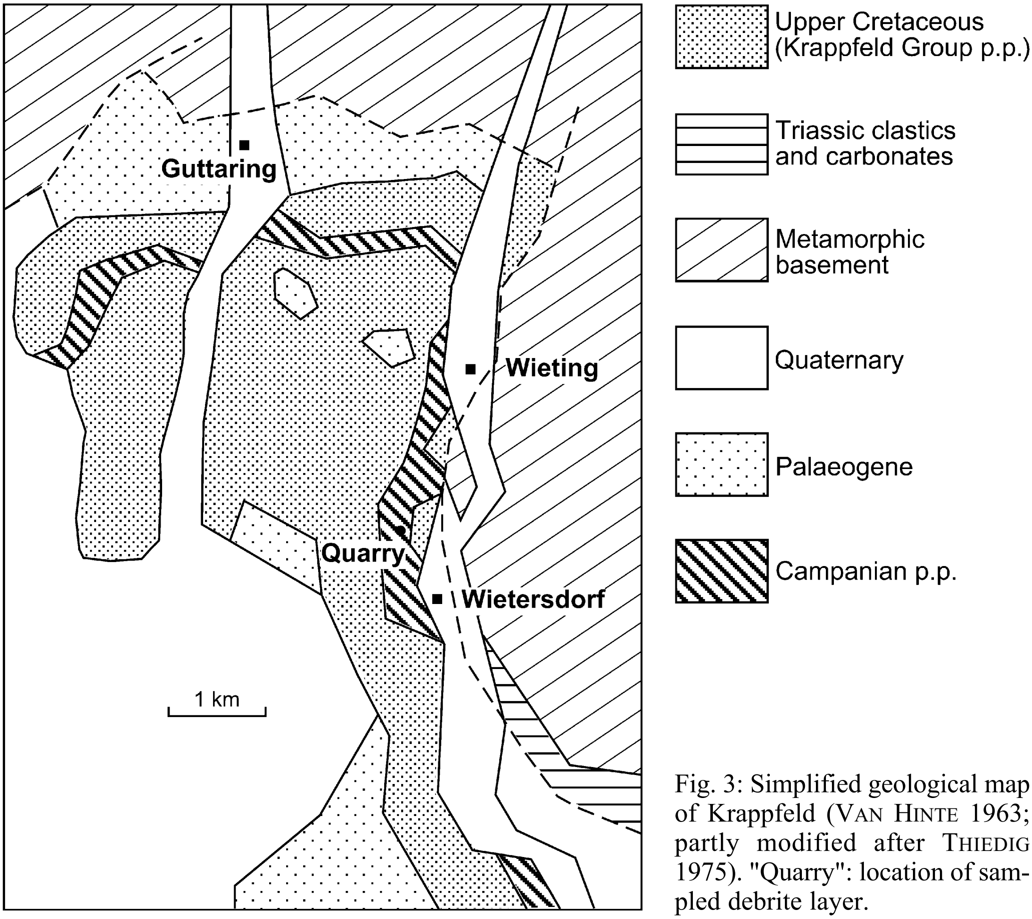


Fig. 3: Simplified geological map of Krappfeld (VAN HINTE 1963; partly modified after THIEDIG 1975). "Quarry": location of sampled debrite layer.

(THIEDIG 1975). The debrite layer described herein is the most conspicuous, thickest bed in outcrop. The debrite sharply overlies thin-bedded, dark grey marls along a slightly erosive, gently wavy boundary (pl. 1). The entire event interval is about 10 m in thickness, but lithoclasts are present only in its lower 2.5-3 meters (pl. 1), and fine up-section (THIEDIG 1975). Limestone clasts are up to about 1 m in diameter, but most are a few centimeters to about 30 cm in size. In addition, deformed intra-plasticlasts a few decimeters to a few meters in size of deep-water marls are common (pl. 1, pl. 2). Isolated fossils such as rudists and corals also are present (pl. 2). Moreover, a few clasts of Triassic dolomite, banded lydite, well-rounded quartz gravels, light-brown quartzites, and small clasts of slates were mentioned by THIEDIG (1975: 506). Most of the limestone clasts, also the large ones, are subangular to well-rounded; therefore, THIEDIG (1975) termed the debrite "Knödelbrekzie", perhaps as an hommage to what he saw on the local menu most evenings. The matrix of the debrite layer is a dark grey marl rich in planktic foraminifera. THIEDIG (1975: 509 ff.) concluded that the Knödelbrekzie originated from a turbidity current. We concur with this interpretation. The normal grading of clast size (over the entire event interval), and the intra-plasticlasts of marl that may have been ripped up upon passage of a turbulent fluidal flow are consistent with

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

Tab. 2: Carbonate lithoclasts from the Wietersdorf debris flow, their interpreted depositional environment, and energy index of PLUMLEY et al. (1962). Energy indices such as II/IV denote prevalent water energy regime (II) and episodic water energy regime (IV).

Sample number	Texture, sorting	Main constituents	Interpreted depositional environment (energy index)
K1	coral-clastic floatstone, very poorly sorted, matrix is microbioclastic packstone	fragments from coral heads, branched corals, skeletal sponges, smaller benthic foraminifera	outer platform (index III/IV), moderate water energy, episodic high-energy events
K2	foraminiferal packstone to grainstone, moderately well-sorted	miliolids, textulariines	inner platform (index II-III) or protected portion of outer platform
K3	bioclastic packstone, very poorly sorted	small rudist fragments, smaller benthic foraminifera, *Pseudosiderolites*	outer platform (index III/V), moderate water energy, episodic high-energy events
K4	bioclastic floatstone, very poorly sorted	large rudist fragments	inner platform (index II/IV), episodic high-energy events
K5	bioclastic floatstone, poorly sorted, matrix: bioclastic packstone to wackestone	mollusc fragments, fragments from branched corals, small toppled rudists (*Hippurites*), miliolids	outer platform (index II/IV)
K6	bioclastic floatstone, very poorly sorted	fragments from coral heads, branched corals, rudists	outer platform (index III/IV)
K7	rudist-clastic grainstone, moderately well to well-sorted	rounded, micrite-rimmed rudist fragments	outer platform (index IV-V)
K8	rudist-clastic packstone	rudist fragments	outer to inner platform (index III)
K9	bioclastic floatstone, poorly sorted, matrix: bioclastic grainstone	mainly unmicritized fragments from rudists, corals, serpulids, smaller benthic foraminifera, pellets, fragment of *Pseudopolyconites*, crustacean pellets	outer platform (index II-IV)
K10	rudist floatstone to rudstone, very poorly sorted, matrix: poorly sorted bioclastic packstone	mainly fragments of radiolitids (incl. *Pseudopolyconites*), few smaller benthic foraminifera	outer to inner platform (index II-III)
K11	bioclastic packstone to grainstone, very poorly sorted	subrounded to well-rounded, micrite-rimmed fragments of corals, rudists and red algae	outer platform (index III-IV)

transport and deposition from suspension (cf. SHANMUGAM 1997). Alternatively, the marl plasticlasts originated from mixing of slump phacoids into an evolving debris flow to turbidity current; both possibilities are not mutually exclusive. During deposition, in its basal part, the turbidity current probably passed through a short debris-flow stage. This is suggested by lack of deep scours at the base of the debrite and by our observation that, despite normal grading on the scale of the entire bed, the lithoclasts in the basal 1-2 m of the layer are not vertically arranged according to size. Other aspects of the debrite are discussed farther below.

Limestone clasts

Composition and texture

Many of the rounded clasts show more-or-less deep, irregular "pits" down to a few centimeters in depth and a few millimeters to a few centimeters in width. The shape of these "pits" is highly variable. Some clasts contain *Trypanites* down to several centimeters in depth. In thin section, many clasts show a finely serrated to deeply pitted outline at their surface. Both the described "pits" and Trypanites-borings are filled with the debris flow

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

Tab. 2 continued.

Sample number	Texture, sorting	Main constituents	Interpreted depositional environment (energy index)
K12	peloidal grainstone, moderately well-sorted	peloids (more-or-less micritized fragments of rudists), fragments of red algae, calcareous green algae, miliolids, textulariines	inner platform (index II-III), or protected portion of outer platform
K13	bioclastic packstone, poorly sorted	larger fragments of branched corals, small rhodoliths, microgastropods, dasyclad fragments, micritized unidentifiable biodetritus	protected part of outer platform (index II/IV)
K14	bioclastic grainstone to packstone, very poorly sorted	rudist fragments (incl. *Pseudopolyconites*), many miliolids and other smaller benthic foraminifera	inner platform (index II-III)
K15	bioclastic packstone to floatstone, very poorly sorted	unmicritized fragments of rudists and corals	outer platform (index III/IV)
K16	bioclastic grainstone, moderately well-sorted	more-or-less micritized and rounded fragments of rudists, corals, coralline algae, diverse smaller benthic foraminifera miliolids	protected portion of outer platform (index II/IV)
K17	bioclastic grainstone, moderately sorted	more-or-less micritized and rounded rudist fragments, miliolids	outer platform (index IV-V)
K18	bioclastic floatstone to rudstone, very poorly sorted, matrix: very poorly sorted biocl packstone to wackestone	fragments from branched corals, coral heads, calcisponges, demosponges	outer platform, reefal s. l. (index II-III)
K19	bioclastic packstone, very poorly sorted	fragments of rudists, chaetetids, corals	outer platform (index II-III)
K20	bioclastic grainstone to packstone, very poorly sorted	rudist fragments, many miliolids and other smaller benthic foraminifera, red algal fragments, few echinoderm fragments	inner platform (index III-IV), or protected portion of outer platform
K21	bioclastic grainstone, moderately sorted	unidentifiable bioclasts, miliolids	platform (index II-III)
K22	bioclastic grainstone, very poorly sorted, with parallel lamination	rudist fragments	outer platform (index IV-V)
K23	coral-clastic floatstone	large fragments of branched corals	outer platform (index III/IV)

matrix (pl. 3). The carbonate clasts are pure limestones that, according to texture and bioclasts, accumulated in protected, restricted shallow subtidal (e. g. miliolid-ostracod wackestones) to high-energy, open subtidal environments (e. g. rudstones of debris of corals, skeletal sponges and rudists) (tab. 2, pl. 3). Both in the debrite and in the sample of clasts extracted, most clasts are bioclastic packstones to grainstones to rudstones. Bioclastic packstones to grainstones typically are poorly sorted, bioturbated, and consist of both angular and more-or-less micritized, rounded bioclasts. In a few grainstone clasts, platy components are oriented, suggesting hydrodynamic lamination. The bioclastic fraction is dominated by fragments of rudists and, locally, of corals (plocoid, thamnasterioid and meandroid forms). Other constituents of bioclastic limestones include benthic foraminifera (see below), and fragments of echinoids, coralline algae, *Pseudolithothamnium album*, brachiopods, non-rudist bivalves, bryozoans, skeletal sponges (e. g. *Vaceletia*) and calcareous green algae (e. g. *Permocalculus*). Bioclastic rudstones consist of fragments of corals and/or rudists in a matrix of poorly sorted bioclastic wackestone to packstone to grainstone. A few clasts consist of rudist-clastic wackestone with entire rudists, or of peloidal-foraminiferal grainstone.

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

Interpretation

The described "pits" on the surface of many clasts as well as the *Trypanites* ichnofacies were produced by rasping and boring organisms, when the clasts were already in existence. Carbonate clasts penetrated by *Trypanites* form in rocky to gravelly shore zones (e. g. SANDERS 1997, GIBERT et al. 1998). Shores with rock cliffs and gravelly to sandy pocket beaches are widespread on exposed, or partly exposed, carbonate shelves (SPENCER & VILES 2002). The bioclastic packstones to rudstones were deposited in a shallow, open subtidal environment of moderate to intermittently high water energy. Peloidal-foraminiferal grainstones to packstones may accumulate in protected portions of carbonate shelves (e. g. EBANKS 1975), or from episodically active sand bodies on the external platform (e. g. HINE et al. 1981). Miliolid wackestones to mudstones typically form in sheltered, shallow subtidal lagoonal areas that yet may be situated close to the platform margin (e. g. COLBY & BOARDMAN 1989). Depending on shape, size, energy exposure and facies architecture of a carbonate shelf, facies belts may be of highly variable width (e. g. WILSON 1975). During the Late Cretaceous, bioclastic limestones with corals and rudists typically accumulated in external platform belts a few hundreds of meters to about 10 kilometers in width (e. g. SARTORIO & VENTURINI 1988, SANDERS 1996). In the clast spectrum, the prevalence of bioclastic packstones to rudstones, and the absence of lithologies indicative of larger tidal flats (e. g. loferites, stromatolithic mudstones) suggest that the eroded carbonate shelf lacked large tidal flats, or that the clasts were derived only from the external shelf portion.

Diagenesis

The limestone clasts record three distinct diagenetic successions (termed A, B and C in tab. 3). Some grainstones to rudstones are lithified by finely crystalline equant calcite spar, overlain by blocky calcite spar. Aragonite of coral skeletons and of the hypostracum of rudists is replaced by blocky calcite spar. Several clasts record a more complex diagenesis. In these, a first cement generation is represented by an isopachous fringe of equant calcite spar or of dog tooth spar, or syntaxial cement on echinoderm grains. The precipitation of these cements was followed by formation of solution pores; these pores, in turn, are geopetally filled by laminated lime mudstone and/or micropeloidal limestone (pl. 3). In sample K 18, an isopachous radial-fibrous cement had precipitated after aragonite dissolution and before geopetal infill of lime mudstone to micropeloidal packstone. Commonly, however, the geopetal fills are overlain by isopachous calcite cement with a relictic, radial-fibrous to acicular fabric. The cement fringes, in turn, are overlain by blocky calcite spar. In other clasts, the geopetal fills are absent, and the inner surface of formely aragonitic bioclasts is coated by a thin, isopachous fringe of equant calcite spar, overlain by blocky calcite spar. In sample K 14, both geopetal infills and cements are absent, and biomoulds of formely aragonitic bioclasts or aragonitic shell parts are filled by a wackestone rich in planktic foraminifera (see also pl. 3).

Interpretation

In limestone clasts with diagenetic pathway C (see tab. 3), typically grainstones to rudstones, precipitation of isopachous fringes of equant spar or of fringes of dog tooth spar proceeded in a phreatic environment, under shallow burial. The following dissolution of

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

Tab. 3: Diagenetic successions recorded in limestone clasts of the Wietersdorf debrite.

pathway A
1 - aragonite dissolution 2 - aragonite biomoulds filled by planktonic foraminiferal wackestone (debrite matrix)
pathway B
1 - finely crystalline equant calcite spar 2 - blocky calcite spar
pathway C (*with some variation*)
1 - isopachous fringe of equant calcite spar/ dog tooth spar/ syntaxial cement (on echinoderm grains) 2 - microkarstification 3 - isopachous radial-fibrous cement (locally) 4 - geopetal infill of laminated lime mudstone and/or micropeloidal packstone to grainstone into aragonite biomoulds and into microkarstic pores 5 - isopachous fringe of calcite cement with relictic, radial-fibrous to acicular fabric 6 - blocky calcite spar

aragonite and microkarstification records influx of meteoric water because of sea-level fall or local emersion. The filling of solution pores by lime mudstone and micropeloidal pack-grainstone, and presence of isopachous cements above the fills record resubmergence of the exposed carbonate shelf, or the exposed portion thereof, in marine waters. Such diagenetic histories are common on carbonate platforms. In some clasts, the solution pores stayed open, and were filled only by the planktic foraminiferal wackestone that constitutes the matrix of the debrite.

Overall, the limestone clasts record the following history (fig. 4). (1) Deposition mainly of lime-muddy to winnowed bioclastic sands in shallow subtidal, low-energy to open high-energy environments on the external portion (hundreds of meters to kilometers in width?) of a carbonate shelf. (2) Early cementation in a shallow burial, phreatic environment. (3) Aragonite dissolution and (micro)karstification when the carbonate shelf (or parts thereof) was subaerially exposed. (4) Platform re-flooding, deposition of internal sediments and, later, precipitation of marine cements in remaining open portions of solution pores. (5) Precipitation of blocky calcite spar in a phreatic, burial environment. (6) Sea-level fall, erosion, and formation of limestone clasts along a rocky to gravelly shore. (7) Transport of the limestone clasts into deep water, and infill of planktic foraminiferal marl into remaining open pores.

Foraminifera and rudists

With respect to abundance, the benthic foraminiferal fauna of the clasts is dominated by small miliolids and small textulariines, as characteristic of Late Cretaceous, shallow subtidal, pure carbonate environments dominated by rudist-clastic sand and lime mud (cf. SARTORIO & VENTURINI 1988). Ranges of smaller benthic foraminiferal genera and species commonly are large (tab. 4). The known ranges of *Reticulinella fleuryi*, *Pseudosiderolites* and, perhaps, also of *Accordiella* (pl. 4) may support an age difference between the limestone clasts and the depositional age of the debrite layer. The presence of benthic foraminifera, however, is strongly controlled by local environmental conditions,

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

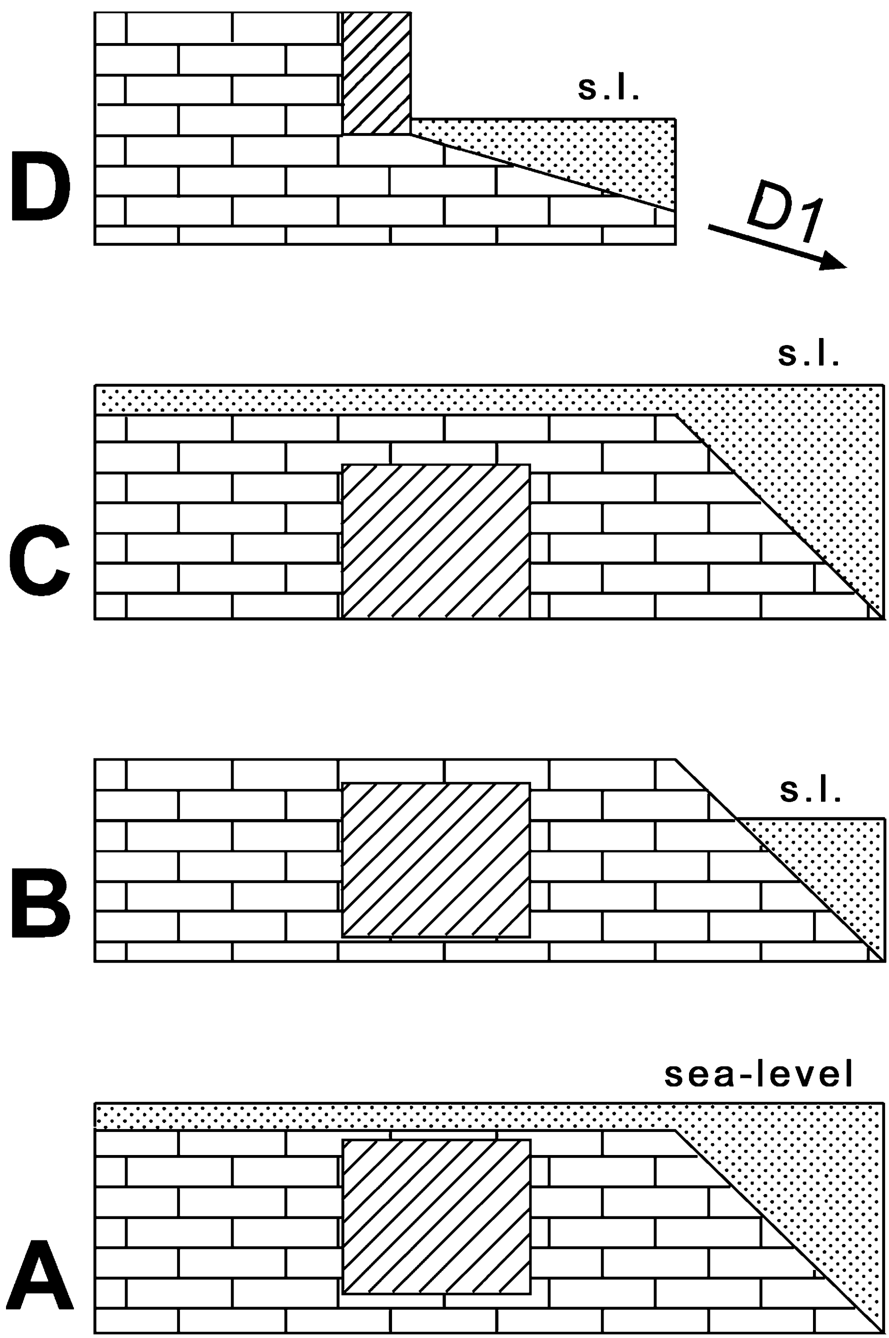


Fig. 4: Depositional history recorded by limestone clasts of the "Knödelbrekzie" debrite. Stippled: sea. s.l. = sea-level. Cross-hatched: schematic position of eroded sediments. A: Deposition on external carbonate shelf. B: Subaerial exposure. Vadose diagenesis and (micro)karstification. C: Reflooding and carbonate deposition. D: Sea-level fall, subaerial erosion, formation of limestone clasts along a rocky to gravelly shore. D1: Transport of limestone clasts in a turbidity current.

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

Tab. 4: Alphabetic list of benthic foraminifera identified in the limestone clasts of the Knödelbrekzie debrite. Taxa in bold were also mentioned from the Upper Cretaceous of the Northern Calcareous Alps. n. d. = not determined

Genus	Species	Range	Sample
Accordiella	*conica*	Coniacian-Campanian, ?Maastrichtian (Pyrenees)	K2/1, K2/2, K2/3, K14/1.1, K16/1, K20/1, K20/2, K20/3
Bolivinopsis	n. d.	Late Cretaceous	K1, K2/1, K2/2, K2/3, K9/1.3, K12, K14/1.1, K18/2, K20/1-3
Calveziconus	*lecalvezae*	Campanian (at least)	K2, K20
Cuneolina	sp.	genus: Valanginian to Maastrichtian	K2/1, K2/2, K2/3, K12, K14, K20
Cuneolina	cf. *kethini*	Unknown at present. Genus: Valanginian-Campanian-?Maastrichtian	K12
Dicyclina	*schlumbergeri*	Cenomanian to Maastrichtian	K2/1, K2/2, K2/3, K12, K14/1.1, K19
Fleuryana	*adriatica*	Maastrichtian	K20/1, K20/3, K20/4
Fleuryana	sp.	Range of genus poorly known: Santonian-Maastrichtian	K2
Lenticulina	sp.	Triassic to Holocene	K3, K11/1, K11/2.1, K11/2.2,
Marssonella	***oxycona***	Genus: Cretaceous	K5, K12
Marssonella	cf. *oxycona*	Genus: Cretaceous	K9
Minouxia	sp.	Santonian to Maastrichtian	K2
Mississippina		not precisely known	K19
Orbitoides		Late Santonian to Maastrichtian	K15
Pseudosiderolites	sp.	Campanian to ?Maastrichtian	K3
Reticulinella	***fleuryi***	Late Santonian-Early Campanian at type locality	K20/1, K20/2
Questionable identifications or taxa of uncertain taxonomic affiliation (sample no.): *Abrardia* (K5, K10, K12), *Accordiella* (K12), *Calveziconus* (K14), *Charentia* (K12), *"Debarina"* (K2), *Fleuryana* (K18), *"Hemicyclammina"* (K12), *Lituola* (K12, K19), *Mississippina* (K2), *Nezzazatinella* (K9, K20), *Nummofallotia* (K20), *Pseudosiderolites* (K11), *Vercorsella* (K20)			
Not determined at genus level (sample no.): haplophragmoidids (K2, K14, K15, K18), small rotaliids (K14), textulariina (several samples), miliolina (small "miliolids") (several samples)			

and full chronostratigraphic ranges are still poorly defined for many areas of the Tethys. The foraminifera *Dicyclina*, *Accordiella* and *Fleuryana* are common in Upper Cretaceous southern Tethys biofacies, but to date were not mentioned from the Gosau Group of the Northern Calcareous Alps (cf. tab. 4). In particular, *Dicyclina* is widespread and common in Cenomanian to Maastrichtian carbonate and mixed clastic-carbonate successions from Southern France to the Dinarids (e. g. SARTORIO & VENTURINI 1988) and to the area of Krappfeld in the Central Alps. Similarly, by their chronostratigraphic range, both *Accordiella conica* (base Coniacian to top Campanian) and *Fleuryana* (Santonian-Maastrichtian) might well be expected to occur in the Northern Alps. The rudist fauna includes both specimens within the limestone clasts and isolated in the debrite (tab. 5, pl. 5, pl. 6). The assemblage is characterized by the hippuritids *Vaccinites vesiculosus*, *V. ultimus*, *Hippurites colliciatus* and *H. heritschi*. This assemblage seems to be widespread in the lower to lower middle Campanian (T. Steuber, pers. comm., 2004).

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

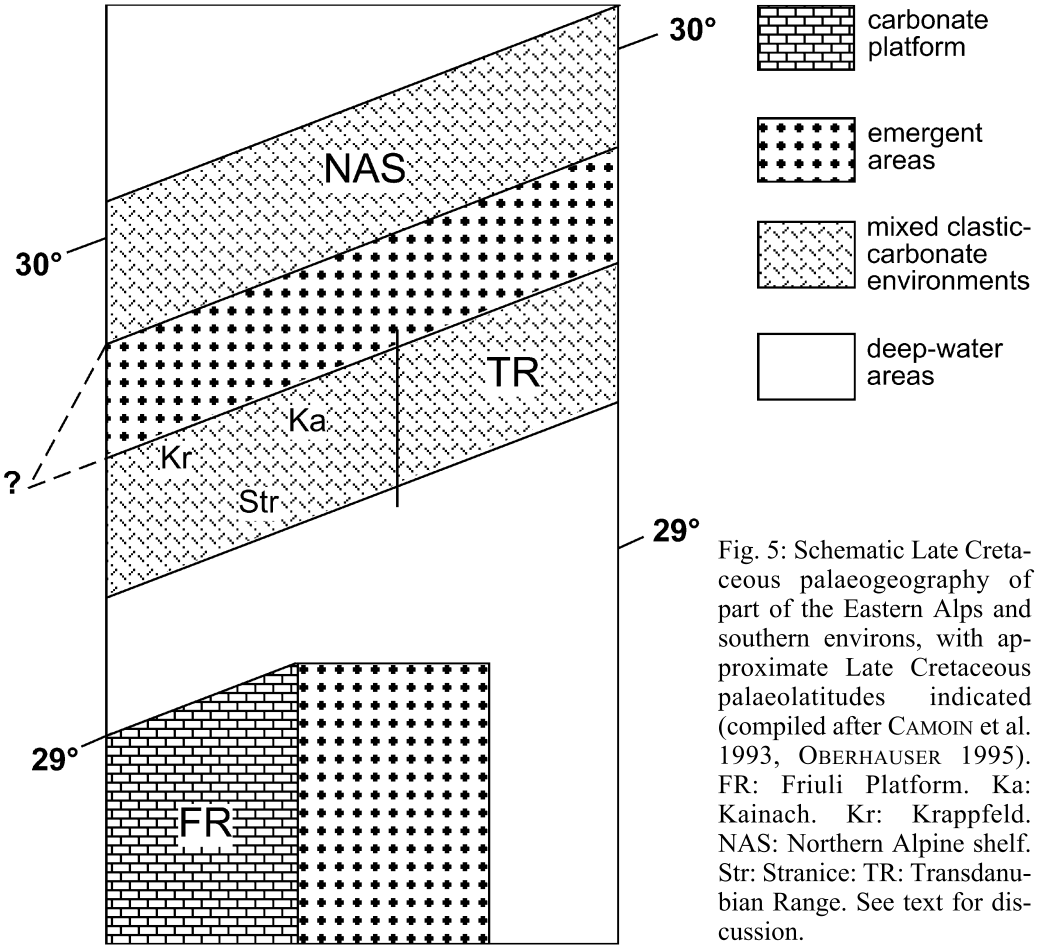


Fig. 5: Schematic Late Cretaceous palaeogeography of part of the Eastern Alps and southern environs, with approximate Late Cretaceous palaeolatitudes indicated (compiled after CAMOIN et al. 1993, OBERHAUSER 1995). FR: Friuli Platform. Ka: Kainach. Kr: Krappfeld. NAS: Northern Alpine shelf. Str: Stranice: TR: Transdanubian Range. See text for discussion.

Discussion

The carbonate shelf that delivered the limestone clasts is elusive. In situ shallow-water limestones are present at Kainach and Sankt Paul in Lavanttal (fig. 2). At Kainach, limestones comprise only a very small portion of the succession. At Sankt Paul, a succession at least a few tens of meters thick of poorly exposed, pure shallow-water limestones is present. These limestones accumulated on a carbonate shelf, or on the pure carbonate sector of a mixed clastic-carbonate shelf. Because of poor outcrop and limited preservation, however, no further conclusions on this shelf are possible. At Stranice in Slovenia, north of the peri-Adriatic lineament, erosional remnants of a carbonate platform succession are present (fig. 5) (PLENICAR & PREMRU 1983, PLENICAR & SRIBAR 1992). Together, this indicates that, during Campanian time, southward of Krappfeld a larger carbonate shelf or several smaller carbonate shelves separated by seaways existed (cf. PLENICAR 1993). Although this shelf, or these shelves, were separated from the Friuli platform (fig. 5), their rudist fauna is similar (cf. CAFFAU et al. 1992, SWINBURNE & NOACCO 1993).

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

Tab. 5: Rudists (Hippuritacea) of the Wietersdorf debrite.

Family	Genus	Species, presence	Source	Remarks
Hippuritidae	*Vaccinites*	*vesiculosus*	this paper	Range: Campanian (mentioned by KÜHN 1960 as *Hippurites atheniensis*)
		ultimus	this paper	Range: Campanian (mentioned by KÜHN 1960 as *Hippurites cornuvaccinum* and *Hippurites gaudryi*)
	Hippurites	*colliciatus*	this paper	Range: Campanian (mentioned by LUPU 1977 as *Hippurites castroi*, figured in THIEDIG 1975)
		heritschi	KÜHN (1960)	Range: Campanian to ?Maastrichtian
Radiolitidae	*Radiolites*	cf. *angeiodes*	KÜHN (1960), this paper	Range of *angeiodes*-group: middle Turonian to Maastrichtian.
	Pseudopolyconites	sp.	this paper	Range of genus: Santonian to Maastrichtian (range not well-established)
	Joufia	sp.	LUPU (1977), this paper	Range: Campanian to ?Maastrichtian

Event beds shed from carbonate shelves subject to deep erosion typically contain lithoclasts derived from inner to outer platform successions, comprising a chronostratigraphic range easily resolvable by index fossils (e. g. VECSEI & SANDERS 1997). In the Wietersdorf debrite, by contrast, the derivation of clasts from outer platform environments, and the absence of clasts of peritidal inner platform environments suggest that the erosional downcut was confined to a relatively narrow stratigraphic column. How did these clasts make their way from the shore zone across the shelf break? The clasts may have been transported from the inner shore zone towards or across the edge of a narrow, steep insular shelf by currents induced by storms or earthquakes; from there, they may have travelled another time in a turbidity current that, perhaps, originated by slumping. Alternatively, the clasts were transported across the shelf break and in the turbidity current during the same event (severe storm or tsunami backflow).

Conclusions

(1) The "Knödelbrekzie" debrite layer is probably of late Campanian age. The debrite is rich in limestone clasts derived from a lower to middle Campanian external platform succession.

(2) Before deposition in the debrite, most of the limestone clasts were shaped by abrasion and bioerosion in a rocky to gravelly shore zone. This shore zone was associated with sea-level fall and subaerial exposure of an unpreserved carbonate shelf.

(3) The benthic foraminiferal fauna of the limestone clasts is dominated by textulariines and miliolines, and contains taxa that, to date, were not mentioned from the Upper Cretaceous of the Northern Calcareous Alps. The rudist fauna is dominated by hippuritids. Strontium isotope ratios of rudist shells (produced by previous authors) indicate an early middle Campanian age. This indicates an age difference of a few millions of years between the rudists and the late Campanian deposition of the debrite layer.

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

Acknowledgements

The Wietersdorfer Zementwerke AG are thanked for allowing access to the outcrop. An instructive review by Michael Wagreich, Vienna, and comments of Thomas Steuber, Bochum, on rudist assemblages contributed to the quality of the paper. Financial support from project 10719-GEO (to D. S.) from the Austrian Research Foundation, and from Acciones Integradas Spain-Austria HU1996-0027, and support grants 1997SGR-00250, 1999SGR-00099, 2001SGR-00192 to "Grup del Cretaci i Terciari inferior" from Generalitat de Catalunya (to J. M. P.) are gratefully acknowledged.

References

BOSELLINI, A. (2002): Dinosaurs "rewrite" the geodynamics of the eastern Mediterranean and the paleogeography of the Apulia Platform. – Earth-Sci. Rev., **59**: 211-234. – Amsterdam.

CAFFAU, M., PIRINI RADRIZZANI, C., PLENICAR, M. & PUGLIESE, N. (1992): Rudist fauna and microfossils of the late Senonian (Monte Grisa area, Karst of Trieste, Italy). – Geol. Rom., **28**: 163-171. – Roma.

CAMOIN, G., BELLION, Y., BENKHELIL, J., CORNEE, J. J., DERCOURT, J., GUIRAUD, R., POISSON, A. & VRIELYNCK, B. (1993): Late Maastrichtian paleoenvironments (69.5-65 Ma). – In: DERCOURT, J., RICOU, L. E. & VRIELYNCK, B. (eds.): Atlas Tethys: Paleoenvironmental maps. Maps. BEICIP-FRANLAB, Rueil-Malmaison. – Paris.

COLBY, N. D. & BOARDMAN, M. R. (1989): Depositional evolution of a windward, high-energy lagoon, Graham's Harbor, San Salvador, Bahamas. – J. Sed. Pet., **59**: 819-834. – Tulsa.

DE CASTRO, P., DROBNE, K. & GUSIC, I. (1994): *Fleuryana adriatica*, n. gen., n. sp. (Foraminiferida) from the uppermost Maastrichtian of the Brac Island (Croatia) and some other localities on the Adriatic carbonate platform. – Razprave IV. Razreda Sazu. **35**/8: 129-149. – Ljubljana.

EBANKS, W. J. (1975): Holocene carbonate sedimentation and diagenesis, Ambergris Cay, Belize. – In: K. F. WANTLAND, W. C. PUSEY III, (eds.): Belize Shelf – Carbonate Sediments, Clastic Sediments, and Ecology. Am. Assoc. Petrol. Geol. Studies in Geology, **2**: 234-296. – Tulsa.

FAUPL, P. & WAGREICH, M. (2000): Late Jurassic to Eocene palaeogeography and geodynamic evolution of the Eastern Alps. – Mitt. Österr. Geol. Ges., **92**: 79-94. – Wien.

GIBERT, J. M., MARTINELL, J. & DOMÉNECH, R. (1998): *Entobia* ichnofacies in fossil rocky shores, Lower Pliocene, northwestern Mediterranean. – Palaios, **13**: 476-487. – Tulsa.

HINE, A. C., WILBER, R. J. & NEUMANN, A. C. (1981): Carbonate Sand Bodies Along Contrasting Shallow Bank Margins Facing Open Seaways in Northern Bahamas. – Am. Assoc. Petrol. Geol. Bull., **65**: 261-290. – Tulsa.

KÜHN, O. (1960): Die Rudistenfauna von Wietersdorf in Kärnten. – Carinthia II, **70**: 47-50. – Klagenfurt.

LUPU, D. (1977): Sur la présence du genre *Joufia* BOEHM dans le Maastrichtien de Wietersdorf-Krappfeld (Carinthie-Autriche). – Rev. roumaine Géol., Géophys. et Géogr., (Géologie), **21**: 131-136. – Bucuresti.

NEUBAUER, F. DALLMEYER, R. D., DUNKL, I. & SCHIRNIK, D. (1995): Late Cretaceous exhumation of the Gleinalm dome, Eastern Alps: kinematics, cooling history, and sedimentary response in a sinistral wrench corridor. – In: NEUBAUER, F. & WALLBRECHER, E. (eds.): Tectonics of the Alpine-Carpathian-Pannonian Region. – Tectonophysics, **242**: 79-98.

OBERHAUSER, R. (1995): Zur Kenntnis der Tektonik und der Paläogeographie des Ostalpenraumes zur Kreide-, Paleozän- und Eozänzeit. – Jb. Geol. Bundesanstalt, **138**: 369-432. – Wien.

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

PLENICAR, M. & PREMRU, U. (1983): Die Entwicklung der Kreideschichten Sloweniens. – Zitteliana, **10**: 191-194. – München.

—— & SRIBAR, L. (1992): Le récif de rudistes près de Stranice (N. O. de la Yougoslavie). – Geol. Rom., **28**: 305-371. – Roma.

—— (1993): The southern margin of the Styrian Cretaceous biolithitic complexes. – Mining and Metallurgy Quarterly (Rudarsko-metallurski Zbornik), **40**: 233-240. – Ljubljana.

PLUMLEY, W. J., RISLEY, G. A., GRAVES, R. W. & KALEY, M. E. (1962): Energy index for limestone interpretation and classification. – Am. Assoc. Petrol. Geol. Mem., **1**: 85-107. – Tulsa.

PONS, J. M. & SANDERS, D. (2000): Late Cretaceous rudist faunas from the Eastern Alps, Austria. – Sixth Internat. Cretaceous Symp., Vienna, Abstracts, p. 106. – Wien.

RATSCHBACHER, L., FRISCH, W., NEUBAUER, F., SCHMID, S. M. & NEUGEBAUER, J. (1989): Extension in compressional orogenic belts: The Eastern Alps. – Geology, **17**: 404-407. – Boulder.

SANDERS, D. (1996): Rudist biostromes on the margin of an isolated carbonate platform: The Upper Cretaceous of Montagna della Maiella, Italy. – Eclogae geol. Helv., **89**: 845-871. – Basel.

—— (1997): Upper Cretaceous transgressive shore zone successions ("Untersberger Marmor" Auct.) in the eastern part of the Tyrol (Austria): an overview. – Geol. Paläont. Mitt. Innsbruck, **22**: 101-121. – Innsbruck.

SARTORIO, D. & VENTURINI, S. (1988): Southern Tethys Biofacies. – Agip S. p. A., S. Donato Milanese, 235 pp.

SCHÖNFELD, S. & BURNETT, J. (1991): Biostratigraphical correlation of the Campanian-Maastrichtian boundary: Lägerdorf-Hemmoor (northwestern Germany), DSDP Sites 548A, 549, and 551 (eastern North Atlantic) with paleobiogeographical and paleoceanographical implications. – Geol. Mag., **128**: 479-503. – Herts.

SHANMUGAM, G. (1997): The Bouma sequence and the turbidite mind set. – Earth-Sci. Rev., **42**: 201-229. – Amsterdam.

SPENCER, T. & VILES, H. (2002): Bioconstruction, bioerosion and disturbance on tropical coasts: coral reefs and rocky limestone shores. – Geomorphology, **48**: 23-50. – Amsterdam.

SWINBURNE, N. H. M. & NOACCO, A. (1993): The platform carbonates of Monte Jouf, Maniago, and the Cretaceous stratigraphy of the italian Carnian Prealps. – Geologia Croatica, **46**: 25-40. – Zagreb.

THIEDIG, F. (1975): Submarine Brekzien als Folge von Felsstürzen in der Turbidit-Fazies der Oberkreide des Krappfeldes in Kärnten (Österreich). – Mitt. Geol.-Paläont. Inst. Univ. Hamburg, **44**: 495-516. – Hamburg.

VAN HINTE, J. E. (1963): Zur Stratigraphie und Mikropaläontologie der Oberkreide und des Eozäns des Krappfeldes (Kärnten). – Jb. geol. Bundesanstalt, Sdb. **8**, 147 pp. – Wien.

VECSEI, A. & SANDERS, D. (1997): Shelf margin aggradation and emersion related to sea-level highstand and lowstand shedding, Eocene-Oligocene of Maiella carbonate platform, Italy. – Sediment. Geol., **112**: 219-234. – Amsterdam.

WAGREICH, M. & FAUPL, P. (1994): Palaeogeography and geodynamic evolution of the Gosau Group of the Northern Calcareous Alps (Late Cretaceous, Eastern Alps, Austria). – Palaeogeogr., Palaeoclimatol., Palaeoecol., **110**: 235-254. – Amsterdam.

—— & KRENMAYR, H.-G. (1993): Nannofossil biostratigraphy of the Late Cretaceous Nierental Formation, Northern Calcareous Alps (Bavaria, Austria). – Zitteliana, **20**: 67-77. – München.

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

—— & SIEGL-FARKAS, A. (1999): Subsidence analysis of Upper Cretaceous deposits of the Transdanubian Central range (Hungary). – Abh. geol. Bundesanstalt, **56**/1: 435-438. – Vienna.

WILLINGSHOFER, E., NEUBAUER, F. & CLOETINGH, S. (1999): The significance of Gosau-type basins for the Late Cretaceous tectonic history of the Alpine-Carpathian belt. – Phys. Chem. Earth (A) **24**: 687-695. – Amsterdam.

WILSON, J. L. (1975): Carbonate Facies in Geologic History. – 471 pp. – Berlin (Springer).

Plate 1

Above: Sampled outcrop portion of "Knödelbrekzie" debrite, summer 1997. Black line indicates bedding, top to right. The debrite is immediately underlain by a package a few decimeters thick of back-weathering, dark grey marls. In the debrite, subangular to rounded clasts of shallow-water limestones, and slabs of marl intra-plasticlasts (labelled i) that may attain more than 10 m in length are obvious. Person for scale.

Below: Base and basal part of debrite interval, with load-induced deformation of underlying marlstone. Lithoclasts are shallow-water limestones derived from external platform environments. Note subangular to rounded shape of clasts. Hammer is 30 cm in length.

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

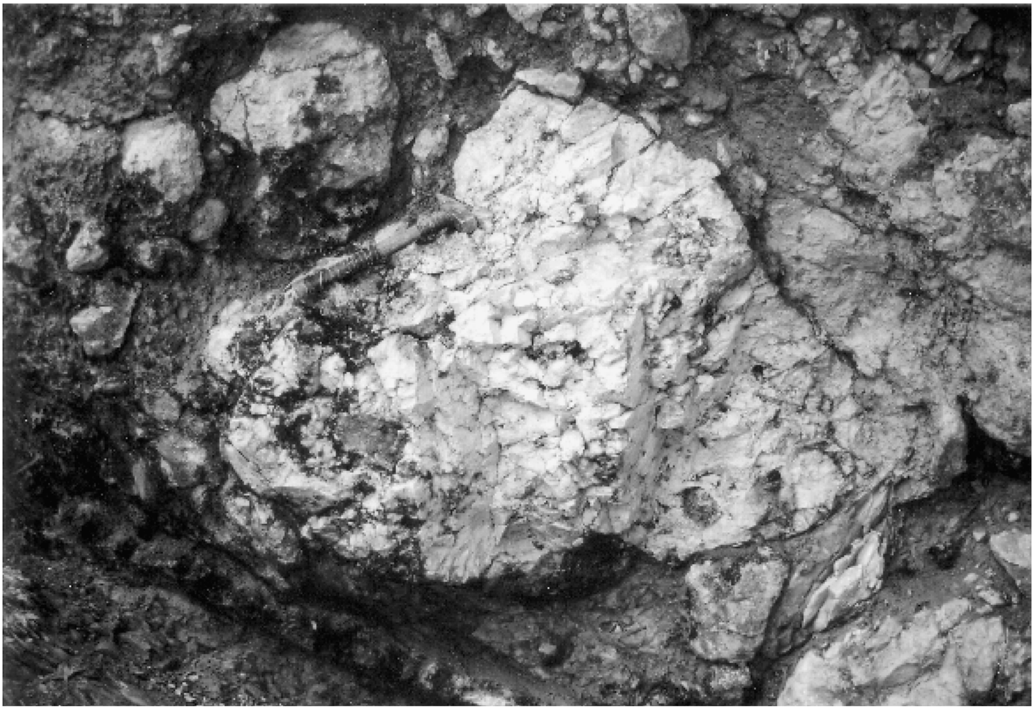
©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

Plate 2

Above: Base and basal part of debrite interval. Clast of limestones rich in corals and rudists. Some of the corals and of the rudists are preserved as moulds. Hammer is 33 cm in length.

Below: Transversal view of lower valve of *Joufia* sp. preserved isolated in the debrite interval. A geopetal infill of marlstone is similar to the marl in which the shell is embedded, and is concordant with bedding dip. Shell is about 11 cm in diameter.

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at



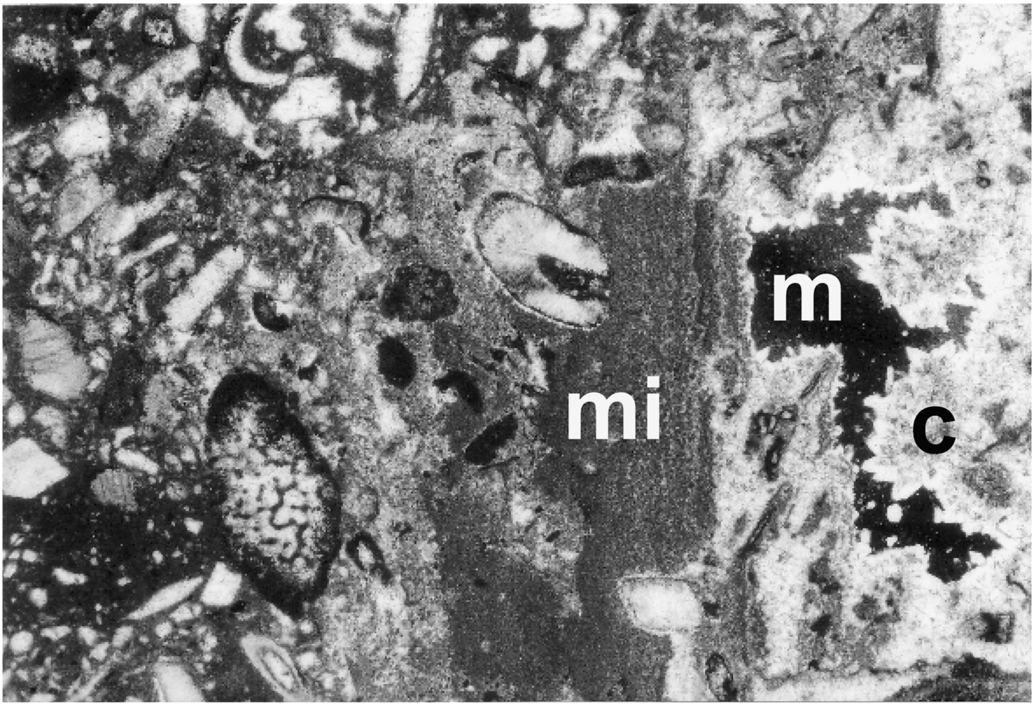
©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

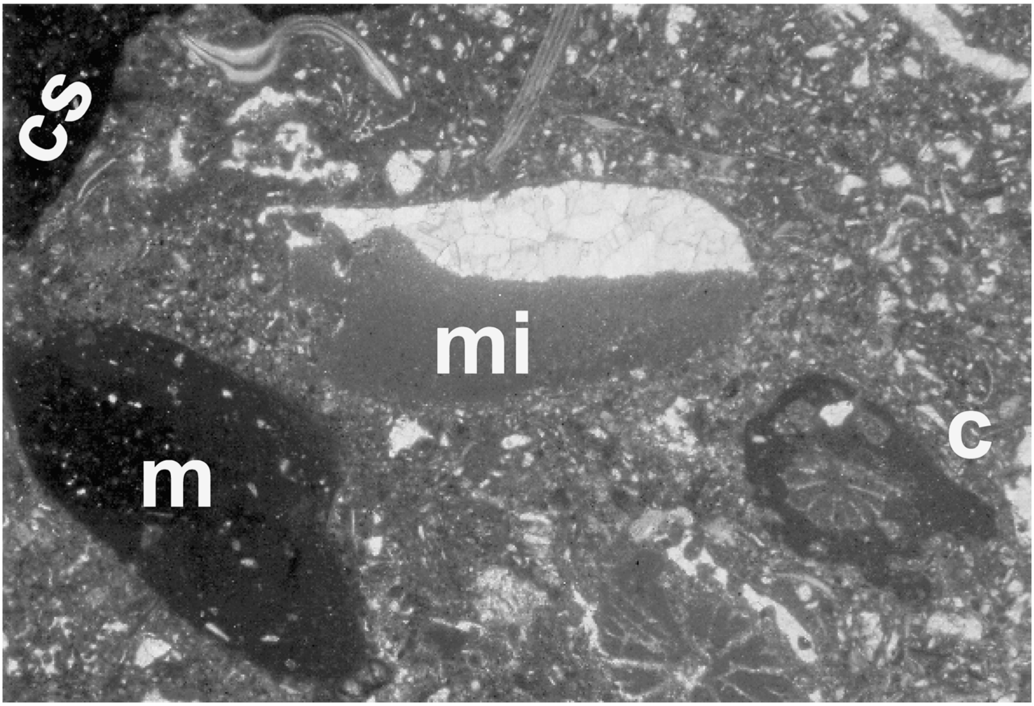
Plate 3

Above: Very poorly sorted bioclastic packstone to grainstone with angular to micrite-rimmed fragments mainly of corals, rudists and coralline algae. Original top of limestone bedding to right. After development of dissolution pores (probably of meteoric origin), precipitation of a thin fringe of dog tooth spar (thin white fringes) was followed by geopetal infill of micropeloidal grainstone (mi). Grainstone mi was followed by precipitation of an isopachous cement (c) with dog tooth spar outline. Below the dog tooth crystals, however, a radial-cryptofibrous cement is present (slightly patchy areas). The remnant pore space was filled by the matrix (m) of the debrite. Sample K 11. Width of view 17 mm.

Below: Marginal portion of limestone clast (cs = clast surface), and matrix of debrite. The clast is a very poorly sorted bioclastic packstone with mainly angular fragments of corals (c; cf. *Procladocora*), rudists, echinoderms and brachiopods. Note (1) early biomould with geopetal fill of micropeloidal grainstone (mi), and with blocky calcite spar, (2) coral partial mould (c) filled by the matrix of the debrite (darker areas), and (3) *Trypanites* filled by matrix (m) of the debrite. Sample K 15. Width of view 17 mm.

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at





©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

Plate 4

Figs. 1, 2 and 7: ***Cuneolina ketini*** **Inam** (x100). 1,2- Sections parallel to the axial one, showing a triangular deuteroconch with exoskeleton elements, and the beams and rafters on the adult chambers arranged in a subepidermal network. 7, Oblique section showing the exoskeletal subepidermal network. Pictures 1 and 2 from sample K20. Picture 7 from sample K12.

Figs. 3-6, 9: ***Reticulinella fleuryi*** **Cvetko, Gusic & Schroeder** (x100). 3, Equatorial section showing almost three whorls. 4, Oblique tangential section showing the septula (vertical partitions), some "planchers" (horizonal partions) and the preseptal passage. 5. Subaxial section (slightly oblique) showing the septula. 6 and 9, Oblique sections. All pictures from sample K20.

Figs. 8, 12: ***Fleuryana adriatica*** **De Castro, Drobne & Gusic** (x100). 8, Tangential section showing two whorls, and a single aperture with a lip. 12, Equatorial section showing three and a half whorls. All pictures from sample K20.

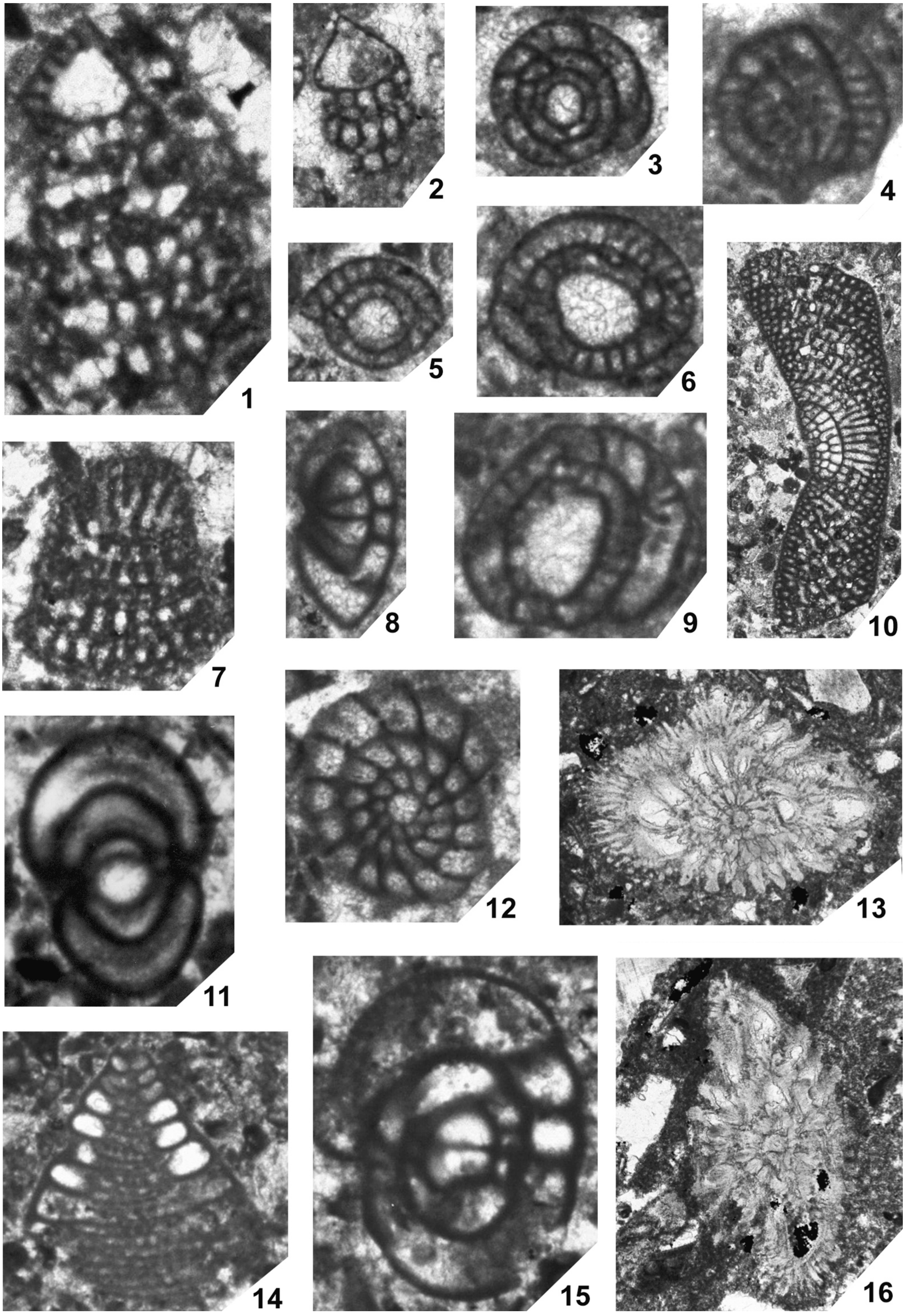
Fig. 9: ***Dicyclina schlumbergeri*** **Munier-Chalmas** (x25). Oblique section showing several whorls and the exoskeleton constituted by beams and rafters. Picture from sample K12.

Figs. 11, 15: ***Fleuryana* ? sp**. (x100). 11, Axial section showing an inflated biumbilicate specimen with an arcuate aperture; compare this picture with *Fleuryana* sp. in fig. 9, plate 4 of De Castro, Drobne & Gusic (1994). 15, Oblique section. All pictures from sample K2.

Figs. 13, 16: ***Pseudosiderolites*? sp**. (x50). 13,16. Oblique sections showing the well developed enveloping canal system in the periphery. All pictures from sample K3.

Fig. 14: ***Accordiella conica*** **Farinacci** (x50). Axial section showing the endoskeleton (pilars) in the central area of the shell. Picture from sample K2.

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at



©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

Plate 5

Hippuritidae from Krappfeld; transverse section of left valves.

Fig. 1: ***Vaccinites vesiculosus* (Woodward)**; PUAB-42957.

Fig. 2: ***Vaccinites vesiculosus* (Woodward)**; PUAB-42954.

Fig. 3: ***Vaccinites ultimus*** **Milovanovic**; PUAB-42955.

Fig. 4: ***Vaccinites ultimus*** **Milovanovic**; PUAB-42934.

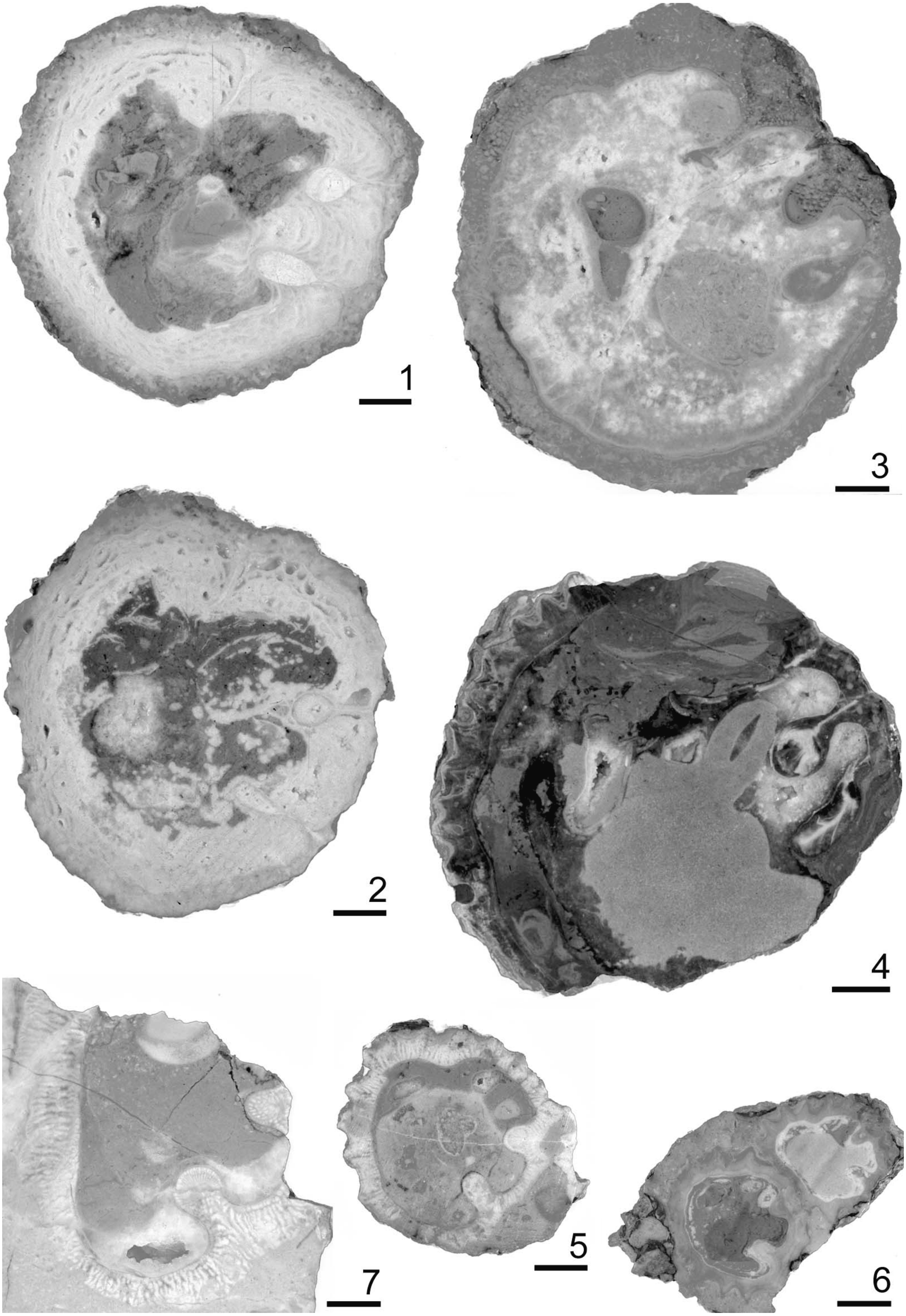
Fig. 5: ***Hippurites colliciatus*** **Woodward**; PUAB-42933.

Fig. 6: ***Hippurites colliciatus*** **Woodward**; PUAB-42924; two attached left valves.

Fig. 7: ***Hippurites colliciatus*** **Woodward**; PUAB-42950; incomplete big specimen.

Scale-bar represents 10 mm.

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at



©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at

Plate 6

Radiolitidae from Krappfeld.

Fig. 1: ***Joufia* sp.**; PUAB-42919; transverse section of the upper (left) valve.

Fig. 2: ***Joufia* sp.**; PUAB-42958; lateral view.

Fig. 3: Same specimen; transverse section of the lower (right) valve.

Fig. 4: ***Joufia* sp.**; PUAB-42919; transverse thin section of the upper (left) valve.

Fig. 5: ***Pseudopolyconites* sp.**; PUAB-74396; transverse section of the lower (right) valve.

Fig. 6: Same specimen; transverse thin section of the lower (right) valve.

Fig. 7: Same specimen and section; detail of the outer shell structure.

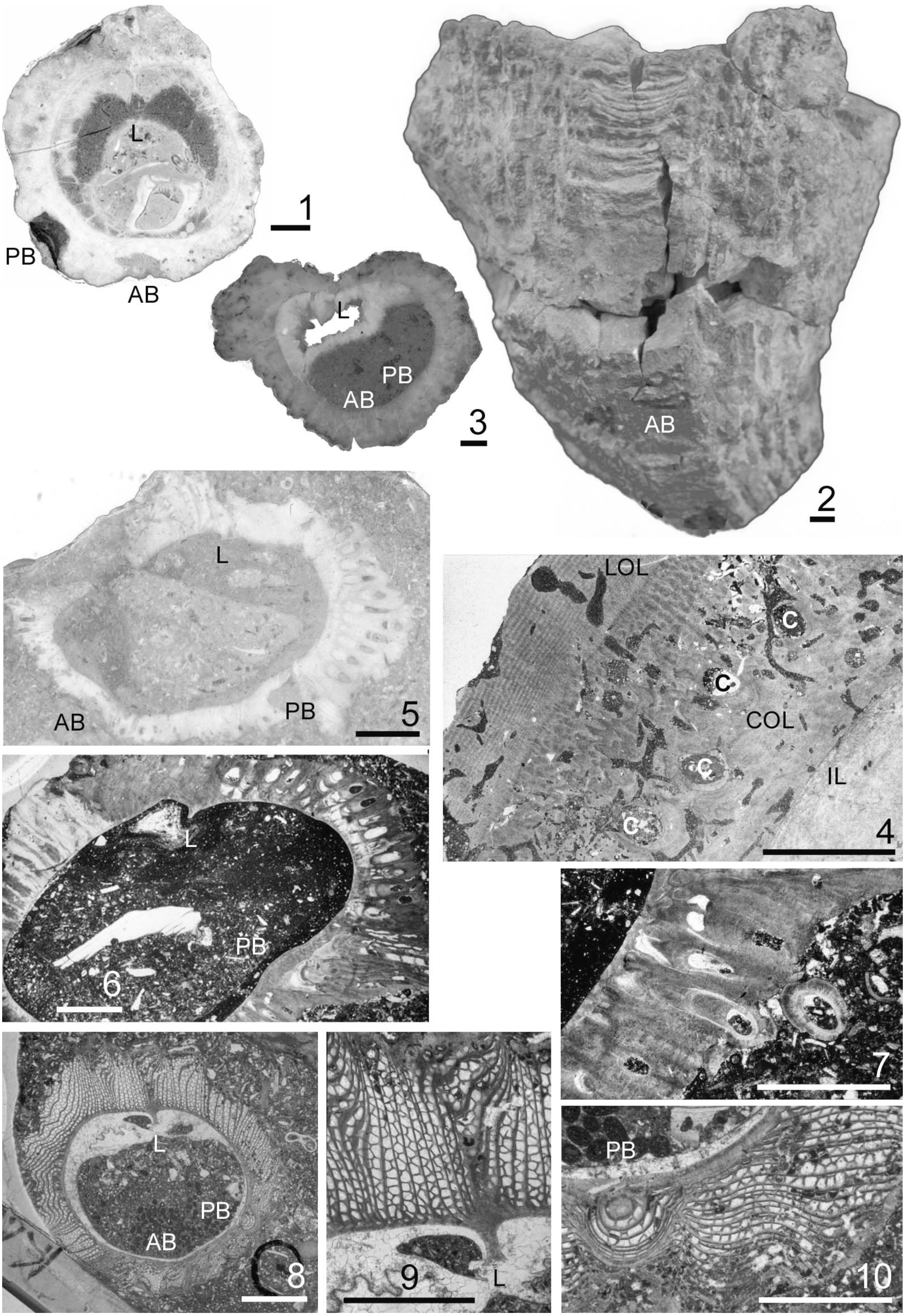
Fig. 8: ***Radiolites* sp. gr. *angeiodes* (Picot de Lapeirouse)**; PUAB-74397; transverse thin section of the lower (right) valve.

Fig. 9: Same specimen and section; detail of the outer shell structure around the ligamentary crest.

Fig. 10: Same specimen and section; detail of the outer shell structure around the posterior radial band.

Scale-bar represents 10 mm in Figs 1-3 and 5 mm in Figs 5-10; AB= anterior radial band; PB= posterior radial band; L= ligamentary crest; LOL= lamellar outer shell layer; COL= canaliculate outer shell layer; IL= inner shell layer; C= canal.

©Naturhistorisches Museum Wien, download unter www.biologiezentrum.at



ZOBODAT - www.zobodat.at

Zoologisch-Botanische Datenbank/Zoological-Botanical Database

Digitale Literatur/Digital Literature

Zeitschrift/Journal: Annalen des Naturhistorischen Museums in Wien

Jahr/Year: 2004

Band/Volume: 106A

Autor(en)/Author(s): Sanders Diethard, Pons Josep Maria, Caus Esmeralda

Artikel/Article: Shallow-water limestone clasts in a Campanian deep-water debrite (Krappfeld, Central Alps, Austria): implications for carbonate platform history 139-165