

Axel Emmerich · Valeria Zamparelli ·
Thilo Bechstädt · Rainer Zühlke

The reefal margin and slope of a Middle Triassic carbonate platform: the Latemar (Dolomites, Italy)

Received: 9 January 2004 / Accepted: 14 October 2004 / Published online: 4 March 2005
© Springer-Verlag 2005

Abstract The Latemar is a mainly aggrading platform, but shows repeated backstepping during its entire development. The behaviour of the slope does not reflect accommodation changes and lateral consistencies of the lagoonal interior; the Latemar contemporaneously reveals different, even contrasting depositional characteristics. The slope of the late stage platform evolution corresponds at least partially to the “base-of-slope apron” model. Controlling factors on slope evolution are of tectonic (proximity of the Stava Line) and autocyclic (repeated oversteepening) nature. Other factors are insignificant and/or overprinted.

The reef-facies at Latemar reveals a complex facies pattern; it varies along and across the margin and is rich in encrusting sponges, corals, biogenic crusts and “Microproblematica”. Some biota or fossil assemblages—e.g. foraminifers (*Abriolina mediterranea*, *Turrioglomina scandonei*) or “*Tubiphytes*” *multisiphonatus* thrombolites—have not been described in the Dolomites before. Biostratigraphic evidence from the uppermost reef-facies confirms a mainly Anisian age of the outcropping platform interior.

Keywords Carbonate slope · Depositional model · Reefal zonation · Late Anisian · Middle Triassic · Dolomites

Introduction

Since von Richthofen discovered the organic origin of the Triassic carbonate masses (von Richthofen 1860), the carbonate reefs in the Dolomites have been a major study area for carbonate platforms and especially for the research on fossil reefal communities. Owing to the dolomitisation of most of the carbonate platforms in the Dolomites, many studies of reefal fossil assemblages focus on the so-called Cipit boulders. These are reef talus blocks transported to allochthonous positions on toe-of-slope and basin margin areas prior to platform-wide dolomitisation. Cipit boulders document the composition of Anisian to Carnian reefs in the Dolomites (e.g. Cuif 1974; Fürsich and Wendt 1977; Biddle 1981; Fois 1982; Brandner et al. 1991; Flügel 1991; Senowbari-Daryan et al. 1993; Russo et al. 1998). Only a few in-situ reefs in the Dolomites have been studied so far (Latemar: Harris 1993; Marmolada: Blendinger 1986; Mt. Cenera: Fois and Gaetani 1984; complete review on Triassic reefs with a compendium of references in Flügel 2002). As the reefal Cipit boulders are located at allochthonous, distal positions, studies of platforms in the Dolomites also focus on carbonate slopes and slope-basin relationships. Many research since von Richthofen (1860) has been carried out on facies patterns and geometries of platform-to-basin transitions (e.g. Mojsisovics 1879; Hummel 1928; Pia 1937; Leonardi 1967; Bosellini and Rossi 1974; Gaetani et al. 1981; Bosellini 1984; Blendinger 1986; Bosellini and Stefani 1991; Bosellini et al. 1996; Harris 1994; Maurer 2000).

Owing to its excellent outcrops, largely absent dolomitisation and early Middle Triassic (Anisian) setting, the Latemar is ideally suited for the study of an in-situ reefal community and carbonate platform after the faunal crisis at the Palaeozoic/Mesozoic boundary. The base for this study are new, detailed investigations on the lithofacies and geometries of the reef and slope as well as on the reef fossil assemblages. The aim of this study is (1) to identify the processes controlling slope and ultimately platform architecture development, (2) to investigate a possible evolution of fossil assemblages in time and their

A. Emmerich (✉) · T. Bechstädt · R. Zühlke
Geologisch-Paläontologisches Institut,
Ruprecht-Karls-Universität Heidelberg,
Im Neuenheimer Feld 234, 69120 Heidelberg, Germany
e-mail: emmerich@uni-hd.de
Tel.: +49-6221-544831
Fax: +49-6221-545503

V. Zamparelli
Dipartimento di Scienze della Terra,
Università degli Studi di Napoli Federico II,
Largo San Marcellino 10, 80138 Napoli, Italy

distribution within the reef and (3) to assess an Anisian/Ladinian age of the reefal fossil assemblages as inferred from the chronostratigraphic framework of the lagoon.

Geological setting

The carbonate platform of the Latemar is located at the southwestern part of the Dolomites, Northern Italy (Fig. 1(1–2)) forming a small mountain range west of Bozen/Bolzano with its longest extension from SE to NW of approximately 5 km. Primary lithofacies distributions and fossil assemblages are very well visible and preserved

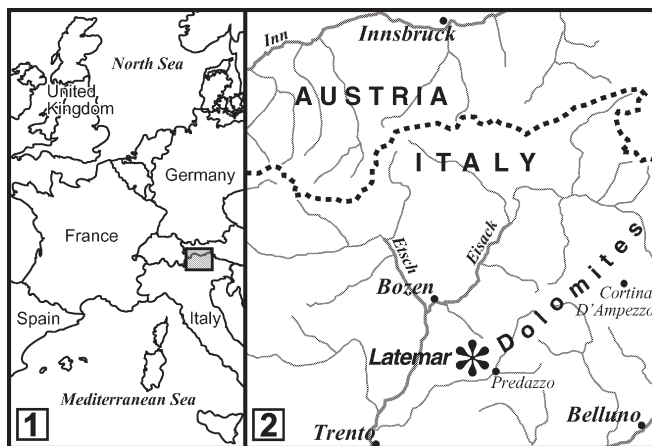


Fig. 1 (1): General position of the study area and its surroundings within Western Europe (*grey rectangle*). (2): Detailed position of the study area within the Southern Alps of Northern Italy; the Latemar is marked by an *asterisk*

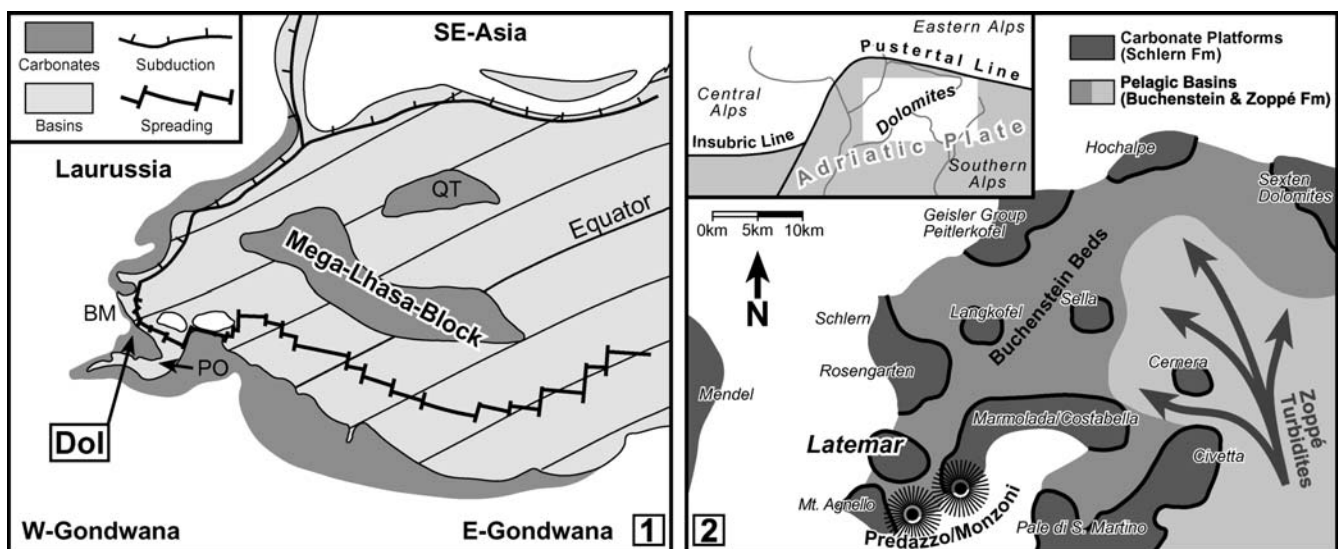


Fig. 2 (1): Simplified Middle Triassic palaeogeographic map of the western Tethys (after Dercourt et al. 2000). *Dol* Dolomites, *PO* Pindos-Olonos-Trough, *BM* Bohemian Massif, *QT* Qiantang-Terrane. Legend of map units/symbols in the upper left corner. (2): Schematic palaeogeographic map of the western Dolomites during

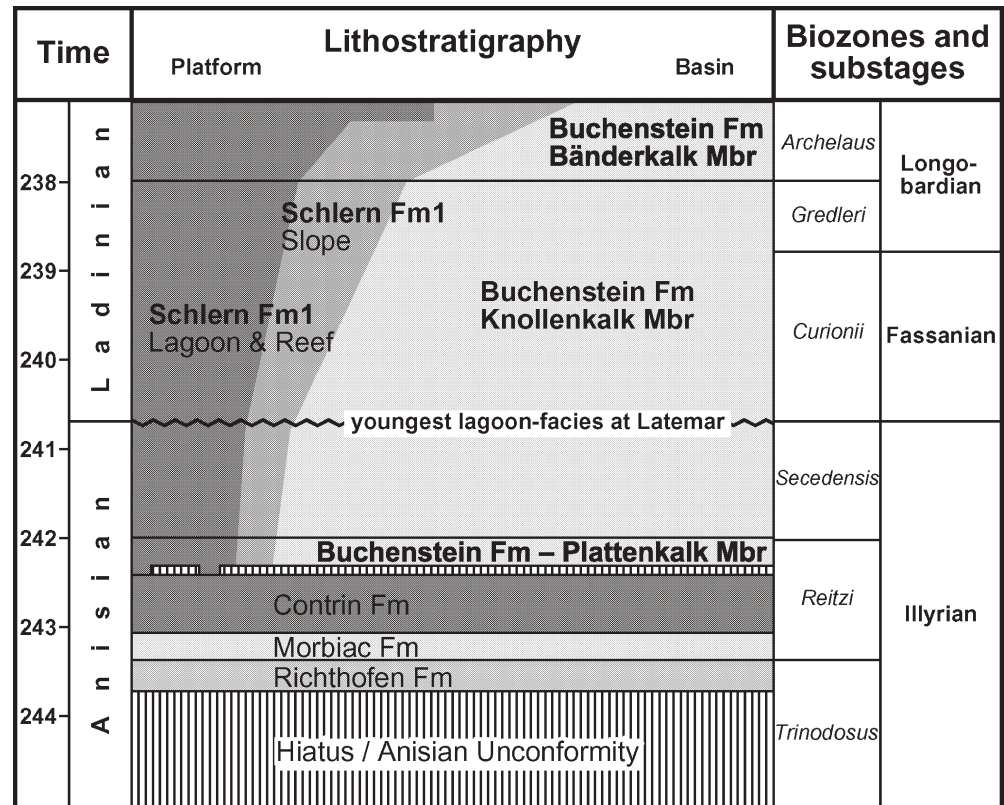
in the so-called “Latemar limestone” (Gaetani et al. 1981) which is a local variation of the Schlern Fm 1 (sensu Brandner 1991). Throughout the Triassic, the Dolomites are situated on the Adriatic Plate. This area between former Laurussia and Gondwana represents the eastern margin of a highly dismembered passive continental margin with transpressive-transpressive tectonics and mixed carbonate-clastic sedimentation (Blendinger 1985; Doglioni 1987; Dercourt et al. 2000; Fig. 2(1–2)).

Few studies on reefs in the Dolomites (Fois and Gaetani 1984; Senowbari-Daryan et al. 1993) investigate the Anisian recovery of carbonate producing organisms from the mass extinction at the end of the Permian where 62% of marine invertebrate families (McKinney 1985) and up to 96% of species (Raupe 1979) are extinguished. All previous studies observe a recovery during the Anisian when many reefal biota (calcsponges, calcareous algae, few “Microproblematica” and few scleractinians) occur for the first time in the Dolomites again since the Permian-Triassic crisis. This is confirmed by recent literature (Twitchett 1999) reporting a gradual reappearance of trace fossils throughout the Lower Triassic of the Dolomites (Werfen Fm) and a complete recovery already in the Uppermost Scythian (top of Werfen Fm). Furthermore, studies from other Triassic reefal locations of the world also indicate a recovery of calcimicrobial buildups during the Anisian (for complete discussion and references refer to Flügel 2002).

First carbonate ramps in the Dolomites do not develop until the Early Anisian (Sarl Fm; De Zanche and Farabegoli 1988; Zühlke 2000). The Middle to Late Anisian Dont Fm contains simple mounds only (Fois and Gaetani 1984). Carbonate ramps of Late Anisian times (e.g. Contrin Fm; Fig. 3) are primarily made up of microbial

the Late Anisian/Early Ladinian (after De Zanche and Farabegoli 1988). Legend of lithostratigraphic units in the upper right corner. *Inset* generalised map of the Southern Alps with an indication of major tectonic lines, *white rectangle* marks the Dolomites

Fig. 3 Anisian/Ladinian lithostratigraphic succession and platform-to-basin relationships of the southwestern Dolomites. Formations below the Schlern Fm 1 (sensu Brandner 1991) record a transition from terrestrial environments to carbonate ramp settings. Younger carbonate platforms—e.g. the neighbouring Rosengarten/Catinaccio (see Fig. 2(2))— show progradation mainly in the *Gredleri* and *Archelaus* zone (Maurer 2000). The preserved succession at Latemar, however, reaches only until the top of the *Secedensis* zone (as marked by the zig-zag line; Zühlke et al. 2003). Timescale in million years after Mundil et al. (1996, 2003) and Lehrmann et al. (2002). Biozones, substages and position of Anisian/Ladinian boundary after Brack and Rieber (1993)



carbonates with subordinate frame-building organisms. True frame-builders—i.e. scleractinian corals—are still suffering from the severe faunal crisis at the end of the Permian (scleractinian “reef gap” in the Early Triassic; Flügel and Stanley 1984; Flügel 1994). Another reason for the Anisian onset of platform development in the Dolomites may be the regional lowstand during the Early Triassic (Scythian until earliest Anisian; Ruffer and Zühlke 1995) and clastic input from the west and south inhibiting platform growth. Anisian subaerial exposure (Anisian unconformity, Fig. 3) in the westernmost Dolomites restricts carbonate ramps to the central and eastern Dolomites. From the Late Anisian onward, flooding of subaerial structural highs in the area of the western Dolomites creates sufficient accommodation space for carbonate ramp and later platform development (De Zanche and Farabegoli 1988; Ruffer and Zühlke 1995). Carbonate platforms with highly diversified reefs do not exist prior to the Late Anisian (Schlern Fm 1 sensu Brandner 1991; Fig. 3). From the Late Anisian on into the Late Ladinian, a considerable submarine relief with only some emersive parts prevails in the area of the Dolomites. Middle Anisian transpressive-transpressive tectonics dismember the continental shelf into structural highs and lows creating subsequently strong regional differences in facies (i.e. “Fazies Heteropie” sensu Bechstädt and Brandner 1970; Blendinger 1985; Doglioni 1987; Zühlke 2000). In Late Anisian to Early Ladinian times, shallow marine subtidal carbonate ramps and platforms (Contrin Fm and later Schlern Fm) exist near deep marine stagnant basins

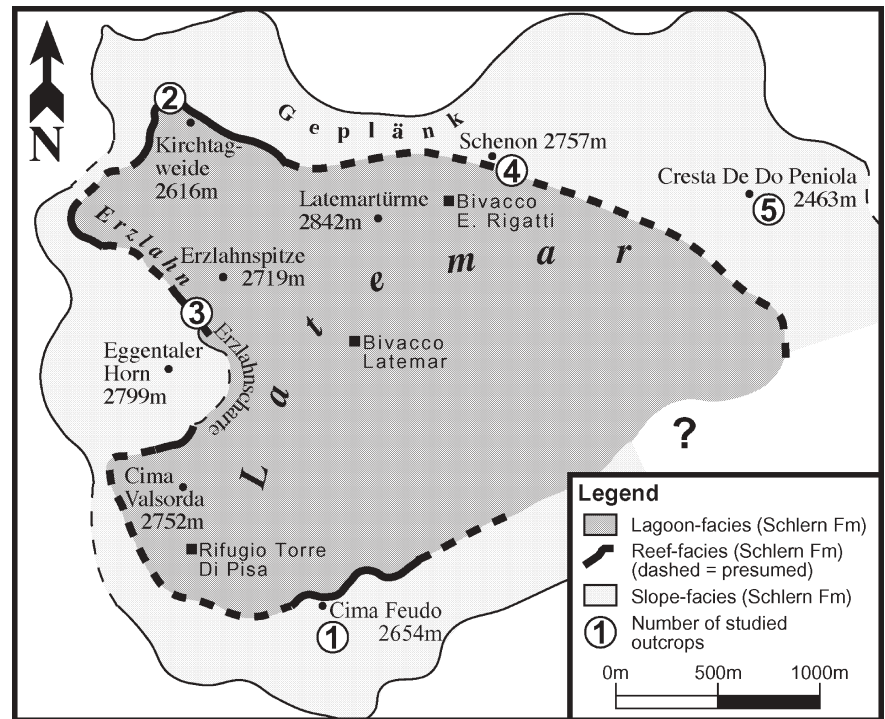
containing fine grained chert- and organic-rich sediments (Moena Fm and later Buchenstein Fm; Figs. 2(2) and 3). Structural highs of the dismembered carbonate ramp (Contrin Fm) are the nuclei of the Schlern Fm 1 platforms in the Late Anisian (Masetti and Neri 1980; Gaetani et al. 1981).

Evolution of most of the platforms like Rosengarten/Catinaccio, Schlern/Sciliar and Monte Agnello neighbouring the study area and probably also the evolution of the Latemar itself ended with the extrusion of the Longobardian Wengen Fm volcanics. Hence, the proximity of the volcanic centre of Predazzo/Monzoni as one of the possible sources of these volcano-clastic deposits plays a crucial role for the platform development in the SW Dolomites (Fig. 2(2)). This volcanic centre is controlling regional subsidence and accommodation development with deep reaching faults and magmatic updoming (Doglioni 1984) as well as terminating platform growth with phreatic eruptions (e.g. Viel 1979a, b).

Previous research

The Latemar is an atoll-like isolated carbonate platform (Schlern Fm 1; Fig. 4) with a central lagoon surrounded by a marginal reef-rim and platform slope building up from an initially emersive structural high of the Contrin ramp (e.g. Gaetani et al. 1981; Goldhammer and Harris 1989; Egenhoff et al. 1999). Slope sediments of the platform—i.e. slope-facies of the Schlern Fm— interfin-

Fig. 4 Schematic geological map of the Latemar; legend of map units in the lower right corner; numbers from 1 to 5 refer to outcrops described in this study (1: Cima Feudo, 2: Kirchtageweide, 3: Erzlahnscharte, 4: Schenon, 5: Cresta De Do Peniola)



ger with deep marine deposits of the Buchenstein Fm in the adjacent basins. The platform top is shallow subtidal to shallow intertidal (Gaetani et al. 1981), the adjacent basins reach depths of about 800 to 1,000 m (Brack and Rieber 1993). The platform top of the atoll-like Latemar platform has a diameter of roundabout 3 km (Fig. 4) and the lagoonal infill consists of at least 720 m stacked carbonate deposits with a highly cyclic arrangement (Goldhammer and Harris 1989; Egenhoff et al. 1999; Zühlke et al. 2000; Zühlke et al. 2003).

Lagoon-facies

Most of the research has dealt with the cyclic lagoonal interior of the Latemar, the age of which being controversially discussed in literature (e.g. Hardie and Hinnov 1997; Brack et al. 1997). More recent studies show that the age of the youngest Latemar strata is latest Anisian/earliest Ladinian (position of Anisian/Ladinian boundary sensu Brack and Rieber 1993; chronostratigraphy: Mundil et al. 1996; Mundil et al. 2003; bio-/cyclostratigraphy: Brack et al. 1996; Zühlke et al. 2000; Zühlke et al. 2003). The top of the preserved lagoonal succession at Latemar is attributed to the uppermost *Secedensis* to lowermost *Curionii* zone. As a consequence, the cycle duration of sea-level oscillations causing the rhythmic bedding pattern in the lagoon must be significantly shorter than Milankovitch periods (Zühlke et al. 2000; Zühlke et al. 2003). The lagoon-facies can be subdivided in four (Goldhammer and Harris 1989) to six (Egenhoff et al. 1999) units by sequence stratigraphic and/or lithological/

microfacies means. This paper follows the subdivision proposed by Egenhoff et al. (1999; Fig. 5).

Slope-facies

According to Gaetani et al. (1981), the platform is mainly aggrading during its early evolution ("Lower Edifice"). Goldhammer and Harris (1989) observe a rapidly prograding slope during the last stages of platform evolution (Fig. 6(1)). This is however not based on direct observations but merely on "the extent of the foreslope" and on the comparison with other—but distinctly younger—Ladinian platforms in the Dolomites (Goldhammer and Harris 1989; p. 324). Indeed, late stage progradation is a common feature of (Middle to Late) Ladinian platforms in the Dolomites, and this might also be the case at Latemar. But the succession preserved at Latemar records Late Anisian to earliest Ladinian times only (Fig. 5). In this context, a comparison with later stages of much younger platforms (e.g. Rosengarten and Schlern) does not seem appropriate. Harris (1994) describes a slope which is not controlled by the high-frequency cyclic rhythms identified in the shallow-water lagoon-facies. However, graded grainstones of the toe-of-slope bypassing the foreslope are reported to be related to times of platform submergence. Slope deposition is mainly episodic and localised with clinofolds originating as slope failures. According to this study, the progradation during the last stage of platform growth is even more pronounced than previously recognised (Harris 1994; p. 133).

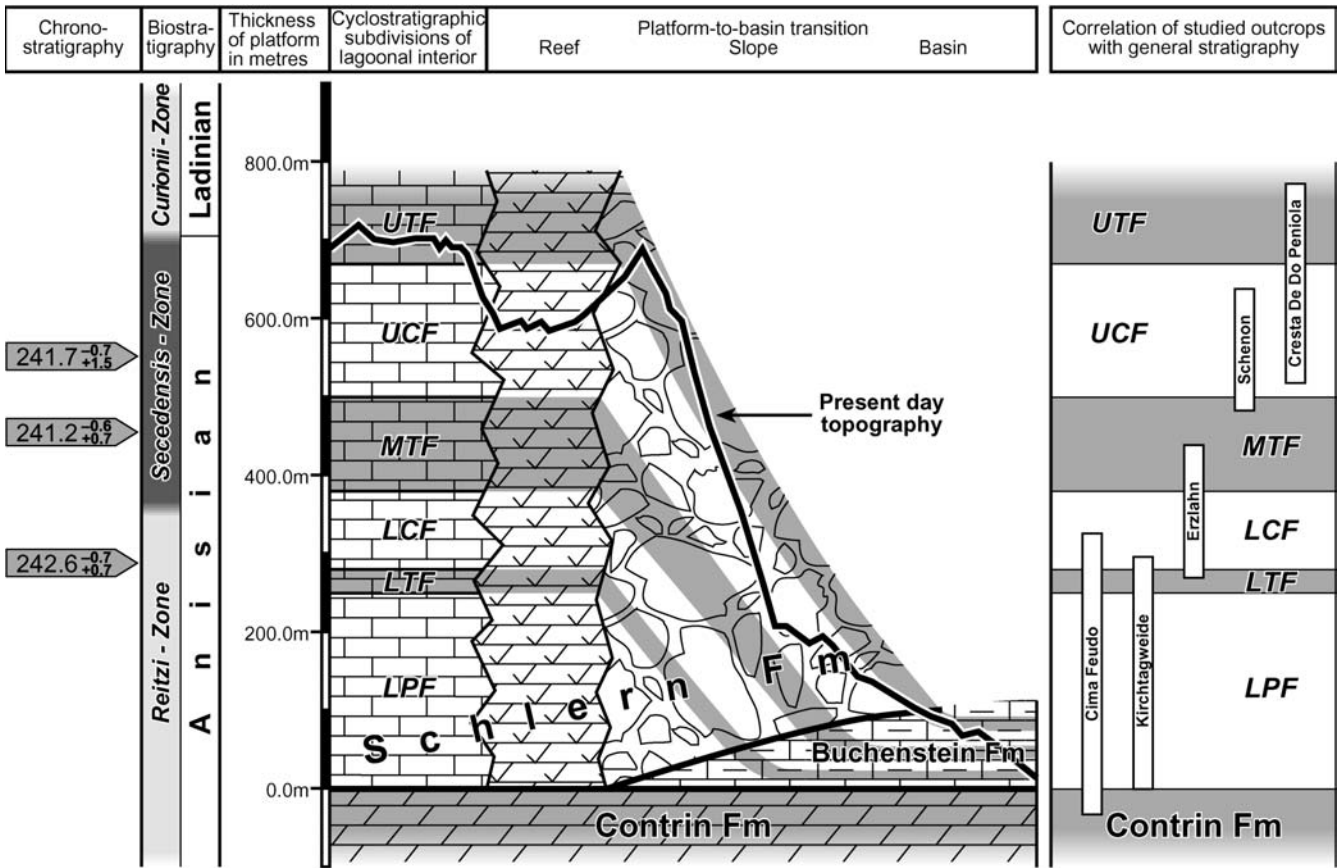


Fig. 5 Stratigraphic succession of the Latemar and correlation of studied outcrops; chronostratigraphy of the Latemar succession after Mundil et al. (2003); biostratigraphy and position of Anisian/Ladinian boundary after Brack and Rieber (1993); cyclostratigraphic subdivision of the lagoonal interior after Egenhoff et al. (1999); platform-to-basin transition in the middle of the figure not

to scale, vertically exaggerated; correlation of studied outcrops at right-hand side. Abbreviations after Egenhoff et al. (1999): *LPF* Lower Platform Facies, *LTF* Lower Tepee Facies, *LCF* Lower Cyclic Facies, *MTF* Middle Tepee Facies, *UCF* Upper Cyclic Facies, *UTF* Upper Tepee Facies

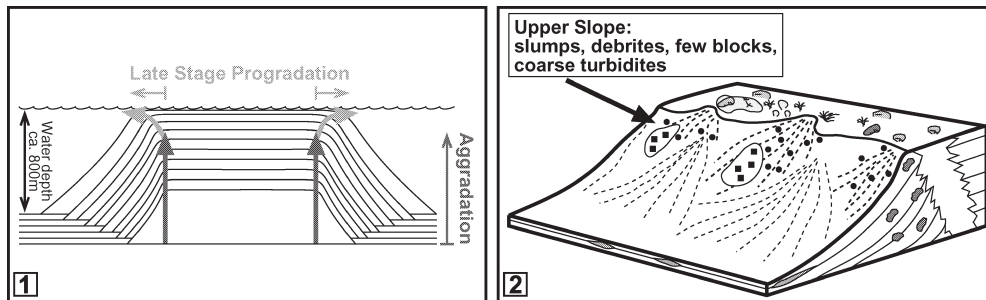


Fig. 6 (1): Schematic cross section of the Latemar platform according to Goldhammer and Harris (1989) using (Bosellini’s 1984 “Ladinian model”) (vertically exaggerated, not to scale). The carbonate platform is vertically aggrading until its last stage of evolution where progradation similar to the adjacent Rosengarten platform occurs (for more details see Bosellini and Stefani 1991;

Maurer 2000). Flat lying strata in the basin are deposits of the coeval Buchenstein Fm. (2): Schematic cross section through a carbonate slope corresponding to the type “slope-apron” (vertically exaggerated, not to scale; sensu Mullins 1983 and Mullins and Cook 1986). *Squares* are blocks in slumps, *small circles* blocks in debris. Reef and lagoon are roughly sketched

The studies on the slope of the Latemar by Goldhammer and Harris (1989) and Harris (1994) are in accordance with the so-called “Ladinian model” of Bosellini (1984; Fig. 6(1)). In this model, the slope progrades over basinal sediments and the lagoonal interior aggrades simultaneously. Continuous and uniform subsi-

dence takes place and coeval basins deepen because of their distinctly lower sedimentation rates (Bosellini 1984). This pattern of carbonate sedimentation is assumed to lead to net deposition on the entire platform-to-basin transition. Hence the slope of the “Ladinian model” should be depositional and correspond to the “slope-

apron" facies model sensu Mullins (1983) and Mullins and Cook (1986). In this model, channeling and bypass sedimentation to the toe-of-slope is absent and the deposits on the slope consist of broad, sheet-like debris-flows (Fig. 6(2)). The crux of this interpretation however is that the original model of Mullins (1983) and Mullins and Cook (1986) requires gentle slopes with an inclination of less than 4°. Contrarily, almost all carbonate slopes in the Dolomites reveal steep slope angles with clinofolds dipping at 20 to 50° towards the basins. These clinofolds reflect primary angles of repose and/or tracts of mass transport (Bosellini 1984; Kenter 1990).

Retrogradation of the platform margin during times of early platform evolution ("Lower Edifice", synonymous with Lower Platform Facies, LPF, in Fig. 5), aggradation during later times of platform development and eventual drowning of the platform is reported by De Zanche et al. (1995). This "anomalous" behaviour—with respect to other platforms in the Dolomites—of the Latemar is thought to be related to the vicinity of the volcanic centre at Predazzo/Monzoni (see Fig. 2(2)). According to these authors, the "Lower Edifice" platform growth ends in the Upper Fassanian (i.e. the *Curionii* zone) where the drowning platform is covered by a "pelagic drape" (De Zanche et al. 1995; p. 140). This feature/observation is not supported by any other study. We also consider this as an unlikely case, as (1) the "pelagic drape" is not present at the described locality and (2) volcanic deposits on the immediately neighbouring Mt. Agnello platform (Fig. 2(2)) directly overly its lagoonal interior without a "pelagic drape" at the contact.

The asymmetry of the platform and its respective margin with steep clinofolds and slump scars on the SW side and more gentle dipping strata on the NW side is attributed by Egenhoff et al. (1999) to windward-leeward effects and different nutrient influx. However, this is in contrast to the concept of a tectonically controlled platform (Doglioni 1984; Bosellini 1989; Emmerich 2001). Emmerich (2001) and Knopp (2002) propose a more differentiated concept of the slope, where aggradation, progradation and backstepping of the margin can occur simultaneously on the Latemar platform but at different exposures creating different, sometimes even contrasting sedimentological settings.

Reef-facies

The reef belt of the Latemar platform has a width of several tens of metres (Gaetani et al. 1981; Goldhammer and Harris 1989) and is mainly made up of microbial crusts (i.e. "*Tubiphytes*" sp.) and syndepositional cements (Harris 1993; Stefani et al. 2001). The model of Harris (1993) is in tune with previous models of reefs in the Dolomites (e.g. Flügel 1991; Brandner et al. 1991). According to Harris (1993), the reef of the Latemar is laterally consistent and organised in several facies belts (Fig. 7)—its protagonist "*Tubiphytes*" generally found in the boundstone facies. Scleractinian corals are rare and

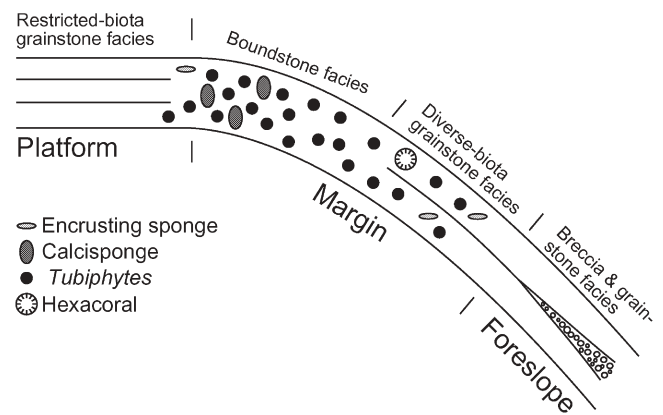


Fig. 7 Reef model of the Latemar margin according to Harris (1993; p. 39) illustrating topography and biological zonation

form only small heads on the uppermost foreslope. Hence, the reefal content of the Latemar is generally comparable to other Anisian reefs in the Dolomites, e.g. the Olang area. The crux of Harris' study (1993) on the reef is, that its data is derived from two outcrops exclusively, one on the SW side of the Latemar (Cima Feudo area, location 1 in this study; Fig. 3) and another one on the western side (area around Gamsstallscharte/Forcella dei Camosci, close to location 3 in this study; Fig. 3). This shortcoming might explain the more diversified fauna as identified recently by Zamparelli et al. (2001) and Emmerich et al. (2002).

Lithofacies and palaeontology

Methods

Detailed facies, sedimentological and palaeontological analyses (logging, facies mapping, lateral tracing of physical surfaces, thin sections) of the margin facies zonation were carried out at five outcrops (Fig. 4), three vertical sections and one detailed, continuous platform margin transect. The respective margins were investigated and sampled every 2 to 5 m at the sections/transect. Quantitative microfacies analyses were carried out on polished slabs (up to several dm in size) and thin sections (4×6 cm). Overall, we collected and analysed 247 specimens and 154 thin sections.

Lithofacies types of the slope

Detailed microfacies investigations reveal the lithofacies associations of the slope described in Table 1.

General biotic content of the reef-facies

A listing of all biota encountered in the reef-facies at Latemar is given in Table 2. According to the schemes of

Table 1 List of lithofacies associations of the slope-facies

Number	Class	Type	Subtype	Description	Number
LF1	Resediments	Megabreccia		Abundance of megablocks (size up to several metres in diameter); grain- and/or mudsupported; neither grading nor bedding, homogeneous mixing	LF1
LF2a		Calcutur- bidites	Grainsize 1	Lithoclastic rudstones; mud-free, owing to abundant cement between the clasts transition to microbreccia; angular to well-rounded clasts; origin of components: lagoon and reef, clasts of the slope are rare; size of components: few mm to a some cm	LF2a
LF2b			Grainsize 2	Lithoclastic rudstones with LF4 wackestones (fine-grained peloids and bioclastic material) filling inter-particle porosity; mostly grain-supported, sometimes transition towards floatstones; origin of components: lagoon and reef, clasts of the slope are rare; size of components: some mm to a few cm	LF2b
LF3a			Grainsize 3	Floatstones with bimodal grainsize distribution: fine-grained peloids in the matrix (LF4) together with litho- and/or bioclasts up several cm; lithoclasts of LF3a are of the same origin as those of LF2a/b; bioclasts are mainly fragments of “ <i>Tubiphytes</i> ” sp., others are: peloids, fragments of echinoids, filaments, annelids, fragments of calcareous algae and small cephalopods	LF3a
LF3b			Grainsize 4	Well-sorted grainstones, consisting of peloids solely; very fine-grained, grainizes ranging from 0.2 to 0.7 mm; sometimes cross bedding; often fining-upward trends	LF3b
LF4		Background sedimentation		Wacke-/packstones with components like small lithoclasts, grapestone/oncoid fragments, fragments of <i>Olangocoelia</i> sp., peloids, fragments of echinoids and shells; sedimentary characteristics are bioturbation and geopetals; LF4 is mainly the product of normal background sedimentation on the slope, but also filling interstices in LF1 and LF2a/b	LF4
LF5		Slumping		Pure mudstones fractured through slumping before lithification; calcitic block and radiaxial-fibrous cements fill interstices; LF5 mudstones contain no components, merely some peloids <0.5 mm	LF5
LF6		Deposits of open marine biota		Bioclastic rudstone; bioclastic components are <i>Daonella</i> sp. and small cephalopods solely; bivalve shells are closely packed and stacked one above the other; interstices are filled with cement and sometimes sediment (wackestones with red micrite and fragments of echinoids); geopetals	LF6
LF7	Neptunian dykes			Red calcitic mudstones; restricted occurrence of cephalopods and open marine foraminifers, such as: nodosarids, <i>Abriolina mediterranea</i> and porcellaneous forams (<i>Ophitalmidium</i> sp.); other components are: lithoclasts of the same LF type, fine-grained peloids and coprolites (<0.5 mm), specialised dwarf fauna (ostracods, micro-filaments); closely packed layers of radiaxial-fibrous cements parallel the walls of the dykes and are often micritised	LF7

Table 2 List of biota encountered in the slope- and reef-facies of the Latemar

"Sphinctozoans"	<i>Celyphia</i> n. sp.?	
	<i>Celyphia? minima</i> Senowbari-Daryan, Zühlke, Bechstädt and Flügel, 1993	Anisian
	<i>Celyphia zoldana</i> Ott, Pisa and Farabegoli, 1980	Anisian
	<i>Colospongia</i> sp.	
	<i>Colospongia catenulata catenulata</i> Ott, 1967	Ladinian
	<i>Deningeria</i> sp.	
	<i>Deningeria crassireticulata</i> Senowbari-Daryan, Zühlke, Bechstädt and Flügel, 1993	Anisian
	<i>Follicatena cautica</i> Ott, 1967	Ladinian
	<i>Solenolmia manon manon</i> (Münster, 1841)	Anisian/Ladinian
	<i>Thaumastocoelia dolomitica</i> Senowbari-Daryan, Zühlke, Bechstädt and Flügel, 1993	Anisian
	<i>Vesicocaulis oenipontanus</i> (Ott, 1967)	Ladinian
	<i>Meandrostia triassica</i> Senowbari-Daryan, Zühlke, Bechstädt and Flügel, 1993	Anisian
	<i>Olangocoelia otti</i> Bechstädt and Brandner, 1970	Anisian
	<i>Margarosmia</i> sp.	
<i>Retiophyllia</i> sp.		
<i>Zardinophyllum</i> sp.?		
Bryozoans	<i>Reptonoditrypa cautica</i> Schäfer and Fois, 1987	Anisian
"Microproblematica"	<i>Anisocellula fecunda</i> Senowbari-Daryan, Zühlke, Bechstädt and Flügel, 1993	Anisian
	<i>Baccanella floriformis</i> Pantic, 1971	Anisian/Ladinian
	<i>Bacinella ordinata</i> Pantic, 1972	Anisian/Ladinian
	<i>Ladinella porata</i> Ott, 1968	Ladinian
	<i>Plexoramea cerebriformis</i> Mello, 1977	Anisian/Ladinian
	<i>Radiomura cautica</i> Senowbari-Daryan and Schäfer, 1979	Ladinian
	" <i>Tubiphytes</i> " n. sp.?	
	" <i>Tubiphytes</i> " <i>gracilis</i> Schäfer and Senowbari-Daryan, 1983	Anisian/Ladinian
	" <i>Tubiphytes</i> " <i>multisiphonatus</i> Schäfer and Senowbari-Daryan, 1983	Anisian/Ladinian
	" <i>Tubiphytes</i> " <i>obscurus</i> Maslov, 1956	Anisian/Ladinian
Dasycladaleans	<i>Diplopora annulata</i> Schafhäütl, 1863	Anisian/Ladinian
	<i>Diplopora nodosa</i> Schafhäütl, 1863	Anisian/Ladinian
	<i>Macroporella</i> sp.	
	<i>Pseudodiplopora</i> sp.	
	<i>Teutloporella</i> sp.	
	<i>Zornia obscura</i> Senowbari-Daryan and Di Stefano, 2001	Anisian/Ladinian
Solenoporaceans	<i>Solenopora</i> sp.	
Porostromata	<i>Parachaetetes</i> cf. <i>triasinus</i> Vinassa De Regny, 1915	Anisian/Ladinian
	<i>Ortonella</i> sp.	
"Microbial crusts"	<i>Girvanella</i> sp.	
"Spongiostromata" Auct.		
Foraminifers	<i>Abriolina mediterranea</i> Luperto, 1963	Anisian/Ladinian
	<i>Arenovidalina Chiangchiangensis</i> Ho, 1959	Anisian
	<i>Aulotortus? eotriassicus</i> Zaninetti, Rettori and Martini, 1994	Anisian
	<i>Bulloporella</i> sp.	
	<i>Diploporina</i> cf. <i>astrophimbriata</i> Kristan-Tollmann, 1964	Anisian/Ladinian
	<i>Duostomina</i> sp.	
	<i>Earlandia</i> sp.	
	<i>Earlandinita</i> sp.	
	<i>Endoteba</i> sp.	
	<i>Endoteba</i> ex gr. <i>obturata</i> (Brönnimann and Zaninetti, 1972)	Anisian/Ladinian
	<i>Endotriada</i> cf. <i>tyrrhenica</i> Vachard, Martini, Rettori and Zaninetti, 1994	Anisian/Ladinian
	<i>Endotriadella</i> sp.	
	<i>Endotriadella wirzi</i> (Koehn-Zaninetti, 1968)	Anisian
	<i>Flatschkofelia anisica</i> Rettori, Senowbari-Daryan and Zühlke, 1996)	Anisian
	<i>Gaudrinella</i> sp.	
	<i>Krikoumbilica pileiformis</i> He, 1984	Anisian/Ladinian
	Nodosaridae	
	<i>Lamelliconus</i> ex gr. <i>ventroplanus</i> Oberhauser, 1957	Anisian?/Ladinian
	? <i>Ophthalmidium</i> sp.	
	<i>Palaeolituonella meridionalis</i> (Luperto, 1965)	Anisian/Ladinian
	<i>Paraophthalmidium</i> sp.	
	<i>Reophax</i> sp./ <i>Ammobaculites</i> sp.	
	? <i>Textularia</i> sp.	
	<i>Tolypammina</i> sp.	
	<i>Trochamminidae</i> sp.	
	<i>Turriplomina</i> sp.	
	<i>Turriplomina mesotriassica</i> (Koehn-Zaninetti, 1968)	Anisian/Ladinian
	<i>Turriplomina scandonei</i> Zaninetti, Ciarapica, Martini, Salvini-Bonnard and Rettori, 1987	Anisian/Ladinian
	<i>Spirorbis</i> sp.	
	<i>Favreina</i> sp.	
<i>Thaumatoporella</i> cf. <i>parvovesiculifera</i> Raineri, 1922	Anisian/Ladinian	
<i>Daonella</i> sp.		
Worm tubes		
Decapod coprolites		
Algae incertae sedis		
Pelecypods		
Ammonoids		
Gastropods		
Ostracods		
Echinoids		

primary and secondary frameworks of Scoffin and Garrett (1974), Fagerstrom (1987) and Tucker and Wright (1990) our detailed investigation of the reef-facies prove some fossil assemblages to be primary (F1 to F6) and others to be secondary framebuilders (F7 to F9). The secondary framebuilders (encrusting organisms like “*Tubiphytes*” group and *Bacinella ordinata*) are of equal importance for the buildup of the Latemar reef as the primary ones. Secondary framebuilders are associated with all fossil assemblages of the reef front.

Fossil assemblages of primary reef-builders

The numbering of the fossil assemblages is in accordance with their occurrence from reef front (F1) to back reef (F6).

F1—*Solenoporacean* bafflestones

Red algae with large branches are the protagonists of this fossil assemblage, other components are present to a small extent only. However, this fossil assemblage is only of local importance at Latemar’s reef. The solenoporaceans are represented by *Parachaetetes* cf. *triasinus* (Fig. 8(1–2,4)) and *Solenopora* sp. (Fig. 8(3)). In some cases they are associated with or encrusted by secondary reef builders like “*Tubiphytes*” *obscurus* (F8; Fig. 12(3–5,10–11)), *Bacinella ordinata* (F9; Figs. 12(1–2) and 16(29)), porostromate algae (*Ortonella* sp., Fig. 8(7,9)) and small encrusting foraminifers (*Flatschkofelia anisica*, Fig. 15(35–36), *Tolypamina* sp., Fig. 16(1)). The delicate, baffling solenoporaceans show close intergrowth with similarly branching *Margarosmilia* sp.-type scleractinians (Fig. 8(8,10)) or bryozoans (Fig. 8(5–6)). F1 never occurs together with robust, *Retiophyllia* sp.-framestones (Fig. 8(11)). From the palaeoenvironmental point of view, this fossil assemblage is located at the reef front below the mean wave base.

F2—“*Sphinctozoan*”-“*Tubiphytes*” bind-/bafflestones

“*Sphinctozoan*” sponges are the most important primary constituents of the reef-facies at Latemar. Owing to the different growth behaviour of each species, they form both bafflestones and bindstones. Small segmented sponges are very abundant and mostly encrusting. Together with “*Tubiphytes*” group (Fig. 12(10,11)) and *Bacinella ordinata* (Figs. 12(1–2) and 16(29)) they form the largest part of the framework contributing to the growth of the reefal margin. These “*sphinctozoan*” sponges are equally represented by *Celyphia zoldana* (Fig. 9(1–7,12)) and *Celyphia?* *minima* (Figs. 9(8–11,13) and 10(1–3)). The latter is exemplified by possibly two species, one of them could be new. In some cases, *Celyphia zoldana* and *C.?* *minima* are accompanied by *Follicatena cautica* (Fig. 11(12–13)) another encrusting sponge. Where encrusting “*sphinctozoans*” are less fre-

quent, large isolated sponges like *Vesicocaulis oenipontanus* (Fig. 10(4–6)), ?*Colospongia* sp. (Fig. 10(7–8)), *Colospongia catenulata catenulata* (Fig. 11(7,10)), *Solenolmia manon manon* (Fig. 11(3–5,11)), *Deningeria* sp. (Fig. 11(8,14)), *Thaumastocoelia dolomitica* (Fig. 11(6)) and—in a few cases only—*Meandrostia triassica* (Fig. 11(9)) form bafflestones. These bafflers are generally surrounded and stabilised by biogenic crusts.

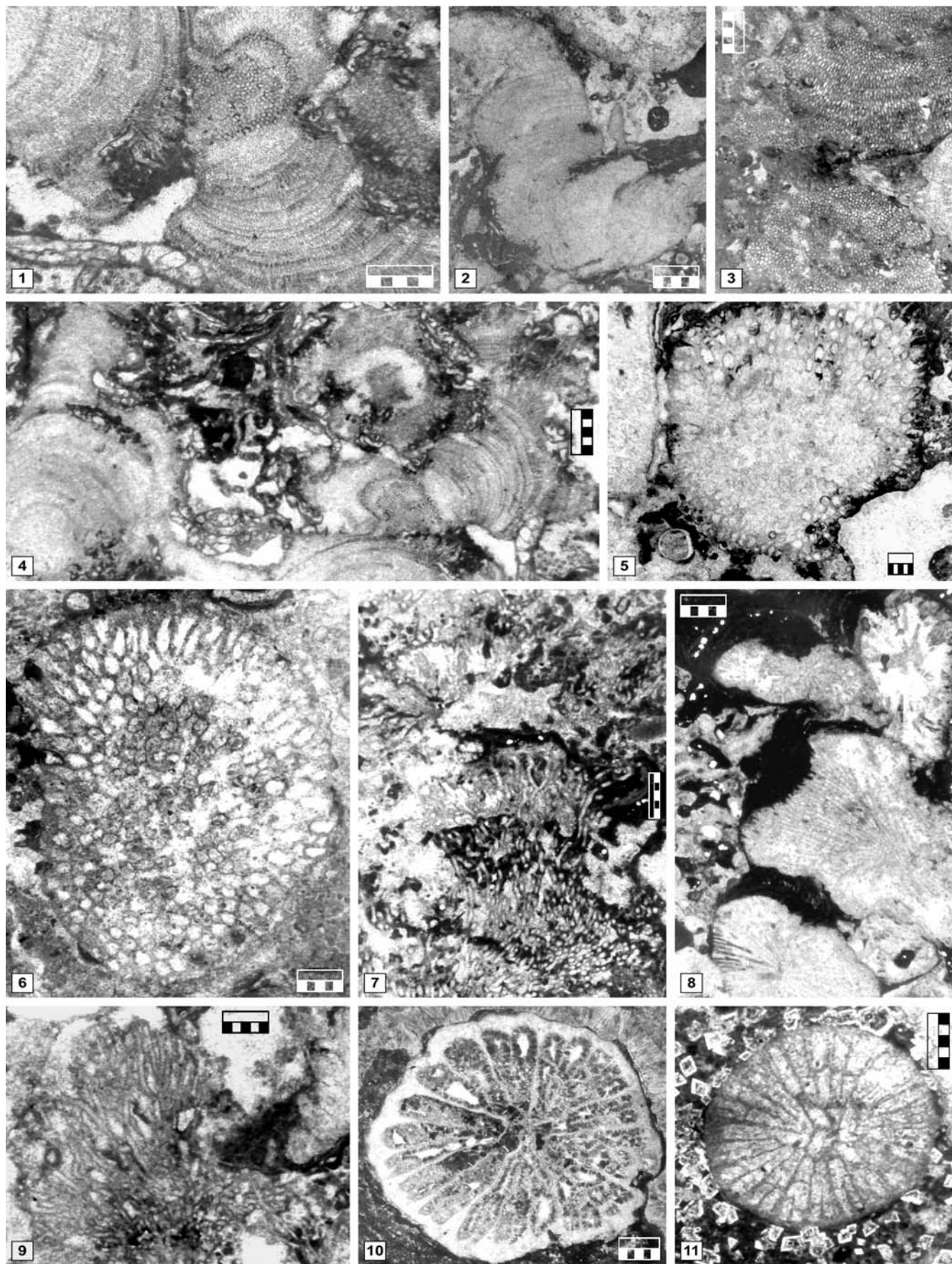
F3—“*Sphinctozoan*”-coral-bryozoan bafflestones

In this fossil assemblage, encrusting “*sphinctozoan*” sponges like *Celyphia zoldana*, *Celyphia?* *minima* (Figs. 9(1–13) and 10(1–3)) and isolated chambers of *Deningeria* sp. (Fig. 11(8,14)) are associated with hexacorals of varying abundance (*Margarosmilia* sp., Fig. 8(8)) and often display microboring. The corals are usually covered by biogenic crusts and are very recrystallised (Fig. 10(12–13)). Bryozoans—*Reptonoditrypa cautica* (Figs. 8(5–6) and 10(12)) exclusively—are similarly seldom. *Bacinella ordinata* (Figs. 12(1–2) and 16(29)), “*Tubiphytes*” *obscurus* (Fig. 12(3–5,10–11)) and other “*Microproblematica*” (e.g. *Radiomura cautica*, Fig. 12(8–9)) complete this fossil assemblage. Small foraminifers can be found in the trapped (baffled) sediment (duostominids, e.g. *Diplostromina* cf. *astrophimbriata*, Fig. 15(16–18), *Duostromina* sp., Fig. 15(19–20), and Endotriadidae, e.g. *Endotriadella* sp., Fig. 15(22), *Endotriada* cf. *tyrrhenica*, Fig. 15(23), and *Endotriadella wirzi*, Fig. 15(27–28)), whereas sessile foraminifers indicate intergrowth with biogenic crusts.

The delicate branches of the scleractinian bafflers are closely spaced and very ramified. Often, they are associated with encrusting sponges and species of the “*Tubiphytes*” group. The high number of septa, the branching growth and the size of the corallites indicates a similarity to *Margarosmilia* sp. (Fig. 10(12–13)). F3 is not very robust, however, it may form rather large colonies or patches, as blocks of this fossil assemblage with a diameter of 4 m to 5 m are encountered on the slope (upper part of Cresta De Do Peniola). Trapped sediment are wacke-/packstones of the lagoon sometimes associated with “*Tubiphytes*” encrustations (Fig. 12(11)). Solenoporaceans are also part of this faunal assemblage and often indicate microboring and/or micritisation of surfaces (Fig. 8(1–2,4)).

F4—*Scleractinian* framestones

Generally, corals are primary framebuilders of the bioconstructions at Latemar. Later stages of reef development show the encrustation and overgrowth by secondary framebuilders like algae and/or microbial crusts. The scleractinians of F4 are mainly characterised by isolated, thick and tall corallites and are less commonly cerioid (branched). A patch-reef-like growth is typical, colonies are up to 3 m wide and 1 m high. These isolated coral knobs are laterally not continuous and their framestones



are very often recrystallised. A low number of septa and a robust nature of the stems point to the identification as *Retiophyllia* sp. (*Retiophyllia* sp. 2 sensu Senowbari-Daryan et al. 1993). The biggest colonies are found in-situ at Kirchtageweide and in blocks on the slope at Cresta De Do Peniola. In-situ colonies at Cima Feudo and Erzlahn are smaller and the individuals are less robust (Fig. 8(11)).

F5—*Microbialites/microbialitic bindstones*

The framework of this facies or fossil assemblage comprises different microbial crusts of cyanobacterial activity. The largest occurrence of F5 is at Erzlahn where the bioconstruction forms an elongated structure (microbial/algal ridge). Stromatolitic and clotted-thrombolitic fabrics are the vital part of this fossil assemblage (Fig. 14(7–9)). Both fabrics reveal a close intergrowth and an equal volumetric percentage. The biogenic crusts reveal different, alternating levels of growth (thrombolitic-stromatolitic) and contain intercalated fragments of cyanobacterial algae like *Girvanella* sp. and sessile foraminifers (nubecularids, Fig. 16(1)). Layers of the crusts are quite often replaced by *Baccanella floriformis* (Fig. 16(25,28)) on the inside and/or cements on the outside. In a few cases only, “*Tubiphytes*” group and *Bacinella ordinata* (Figs. 12(1–2) and 16(29)) are part of this symbiotic growth.

However, F5 is not very frequent at Latemar compared to its abundance in bioconstructions of other Middle and Upper Triassic reefs in the area of the western Tethys. Like in other palaeoenvironmental reconstructions (e.g. Flügel 2002 and references therein), this assemblage pertains to the reef crest area. Seldomly, F5 occurs together with “*Tubiphytes*” group associations also in the upper part of the slope.

F6—“*Tubiphytes*” *multisiphonatus* thrombolites

The term “thrombolite” in F6 is used sensu Riding (1991). This fossil assemblage is characterised by the overwhelming presence of “*Tubiphytes*” *multisiphonatus*. Its branches form large colonies of 2–3 m width and 0.5–0.7 m height with different levels/layers of growth

(Fig. 13). The radially growing, slender branches of “*Tubiphytes*” *multisiphonatus* consist of a central tubular channel (“thallus”) embedded in a network of micritic filaments (Fig. 14(1–2,4–6)). Sometimes peloids are incorporated in the micritic surroundings of the central tubes, sometimes they are part of the sediment between the branches (Fig. 14(3)). Longitudinal sections of this framestone reveal the thin, subparallel to parallel “thalli” to be closely associated with large amounts of cements between the branches of a colony. The tubes of “*Tubiphytes*” *multisiphonatus* are sometimes very sinuous (undulated) and not as strictly upright as in the original literature (cf. Schäfer and Senowbari-Daryan 1983). Oblique and transverse sections show the network of the tubes. Trapped matrix sediment bears irregular fragments of algae (*Thaumatoporella* cf. *parvovesiculifera*, Fig. 14(3)), peloids and seldomly small foraminifers (*Endotriadella* sp., Fig. 15(22)).

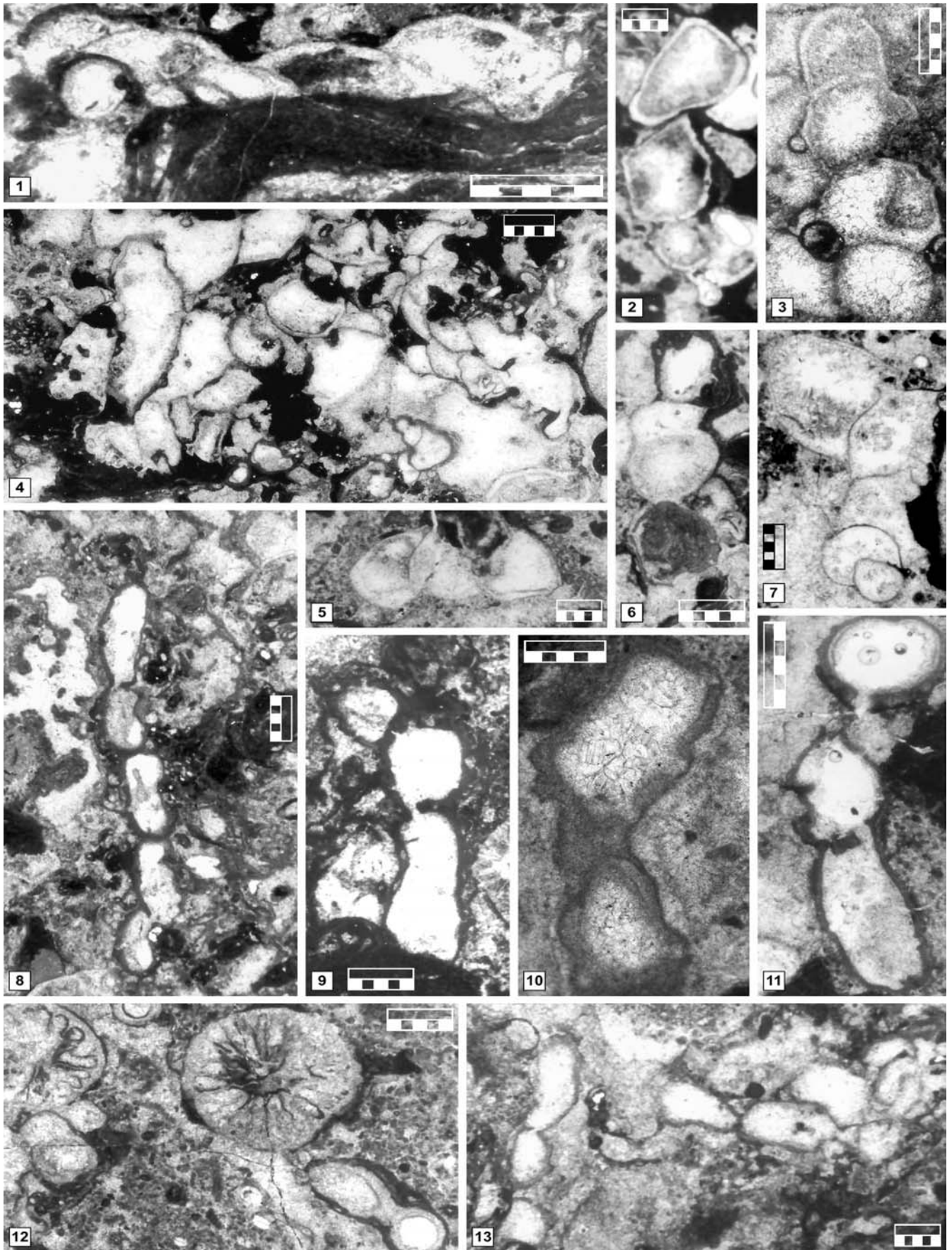
The space between the branches contains abundant cements of early marine (isopachous calcite crusts) and shallow burial diagenesis (block calcite). However, the cement filled “voids” between the “branches” are seemingly formed by diagenetic alterations. The bioclastic components incorporated by micritic filaments around the tubes of “*Tubiphytes*” *multisiphonatus* show abrupt terminations at the “branch”-cement-contact. The outer surfaces of the “branches” are very irregular—like attacked and destroyed by fringing cements. This leads to the assumption that the visible organisation of branches and cements might not reflect primary facies. Nevertheless, early syn-depositional cements must play a crucial role during buildup of these thrombolites; at later stages, they might be replaced by secondary cements during fluid migration.

Ten to twenty centimetre thick lenses of small bivalves (1–2 cm in diameter; heavily dolomitised; possibly *Daonella* sp.) between the thrombolites are evidence for a regime of low wave energy. The proximity of the thrombolites to the lagoon-facies indicates a sheltered position at the back-reef margin. The strata on which the colonies are growing (pack-/grainstones of the lagoon), dip towards the centre of the Latemar lagoon. Therefore, a depression (back-reef lagoon) exists between the reef and the tepee belt which is the palaeobathymetrically most elevated part of the atoll.

Our facies and palaeontological investigations allow the deduction of a detailed growth development of the thrombolites (Fig. 13). Buildup starts with several sub-parallel tubes ramifying towards the end of the first growth stage forming a pillow-like nucleus on which new levels/layers of “*Tubiphytes*” *multisiphonatus* grow. The first, nucleus-like stage is rather small, with some dm in diameter, several cm in height. The next layers are up to a few tens of centimetres thick. These layers are easily distinguishable in outcrop, whereas in microfacies a separation of layers is not as obvious. Here, the bush-like ramification and radial growth of colonies prevails.

“*Tubiphytes*” *multisiphonatus* (Schäfer and Senowbari-Daryan 1982, 1983) versus *Axopora aggtelekensis* Scholz (1972):

Fig. 8 Anisian reef limestones from the Latemar, Dolomites, Italy: solenoporacean and porostromate algae, bryozoans and corals. Scale bar 1 mm with subdivisions of 200 μ m unless otherwise stated. (1–2,4): Nodular to branched thalli of *Parachaetetes* cf. *triasinus* Vinassa de Regny. Small cells and horizontal elements indicate growth stages. Microboring and presence of microproblematica (*Bacinella* sp.) are typical; (Cresta De Do Peniola). (3): *Solenopora* sp.; (Cima Feudo, scale bar 2 mm with subdivisions of 400 μ m). (5–6): *Reptonoditrypa cautica* Schäfer and Fois, the only bryozoan found in the Latemar area. Evidence of microboring on the surface; (Cresta De Do Peniola). (7,9): Porostromate algae: *Ortonella* sp.; (Cresta De Do Peniola). (8): Cerioid corals (*Margarosmia* sp.); (Cresta De Do Peniola). (10): Transverse section of a coral with an affinity to *Zardinophyllum* sp.; (Schenon, scale bar 2 mm with subdivisions of 400 μ m). (11): Transverse section of an isolated *Retiophyllia* sp.; (Erzlahn)



The microfacies appearance of “*Tubiphytes*” *multisiphonatus* at Latemar corresponds fully to the description given by Schäfer and Senowbari-Daryan (1983) from the type locality at Hydra (Greece) apart from the undulated nature of its tubes. In the original material from Hydra (Greece), the “thalli” are not sinuous (undulated) but mostly upright. With respect to the outcropping thrombolite, several microfacies features and most importantly with respect to its palaeoecological position, strong affinities also exist with the description given by Scholz (1972) of thrombolite-like structures in an Anisian reef (Illyrian) from the Aggtelek Mountains in Hungary. However, Scholz (1972; pp.344–345) attributes the colonies to hydrozoans (*Axopora aggtelekensis* Scholz) despite missing tabulae. He furthermore interpreted the micritic filaments surrounding the central channels as “coenenchyma” (Scholz 1972, Plate 5). For a comparison of both occurrences, please refer to Table 3. A further occurrence of “*Tubiphytes*” *multisiphonatus* thrombolites is located in the Lombardic Alps (Concarena; Seeling et al. 2005). A comparison between our samples and those from the Lombardic Alps proved both to be identical (Table 3).

Fossil assemblages of secondary reef-builders

F7—*Olangocoelia* bindstones

Olangocoelia otti bindstones are characterised by the crust-like, catenulate arrangement of their small globular or oval chambers around cavities between talus blocks and mostly bioclasts (Figs. 10(14) and 11(1–2)). The central

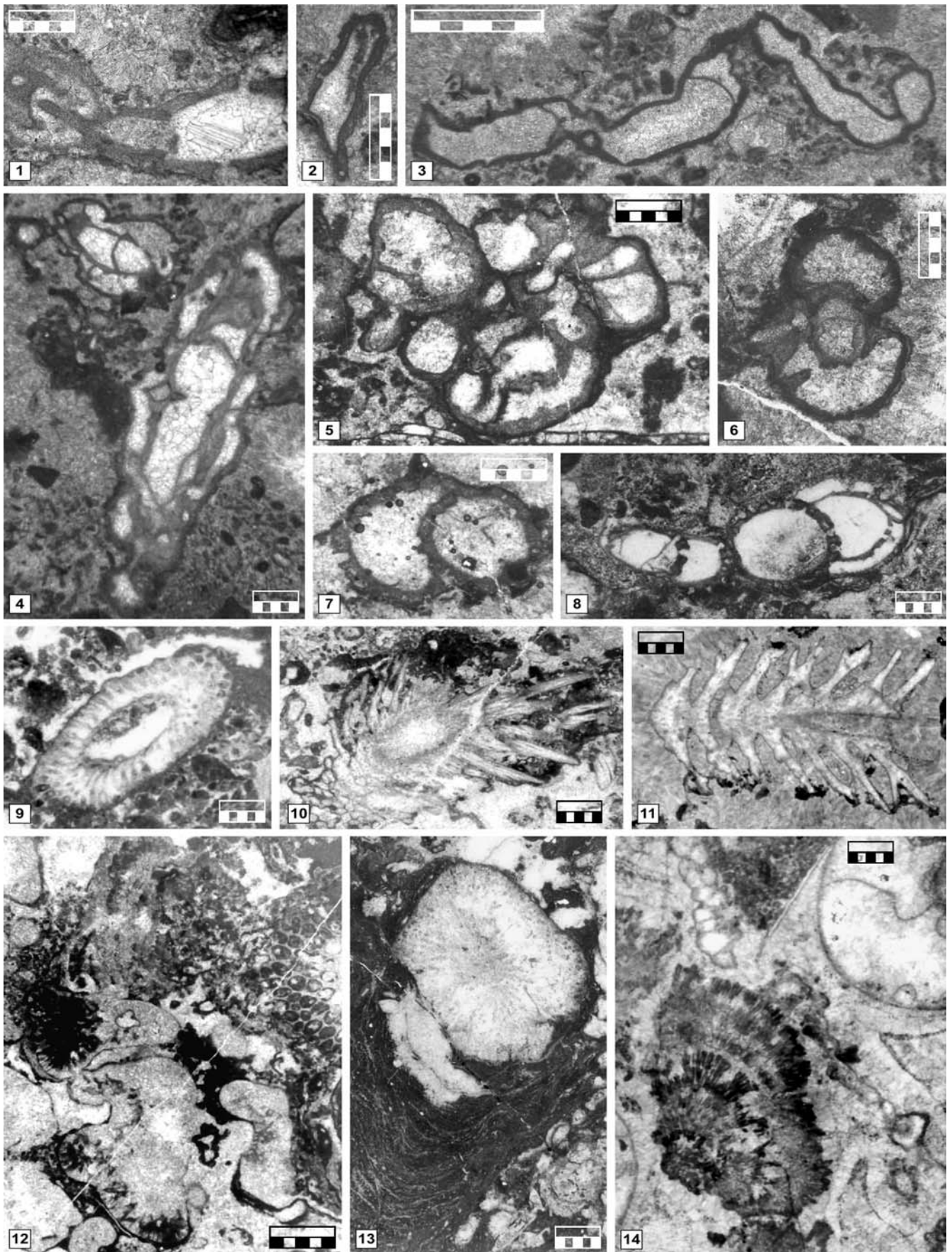
cavities are usually filled with synsedimentary isopachous cement. F7 is commonly found as reworked clasts on the slope, scarcely in-situ. It is frequently associated with biota of the platform margin, but also with pelagic organisms (*Daonella* sp. and cephalopods), lagoonal algae (Porostromata and dasycladaleans, Fig. 10(9–11)) and/or benthonic foraminifers (duostominids, e.g. *Diplotremina* cf. *astrophimbriata*, Fig. 15(16–18), and *Duostomina* sp., Fig. 15(19–20), Endotebidae, e.g. *Endoteba* ex gr. *obturata*, Fig. 15(21), and *Endoteba* sp., Fig. 15(24–26), and Endotriadidae, e.g. *Endotriadella* sp., Fig. 15(22), *Endotriada* cf. *tyrrhenica*, Fig. 15(23), and *Endotriadella wirzi*, Fig. 15(27–28)). Porostromata are mainly represented by the *Ortonella* species (Fig. 8(7–9)). The large fragments of its thalli are characterised by dark, obvious, linear tubes with a low angle of bifurcation, typical for *Ortonella* sp. Sessile foraminifers, biogenic crusts and “*Tubiphytes*” group (Fig. 12(11)) concur to stabilise autochthonous fine-grained sediments (LF5) and resedimented lithoclastic material (LF2). The occurrence of reefal detritus and open marine cephalopods points towards a setting on the uppermost slope. Hence this fossil assemblage is found in the lower parts of the Cresta De Do Peniola sections and on the uppermost slope at Cima Feudo and Schenon. At Latemar however, F7 is only of local and minor importance unlike at other, but slightly older Anisian reefs of the Dolomites where *Olangocoelia otti* is an important reef-builder (Fois and Gaetani 1984; Senowbari-Daryan et al. 1993).

F8—“*Tubiphytes*”-“*Microproblematica*” bindstones

Despite being a secondary reef-builder, this fossil assemblage is the most important faunal association at Latemar. Its distribution ranges from the upper slope to the central reef concurring to the stabilisation of carbonate sediments and primary reefal frameworks. F8 is rich in different species of the “*Tubiphytes*” group (“*Tubiphytes*” *gracilis* in fragments only, “*Tubiphytes*” *obscurus* most frequently and “*Tubiphytes*” sp.) generally associated with biogenic crusts within the framework of biogenic structures. “*Microproblematica*” are equally abundant and mainly represented by *Plexoramea cerebriiformis* (Figs. 12(6–7) and 16(23–24)), *Bacinella ordinata* (Figs. 12(1–2) and 16(29)) and only in a few cases—i.e. in the upper parts of the Cresta De Do Peniola sections—by *Ladinella porata* (Fig. 16(27)).

The “*Tubiphytes*” group at Latemar’s reef is characterised by different, heterogeneous microfabrics. Their common characteristics are circular tubes or central channels in the middle of micritic crusts with undulated laminae or reticular tissue. The smaller species of this fossil assemblage is referred to “*Tubiphytes*” *gracilis*, showing a dense network of small and very irregular branches. Sometimes “*Tubiphytes*” *gracilis* is associated with other encrusting organisms like sessile foraminifers or *Ladinella porata* (Fig. 16(27)). In some cases it is not possible to distinguish between individuals of *Plexo-*

Fig. 9 Anisian reef limestones from the Latemar, Dolomites, Italy: sponges (*Celyphia* sp.) and corals. Scale bar 1 mm with subdivisions of 200 μ m. (1): *Celyphia zoldana* Ott, Pisa and Farabegoli. Section through several chambers of an encrusting specimen together with “*Tubiphytes*”-like crusts; (Cresta De Do Peniola). (2–3): *Celyphia zoldana* Ott, Pisa and Farabegoli. Longitudinal section through four chambers of recrystallised specimens; (Cresta De Do Peniola). (4): Several chambers of *Celyphia zoldana* overgrown by “*Tubiphytes*”-like crusts and sessile foraminifers; (Cresta De Do Peniola). (5–7): *Celyphia zoldana* Ott, Pisa and Farabegoli. Section through some chambers of recrystallised specimens. The chambers are infilled with calcitic cement and/or sediment (5); ((5–6): Cresta De Do Peniola; (7): Schenon). (8): *Celyphia? minima* Senowbari-Daryan, Zühlke, Bechstädt and Flügel. Longitudinal section through several pear-shaped chambers characterised by ostia with short exauli on the surface of the wall; (Cresta De Do Peniola). (9): *Celyphia? minima* Senowbari-Daryan, Zühlke, Bechstädt and Flügel. Section through three chambers. The wall and roof of the chambers are pierced by several pores. According to Senowbari-Daryan et al. (1993, Pl.45, Fig. 4), the attribution of this sponge to *Celyphia? minima* is not sure and it could probably be a new species; (Cresta De Do Peniola). (10): *Celyphia? minima* Senowbari-Daryan, Zühlke, Bechstädt and Flügel. Section through two oval shaped chambers. In the wall of the chambers, large ostia with short exauli are evident; (Cresta De Do Peniola). (11): *Celyphia? minima* Senowbari-Daryan, Zühlke, Bechstädt and Flügel. Section through three chambers; (Cresta De Do Peniola). (12): Microfacies with corals (*Zardinophyllum* sp.?) and small chambers of sponges cf. to *C. zoldana*; (Schenon). (13): Several specimens of small encrusting sponges cf. to *Celyphia? minima*; (Cima Feudo)



ramea cerebriformis and of the “*Tubiphytes*” group (Figs. 12(6–7) and 16(23–24); for intergrowth of both species see also Enos et al. 1997). Compared to other Anisian reefs in the Dolomites like in the Olang area (Fois and Gaetani 1984; Senowbari-Daryan et al. 1993), “*Tubiphytes*” group and “*Microproblematica*” are much more abundant at Latemar.

F9—*Bacinella* bindstones

This fossil assemblage is not a major constructor of the reef-facies but is always assisting in the stabilisation of primary frameworks. Only in some cases, *Bacinella*-bindstones form primary fabrics where their framework is almost exclusively organised by this species. *Bacinella* sp. (Figs. 12(1–2) and 16(29)) is heavily encrusting sponges, corals and fragments of the “*Tubiphytes*” group. “*Microproblematica*” are generally of major importance for this fossil assemblage. Among the most abundant are the “*Tubiphytes*” group and *Radiomura cautica* (Fig. 12(8–9)). This faunal assemblage is also associated with bryozoans, bundles of Porostromata as well as some sponges, few dasycladaleans and encrusting sessil foraminifers (nubecularids, Fig. 16(1)). The isolated parts of the *Bacinella ordinata*-mesh have large, ordinate cells, whereas the dense, encrusting parts (*Bacinella* sp.) reveal closer spaced and less regular cells. The matrix of the boundstones are wacke-/packstones with peloids. Cavities are recrystallised and also covered with *Bacinella* sp. Duostominids (Fig. 15(16–20)), Endotebidae (Fig. 15(21,24–26)), fragments of sessil foraminifers and *Palaeolituonella meridionalis* (Fig. 16(5–14)) are the most abundant foraminifers within the intercalated sediment.

Fig. 10 Anisian reef limestones from the Latemar, Dolomites, Italy: sponges, corals and algae. Scale bar 1 mm with subdivisions of 200 μm . (1–3): *Celyphia? minima* Senowbari-Daryan, Zühlke, Bechstädt and Flügel. (1): Oblique section through two chambers exhibiting ostia with exauli and pores in the wall; (Cresta De Do Peniola). (2): Irregular chamber with evidence of ostia in the wall; (Cresta De Do Peniola). (3): Irregular, barrel-shaped chambers with some vesiculae; (Cresta De Do Peniola). (4–6): *Vesicocaulis oenipontanus* (Ott). (4): Longitudinal section through several oval-shaped, imperforate chambers. The transverse section provides evidence for the canal-system and the vesiculae; (Cresta De Do Peniola). (5–6): Oblique and transverse section with canal-system and vesiculae; (Cresta De Do Peniola). (7): *?Colospongia* sp. This sponge exhibits numerous pores in the wall as well as ostia. It displays some affinities with the specimen of Fig. 9(9), but has most probably to be described as a new sponge; (Cresta De Do Peniola). (8): *?Colospongia* sp.; (Cresta De Do Peniola). (9–11): Dasycladalean algae from back-reef limestones. (9): *Pseudodiplopora* cf. *proba* (Pia); (Schenon). (10): *Teutlopora* cf. *echinata* Ott; (Cresta De Do Peniola). (11): *Diplopora nodosa* Schafhäütl; (Schenon). (12): Coral/bryozoan/“*Tubiphytes*” boundstone microfacies. Irregular thamnasteroid corals together with bryozoa *Reptonoditrypa cautica* and “*Tubiphytes*”-like group fragments; (Cresta De Do Peniola). (13): Coral (*Margarosmia* sp.) surrounded by microbial encrustations; (Cresta De Do Peniola). (14): *Olangocoelia*/Porostromata floatstone microfacies. This microfacies is rich in fragments of different Porostromata, cephalopods and isopachous cements; (Cima Feudo)

Fossil assemblages of the lagoon

F10—Lagoonal wacke-/pack-/grainstones

The wacke-/pack-/grainstones of the lagoon-facies are part of the margin at the transition from back reef to tepee belt. They are full of fragments of dasycladaleans (*Diplopora nodosa*, *Teutlopora* sp. and *Macroporella* sp., Fig. 10(9–11)), *Zornia obscura* (Fig. 14(10), probably fragments of dasycladalean algae), benthic foraminifers (aulotortids, Fig. 15(12,14), *Earlandinita* sp., Fig. 15(29–31), *Reophax/Ammobaculites* sp., Fig. 16(2–3), and *?Textularia* sp., Fig. 16(4)), gastropods, bivalves and worm tubes (Fig. 16(18–22)). The presence of lithoclasts indicates levels of higher energy. In some cases pelagic material (*Daonella* sp. and cephalopods) is washed into the lagoon by storms. For a detailed analysis and description of lagoonal facies at Latemar refer to Egenhoff et al. (1999).

Studied outcrops

The database for our study is provided by five outcrops of the reef- and slope-facies at different exposures of the buildup and at different times of platform evolution: (1) Cima Feudo, (2) Kirchtageweide, (3) Erzlahn, (4) Schenon and (5) Cresta De Do Peniola (see Figs. 4 and 5). At the first three outcrops, palaeontological investigations were carried out on in-situ reefs, at the latter two on reefal blocks within the slope-facies. The first four locations offer the possibility to study the platform-to-basin transition at approx. right angles to the margin. The last locality (Cresta De Do Peniola) provides a transect through the upper slope parallel to the margin. All of the locations can be tied into the bio-/chronostratigraphic framework of the cyclic lagoonal succession. The array of the studied outcrops covers the entire time of platform evolution (Fig. 5).

Cima Feudo

This location (Fig. 4) comprises the entire western flank of Cima Feudo until its summit—the highest point of the SW ridge of the Latemar. The studied interval of platform evolution ranges from lowermost LPF to middle LCF (Fig. 5).

Architecture and sedimentology of the slope

Cima Feudo offers the unique possibility to trace and correlate clinofolds of the slope from the margin to their termination at the toe-of-slope. Platform evolution at this locality can be studied from Contrin times on (see Figs. 5 and 17(1)). The NNW part of the Cima Feudo platform-to-basin transition (i.e. on the left-hand side in Fig. 17(1); NNW of the presumed slump scar) provides insight into

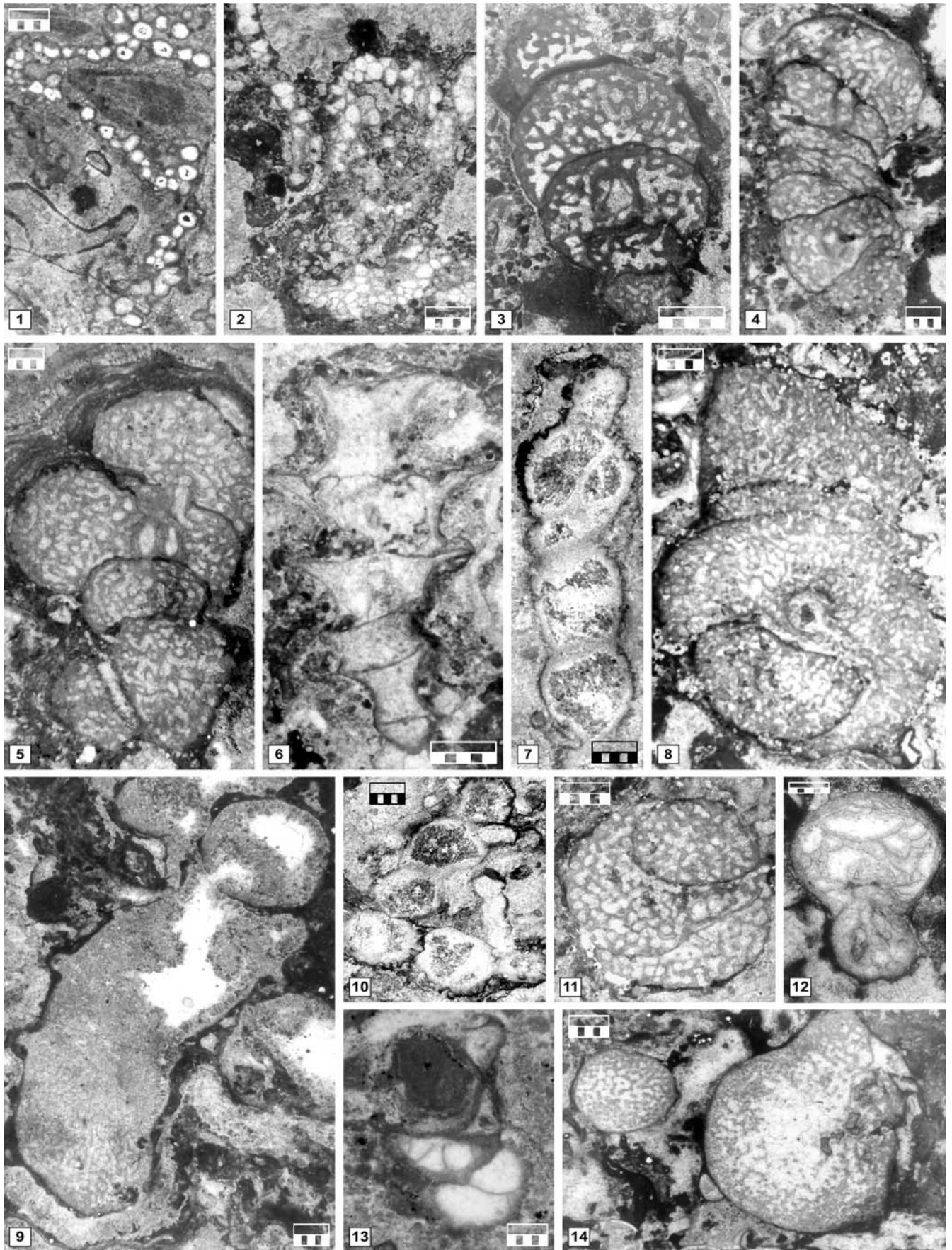


Table 3 Comparison of “*Tubiphytes*” *multisiphonatus* findings from Scholz (1972) and (Schäfer and Senowbari-Daryan 1982, 1983) with the thrombolites described from Latemar (Dolomites) and Concarena (Lombardic Alps)

Location	Aggtelek, Hungary	Hydra, Greece	Latemar, Italy	Concarena, Italy
Formation	Aggtelek Reef Fm (Wetterstein Fm)	Pantokrator Limestone	“Latemar Limestone”, reef-facies (Schlern Fm)	Esino Fm, reef-facies
Author	Scholz (1972)	Schäfer and Senowbari-Daryan (1982, 1983)	this study	Seeling et al. (2005) and this study
Age	Anisian (Early Pelsonian-Upper Illyrian)	Carnian/Norian	Anisian/Ladinian (Middle Illyrian-Earliest Fassanian)	Ladinian/Carnian
Taxa	Hydrozoa	Microproblematica	Microproblematica	Microproblematica
Species	<i>Axopora aggtelekensis</i>	“ <i>Tubiphytes</i> ” <i>multisiphonatus</i>	“ <i>Tubiphytes</i> ” <i>multisiphonatus</i>	“ <i>Tubiphytes</i> ” <i>multisiphonatus</i>
Diameter of central tubes	40–60 μm	50–60 μm	50 μm	40–50 μm
Thickness of “branch”	200–400 μm (measured from Plate V, p.356)	500–1100 μm (measured from Plate 10, p.152)	200–800 μm	400–800 μm
Length of “branches”	0.3–0.7 cm (oblique section?, measured from Plate V, p.356)	“several cm” (Schäfer and Senowbari-Daryan 1983, p.129)	up to 3 cm	up to 5 cm
Height of bushlike “thalli”	10–15 cm	5 cm	10–30 cm	10–30 cm
Maximal dimensions of thrombolite	?	?	height: 70 cm; length: 300 cm	height: 70 cm; length: 300 cm
Palaeoposition	“protected parts of the central reef”, i.e. transition to back reef (cf. p.341)	transition from reef to lagoon (Schäfer and Senowbari-Daryan 1982, p.155–156; Schäfer and Senowbari-Daryan 1983, p.127)	back reef	back reef, transition to the lagoon
Cements	fibrous calcite	?	isopachous calcite around the branches and block calcite	isopachous calcite around the branches and block calcite
Thickness of micritic filaments surrounding central tubes	- (“Coenenchyma”, see p.345)	5–10 μm	ca. 5 times smaller than central tube (i.e. ca. 10 μm)	ca. 5 times smaller than central tube (i.e. ca. 10 μm)

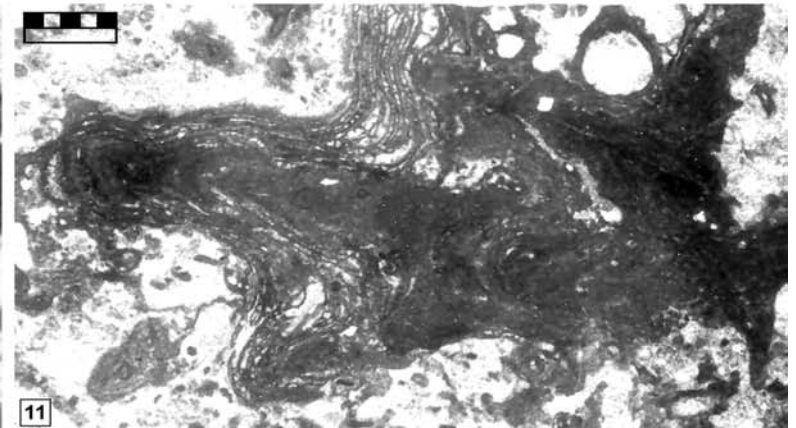
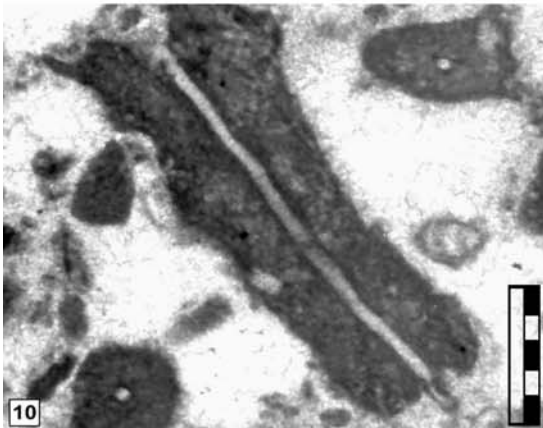
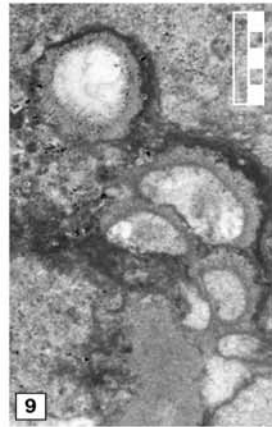
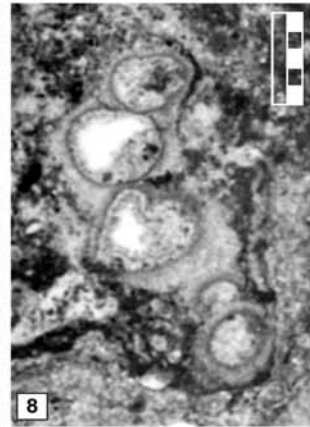
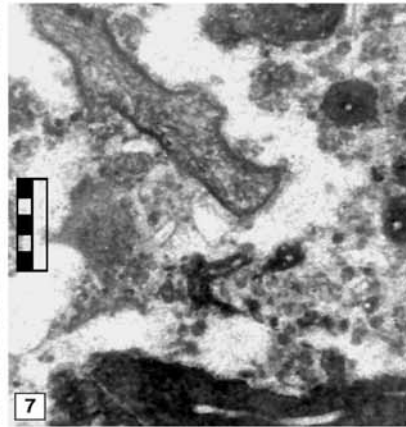
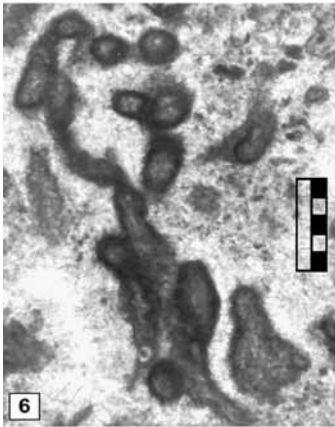
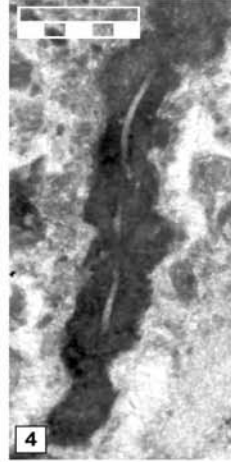
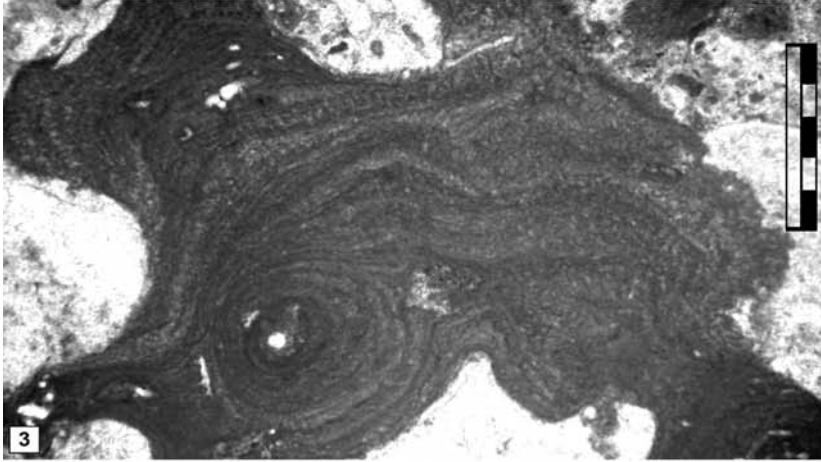
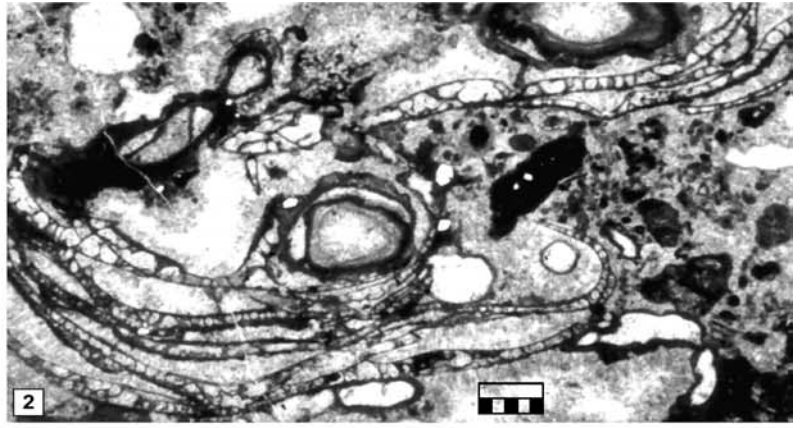
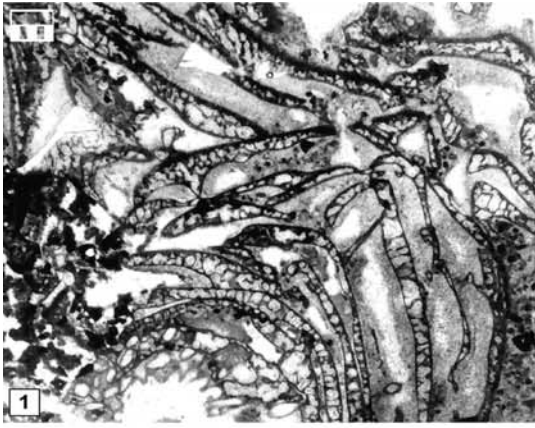
an undisturbed stratigraphic succession. The mainly subtidal platform of LPF times—“Lower Edifice” sensu Gaetani et al. (1981)—conformably overlies the Contrin

Fm and possibly builds up from a very thin and proximal facies of the Buchenstein Fm. The reefal margin of this early period is not preserved, it is eroded and must lie outside the pictured area to the SSE where the basin is situated (right-hand side in Fig. 17(1)).

Fig. 11 Anisian reef limestones from the Latemar, Dolomites, Italy: *Olangocoelia otti* Bechstädt and Brandner and sponges (siphonozoans and inozoans). Scale bar 1 mm with subdivisions of 200 μm unless otherwise stated. (1–2): A characterising feature of *Olangocoelia otti* Bechstädt and Brandner (sponge or algae?) is the chain-like, in line arrangement of its small chambers surrounding cavities (1). However, sometimes *O. otti*-chains are irregularly distributed within the sediment (2). The interior of its chambers is usually infilled with calcite. ((1): Cima Feudo, scale bar 2 mm with subdivisions of 400 μm ; (2): Schenon). (3–5): *Solenolmia manon manon* (Münster), a common, large segmented sponge in Anisian to Carnian reef carbonates of the Alpine-Mediterranean region. (3): Longitudinal section exhibiting the reticular filling structures and the spongocoel; (Cresta De Do Peniola). (4–5): Longitudinal and oblique sections exhibiting the retrosiphonate spongocoel. In (5), the sponge is overgrown by biogenic crusts; (Cima Feudo). (6): *Thaumastocoelia dolomitica* Senowbari-Daryan, Zühlke, Bechstädt and Flügel. Longitudinal section through several barrel-shaped chambers. There is no evidence of pores between roof chambers and vesiculae; (Cima Feudo). (7): *Colospongia catenulata catenulata* Ott. Single, monoliform stem without central tube and porate walls of the chambers; (Schenon). (8): *Deningeria* cf. *crassireticulata* Senowbari-Daryan, Zühlke, Bechstädt and Flügel; (Cima Feudo). (9): *Meandrostia triassica* Senowbari-Daryan, Zühlke, Bechstädt and Flügel; (Cima Feudo). (10): *Colospongia catenulata catenulata* Ott; (Schenon). (11): *Solenolmia manon manon* (Münster); (Cima Feudo). (12–13): *Follicatena cautica* Ott; ((12): Cima Feudo; (13): Schenon; scale bar 2 mm with subdivisions of 400 μm). (14): Isolated globular/oval chambers of *Deningeria* sp.; (Cresta De Do Peniola)

However, if the flat lying strata are traced from the lagoonal interior (NNW) towards the basin (SSE), they terminate against an antithetically tilted block of lagoon-facies in the centre of the picture (Fig. 17(1), large striped area; signature: megablock). The size of the block is considerable, it is approx. 400 m thick and 200 m wide. In the direction of the palaeo-basin (SSE), two additional areas of lagoon-facies are distinguishable by their different dip. The proximal one dips towards the basin (Fig. 17(1), small striped area; signature: megablock), the more distal one is horizontally stratified, conformably overlies Buchenstein Fm and seems to be in-situ (Fig. 17(1), signature: in-situ lagoon-facies). All three areas reveal an erosive top and are covered by slope deposits of LTF and LCF times. This facies boundary is relatively distinct and was mapped in the field (Fig. 17(1), signature: erosional surface). Reef-facies is—as mentioned above—absent in the lower part of the succession and reappears in the LTF underneath the summit of Cima Feudo.

The buildup phase of the LPF platform at this outcrop continues until a giant failure of the platform flank at the verge from LPF to LTF removes slope, margin and parts of the lagoon. The downward movement of the lagoonal megablock shows a throw of approx. 100 m alongside a listric fault plane (Fig. 17(1), signature: presumed slump



scar). As the block moves downward, it crushes the footwall and pushes up another block at its front. Subsequently the platform margin backsteps and re-establishes itself at the former interior of the platform (Fig. 17(1), signature: reef-facies). The interval following this catastrophic event is characterised by the re-establishment of a depositional slope. The giant slump is subsequently buried underneath carbonate slope sediments. Drowning of the platform and development of a “pelagic drape” (De Zanche et al. 1995; p.140) cannot not be observed. The contrary is the case, the platform margin is successfully keeping up with relative sea-level rise and newly created accommodation space above the mega-block is filled with slope deposits.

The sheer size of this slump implies that instability of the margin or slope is not the only reason for the collapse. It is most probably caused by a combination of synsedimentary tectonic movement and lithological weakness. Anisian faults are known from the Northern Dolomites (Bechstädt and Brandner 1970) and sinistral transpression with deep-reaching faults is ongoing near the study area until the Longobardian (Doglioni 1984). The resulting flower structures and domal uplifts are paving the way for the eruption of the Wengen Grp volcanics (Doglioni 1983). Evidence for regional volcano-tectonic activities in the surroundings of the Latemar is the proximity of the volcanic centre of Predazzo/Monzoni above the Stava Line-Cima Bocche Anticline (Doglioni 1984). The observation of a tectonically controlled and/or mutilated platform generally corresponds with Doglioni (1984), Bosellini (1989) and De Zanche et al. (1995), although differences exist with respect to mechanisms, size and timing of the backstepping of the LPF platform.

Sedimentology and general palaeontology of the reef

Microfacies mapping along a reef transect (length: 300 m; line A–B in Fig. 17(1)) at the stratigraphically highest

Fig. 12 Anisian reef limestones from the Latemar, Dolomites, Italy: microproblematica. Scale bar 1 mm with subdivisions of 200 μm unless otherwise stated. (1–2): *Bacinella ordinata* Pantic, a common, encrusting microproblematicum together with sponges, algae and bryozoans; (Cresta De Do Peniola). (3–5): “*Tubiphytes*” *obscurus* Maslov, a very abundant organism in the Anisian reef facies of Latemar, generally present with different types of the “*Tubiphytes*” group and other microproblematica; ((3): Cresta De Do Peniola; (4): Schenon; (5): Cresta De Do Peniola). (6): “*Tubiphytes*” cf. *carianthicus* Gaetani and Gorza. This specimen seems to be an intermediate, distinguishable form between “*Tubiphytes*” *carianthicus*=*Plexoramea cerebriformis* Mello and “*Tubiphytes*” *obscurus*; (Schenon). (7): Association of “*Tubiphytes*” *obscurus* and *Plexoramea cerebriformis* Mello; (Cresta De Do Peniola). (8–9): *Radiomura cautica* Senowbari-Daryan and Schäfer, a rare microproblematicum in the Anisian reef-facies of the Latemar; ((8): Cresta De Do Peniola; (9): Schenon). (10): Longitudinal and transverse sections of “*Tubiphytes*” *obscurus*; (Schenon; scale bar 500 μm with subdivisions of 100 μm). (11): Association of “*Tubiphytes*” *obscurus* and microbial encrustations, a very common microfacies of the Anisian reef-facies of the Latemar; (Cresta De Do Peniola)

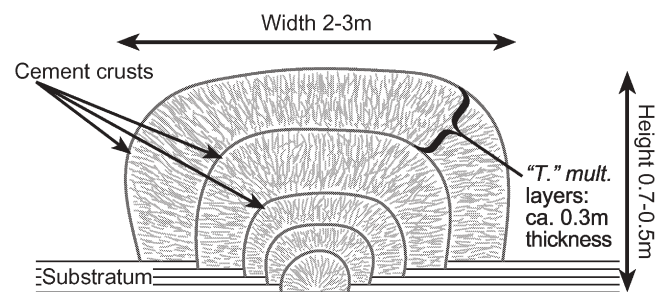
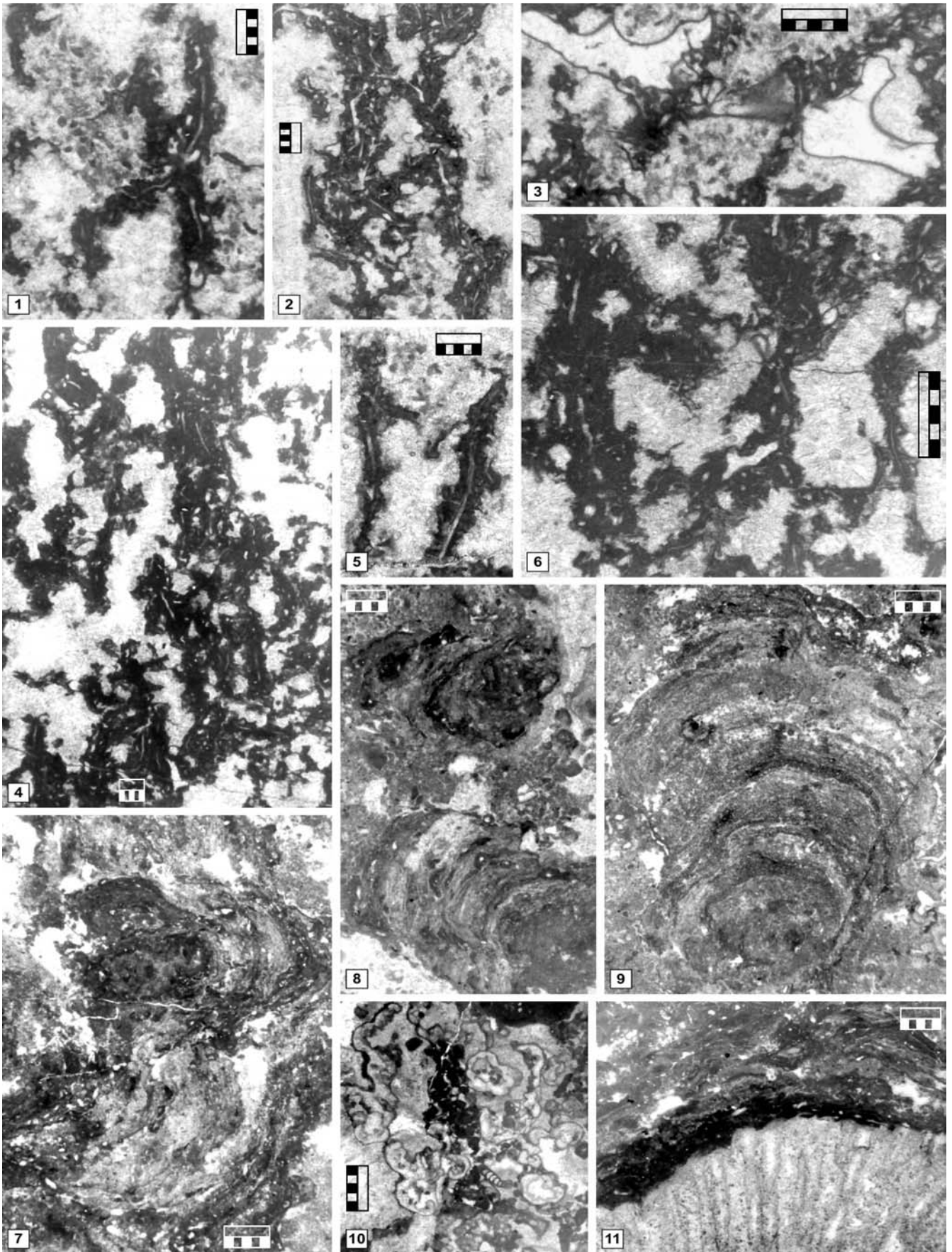


Fig. 13 Idealised sketch of “*Tubiphytes*” *multisiphonatus* thrombolites at Erzlahn (location 3). The thrombolite is made up of a repetition of several, concentric layers of branches—each one with bush-like ramifications and separated by thin cement layers. Not to scale. Abbreviations: “*T. mult.*”: “*Tubiphytes*” *multisiphonatus*

point of Cima Feudo covers the transition from lagoonal interior across the in-situ margin to the upper foreslope. The transect runs in a single stratigraphic level and is time-equivalent with the uppermost LTF to lowermost LCF lagoonal strata (Fig. 5).

The transect begins in the lagoon with wacke-/pack-/grainstones (F10), characterised by the presence of bioclastic material (gastropods, pelecypods), dasycladalean algae (Fig. 10(9–11)), peloids and benthic foraminifers. Among the most abundant foraminifers are Duostominidae, Endotriadidae and Endotebidae (classification sensu Vachard et al. 1994). The proximity of the reef is indicated by typical detritus like fragments of worm tubes (*Spirorbis* sp., Fig. 16(18–22)), of sponges (e.g. *Olangocoelia otti*), of “*Tubiphytes*” group and of “Microproblematica” like *Plexoramea cerebriformis*, *Bacinella ordinata* and *Baccanella floriformis*. The abundance of these components increases towards to the reef where these biota are eventually found in-situ. “*Tubiphytes*”-rich wackestones are the main indicator of the reefal margin (F8). Foraminifers like *Palaeolituonella meridionalis* and small, micritic worm tubes are present in the central part of the reef-facies. Biogenic crusts together with “*Tubiphytes*” group (F5) intercalated with boundstones of *Celyphia? minima*, *Deningeria* sp., *Celyphia zoldana* and *Thaumastocoelia dolomitica* (F2) characterise the reef-facies above the foreslope.

An important feature of this reef is the overwhelming abundance of calcisponges (*Solenolmia manon manon*, *Deningeria crassireticulata*, *Meandrostia triassica* and *Follicatena cautica*) which are usually well preserved, as well as small blocks (or in-situ heads?) of large, robust scleractinian corals (*Retiophyllia* sp.) at the uppermost foreslope (F4). At Cima Feudo, “Microproblematica” like *Anisocellula fecunda* (Fig. 16(26)), *Bacinella ordinata* and *Baccanella floriformis* are less important and less frequent reef-builders than in other Anisian reefs (e.g. Olang area; Senowbari-Daryan et al. 1993). The occurrence of small foraminifers like *Turriglomina mesotriassica* (Fig. 15(8–9)) indicates the upper part of the slope. Abundant bioclasts (fragments of *Olangocoelia otti*, cephalopods, Porostromata and solenoporaceans; Fig. 10(14)) together with at least two generations of



cement—isopachous and block cement—fill the cavities between the reef talus blocks.

In summary, the reef at Cima Feudo reveals a low initial topography and bears no signs of emersion. Our study confirms the model of Harris (1993) at this location although the diversity of biota is greater.

Kirchtagweide

This outcrop is located at the northwestern termination of the Latemar and forms a prominent, protruding ridge (Fig. 4). The location Kirchtagweide provides a tectonically undisturbed transect from the lagoonal interior (summit of Kirchtagweide) through a slightly younger reef belt to the coeval toe-of-slope interfingering with basinal sediments of the Buchenstein Fm (summit of Bewaller Köpfl, to the NW of the pictured area in Fig. 17(2), for geographical position and geological context refer to Fig. 17(3)). The studied reef-facies correlates with the uppermost LPF to lower LCF.

Architecture and sedimentology of the slope

In this transect, slope evolution is recorded from the build-up of Schlern Fm upon Contrin Fm. Buchenstein Fm underneath the slope is represented by a very thin (<3 m) and proximal facies. The slope-facies at Kirchtagweide lacks erosional features—its clinofolds are more or less parallel and display a depositional-type slope. Hence, the slope at this NW exposure of the Latemar corresponds to the Ladinian model of Bosellini (1984) and with restrictions to the classification “slope-apron” sensu Mullins (1983) and Mullins and Cook (1986).

Fig. 14 Anisian reef limestones from the Latemar, Dolomites, Italy: “*Tubiphytes*” *multisiphonatus* thrombolites, biogenic crusts and algae. Scale bar 1 mm with subdivisions of 200 μm unless otherwise stated. (1–2,4–6): “*Tubiphytes*” *multisiphonatus* facies. This biota, firstly described by Senowbari-Daryan and Schäfer (1983), is present on the back-reef margin of the reef belt at Latemar with large colonies, up to 3 m wide and 0.7 m tall. Corresponding to Schäfer and Senowbari-Daryan’s original description (1983), longitudinal sections reveal subparallel to parallel tubes embedded in a network of fine micritic filaments forming erect, slender, ramose “thalli”. Large amounts of synsedimentary, isopachous and blocky calcitic cements are present between these “thalli”-like structures of the colonies; (Erzlahn). (3): Peloids and algal remains (similar to *Thaumtoporella* cf. *parvovesiculifera*) in oblique section between the “thalli” of “*Tubiphytes*” *multisiphonatus*; (Erzlahn). (7–9): Biogenic crusts. Bundles of microbial encrustations (“Spongiostromata” Auct.) derived from cyanobacterial activity occur sometimes together with sessile forams. This facies can also be referred to stromatolites/microbialites; (Erzlahn); (8): scale bar 2 mm with subdivisions of 400 μm). (10): *Zornia obscura* Senowbari-Daryan and Di Stefano. This very rare organism (dasyclad?) of the lagoon-facies at Latemar is associated with fragments of other dasycladalean algae; (Erzlahn). (11): Fragment of a coral surrounded by microbial encrustations; (Cima Feudo, scale bar 2 mm with subdivisions of 400 μm)

Sedimentology and general palaeontology of the reef

At least the upper levels of the reef at Kirchtagweide show a progradational pattern. Progradation is in the order of 50–80 m within the recorded interval of reefal build-up (ca. 300 m). The unique feature of the reef-facies at Kirchtagweide is the width of the reef belt (up to 130 m) and the abundant presence of scleractinians. The reef itself is entirely dolomitised, no biota are visible apart from the heavily recrystallised branches of corals (*Retiophyllia* sp.?; Fig. 18). The great abundance of corals suggests a wave-resistant reef front at this exposure. On its eastern termination, the reef is truncated by a fault (Fig. 17(3)) before it disappears into the cirque of the “Geplänk” (Fig. 4).

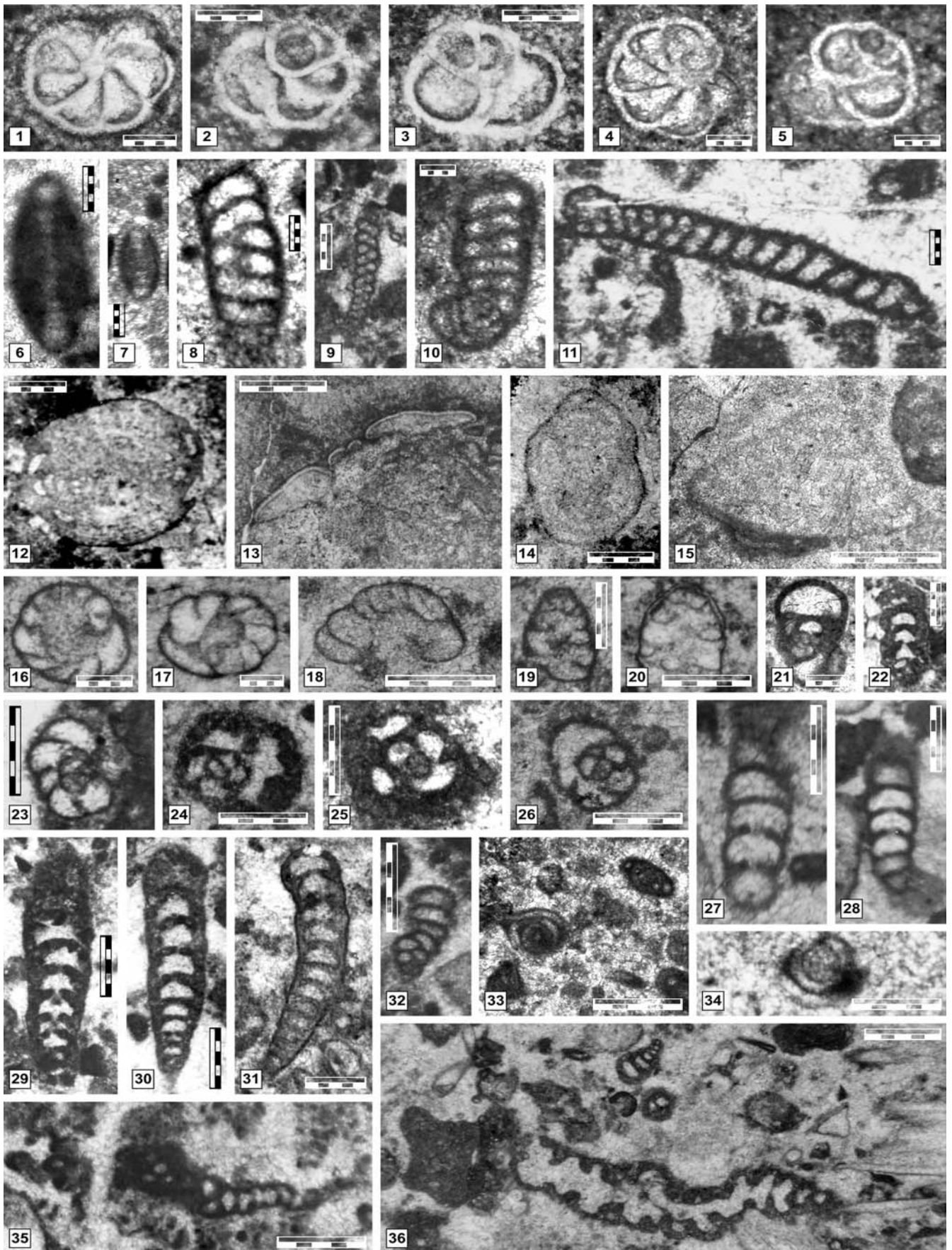
Erzlahn

The so-called Erzlahn is a broad and relatively steep gully with more or less vertical walls on either side located at the NW flank of the Latemar (Fig. 4). The gully follows a postsedimentary, NW-SE trending fault—possibly also a volcanic dyke—dissecting the platform from its margin to the toe-of-slope. Stratigraphic (position of marker horizons) and facies (position of margin) information indicates a negligible displacement along the fault and/or dyke in the order of less than 20 m. The fault/dyke in the Erzlahn separates the platform margin into two different blocks with two different sedimentological settings (Fig. 19(1–2)). The gully itself provides access to these two platform-to-basin transitions (Fig. 19(3)). The southern block of the fault/dyke is a platform-to-basin transition where the reef belt is missing whereas the northern block displays a transect from lagoon across back-reef margin until reef front.

Architecture and sedimentology of the slope

The slope at Erzlahn corresponds to the upper LCF and lower MTF interval of the lagoonal succession (Fig. 5). The most striking feature of the southern side of the Erzlahn is the missing reef (Fig. 19(1), and for detailed geographic position refer to Fig. 19(3); legend of geological map Fig. 17(3)). The contact between lagoon-(SE) and slope-facies (NW) is of erosional nature. Horizontally bedded strata of the lagoon terminate to the NW against a slump scar (slump scar 1 in Fig. 19(1)) and steeply dipping slope-clinofolds (up to 60°, unit 1 in Fig. 19(1)). Slope unit 1 passes basinwards (NW) into significantly less steep clinofolds (unit 2 in Fig. 19(1)). Unit 1 and unit 2 are both erosionally truncated at their top by an unconformity (slump scar 2 in Fig. 19(1)). This slump scar 2 is conformably overlain by a slope unit with partly antithetic dip (unit 3 in Fig. 19(1)).

Before an erosional event creates slump scar 1, probably a normal platform-to-basin transition (i.e. with a reef) existed. After the event, newly created accommo-



dation space is filled with deposits of slope unit 1, most likely too quickly for a stabilising reefal margin to establish. Much of the sediment bypasses the uppermost foreslope and accumulates further downslope (unit 2). Unit 2 is not as steeply stratified as unit 1 and is stabilising the clinofolds of unit 1. But the slope already reaches its maximum of stability, resulting in a second erosional event (slump scar 2) which removes a large quantity of upper slope sediments. Dip measurements in unit 3 above slump scar 2 reveal an inclination of clinofolds towards the lagoon. This antitethic dip is caused by the listric nature of slump scar 2. A couple of metres above it, slope clinofolds are already inclined towards the basin again and reveal dip values between 5° and 15° to the NW. This indicates the re-establishment of a depositional slope after these two erosional events.

Timewise, slump scar 1 corresponds to an onlap structure in the lagoonal-facies at the SE termination of the Latemar. The tilting of the entire platform to the SE might cause the oversteepening of the clinofolds and their subsequent failure in the NW of the platform (Erzlahn, location 3). Similar to the situation at Cima Feudo, the origin of the tilting can be seen in synsedimentary tectonic movements at the nearby Stava Line-Cima Bocche Anticline.

In summary, major backstepping by margin failure is not only restricted to the SW of the Latemar and LPF/LTF at Cima Feudo, it also occurs on the NW side of the platform during the LCF-MTF interval. A model of simple aggradation as main platform growth mode until

the latest stages of platform evolution is not in line with our observations at these two locations.

Sedimentology and general palaeontology of the reef

The reef at this location is exposed at the northern flank of the Erzlahn gully (Fig. 19(2), and for detailed geographic position refer to Fig. 19(3); legend of geological map Fig. 19(3)) and its SW termination. The reef-facies is easily distinguishable from the adjacent lagoon-facies by the absence of stratification and its slight dolomitisation. The outcrops of reef-facies at Erzlahn are scattered and small; nevertheless, they display features very distinct from all other locations at Latemar.

The reef front is represented by some small patch-reef-like structures—up to two metres in diameter—made up of large, robust hexacorals (F4, *Retiophyllia* sp. with corallites of up to 15 mm in diameter). Usually, these framestones are heavily encrusted with “*Tubiphytes*” and other microbes (F8). The encrusted, small coral knobs (reef front) pass laterally—i.e. towards the main outcrop of reef-facies described below and pictured in Fig. 19(2)—into algae dominated boundstones (F5). The centre of the reef is a microbial/algal ridge formed by laminated microbialites (F5). At Erzlahn, this part of the reef-facies is documented by a 10–20 m wide outcrop.

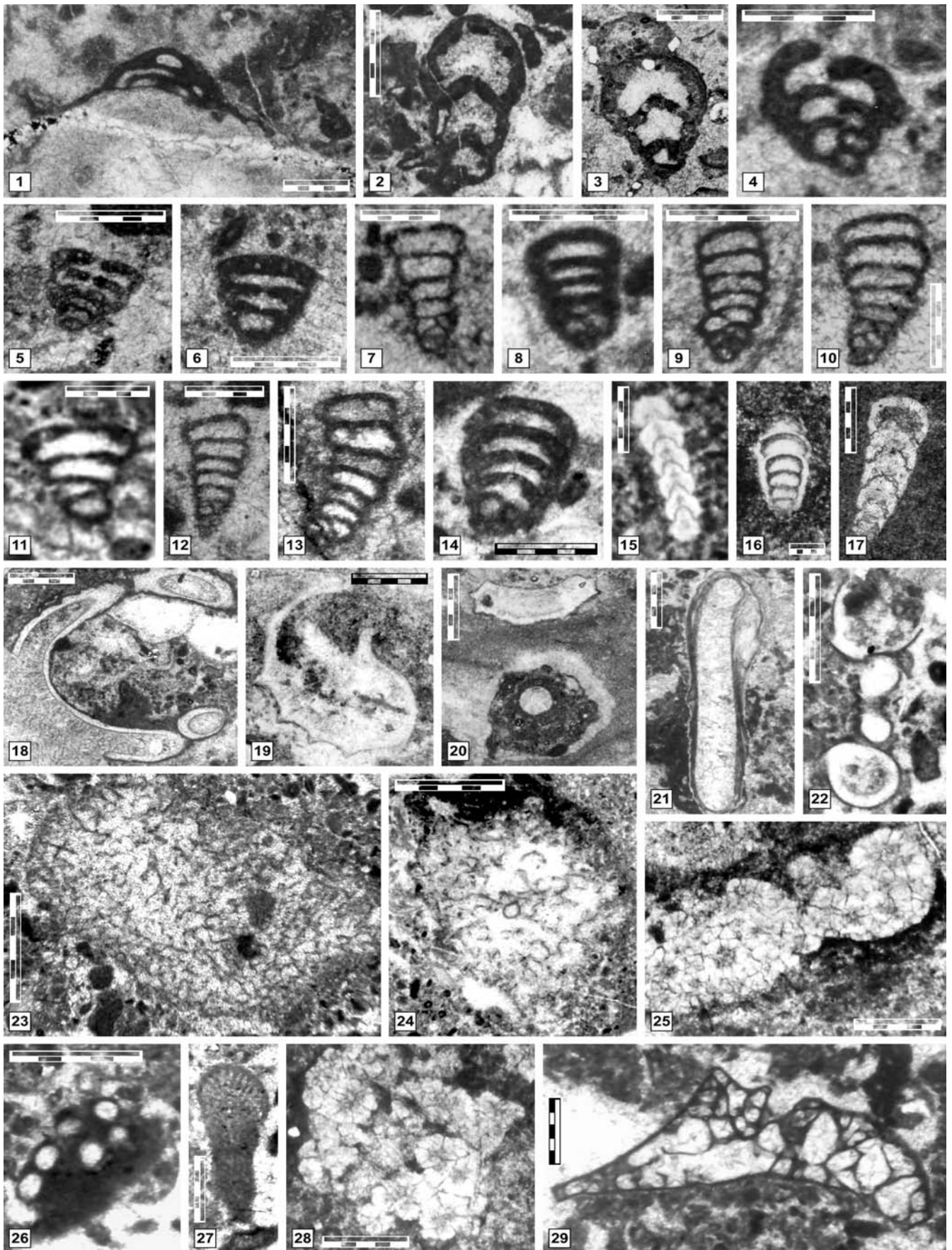
At the northern side of the Erzlahn, the gradual transition from reef-facies to lagoon-facies contains thrombolite-like structures sitting on top of indistinct bedding planes. The strata are slightly dipping away from the observer, i.e. towards the lagoonal interior. Detailed facies mapping showed, that a depression is situated between the reef and the tepee belt, in the direction of the centre of the lagoon. Like at Cima Feudo and Kirchtagweide, the reef shows no sign of emersion, hence the tepee belt is the palaeobathymetrically highest point of the platform margin. The most interesting feature of the reef at this location is the assemblage of “*Tubiphytes*” *multisiphonatus* thrombolites (F6, up to 3 m wide and 0.7 m thick). The framework of these thrombolites is formed by concentrically growing, bush-like layers with a thickness of 20 to 30 cm (for outcrop pictures refer to Fig. 20(1–2)). The organisation of the thrombolites (F6) is shown in Fig. 13.

If outcrop, microfacies and palaeoenvironmental observations are taken into account, it is obvious that the simple reef model of Harris (1993) cannot be applied to the situation at Erzlahn. Harris’ model is based on investigations at Cima Feudo where the topography is the same as at Erzlahn, but facies belts and biota differ strongly.

Schenon

Schenon is one of the highest summits of Latemar’s northern ridge (Fig. 4). Its SW vertical face provides insight into the platform development of UCF times (Fig. 20(3)).

Fig. 15 Anisian reef limestones from the Latemar, Dolomites, Italy: foraminiferal associations. Scale bar 500 μm with subdivisions of 100 μm unless otherwise stated. (1–5): *Abriolina mediterranea* Luperto; (Cresta De Do Peniola, scale bar 100 μm with subdivisions of 20 μm). (6–7): *Arenovidalina chiangchiangensis* Ho; (Cresta De Do Peniola; (6): scale bar 100 μm with subdivisions of 20 μm ; (7): scale bar 200 μm with subdivisions of 40 μm). (8–9): *Turriglomina mesotriatica* (Koehn-Zaninetti); ((8): Cresta De Do Peniola; (9): Cima Feudo; scale bar 100 μm with subdivisions of 20 μm). (10): *Turriglomina* sp.; (Cresta De Do Peniola, scale bar 100 μm with subdivisions of 20 μm). (11): *Turriglomina scandonei* Zaninetti, Ciarapica, Martini, Salvini-Bonnard and Rettori; (Cresta De Do Peniola, scale bar 100 μm with subdivisions of 20 μm). (12): *Aulotortus? eotriaticus* Zaninetti, Rettori and Martini; (Cresta De Do Peniola). (13): *Bullopore* sp.; (Cresta De Do Peniola, scale bar 1 mm with subdivisions of 200 μm). (14): *Aulotortus? eotriaticus* Zaninetti, Rettori and Martini; (Schenon). (15): *Lamelliconus* ex. gr. *ventroplanus* (Oberhauser); (Schenon). (16–18): *Diploremmina* cf. *astrophimbriata* Kristan-Tollmann. ((16–17): Cresta De Do Peniola; (18): Schenon). (19–20): *Duostomina* sp.; (Cima Feudo). (21): *Endoteba* ex gr. *obturata* (Brönnimann and Zaninetti); (Cima Feudo). (22): *Endotriadella* sp.; (Cresta De Do Peniola). (23): *Endotriadella* cf. *tyrrhenica* Vachard, Martini, Rettori and Zaninetti; (Erzlahn). (24–26): *Endoteba* sp.; ((24–25): Schenon. (26): Cresta De Do Peniola). (27–28): *Endotriadella wirzi* (Koehn-Zaninetti); ((27): Cresta De Do Peniola; (28): Erzlahn). (29–31): *Earlandinita* sp.; ((29): Cresta De Do Peniola; (30–31): Cima Feudo). (32): *Gaudrinella* sp.; (Schenon). (33): *Paraophthalmidium* sp.; (Cresta De Do Peniola). (34): ?*Ophthalmidium* sp.; (Cresta De Do Peniola). (35–36): *Flatschkofelia anisica* Rettori, Senowbari-Daryan and Zühlke; (Cresta De Do Peniola)



Architecture and sedimentology of the slope

At Schenon, an in-situ margin is almost absent. Contrary to Erzlahn, the contact between slope and lagoon is not synsedimentary erosional but of postsedimentary tectonic nature. Two faults dissect the platform at Schenon. They both can be traced for up to one kilometre on either side of the pictured area in Fig. 20(3). At this exposure, the preserved slope-facies proves a depositional characteristic of the platform-to-basin transition during UCF times. The clinofolds of the foreslope are subparallel, erosional structures of a larger scale are absent. The preserved slope corresponds to the depositional models proposed by Bosellini (1984) and Harris (1994).

The unique feature of the slope at Schenon is the abundance and size of synsedimentary cement crusts (Fig. 20(4–5)). The thickness of these crusts—up to several centimetres—indicates a proximal talus setting for the blocks where fast, high-energy deposition of large blocks and the absence of fine-grained sediments facilitate effective fluid flow mechanisms and subsequent early marine cementation. As the complete platform margin is eroded after the tectonic displacement, the relationship between slope and platform top is unclear. A possible depositional model for Schenon is proposed in Fig. 21.

General palaeontology of the reef

The reef-facies is found within talus blocks on the upper slope solely. However, the upright position of delicately branched corals (*Margarosmilia* sp.) at a few places suggests the possibility of localised in-situ growth. Some small scleractinian colonies (F3?) seem to be growing on talus blocks of a slope fan. This setting of a proximal talus fan with resedimented reef-facies is supported by the occurrence of biota from different reef palaeoenvironments in the same microfacies. The blocks contain mainly encrusting “sphinctozoan” sponges like *Celyphia zoldana* and *Celyphia? minima* as well as *Colospongia catenulata*

and *Follicatena cautica*. These calcisponges are accompanied by fragments of the “Tubiphytes” group and “Microproblematica” (*Plexoramea cerebriformis* and *Radiomura cautica*). Fragments of cryptically growing sessil organisms like *Olangocoelia otti* (sponge, alga?) are associated with fragments of dasycladaleans (e.g. *Diploporea nodosa*). Foraminifers of the reef and back-reef facies are also abundant, e.g. *Aulotortus? eotriasicus* (Fig. 15(12)), *Flatschkofelia anisica*, duostominids, *Palaeolituonella meridionalis* and Endotebidae. A single occurrence of *Gaudrinella* sp. (Fig. 15(32)) is also observed. Less common components are echinoid fragments and worm tubes.

Cresta De Do Peniola

This outcrop is located at the NE side of Latemar (Fig. 4). Correlation with basal strata (Fig. 22) indicates that the top of the outcropping succession is positioned at the verge from the *Secedensis* to the *Curionii* zone. The SW flank of the Cresta De Do Peniola (Fig. 23) was mapped in detail and sampled along three sections (Fig. 24(1–2)).

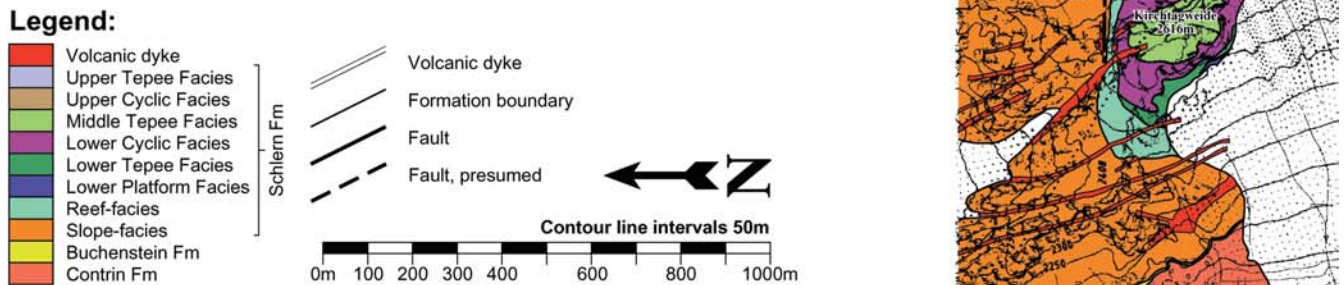
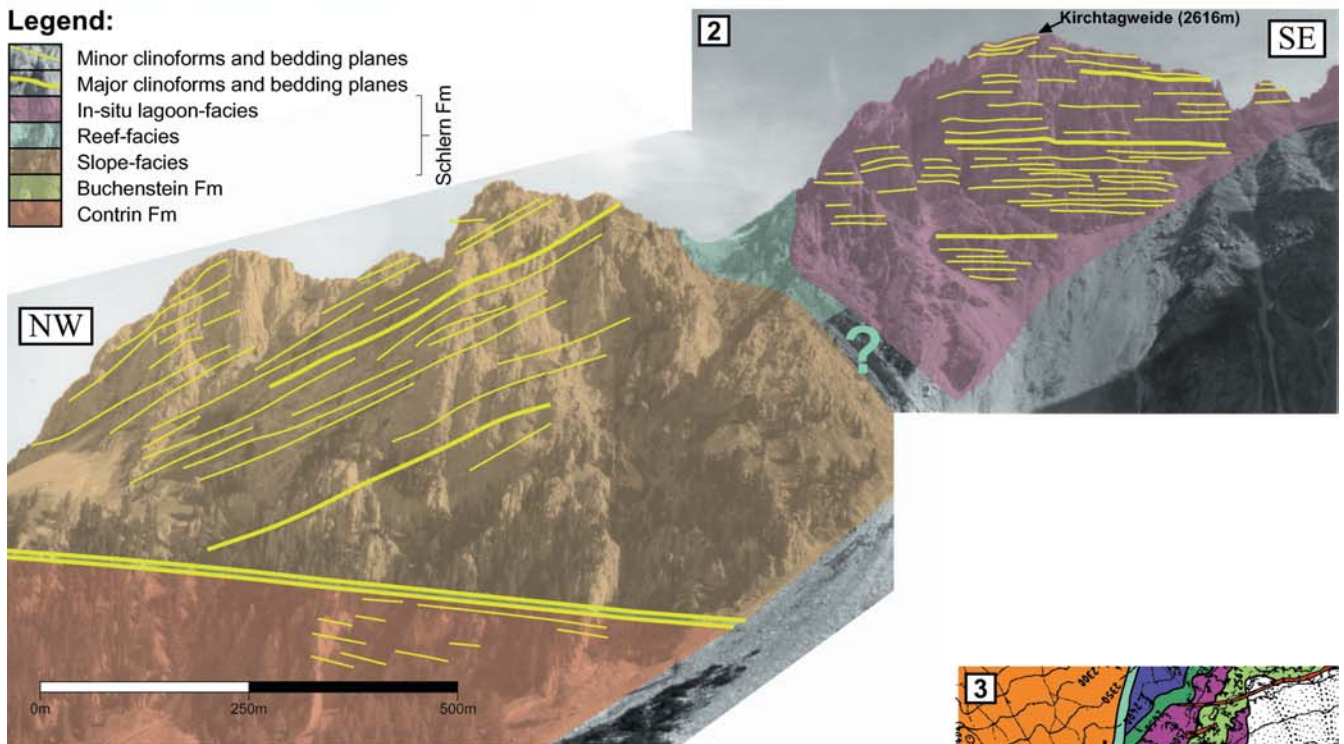
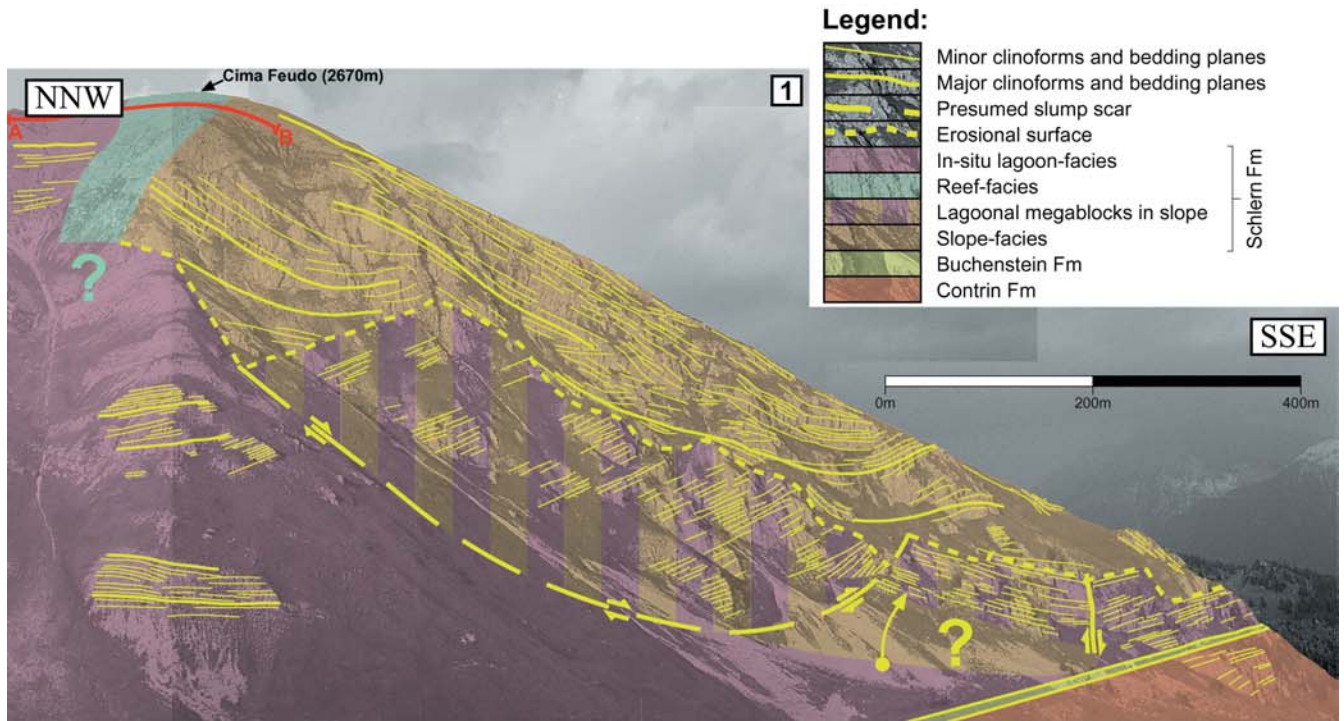
Sedimentological and palaeontological description of the sections

Sedimentological analyses on macro structures, detailed facies mapping and lateral correlation of physical surfaces showed that two units with different lithofacies and sedimentological characteristics are present in this slope transect. (1) The lower unit is more turbiditic and also contains stacked debris flow deposits with components from reef and lagoon (LF2a/b and LF3a/b). Accordingly, there is a broad variety in lithofacies and in the biotic spectrum. (2) The sediments of the upper unit are characterised by abundant megabreccia deposits (LF1) and contain plenty of resedimented material from the slope, but also reefal and lagoonal clasts. In order to define the boundary between these two units more accurately and to track a possible reefal development, three sections at Cresta De Do Peniola were established (Figs. 23 and 24(1–2)): two sections through the entire succession (P1 and P3) and another one through a megabreccia channel in the middle of the succession (P2).

Sections P1 and P2 reveal similar biota in the lower and middle part. With respect to the general content of the previously described locations, P1 and P2 are enriched in benthic foraminifers like *Earlandinita* sp., *Reophax/Ammobaculites* sp., *?Textularia* sp. and *Bacinella ordinata* (F9). The uppermost part of these two sections contains “Tubiphytes” *obscurus*, other “Microproblematica”, sponges (*Vesicocaulis oenipontanus*), corals, Porostromata, *Bacinella ordinata*, *Celyphia zoldana* and eventually *Ladinella porata* for the first time.

Most information on the lower level of the succession comes from P3. Hence, the lithofacies and biotic content of this section is used to describe the basal part of Cresta

Fig. 16 Anisian reef limestones from the Latemar, Dolomites, Italy: foraminiferal associations, wormtubes and microproblematica. Scale bar 500 μm with subdivisions of 100 μm unless otherwise stated. (1): *Tolypammia* sp.; (Schenon). (2–3): *Reophax* sp./*Ammobaculites* sp.; (Cresta De Do Peniola, scale bar 1 mm with subdivisions of 200 μm). (4): *?Textularia* sp.; (Cresta De Do Peniola). (5–14): *Palaeolituonella meridionalis* (Luperto); ((5,7,13): Schenon; (6,8–12): Cresta De Do Peniola; (14): Cima Feudo). (15–17): Lageninid foraminifera; (Cresta De Do Peniola, (16): scale bar 100 μm with subdivisions of 20 μm). (18–22): Worm tubes (*Spirorbis* sp) and encrusting epibiontes of the reef-facies at Latemar; ((18,21–22): Cresta De Do Peniola, (18): scale bar 1 mm with subdivisions of 200 μm ; (19–20): Cima Feudo, scale bar 1 mm with subdivisions of 200 μm). (23–24): *Plexoramea cerebriformis* Mello; ((23): Schenon; (24): Cresta De Do Peniola). (25,28): *Baccanella floriformis* Pantic; (Cima Feudo, scale bar 1 mm with subdivisions of 200 μm). (26): *Anisocellula fecunda* Senowbari Daryan, Zühlke, Bechstädt and Flügel; (Cima Feudo). (27): *Ladinella porata* Ott; (Cresta De Do Peniola, scale bar 1 mm with subdivisions of 200 μm). (29): *Bacinella ordinata* Pantic; (Cima Feudo)



De Do Peniola. This section starts with turbiditic pack-/wackestones (LF3a/b) containing fragments of grapestones with *Olangocoelia otti* (F7) and cavities with isopachous cement. In the following metres, the section cuts through a neptunian dyke (Figs. 23 and 24(2)). Wackestones with encrusting foraminifers (*Bullopore* sp., Fig. 15(13)), fragments of *Olangocoelia otti*, *Plexoramea cerebriformis* and “*Tubiphytes*” sp. (F8) are encountered immediately below the neptunian dyke. These wackestones also contain peloids of the lagoon. The matrix of the neptunian dyke is made up by mud-/wackestones, sometimes red, but always containing fragments of thin pelecypods, foraminifers ostracods, ammonoids and a large amount of coprolites (*Favreina* sp.; Fig. 25(1)). The foraminiferal association consists of small porcellaneous (*Paraophthalmidium* sp., Fig. 15(33), ?*Ophthalmidium* sp., Fig. 15(34), and *Arenovidalina chiangchiangensis*, Fig. 15(6–7)), granular (*Krikoumbilica pileiformis*) and hyaline species (*Abriolina mediterranea*, Fig. 15(1–5), and nodosarids). Above the neptunian dyke, the grain size of debris-flows is increasing and blocks of their basal parts contain *Celyphia? minima*, *Olangocoelia otti* and encrusting “*Tubiphytes*” (F7). Foraminifers like Duostominidae and/or Endotebidae and Endotriadidae are also present. The following debris flow is made up of reef talus blocks with *Baccanella floriformis*, *Bacinella ordinata* and large parts of solenoporaceans (F1). The lithoclasts are partially surrounded by *Celyphia zoldana*. The upper part of this fining upward cycle is characterised by *Daonella* sp. levels (Fig. 25(2)) and serpulids (*Spirorbis* sp.) as well as isopachous cement in cavities. Bryozoan clasts (*Reptonoditrypa cautica*), *Turriplomina mesotriatica* and several “*Microproblematica*” complete the mainly Anisian community. The base of the next turbidite contains fragments of sponges, “*Tubiphytes*” and dasycladaleans. Foraminifers of the back reef—like *Aulotortus? eotriasicus* (see Zaninetti et al. 1994)—are also common. The upper part of this fining-upward microcycle reveals little and large ostracods within the lithoclasts, “*Tubiphytes*” together with *Celyphia? minima* and *C. zoldana*, other “*Microproblematica*” and duostominids. The interval towards the erosional unconformity is characterised by foraminifers such as *Palaeolituonella meridionalis*, *Flatschkofelia anisica*, *Turriplomina scandonei* (Fig. 15(11)), *Turriplomina* sp. (Fig. 15(10)) and *Aulotortus? eotriasicus*. They occur together with reef detritus like “*Tubiphytes*” bindstones (F8), bryozoans encrusted with *Bacinella ordinata* (F3+F9), as well as

Fig. 17 Sedimentology of the slope- and reef-facies at Cima Feudo and Kirchtageide. (1): Panoramic view of the SW flank of Cima Feudo (location 1) with an interpretation of the sedimentary structures. The red line A–B corresponds to the studied reef transect. Legend in the upper right corner. (2): Panoramic view of the SW flank of Kirchtageide (location 2) with an interpretation of the sedimentary structures. Legend in the upper left corner. (3): Geological map of the reef and its surrounding area at Kirchtageide. Panoramic view in 2 is from lower left (NW) to upper right (SE). Legend of the geological map to the left



Fig. 18 Outcrop photograph of a heavily dolomitised scleractinian framestone at Kirchtageide (location 2). Pen for scale; width of picture ca. 10 cm

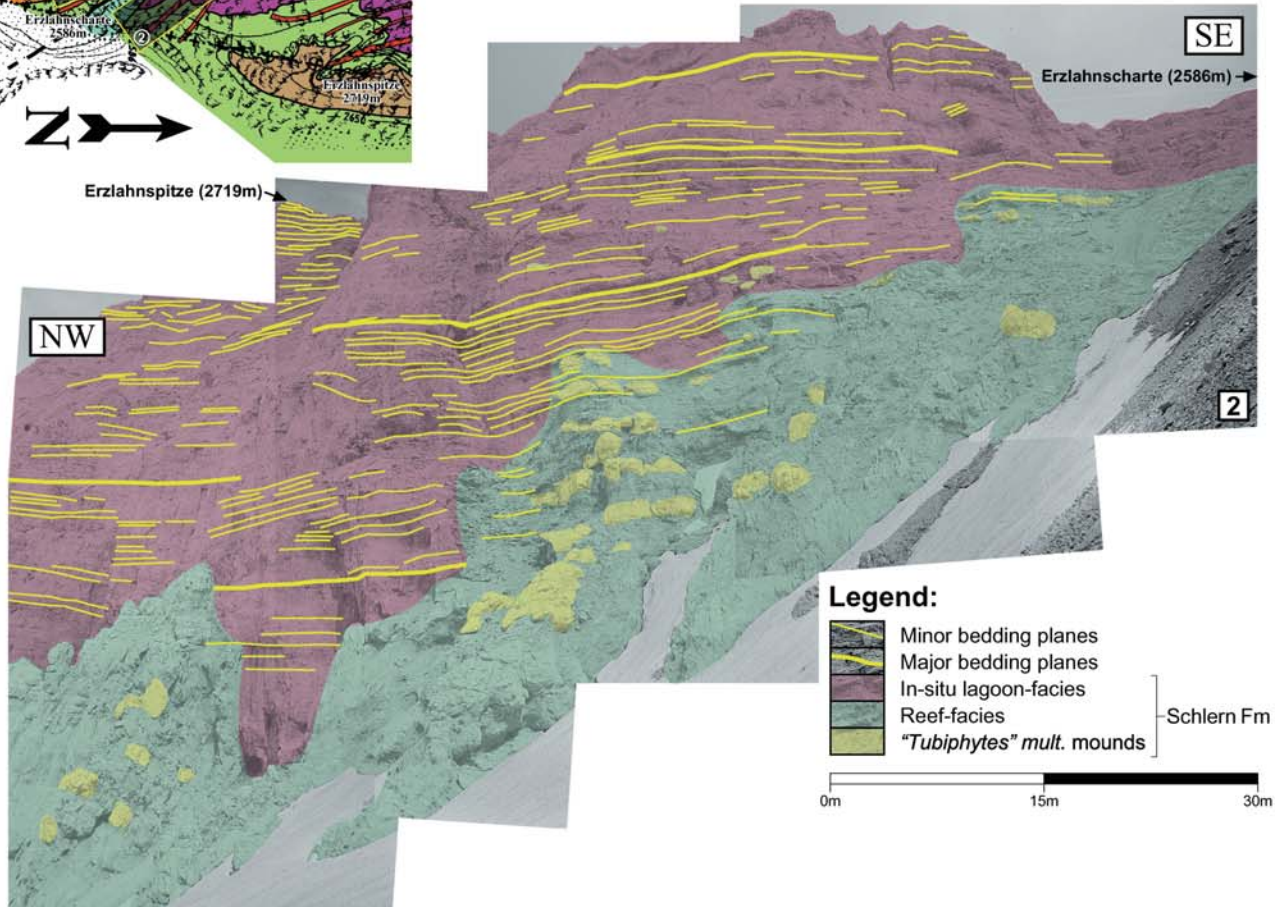
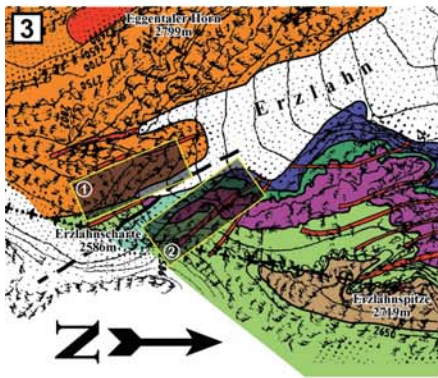
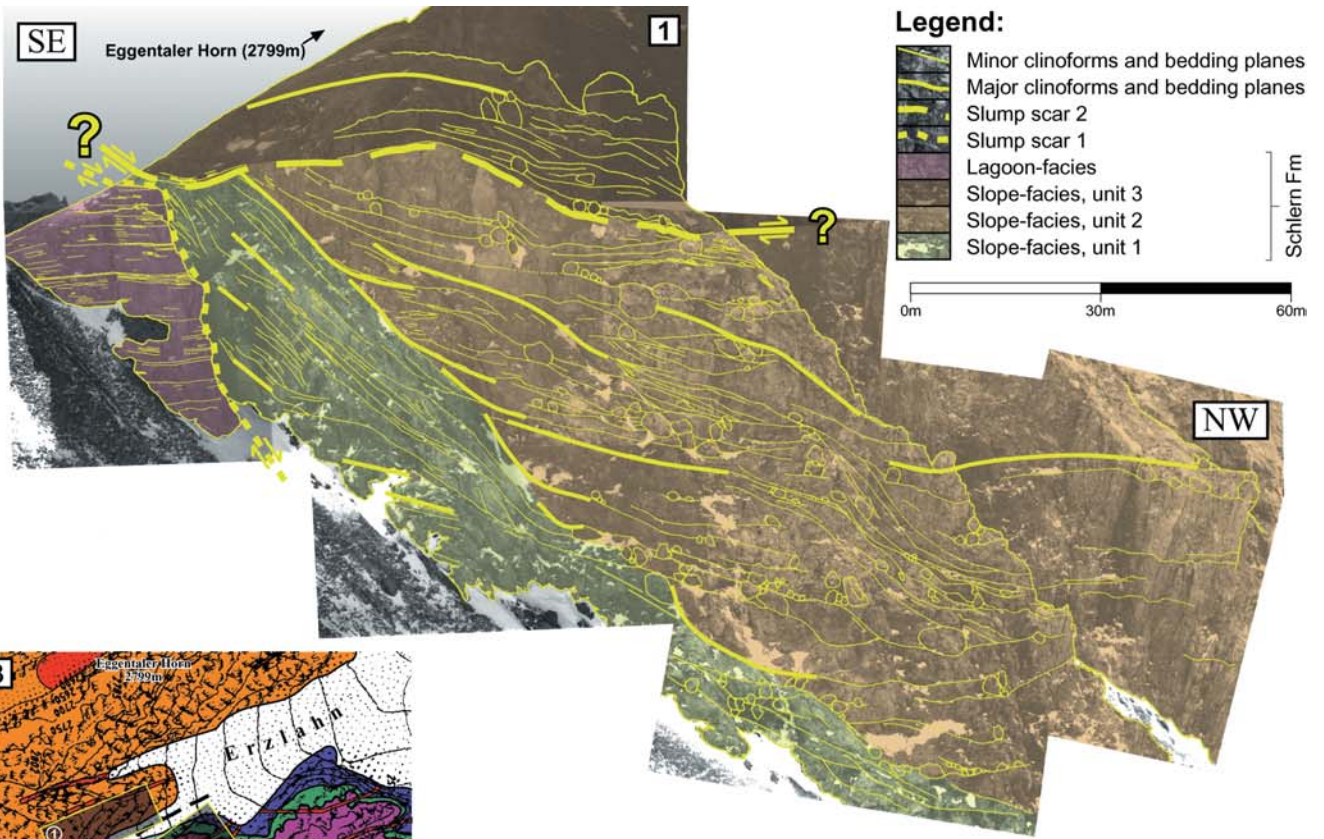
lagoonal detritus like dasycladaleans (*Diplopore* sp.), fragments of nautiloids and Porostromata.

The basal layer of the second unit is very rich in reefal biota. Huge boundstone clasts—up to 4 m in diameter—are made up of *Celyphia zoldana* and *Celyphia? minima*, *Deningeria crassireticulata*, “*Tubiphytes*” *obscurus* (F2), biogenic crusts, cerioid hexacorals like *Margarosmia* sp. (F3), red algae (solenoporaceans), “*Microproblematica*” (*Plexoramea cerebriformis*) and foraminifers like duostominids and *Endotriada* cf. *tyrrhenica* (Fig. 15(23)). Some of the boundstone clasts are made up entirely of red algae (*Parachaetetes* cf. *triasinus*) associated with fragments of *Bacinella ordinata* and “*Tubiphytes*” *obscurus*. Foraminifers of the back reef and reef core (*Aulotortus? eotriasicus*, *Flatschkofelia anisica*) and large sponges (*Solenolmia manon manon*) continue upward until a lateral extension/sheet crack of the neptunian dyke with red micrite (Fig. 25(1)).

Architecture and sedimentology of the slope

The three sections at this location (Figs. 23 and 24(1–2)) reveal the presence of an erosional surface separating two different slope types. Whereas the lower part of the slope at Cresta De Do Peniola is characterised by stacked multiple debris flows and coarse-grained turbidites (LF2a/b and 3a/b; Table 1), the upper part contains abundant megabreccia (LF1 and 2a/b; Table 1).

The lower part of the slope corresponds to the depositional slope type where sedimentation takes place on the entire platform-to-basin transition. Thus, the slope can be classified as “slope-apron” sensu Mullins (1983) and Mullins and Cook (1986). The correlatable erosional surface (Figs. 23 and 24(1–2)) forms a timeline of an interval with net erosion on the slope, i.e. corresponds to a stage of an erosional slope. After this interlude, net de-



position occurs again on the platform-to-basin transition. However, in contrast to the interval below the erosional unconformity, a large amount of sediment bypasses the upper slope through two minor and one major channel to the lower slope. Hence this slope—correlatable with middle UTF times—corresponds to the “base-of-slope apron” type sensu Mullins (1983) and Mullins and Cook (1986). Although the main characteristics of the slope at Cresta De Do Peniola are depositional, no indications of progradational patterns of the margin exist for the latest (UTF) stage of platform development. Contrarily, the platform is aggrading or even backstepping as evidenced by the timeline of an erosional slope.

The other striking feature of this location is a coeval neptunian dyke dissecting slope sediments (Fig. 23). At three levels, the neptunian dyke has thin (<1 m) horizontal, laterally correlatable continuations with sheet-like cement crusts on the walls and bioclastic material within the crack. The biotic content of the trapped mud-/wackestones (radiolarians, cephalopods and *Daonella* sp., Fig. 25(1–2)) point towards open marine conditions. The infill of the neptunian dyke furthermore contains small, rare foraminifers indicating an Anisian to Ladinian age and also open marine conditions. A significant relationship with reefal associations is evidenced by the important occurrence of *Abriolina mediterranea* (Zaninetti et al. 1992)—not previously described in the Dolomites. However, the characterising microfauna of the dyke is made up of filaments and small ostracods (photomicrograph in Fig. 25(1)). Palaeontological and sedimentological evidence—similar biotic content and lateral continuity—imply a common genetic history of the vertical and horizontal fractures. Mechanisms for the synsedimentary opening of the neptunian dyke and its lateral extensions are either extensional tectonics and/or dilatation of slope sediments due to downslope sliding (Winteler et al. 1991; Sarti et al. 2000; Mallarino 2002).

Discussion

Foraminiferal associations

The majority of agglutinated foraminifers commonly found in the lagoonal facies is represented by Duostominidae, Endotriadidae and Endotebidae. The sessile agglutinated *Flatschkofelia anisica* is an equally important element of the epifauna (cf. Rettori et al. 1996) and is also typical for the reef facies in the Olang area (Fois and

Gaetani 1984; Senowbari-Daryan et al. 1993). Among the most frequent benthonic foraminifers at Latemar are *Palaeolituonella meridionalis* and large *Reophax/Amobaculites* occurring in the central reef as well as in the back reef. The small species *Turriglomina mesotriassica* appears in the fine-grained sediments of the slope-facies (cf. ecological distribution proposed by Zaninetti et al. 1990), whereas the larger species *Turriglomina scandonei*—found so far only in the Southern Apennines (Zaninetti et al. 1987)—is also present in boundstone clasts of the slope.

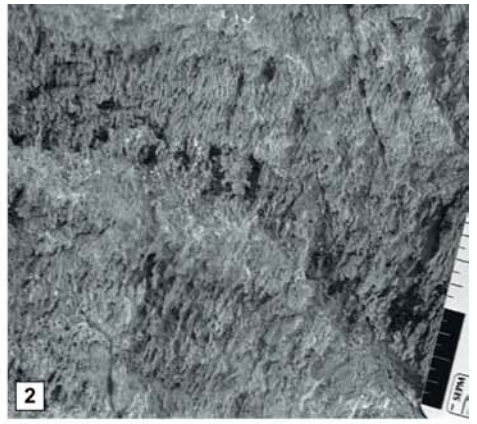
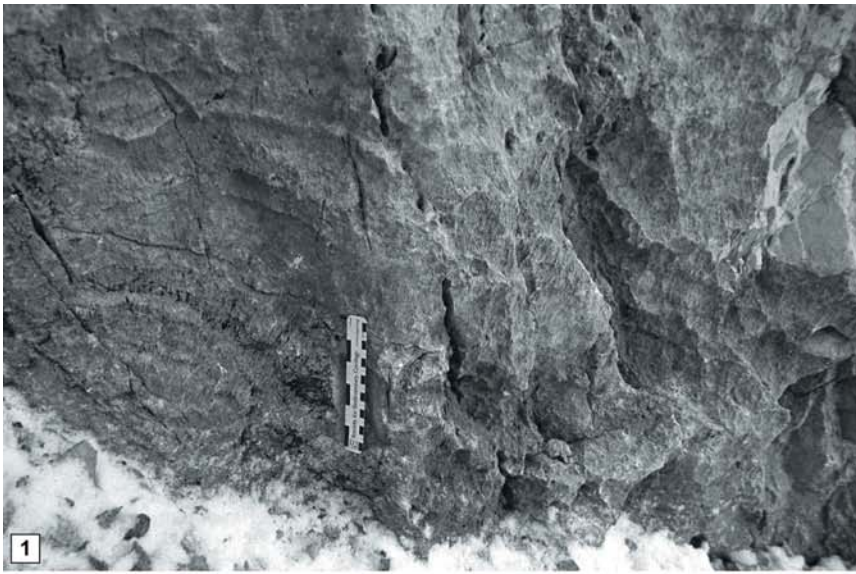
The neptunian dyke at Cresta De Do Peniola contains mudstones with fragments of small nodosarids, well-preserved samples of *Abriolina mediterranea*, together with a fine-grained association of *Arenovidalina chianchiangensis*, *Paraophthalmidium* sp. and ?*Ophthalmidium* sp. The occurrence of *Abriolina mediterranea* at Latemar is important for the correlation with other Tethyan reefs. Apart from the Anisian?-Ladinian reef facies from the Lagonegro area where it has firstly been described by Zaninetti et al. (1992), the genus of *Abriolina* has so far only been found in the Northern Calcareous Alps (Rüffer and Zamparelli 1997), probably in Turkey (Middle Triassic) and Southern China (Zaninetti et al. 1992).

Palaeoecology of the reef-facies at Latemar

The reef model presented in this study is the result of the integration of all data (e.g. biotic content, relationship between faunal associations, different palaeoenvironmental positions, sedimentology) from all studied outcrops. As some outcrops resemble each other—like Schenon and Cima Feudo—only those with the most contrasting features are pictured in the model (Fig. 26). According to the outcrops, three main zones within the reef facies can be defined: (1) reef front, (2) reef crest and (3) back reef. Evidence for emersion of the reef-rim is absent, all reefal zones lie within the range of the mean wave base; i.e. the tepee belt is the palaeobathymetrically highest area of the carbonate platform. Hence high frequency sea-level oscillations as recorded by the lagoonal succession did not affect the reefal margin.

In the reef front, three subzones are distinguished with the help of different fossil assemblages (Fig. 26). Those zones inhabiting sediment baffling organisms with a branching growth are situated beneath the mean wave base (F1 to F3). They have the least potential of preservation in the geological record due to their delicate forms. Clasts of these fossil assemblages are abundant in slope sediments. The base of the branching zone (sensu James 1983) is formed by stabilising algae and is followed by bryozoans, sphinctozoans and delicate branching corals. The wave resistant constructions of scleractinian framestones are located above the mean wave base and within the surf zone (F4; cf. Harris 1993). The reef crest—i.e. the backbone of the reef—is marked by a microbial/algal ridge withstanding wave energy and possibly tidal cur-

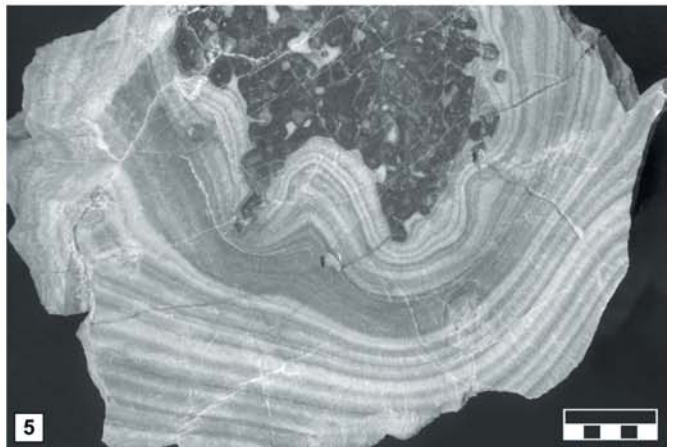
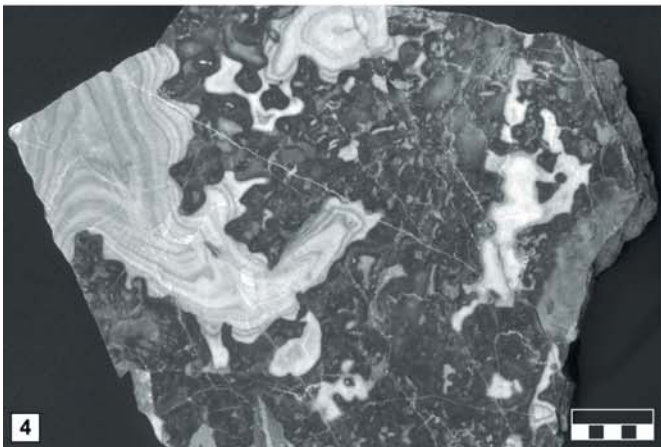
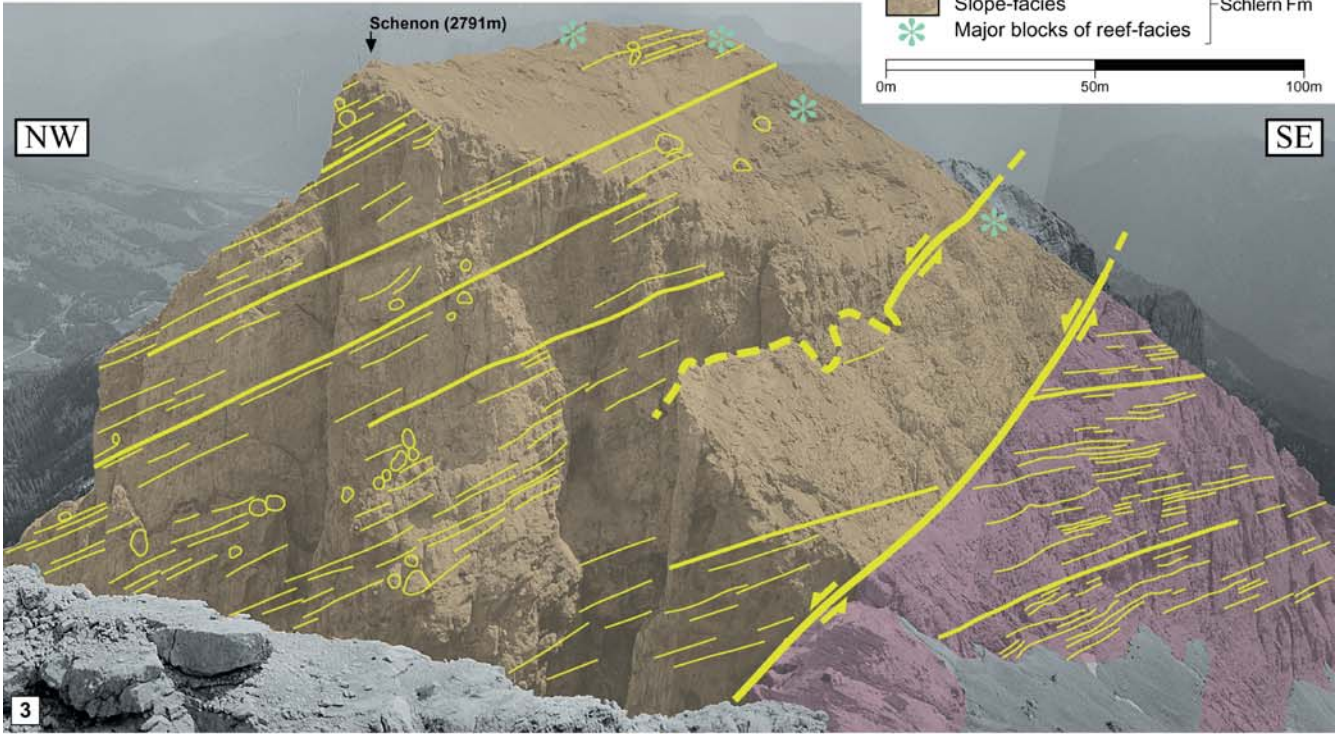
Fig. 19 Sedimentology of the slope- and reef-facies at Erzlahn. (1): Panoramic view of the southern flank of the Erzlahn gully (location 3) with an interpretation of the sedimentary structures of the slope-facies. Legend in the upper right corner. (2): Panoramic view of the northern flank of the Erzlahn gully (location 3) with an interpretation of the sedimentary structures of the reef-facies. Legend in the lower right corner. (3): Geological map of the Erzlahn area. Both panoramic views of the Erzlahn gully are marked by slightly opaque rectangles (*rectangle 1*: northern side, (1); *rectangle 2*: southern side, (2)). For the legend of the geological map refer to Fig. 17(3)



Legend:

-  Minor clinoforms and bedding planes
 -  Major clinoforms and bedding planes
 -  Normal faults
 -  In-situ lagoon-facies
 -  Slope-facies
 -  Major blocks of reef-facies
- } Schlern Fm

0m 50m 100m



rents (F5; cf. Biddle 1981). The transition towards the lagoon is inhabited by patchy thrombolites of “*Tubiphytes*” *multisiphonatus* (F6) becoming less frequent towards the lagoon (cf. Scholz 1972; Schäfer and Senowbari-Daryan 1982, 1983).

The unique feature of the reef-facies at Latemar are lateral variations of its biotic content: (1) The reef at Cima Feudo is characterised by well-preserved sponges. (2) The main feature of the reef at Kirchtageide is the abundant presence of scleractinian corals. (3) So far, Erzlahn is the only occurrence of “*Tubiphytes*” *multisiphonatus* in the reef-facies at Latemar and possibly also in the Dolomites. (4) Schenon, however, reveals a similar biotic content of the reef-facies in talus deposits like the in-situ margin at Cima Feudo. (5) Foraminifers of inter-reef sediment and especially “*Microproblematica*” are abundant at Cresta De Do Peniola; it is also the only “reefal” location with bryozoan heads.

The reasons for such lateral variations within the same reef belt remain unclear as—according to present knowledge—neither palaeo-current nor palaeo-wind directions at Latemar are the cause for such changes in fossil assemblages. Tying these micro-macroscale variations to differences in nutrient influx through synsedimentary volcanic dykes appears too speculative. Even at recent reefs where pronounced micro-macroscale biozonation can be directly observed, the causes for such lateral variations remain often obscure (e.g. James and Ginsburg 1979; Zacher 1980; Iryu et al. 1995).

Biostratigraphical position of the reef

The majority of fossil assemblages presented in our reef concept are of Anisian or Anisian/Ladinian age, only in a few cases Ladinian biota are observed (Table 2; 12 species are Anisian, 21 are Anisian/Ladinian and only 5 are Ladinian). Palaeontological evidence from the reef-facies points in many ways to a predominantly Anisian age of the entire Latemar platform (see also Table 2). Small encrusting “sphinctozoids” like *Celyphia zoldana* and *Celyphia? minima* are generally found in the Anisian and are very common throughout Latemar’s succession, even in the upper part of the sections at Cresta De Do Peniola.

Fig. 20 “*Tubiphytes*” *multisiphonatus* thrombolites at Erzlahn (location 3) and sedimentology of the slope facies at Schenon (location 4). (1): Outcrop photograph of a “*Tubiphytes*” *multisiphonatus* thrombolite; the dense network of the “thalli” and multiple layers of radiating “branches” are clearly visible. Location: southern side of Erzlahn (scale bar; left-hand side: subdivisions in inches, right-hand side: subdivision in centimetres). (2): Detailed outcrop photograph of the same “*Tubiphytes*” *multisiphonatus* thrombolite; “thalli” and the separations between the concentric layers are well visible. Location: southern side of Erzlahn (scale bar; subdivision in inches). (3): Panoramic view of the SW face of Schenon with an interpretation of sedimentary and tectonic structures. Legend in the upper right corner. (4–5): Photograph of polished slabs from talus blocks at Schenon with cement crusts. Scale bar is 1 cm with subdivisions of 2 mm

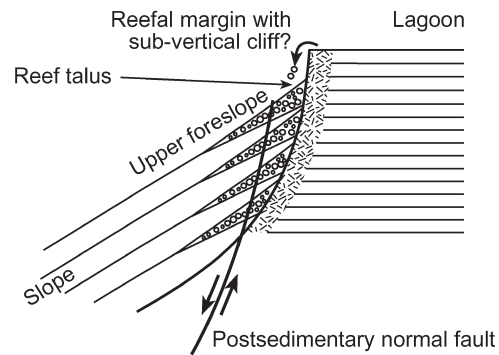


Fig. 21 Schematic sketch of a possible margin scenario at Schenon (location 4). Before a postsedimentary normal fault truncates the margin and juxtaposes slope- and platform-facies, a reefal margin exists. The abundance and size of blocks and cement crusts suggests a proximal talus setting with a steeply cliffed platform margin

The occurrence of age-diagnostic foraminifers throughout the sections at Cresta De Do Peniola until the very top of Latemar also indicates a mainly Anisian age. Typical Ladinian associations are not present; only at the top of the sections at Cresta De Do Peniola there is a slight increase in abundance of rare sponges, foraminifers and “*Microproblematica*” which are generally more frequent in Ladinian reefs (like *Colospongia catenulata*, *Solenolmia manon manon*, *Ladinella porata* etc.).

A possible temporal trend in reefal evolution from Lower Platform Facies (LPF) to Upper Tepee Facies (UTF) has to be excluded as almost the same fossil assemblages can be found in the younger as in the older part of Latemar’s reef. Only a slight development of faunal associations is visible; e.g. bryozoans are present in the lower levels only, which is also the case for *Olangocoelia otti*. However, compared to other outcrops like Cima Feudo or Schenon, the reefal content of the uppermost levels at Cresta De Do Peniola reveal only insignificant deviations from their biotic content. According to the literature, the duration of reefal/platform growth is in the order of one biozone or only slightly more (Brack et al. 1996; Zühlke et al. 2000; Mundil et al. 2003; Zühlke et al. 2003) and thus might be too short to establish any trends of faunal evolution. The lack of a distinct evolution of the reef within the timeframe of platform development—together with the general absence of biota truly indicative of Ladinian age—supports the observations of the above-mentioned authors. The topmost succession at Cresta De Do Peniola corresponds to the youngest strata of the lagoon and is consequently Latest Anisian/Earliest Ladinian (Fig. 22). Most of the typical Anisian “*Tubiphytes*” group boundstones still occur in this—Latest Anisian/Earliest Ladinian—interval of platform growth.

In summary, our palaeontological data from the Latemar reef is in accordance with the chrono-, cyclo- and biostratigraphical data of the lagoon presented by Zühlke et al. (2000), Zühlke et al. (2003) and Mundil et al. (2003). Additionally, the biotic content (dasycladaleans: *Diplopora nodosa*, *Zornia obscura*) of the lagoonal strata analysed at some localities further confirms the latest

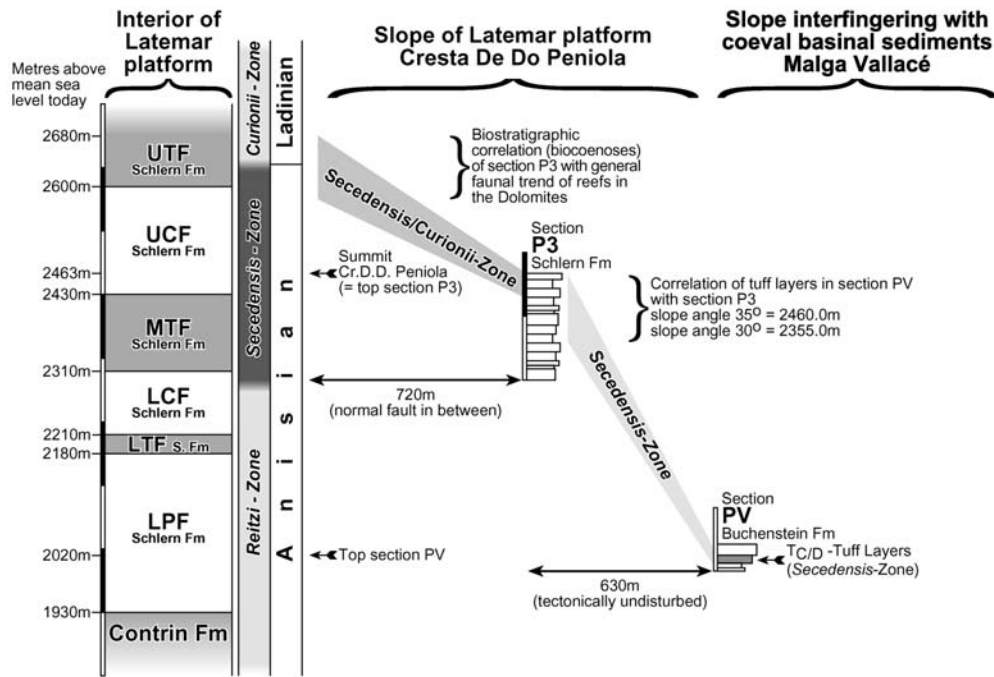


Fig. 22 Correlation of the basal section PV with section P3 at Cresta De Do Peniola (location 5) and with cyclostratigraphic units of the lagoonal interior. At Malga Vallacé (NE in the dip direction of Cresta De Do Peniola), age diagnostic tuff layers (sensu Brack and Rieber 1993) were identified within the Buchenstein Fm; biostratigraphy and position of Anisian/Ladinian boundary after Brack and Rieber (1993). Correlation was realised by measuring the horizontal and vertical distance between these two sections and the slope angle in section P3. Neither faults with vertical throw nor

lateral tectonic movements were observed between these two sections. However, correlation between the lagoonal interior and section P3 is hampered by the presence of a normal fault with unknown displacement. Nevertheless, biostratigraphic data from the reef-facies at Cresta De Do Peniola and the aforementioned correlation with the basal Buchenstein Fm at Malga Vallacé are in accordance. Both indicate an age of uppermost *Secedensis* to lower *Curionii* zone, i.e. uppermost UCF to middle UTF platform times

Anisian/earliest Ladinian age of the reef. Especially *Zornia obscura*—so far described only from Ticino (Ladinian: “Problematikum 1”; Zorn 1971, 1972), Sicily (Anisian?/Ladinian; Senowbari-Daryan and Di Stefano 2001) and Southern China (Upper Anisian: I. Bucur, pers. comm. 2003)—indicates the same biostratigraphical position.

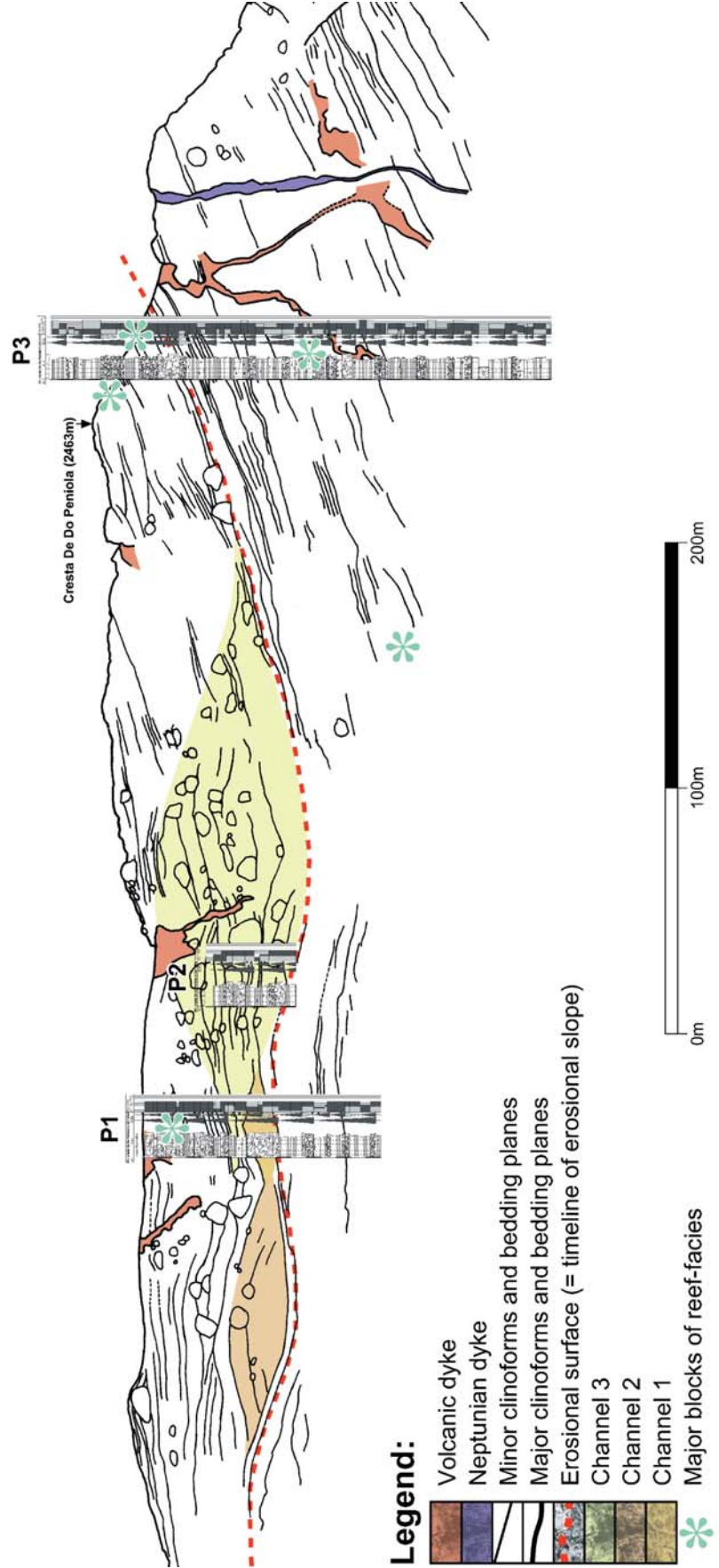
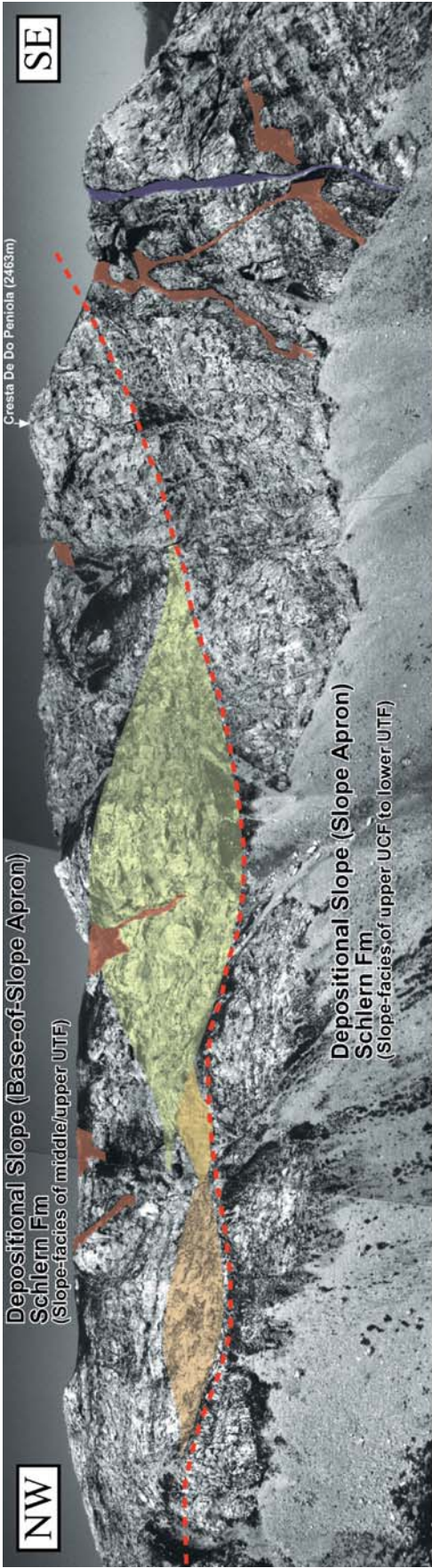
Correlation with other Late Anisian/Early Ladinian reefs of the western Tethys

Compared to other—slightly older—Anisian reefs of the Dolomites as described by Fois and Gaetani (Olang and Mt. Cernera, 1984) and Senowbari-Daryan et al. (Olang, 1993), the Latemar reef reveals significant biotic relations to both areas concerning sponges (e.g. *Celyphia zoldana* and *Olangocoelia otti*), solenoporacean algae, “Microproblematica” (e.g. “*Tubiphytes*” *obscurus* and *Radiomura cautica*) and foraminifers (e.g. duostominids). At Latemar however, *Olangocoelia otti* is encrusting lithoclasts (F7), but it is remarkably rare and not a very important part of all fossil assemblages. F7 is generally present in the lower part of the Cresta De Do Peniola section but seems to become more rare upsection, i.e. towards the Anisian/Ladinian boundary. Differences exist with respect to the presence or absence of certain biota










and our detailed microfacies investigations show, that the Latemar reef is considerably more diversified. This might partly be due to the fact that an in-situ reef at Latemar is compared with Cipit-like reefal blocks at Olang and Mt. Cernera. But the reef in the Olang and Mt. Cernera area certainly contains not as much “*Tubiphytes*” group biota as the studied locations at Latemar, especially as the Cresta De Do Peniola section.

Strong similarities—as far as the reefal margin and slope are concerned—exist with some Anisian platforms of the eastern Tethys (e.g. Guizhou/China; Enos et al. 1997). In this area, “*Tubiphytes*” and “Microproblematica” like *Plexoramea cerebriformis* are the main framework elements. In-situ reef-facies is characterised by sponges, various encrusters and cements. Like at Latemar, corals play a minor role and display a slender, digitate growth. Retreat of the platform margin is observed from the beginning of platform evolution on, although the scale is different (up to 2.7 km margin retreat; Enos et al. 1997).

Fig. 23 Panoramic view of the SW flank of Cresta De Do Peniola (location 5) with an interpretation of the sedimentary structures. Note the position of the sections P1 to P3. The neptunian dyke has several thin, crack-like lateral extensions not shown in this panoramic view, parallel to bedding planes of the slope succession. Legend in the lower left corner



Legend:

-  Volcanic dyke
-  Neptunian dyke
-  Minor clinoforms and bedding planes
-  Major clinoforms and bedding planes
-  Erosional surface (= timeline of erosional slope)
-  Channel 3
-  Channel 2
-  Channel 1
-  Major blocks of reef-facies

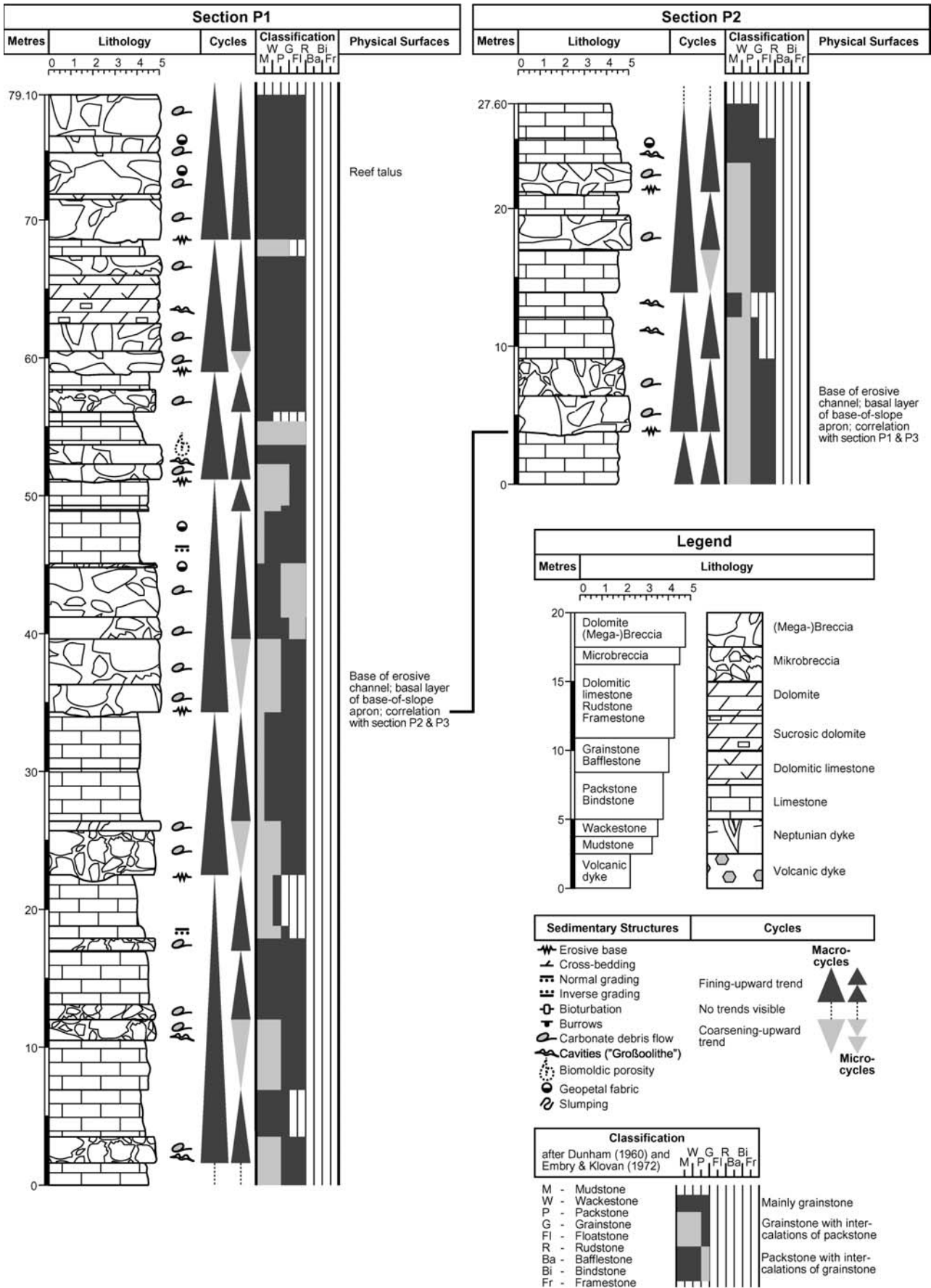


Fig. 24 Section P1, P2 (Fig. 24(1)) and P3 (Fig. 24(2)) through the slope of Cresta De Do Peniola (location 5; for exact position of the sections refer to Fig. 23). Legend of the sedimentological logs on Fig. 24(1)

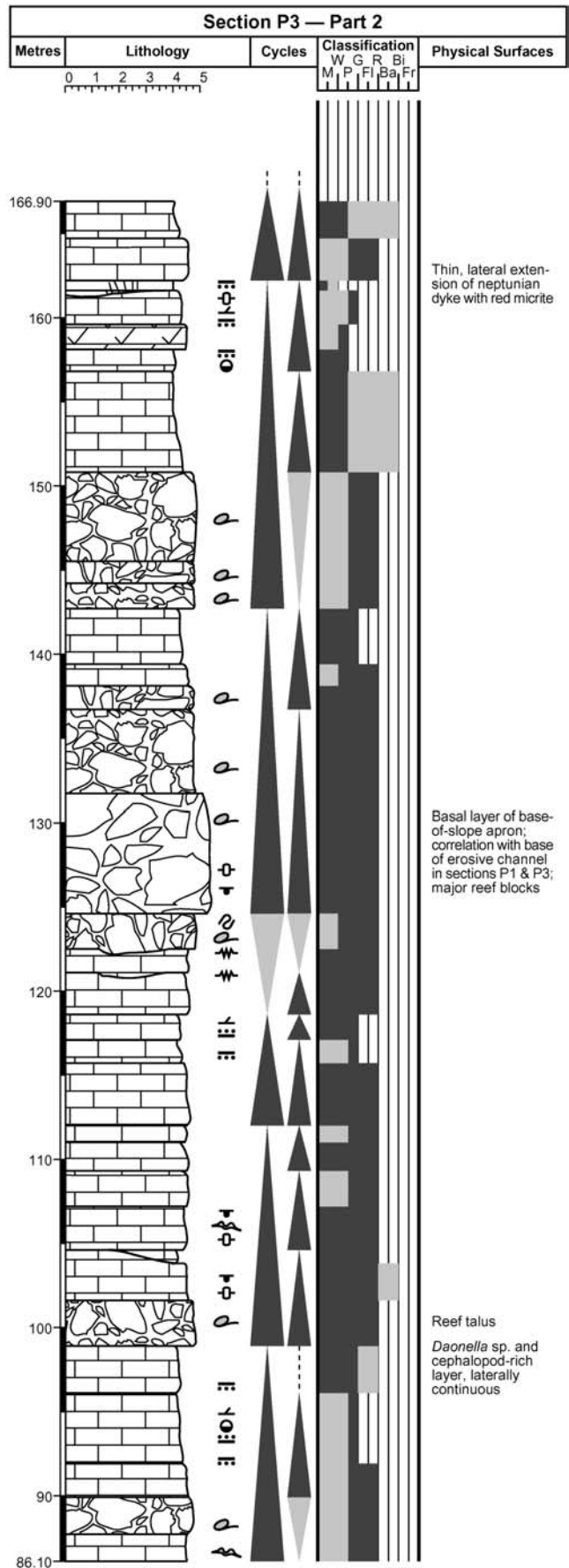
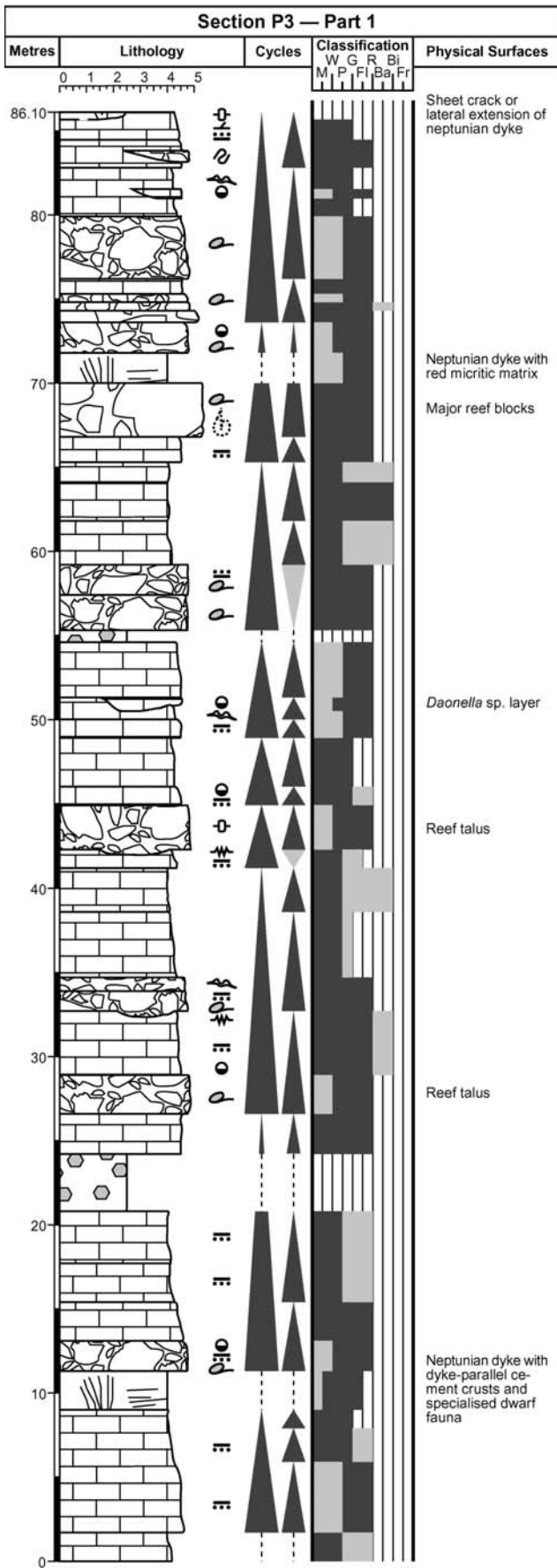


Fig. 24 (continued)

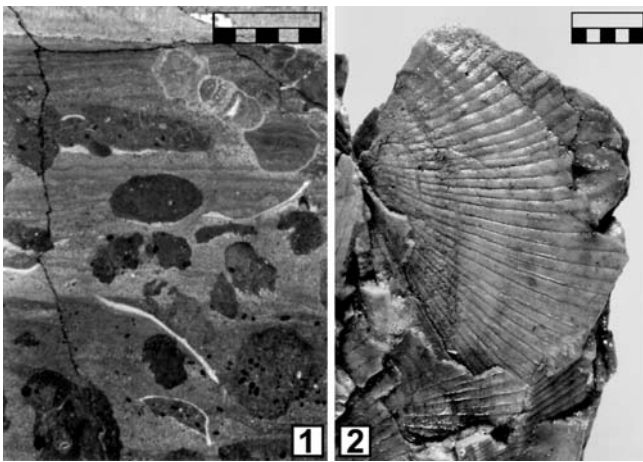


Fig. 25 (1): Photomicrograph of a thin section from the neptunian dyke in Cresta De Do Peniola (location 5). Fine-grained peloidal sediments are bioturbated. Ammonoids and microfilaments indicate open marine conditions. Scale bar is 1 cm with subdivisions of 2 mm. (2): Shells of *Daonella* sp. in a sample from Cresta De Do Peniola (location 5); scale bar is 1 cm with subdivisions of 2 mm

With respect to the Foraminifera in Latemar's reef, similar assemblages and biofacies are found in Late Anisian successions in North Bulgaria (Trifonova and Vaptsarova 1982) and Western Turkey (*Palaeolituonella meridionalis*; Isintek et al. 2000).

As mentioned earlier, the "*Tubiphytes*" *multisiphonatus* findings (originally: hydrozoans; refer to Table 3) in the Anisian to Ladinian Wetterstein reef complex in North Hungary by Scholz (1972) indicates a relationship with at least the situation at Erzlahn. The similarity is further amplified by the distinct zonation of the reef at Aggtelek despite its Anisian to Ladinian age as proven by age-diagnostic foraminifers, dasycladaleans and brachiopods. However, abundant brachiopods and echinoderms are not observed at Latemar.

The most important biotic affinities probably exist with the time equivalent reef described by Scheuber (1990) from the Vicentinian Alps of Northern Italy. The in-situ reef in the area of Recoaro is less diverse than the one described in this study. But the main characteristics are strikingly equal: with respect to the dominating, abundant "*Tubiphytes*" group encrustations, corals are of equally minor importance as reef-building organisms. Foraminiferal assemblages (including *Palaeolituonella meridionalis*) and calcisponge-fossil assemblages are similar as well. The observed biological zonations at the Monte Spitz reef seem to parallel the situation at Cima Feudo. The reefal organisation at Mt. Spitz—with sphinctozoan sponges like *Solenolmia manon manon* in the central reef area together with abundant encrusting "*Microproblematica*"—seems to be a copy of this location at Latemar. The presence of *Olangocoelia otti* at both reefal margins further underlines this impression.

The geographically closest reef is located at the Schlern/Rosengarten platform. But here dolomitisation and scarce in-situ reef-facies hamper an investigation of

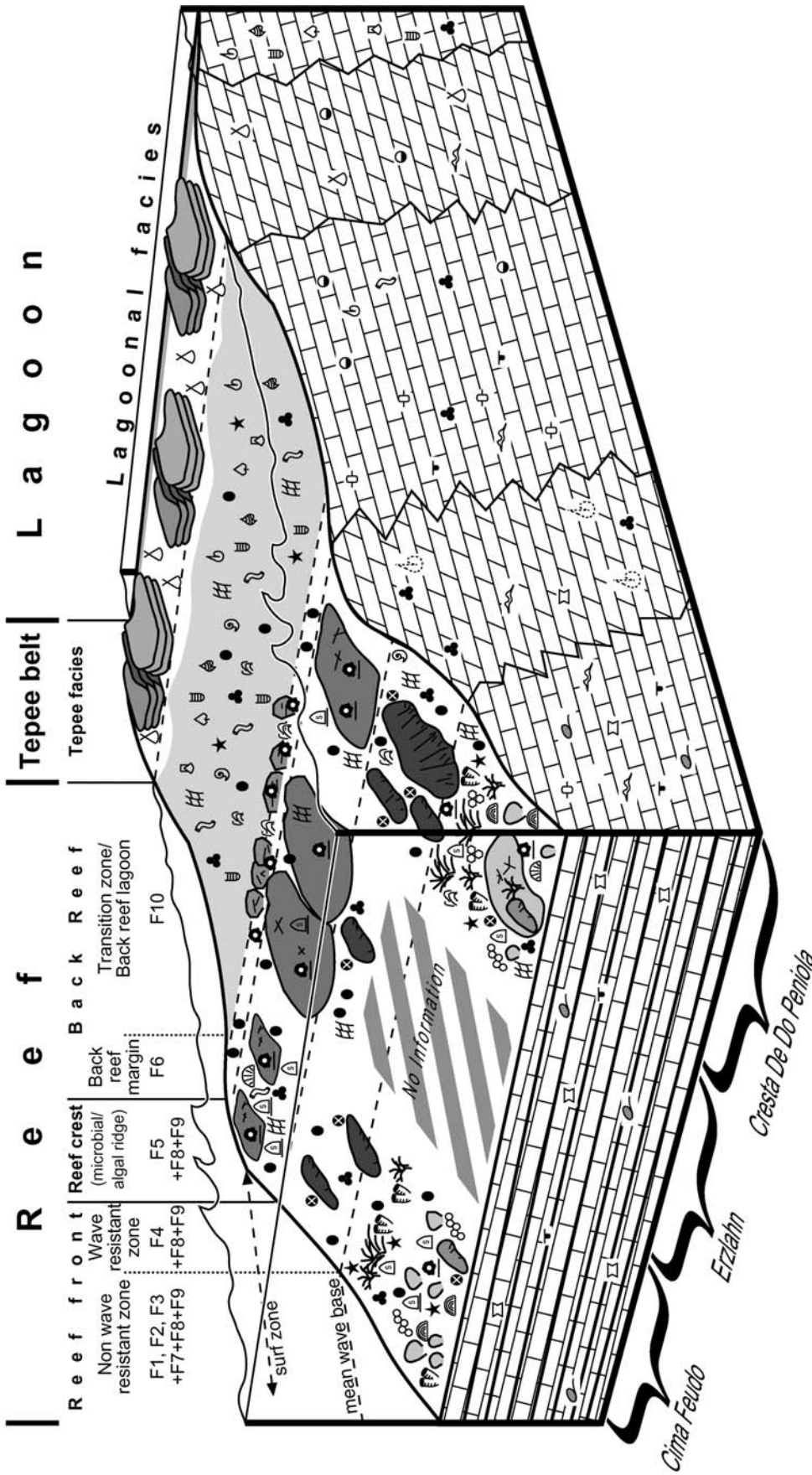
the primary reefal organisation. The reef as derived from the famous Cipit boulders (e.g. Biddle 1981; Brandner et al. 1991) is slightly younger (Early to Upper Ladinian) than at Latemar. But it displays significant similarities, e.g. concerning the abundance of low-growing sessile organisms as evidenced by microbial/biogenic crusts and calcareous algae (*Ortonella* sp., *Parachaetetes* sp., *Solenopora* sp. etc.). Hence, the biotic content is generally correlatable with the upper parts of Cresta De Do Peniola or the heavily encrusted microbial ridge at Erzlahn. According to Biddle (1981), these microbial constructs are wave-resistant. However, the occurrence of many species of corals (e.g. *Margarophyllia* sp., *Proheterastraea* sp. and *Trochastraea* sp.) is not paralleled by Latemar's reef. Additionally, the foraminiferal assemblage at Schlern/Rosengarten differs completely from the one described in this study.

The Ladinian reef of the Marmolada platform in the western Dolomites—as studied by Blendinger (1986)—is mainly made up of solenoporaceans and species of the "*Tubiphytes*" group. Porostromate algae, calcareous sponges and solitary corals play only a minor role. Nevertheless, enormous quantities of reefal debris in slope deposits suggest a considerable productivity of the reef belt. Similar to the location at Schenon, some coralline heads with upright stems (in-situ position) are resting directly upon talus deposits indicating a growth of reefal biota to water depths well below the mean wave base.

The Ladinian to Carnian Sass da Putia build-up as described by Fois (1982) provides insight into its reef-facies through basinal "Cipit" boulders like at Schlern/Rosengarten, but also offers the possibility to investigate an in-situ reefal margin. Its reef is in sedimentological and palaeontological terms comparable to the one at Latemar. The content of encrusters ("*Tubiphytes*" group and microbial crusts) and "*Microproblematica*" (*Baccanella floriformis* and *Bacinella ordinata*) is similar and scleractinians (*Margarosmia* sp.) are equally rare.

In Anisian strata of the Northern Calcareous Alps (e.g. Ruffer and Zamparelli 1997), there are no equivalents of the reefs observed in the Dolomites and its surroundings. Ramps with a low topography prevail. However, Anisian successions (Steinalm Fm) reveal strikingly similar foraminifers, e.g. *Palaeolituonella meridionalis*, *Arenovidalina Chiangchiangensis*, *Abriolina mediterranea* and

Fig. 26 Schematic reef model of the Latemar indicating the three main zones (reef front, reef crest and back reef) together with their characteristic fossil assemblages/facies (F1–F10). The reef is always below sea level, the bathymetrically highest point of Latemar's margin is the tepee belt separating the back reef from the lagoonal interior of the platform (cf. Egenhoff et al. 1999). Organisms with more delicate/branching growth are found beneath the mean wave base, whereas the wave resistant zone is mainly marked by corals and algae. The information for this reef model is derived from three outcrops, Cima Feudo, Erzlahn and Cresta De Do Peniola (from left to right)—each one showing different characteristics. Some features—e.g. "*Tubiphytes*" *multisiphonatus* thrombolites (Erzlahn) or bryozoans (Cresta De Do Peniola)—are observed at one locality only



Sedimentary Structures	Lithology	Growth forms	Reefal biota	Other biota/components
<ul style="list-style-type: none"> Tepees Geopetal fabrics Bioturbation Burrows Cavities Biomoldic porosity Carbonate debris flow 	<ul style="list-style-type: none"> Dolomite/dolomitic limestone Limestone 	<ul style="list-style-type: none"> Thrombolitic Platy or encrusting Robust Head-like or small patches Branching — cerioid 	<ul style="list-style-type: none"> "Tubiphytes" multisiphonatus "Tubiphytes" sp., encrusting Porostromata Solenopora Scleractinians, robust Scleractinians, cerioid Bryozoans Calcisponges Calcisponges, encrusting Olangocella otti (sponge?) 	<ul style="list-style-type: none"> Bioclasts in general Daconella sp. (pelagic bivalve) Other bivalves Cephalopods Gastropods Echinoids Dasycladaleans Microproblematica Foraminifers Worm tubes Plant indents (wood) Peloids Lithoclasts

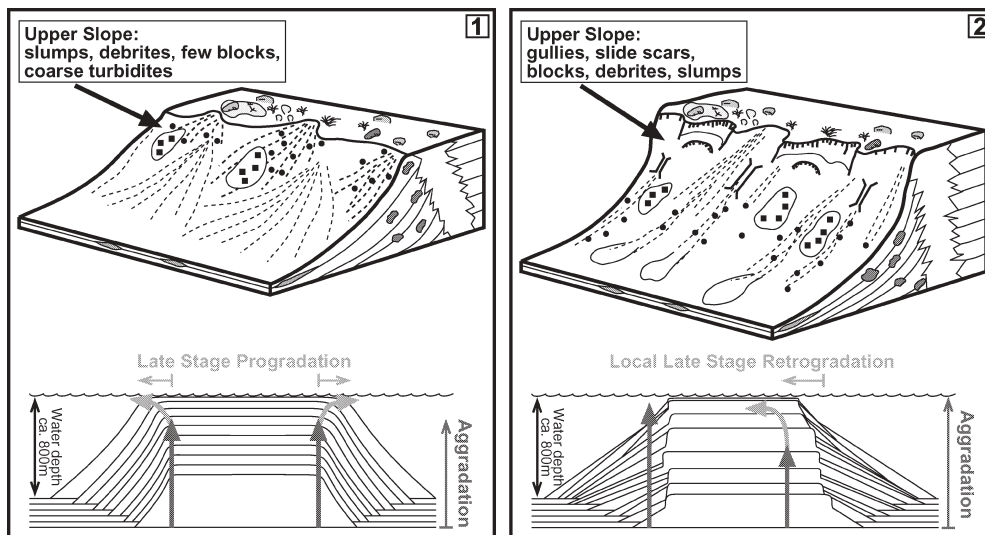


Fig. 27 Comparison of the previous model of the Latemar platform ((1), block diagram above and cross section below; vertically exaggerated, not to scale) with the model proposed in this study ((2), block diagram above and cross section below; vertically exaggerated, not to scale). The model presented in (1) corresponds with

Bosellini (1984), Goldhammer and Harris (1989) and Harris (1994). The model pictured in (2)—based on Mullins (1983) and Mullins and Cook (1986)—is in accordance with the observations of this study. The model shown in (2) allows large quantities of sediment to be bypassed to the toe-of-slope

Turriglomina mesotriassica. Ladinian reefs of the Northern Calcareous Alps are more diverse with respect to sponges and algae but show a similar abundance of encrusting “*Tubiphytes*” group (Rüffer and Zamparelli 1997; Henrich and Zankl 1986). The main difference between Wetterstein Fm-reefs of the Northern Calcareous Alps and the Latemar is the organisation of the margin and its geometries. Wetterstein Fm reefs typically prograde rapidly, show talus breccias with abundant early marine cementation and are characterised by a ramp-like topography (e.g. Henrich and Zankl 1986), all of these features cannot be observed at Latemar.

Controls on slope evolution at Latemar

The slope-facies of the Latemar buildup is far more complex than previously reported in literature (e.g. Goldhammer and Harris 1989; Harris 1994). The generalised view of the firstly aggrading, then prograding depositional slope at Latemar cannot be confirmed by this study. Contrarily, backstepping of the lagoon by margin failure is mainly observed during the later stages of platform evolution (Fig. 27(1–2) for a comparison of both models). Reasons for this behaviour might be accommodation change outpacing a carbonate production rate stretched to its limits.

In the case of the Latemar, variations in tectonic subsidence are the main allocyclic factors for slope evolution. Other parameters like wind and wave directions seem insignificant and/or are being overprinted by variations in tectonic subsidence. Hence, the deduction of a palaeo-wind and/or -wave direction as done by Egenhoff et al. (1999) is not possible. Even more so, as the presumed directions are derived from analyses of small restricted

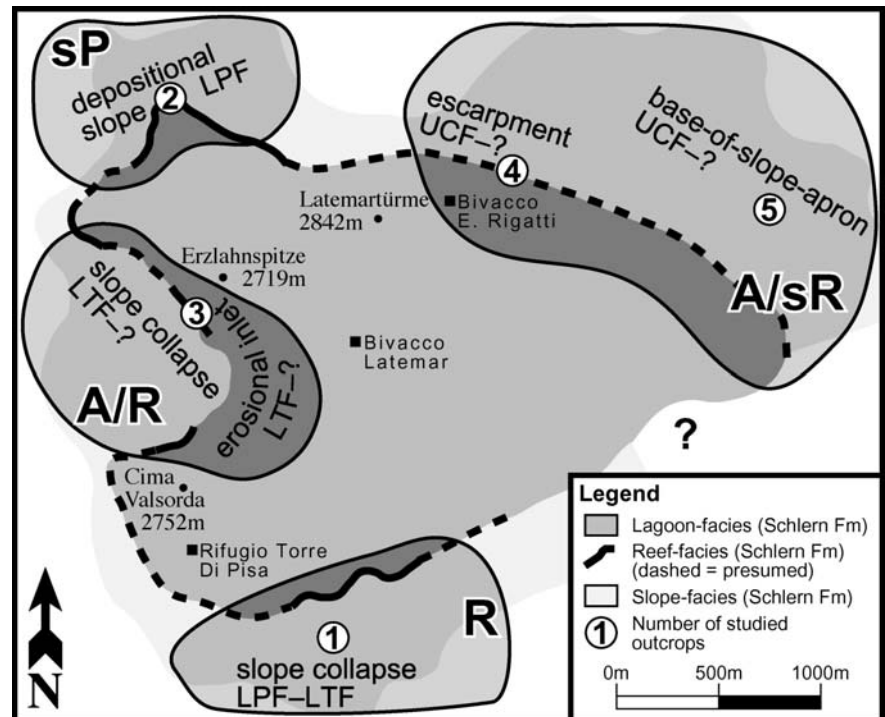
areas at the platform top only (Marmolada: Blendinger 1986; Latemar: Egenhoff et al. 1999). The pronounced asymmetry of many platforms in the Dolomites seems to be entirely related to responses to different tectonic settings (cf. Bosellini 1989).

Controlling factors for the development of the carbonate platforms differ strongly from lagoon to slope. Whereas the lagoon is chiefly controlled by non-orbital and orbitally forced small-scale sea-level oscillations, the slope is largely independent from these high-frequency accommodation changes of the platform top (cf. Bosellini 1989). The high frequency sea-level oscillations recorded by the platform top are not preserved or recorded by neither the platform slope nor the reef (cf. Harris 1994). In addition, the reef is submerged throughout the entire time of platform evolution. This fact rules out sea-level lowstands as causes for the repeated margin collapses.

The slope is a sedimentary environment of episodic and catastrophic events (Coniglio and Dix 1992) destroying any evidence of the accommodation changes as indicated by the lagoonal interior. Therefore, autocyclic processes are of even greater importance for the slope development than for the lagoonal evolution. Cycles of fast accommodation fill-oversteepening-collapse at a platform-wide scale play an important role during slope formation (cf. Crevello and Schlager 1980; Mullins et al. 1986). Autocyclic processes such as Blendinger’s (2001) interpretation of cementation driven self-fracturing of slope sediments at Marmolada are not observed. Fracturing of carbonate sediments at Latemar takes place through movements during re-sedimentation. All blocks from metre to millimetre scale at Latemar are the result of gravity driven brecciation.

Areas with volumetric importance of syndepositional cements are small and restricted to the “*Tubiphytes*”

Fig. 28 Simplified geological map of the Latemar with a summary of the main characteristics of the investigated slope-facies (outcrops 1–5). *R* retrogradation; *sP* slight progradation; *A/R* aggradation to retrogradation; *A/sR* aggradation to slight retrogradation. Legend to the lower right



multisiphonatus thrombolites at Erzlahn, the talus fan at Schenon or the tepee belt. Hence, massive syndepositional cementation accompanied by the formation of cementstones sensu Wright (1992) as a key factor during the build-up of the margin as observed by Russo et al. (2000) at the Marmolada and Stefani et al. (2001) at the Latemar can be excluded. Early lithification/cementation, however, is a key factor at Latemar. Otherwise, it is difficult to explain the nearly vertical cliffs/escarpments created by abundant erosive events, the huge size of the boulders in debris-flow deposits (LF1) and the neptunian dykes. In addition, without extensive early lithification/cementation the Latemar would not build up such a distinct relief above the palaeo sea floor.

Conclusions

The occurrence of *C. zoldana* and *C. minima* together with abundant species of the “*Tubiphytes*” group is a real novelty in the studies on reefs in the Dolomites. *Celyphia zoldana* is usually typical for the Anisian, whereas large species of the “*Tubiphytes*” group are typical for the Ladinian. As a consequence, this is taken as evidence for an Upper Anisian/lowermost Ladinian age of the youngest strata at Latemar. The correlation of slope outcrops with basinal deposits and the projection into nowadays eroded lagoonal strata further constrains the depositional ages of the youngest slope deposits at Latemar (Cresta De Do Peniola; lowermost Ladinian sensu Brack and Rieber 1993). Our studies on the microfacies of reefal clasts at this location indicate that a true boundstone facies with sponges, corals and “*Tubiphytes*” continues up into

the Lower Ladinian. The presence of sponges like *Colospongia catenulata catenulata*, *Solenolmia manon manon*—generally very common in Ladinian communities—and of microproblematica like *Ladinella porata* together with encrusting “*Tubiphytes*” *obscurus* in the upper part of the slope facies at Cresta De Do Peniola supports a position near the Anisian-Ladinian boundary of Latemar’s upper level reef sections.

The concept of the reef-facies at Latemar consists of a very diversified biotic association generally correlatable with other localities of Anisian/Ladinian reefs in the Dolomite area (Fois 1982; Fois and Gaetani 1984; Brandner et al. 1991; Senowbari-Daryan et al. 1993). However, differences exist in the little abundance of *Olangocelia* sp., in the higher diversification proven by thrombolites of “*Tubiphytes*” *multisiphonatus* and the large abundance of “Microproblematica” like “*Tubiphytes*” *obscurus*.

The foraminiferal associations correspond with other Anisian/Ladinian reefs described in literature (e.g. Trifonova and Vaptsarova 1982; Isintek et al. 2000), in particular with the Olang area (Fois and Gaetani 1984; Senowbari-Daryan et al. 1993). Differences are witnessed by the presence of several genera, like *Turriplomina mesotriassica*, *Turriplomina* sp., *Turriplomina scandonei*, *Lamelliconus* ex gr. *ventroplanus* (Fig. 15(15)), *Aulotortus? eotriassicus* and *Abriolina mediterranea*, the latter one found only in the Lagonegro area in Southern Italy and a few other reef localities in the world (Zaninetti et al. 1992). Compared to all other reef assemblages in the Dolomites, foraminiferal associations in the Latemar reef are much more diversified. Additionally, many genera

from Latemar's reef facies have not been described in the Dolomites before.

The slope reveals different depositional characteristics at the same time and at different locations. Additionally, a turnover from "slope-apron" via an erosional slope towards a "base-of-slope apron" is reported from the NE slope (Cresta De Do Peniola). Hence it is impossible to establish a generalising model for the entire platform evolution and all exposures. Instead, several trends are visible at Latemar. The slope of the Latemar is strongly asymmetric; steeply dipping clinoforms and erosional characteristics on the SE side are contrasted by more gentle dipping clinoforms and depositional characteristics on the NW side (Fig. 28). As the SE side of the Latemar is very close to the Stava Line-Cima Bocche Anticline (Doglioni 1983, 1984), this asymmetry is most likely caused by different rates in tectonic subsidence on the respective sides. Furthermore, it is obvious that sudden tectonic movements along this tectonic line cause peaks in tectonic subsidence and consequently trigger giant collapses at the adjacent slope. Retreat of platforms due to tectonic collapses and/or earthquake shocks is a well-documented feature of many Tethyian platforms during the Jurassic rifting stages (e.g. Bernoulli 1964; Bosellini 1973; Castellarin et al. 1978; Mutti et al. 1984). The influence of tectonics and/or earthquakes on slope evolution is also indicated by the coeval neptunian dyke in the slope-facies at Cresta De Do Peniola.

Acknowledgements The authors would like to acknowledge Baba Senowbari-Daryan (University of Erlangen, Germany) for palaeontological discussions. Axel Emmerich thanks the "Studienstiftung des deutschen Volkes" (German National Academic Foundation) and the International Postgraduate Programme (University of Heidelberg, Germany) for financial support during fieldwork and travel. To Ioan Bucur (Cluj-Napoca, Romania), André Freiwald (Erlangen, Germany) and Rüdiger Henrich (Bremen, Germany) we owe many valuable comments on the manuscript.

References

- Bechstädt T, Brandner R (1970) Das Anis zwischen St. Vigil und dem Höhlensteintal (Pragser und Olang Dolomiten, Südtirol). *Festbd Geol Inst, 300-Jahr-Feier Univ Innsbruck*, 9–103
- Bernoulli D (1964) Zur Geologie des Monte Generoso (Lombardische Alpen). *Beitr geol Karte Schweiz, NF, Bern*, 134 pp
- Biddle KT (1981) The basinal Cipit boulders: indicators of Middle to Upper Triassic buildup margins, Dolomite Alps, Italy. *Riv Ital Paleontol Stratigr* 86:779–794
- Blendinger W (1985) Middle Triassic strike-slip tectonics and igneous activity of the Dolomites (Southern Alps). *Tectonophysics* 113:105–121
- Blendinger W (1986) Isolated stationary carbonate platforms: the Middle Triassic (Ladinian) of the Marmolada area, Dolomites, Italy. *Sedimentology* 33:159–183
- Blendinger W (2001) Triassic carbonate buildup flanks in the Dolomites, Northern Italy: breccias, boulder fabric and the importance of early diagenesis. *Sedimentology* 48:919–933
- Bosellini A (1973) Modello geodinamico e paleotettonico delle Alpi Meridionali durante il Giurassico-Cretacico. Sue possibili applicazioni agli Appennini. *Acad naz Lincei, Quad* 183:163–205
- Bosellini A (1984) Progradation geometries of carbonate platforms: examples from the Triassic of the Dolomites, Northern Italy. *Sedimentology* 31:1–24
- Bosellini A (1989) Dynamics of Tethyan carbonate platforms. In: Crevello PD, Wilson JJ, Sarg JF, Read JF (eds) *Controls on carbonate platform and basin development. SEPM Spec Publ* 44:3–13
- Bosellini A, Rossi D (1974) Triassic carbonate buildups of the Dolomites, Northern Italy. In: Laporte LF (ed) *Reefs in time and space. SEPM Spec Publ* 18:209–233
- Bosellini A, Stefani M (1991) The Rosengarten: a platform-to-basin carbonate section (Middle Triassic, Dolomites, Italy). *Dolomieu Conference on Carbonate Platforms and Dolomitization. Guidebook Excursion C*, 1–24
- Bosellini A, Neri C, Stefani M (1996) Geometrie deposizionali e stratigrafia fisica a grande scala di piattaforme carbonatiche triassiche. 78a riunione estiva, Soc geol ital, San Cassiano. *Guidebook* 1–36
- Brack P, Mundil R, Oberli F, Meier M, Rieber H (1996) Biostratigraphic and radiometric age data question the Milankovitch characteristics of the Latemar cycles (Southern Alps, Italy). *Geology* 24:371–375
- Brack P, Mundil R, Oberli F, Meier M, Rieber H (1997) Biostratigraphic and radiometric age data question the Milankovitch characteristics of the Latemar cycles (Southern Alps, Italy). *Reply. Geology* 25:471–472
- Brack P, Rieber H (1993) Towards a better definition of the Anisian/Ladinian boundary: New biostratigraphical data and correlations of boundary sections from the Southern Alps. *Eclogae Geol Helv* 86:415–527
- Brandner R (1991) Geological setting and stratigraphy of the Schlern-Rosengarten buildup and Seiser Alm basin. In: Brandner R, Flügel E, Koch R, Yose LA (eds) *The northern margin of the Schlern/Sciliar Rosengarten/Catinaccio platform. Dolomieu Conference on Carbonate Platforms and Dolomitization. Guidebook Excursion A* pp 4–16
- Brandner R, Flügel E, Senowbari-Daryan B (1991) Microfacies of carbonate slope boulders: indicator of the source area (Middle Triassic: Mahlknecht Cliff, Western Dolomites). *Facies* 25: 279–296
- Castellarin A, Colacicchi R, Praturlon A (1978) Fasi distentive, trascorrenze e sovrascorrimenti lungo la Linea Ancona-Anzio, dal Lias medio al Pliocene. *Geol Romana* 17:161–189
- Coniglio M, Dix GR (1992) Carbonate slopes. In: Walker RG, James NP (eds) *Facies models: response to sea level change. Geol Assoc Canada, Geotext* 1:349–373
- Crevello PD, Schlager W (1980) Carbonate debris sheets and turbidites, Exuma Sound, Bahamas. *J Sediment Petrol* 50:1121–1148
- Cuif JP (1974) Rôle des sclérosponges dans la faune récifale du Trias des Dolomites (Italie du Nord). *Geobios* 7:139–153
- De Zanche V, Farabegoli E (1988) Anisian paleogeographic evolution in the Central-Western Southern Alps. *Mem Sci Geol* 40:399–411
- De Zanche V, Gianolla P, Manfrin S, Mietto P, Roghi G (1995) A Middle Triassic back-stepping carbonate platform in the Dolomites (Italy): sequence stratigraphy and biostratigraphy. *Mem Sci Geol* 47:135–155
- Dercourt J, Gaetani M, Vrielynck B, Barrier E, Biju-Duval B, Brunet MF, Cadet JP, Crasquin S, Sandulescu M (2000) *Atlas Peri-Tethys, Palaeogeographical Maps. CCGM/CGMW, Paris, 24 maps and explanatory notes*, 269 pp
- Doglioni C (1983) Duomo Medio-Triassico nelle Dolomiti. *Rend Soc Geol Ital* 6:13–16
- Doglioni C (1984) Triassic diapiric structures in the Central Dolomites. *Eclogae Geol Helv* 77:261–285
- Doglioni C (1987) Tectonics of the Dolomites. *J Struct Geol* 9:181–193
- Egenhoff SO, Peterhänsel A, Bechstädt T, Zühlke R, Grötsch J (1999) Facies architecture of an isolated carbonate platform: tracing the cycles of the Latemar (Middle Triassic, Northern Italy). *Sedimentology* 46:893–912

- Emmerich A (2001) Fazies und geometrische Entwicklung am Slope einer Mitteltriassischen Karbonatplattform: der Latemar (Dolomiten, Italien). *Gaea heidelbergensis* 9, CD-ROM
- Emmerich A, Zamparelli V, Zühlke R, Bechstädt T (2002) The reef of an Anisian (Middle Triassic) isolated carbonate platform: the Latemar (Dolomites, Italy). 16th Int Sediment Congr, Abstr, Rand Afrikaans Univ, Johannesburg, South Africa: 437–438
- Enos P, Jiayong W, Yangji Y (1997) Facies distribution and retreat of Middle Triassic platform margin, Guizhou province, south China. *Sedimentology* 44:563–584
- Fagerstrom JA (1987) The evolution of reef communities. Wiley, New York, 600 pp
- Flügel E (1991) Environmental analysis of allochthonous carbonate blocks and autochthonous mounds at the northern margin of the Schlern-Rosengarten (Sciliar-Catinaccio) platform. In: Brandner R, Flügel E, Koch R, Yose LA (eds) The northern margin of the Schlern/Sciliar - Rosengarten/Catinaccio platform. Dolomieu Conference on Carbonate Platforms and Dolomitization, Guidebook Excursion A 41–55
- Flügel E (1994) Pangean shelf carbonates: Controls and paleoclimatic significance of Permian and Triassic reefs. In: Klein GD (ed) Pangea: paleoclimate, tectonics, and sedimentation during accretion, zenith, and breakup of a supercontinent. *GSA Spec Pap* 288:247–266
- Flügel E (2002) Triassic reef patterns. In: Kiessling W, Flügel E, Golonka J (eds) Phanerozoic reef patterns. *SEPM Spec Publ* 72:391–463
- Flügel E, Stanley GD (1984) Reorganization, development and evolution of post-Permian reefs and reef organisms. *Palaeontogr Am* 54:177–186
- Fois E (1982) The Sassi da Putia carbonate buildup (Western Dolomites): biofacies succession and margin development during the Ladinian. *Riv Ital Paleontol Stratigr* 87:565–598
- Fois E, Gaetani M (1984) The recovery of reef-building communities and the role of Cnidarians in carbonate sequences of the Middle Triassic (Anisian) in the Italian Dolomites. *Palaeontogr Am* 54:191–200
- Fürsich FT, Wendt J (1977) Biostratonomy and palaeoecology of the Cassian Formation (Triassic) of the Southern Alps. *Palaeogeogr Palaeoclimatol Palaeoecol* 22:257–323
- Gaetani M, Fois E, Jadoul F, Nicora A (1981) Nature and evolution of the Middle Triassic carbonate buildups in the Dolomites (Italy). *Marine Geol* 44:25–57
- Goldhammer RK, Harris MT (1989) Eustatic controls on the stratigraphy and geometry of the Latemar buildup (Middle Triassic), the Dolomites of Northern Italy. In: Crevello PD, Wilson JJ, Sarg JF, Read JF (eds) Controls on carbonate platform and basin development. *SEPM Spec Publ* 44:323–338
- Hardie LA, Hinnov L (1997) Biostratigraphic and radiometric age data question the Milankovitch characteristics of the Latemar cycles (Southern Alps, Italy). *Comment. Geology* 25:470–471
- Harris MT (1993) Reef fabrics, biotic crusts and syndepositional cements of the Latemar reef margin (Middle Triassic), Northern Italy. *Sedimentology* 40:383–401
- Harris MT (1994) The foreslope and toe-of-slope facies of the Middle Triassic Latemar buildup (Dolomites, Northern Italy). *J Sediment Res B* 64:132–145
- Henrich R, Zankl H (1986) Diagenesis of Upper Triassic Wetterstein reefs of the Bavarian Alps. In: Schroeder JH, Purser BH (eds) Reef diagenesis. Springer, Berlin Heidelberg New York: 245–268
- Hummel K (1928) Das Problem des Fazieswechsels in der Mitteltrias der Südtiroler Dolomiten. *Geol Rundsch* 19:223–228
- Iryu Y, Nakamori T, Matsuda S, Abe O (1995) Distribution of marine organisms and its geological significance in the modern reef complex of the Ryukyu Islands. *Sediment Geol* 99:243–258
- Isinteke ID, Altiner D, Koca U (2000) Middle Triassic foraminifera from the type section of the Laleköy Formation (Karaburun Peninsula, Western Turkey): remarks on *Palaeolituonella meridionalis* (Luperto, 1965). *Rev Paléobiol* 19:191–205
- James NP (1983) Reefs. In: Scholle PA, Bebout DG, Moore CH (eds) Carbonate Depositional Environments. *Mem Am Assoc Petrol Geol* 33:345–362
- James NP, Ginsburg RN (1979) Comparative anatomy, organism distribution and Late Quaternary evolution of modern reef margins. In: James NP, Ginsburg RN (eds) The seaward margin of Belize barrier and atoll reefs. *IAS Spec Publ* 3:153–171
- Kenter J (1990) Carbonate platform flanks; slope angle and sediment fabric. *Sedimentology* 37:777–794
- Knopp S (2002) Fazies und Geometrien am Plattform-/Beckenübergang einer Mitteltriassischen, isolierten Karbonatplattform: Der Latemar, SW-Dolomiten, Italien. *Gaea heidelbergensis* 10, CD-ROM
- Lehrmann D, Enos P, Montgomery P, Payne J, Orchard M, Bowring S, Ramezani J, Martin M, Jiayong W, HongMei W, YouYi Y, Jiafei X, Rongxi L (2002) Integrated biostratigraphy, magnetostratigraphy and geochronology of the Olenikian-Anisian boundary in marine strata of Guandao section, Nanpanjiang Basin, South China: implications for timing of biotic recovery from the end-Permian extinction. *I.U.G.S. Subcomm Triassic Stratigr, STS/IGCP 467, Field Meeting, Veszprém, Hungary, 5-8 September, 2002:7-8*
- Leonardi P (1967) Le Dolomiti: Geologia dei Monti tra Isarco e Piave. Manfrini, Rovereto, 1, 1019 pp
- Mallarino G (2002) Crisi delle piattaforme carbonatiche e dinamica deposizionale delle piattaforme pelagiche nel Giurassico della Sicilia occidentale. Unpubl. Ph.D. thesis, Univ Stud Napoli Palermo, Palermo, 201 pp
- Masetti M, Neri C (1980) L'Anisico della Val di Fassa (Dolomiti occidentali): sedimentologia e paleogeografia. *Ann Univ Ferrara, NS, sez IX, 7, 1:1-19*
- Maurer F (2000) Growth mode of middle Triassic carbonate platforms in the Western Dolomites (Southern Alps, Italy). *Sediment Geol* 134:275–286
- McKinney ML (1985) Mass extinction patterns of marine invertebrate groups and some implications for a causal phenomenon. *Paleobiology* 11:227–233
- Mojsisovics E (1879) Die Dolomitriffe von Südtirol und Venetien: Beiträge zur Bildungsgeschichte der Alpen. Holder, Wien, 522 pp
- Mullins HT (1983) Modern carbonate slopes and basins of the Bahamas. In: Cook HE, Hine AC, Mullins HT (eds) Platform margin and deepwater carbonates. *SEPM Short Course* 12: 4.1–4.138
- Mullins HT, Cook HE (1986) Carbonate apron models: alternatives to the submarine fan model for paleoenvironmental analysis and hydrocarbon exploration. *Sediment Geol* 48:37–79
- Mullins HT, Gardulski AF, Hine AC (1986) Catastrophic collapse of the west Florida carbonate platform margin. *Geology* 14:167–170
- Mundil R, Brack P, Meier M, Rieber H, Oberli F (1996) High resolution U/Pb dating of Middle Triassic volcanics: time-scale calibration and verification of tuning parameters for carbonate sedimentation. *Earth Planet Sci Lett* 141:137–151
- Mundil R, Zühlke R, Bechstädt T, Brack P, Egenhoff SO, Meier M, Oberli F, Peterhänsel A, Rieber H (2003) Cyclicities in Triassic platform carbonates: synchronizing radio-isotopic and orbital clocks. *Terra Nova* 15:81–87
- Mutti E, Ricci Lucchi F, Seguret M, Zanzucchi G (1984) Seismoturbidites: a new group of resedimented deposits. *Marine Geol* 55:103–116
- Pia J (1937) Stratigraphie und Tektonik der Prager Dolomiten in Südtirol. Pia, Wien, 248 pp
- Raup DM (1979) Size of the Permo-Triassic bottleneck and its evolutionary implications. *Science* 206:217–218
- Rettori R, Senowbari-Daryan B, Zühlke R (1996) *Flatschkofelia anisica* gen. et sp. nov. (Foraminiferida) from the Middle Triassic (Anisian) of Northern Dolomites, Italy. *Riv Ital Paleontol Stratigr* 102:413–416
- von Richthofen FF (1860) Geognostische Beschreibung der Umgegend von Predazzo, Sanct Cassian und Seiser Alpe in Süd-Tyrol. Perthes, Gotha, 327 pp

- Riding R (1991) Classification of microbial carbonates. In: Riding R (ed) *Calcareous algae and stromatolites*. Springer, Berlin Heidelberg New York, 21–51
- Rüffer T, Zamparelli V (1997) Facies and biota of Anisian to Carnian carbonate platforms in the Northern Calcareous Alps (Tyrol and Bavaria). *Facies* 37:115–136
- Rüffer T, Zühlke R (1995) Sequence stratigraphy and sea-level changes in the Early to Middle Triassic of the Alps: a global comparison. In: Haq BU (ed) *Sequence stratigraphy and depositional response to eustatic, tectonic and climatic forcing*. Kluwer, Amsterdam, pp 161–207
- Russo F, Mastandrea A, Neri C (1998) The Cipit boulders from the surroundings of the Sella massif. In: Perri MC, Spaletta C (eds) *Southern Alps field trip guidebook. Ecos VII. Giorn Geol Spec Issue*, 60:108–115
- Russo F, Mastandrea A, Stefani M, Neri C (2000) Carbonate facies dominated by syndepositional cements: a key component of Middle Triassic platforms. The Marmolada case history (Dolomites, Italy). *Facies* 42:211–226
- Sarti M, Winterer EL, Luciani V (2000) Repeated gravity-controlled fracturing and dilatation of Jurassic limestones over 130 m.y. and filling by episodic microturbidity currents of Cretaceous and Palaeogene sediments (Taormina, Sicily). *Mem Soc Geol Ital* 55:251–260
- Schäfer P, Senowbari-Daryan B (1982) The Upper Triassic Pantokrator limestone of Hydra (Greece): an example of a prograding reef complex. *Facies* 6:147–164
- Schäfer P, Senowbari-Daryan B (1983) Die Kalkalgen aus der Obertrias von Hydra, Griechenland. *Palaeontographica*, B 185: 83–142
- Scheuber M (1990) Der Spitzkalk von Recoaro (Vicentinische Alpen, Norditalien): Sedimentologie, Paläontologie und Paläogeographie eines mitteltriassischen Ablagerungsraumes. *Facies* 23:57–96
- Seeling M, Emmerich A, Bechstät T, Zühlke R (2005) Accommodation/sedimentation development and massive early marine cementation: Latemar vs. Concarena (Middle/Upper Triassic, Southern Alps). *Sediment Geol DOI* 10.1016/j.sedgeo.2004.09.004
- Scholz G (1972) An Anisian Wetterstein limestone reef in North Hungary. *Acta Miner Petrogr Szeged* 20:337–362
- Scoffin TP, Garrett P (1974) Processes in the formation and preservation of internal structure in Bermuda patch reefs. *Proc 2nd Int Coral Reef Symp, Brisbane*, 2:429–448
- Senowbari-Daryan B, Di Stefano P (2001) Middle Triassic dasycladales in Sicily: evidence of an Anisian?-Ladinian carbonate platform. *Acta Geol Hung* 44:95–109
- Senowbari-Daryan B, Zühlke R, Bechstät T, Flügel E (1993) Anisian (Middle Triassic) buildups of the Northern Dolomites (Italy): the recovery of reef communities after the Permian/Triassic crisis. *Facies* 28:181–256
- Stefani MM, Mastandrea AG, Russo F (2001) Massive syndepositional cementation associated with organic matter: a key factor in the depositional dynamics of the Latemar and coeval Middle Triassic carbonate platforms of the Dolomites. In: Wortmann UG, Funk H (eds) *21st IAS Meet Sediment, Abstr Programme, Davos, Switzerland:111*
- Trifonova E, Vaptsarova A (1982) Palaeoecology of Late Anisian foraminifera in part of North Bulgaria. *Geol balkanica* 12:95–104
- Tucker ME, Wright VP (1990) *Carbonate sedimentology*. Blackwell, Oxford, 496 pp
- Twitchett RJ (1999) Palaeoenvironments and faunal recovery after the end-Permian mass extinction. *Palaeogeogr Palaeoclimatol Palaeoecol* 154:27–37
- Vachard D, Martini R, Rettori R, Zaninetti L (1994) Nouvelle classification des foraminifères. *Endothyroides du Trias. Geobios* 27:543–557
- Viel G (1979a) Litostratigrafia Ladinica: una revisione. Ricostruzione paleogeografica e paleostrutturale dell'area Dolomitico-Cadorina (Alpi Meridionali). I. Parte. *Riv Ital Paleontol Stratigr* 85:88–125
- Viel G (1979b) Litostratigrafia Ladinica: una revisione. Ricostruzione paleogeografica e paleostrutturale dell'area Dolomitico-Cadorina (Alpi Meridionali). II. Parte. *Riv Ital Paleontol Stratigr* 85:297–352
- Winterer EL, Metzler CV, Sarti M (1991) Neptunian dikes and associated breccias (Southern Alps and Switzerland): role of gravity sliding in open and closed systems. *Sedimentology* 38:381–404
- Wright VP (1992) A revised classification of limestones. *Sediment Geol* 76:177–185
- Zacher W (1980) Biozonierung und Sediment-Zusammensetzung in einem phippinischen Saumriff bei Lobo, Batangas. *Z dt Geol Ges* 131:793–801
- Zamparelli V, Emmerich A, Bechstät T, Zühlke R (2001) The reefal margin and slope of an isolated Mid-Triassic atoll: the Latemar, Dolomites, Italy. In: Wortmann UG, Funk H (eds) *21st IAS Meet Sediment, Abstr Programme, Davos, Switzerland:115*
- Zaninetti L, Ciarapica G, Martini R, Salvini-Bonnard G, Rettori R (1987) *Turriglomina scandonei*, n.sp., dans les calcaires réci-faux du Trias Moyen. *Rev Paléobiol* 6:177–182
- Zaninetti L, Ciarapica G, Martini R, Rettori R (1990) Paléoécologie des turriglomines (foraminifères) dans le Trias de l'Apennin méridional (bassin de Lagonegro, Italie). *Arch Sci Genève* 43:295–305
- Zaninetti L, Rettori R, Martini R, Cirilli S, Ciarapica G (1992) Il foraminifero *Abriolina* Luperto, 1963 (Trias medio, Appennino meridionale): ridescrizione, tassonomia, nuovi dati sulla distribuzione stratigrafica. *Rev Paléobiol* 11:197–204
- Zaninetti L, Rettori R, Martini R (1994) *Aulotortus eotriasicus*, n.sp., un nuovo foraminifero del Trias medio (Anisico) delle Dinaridi ed Ellenidi. *Boll Soc Paleontol Ital* 33:43–49
- Zorn H (1971) Paläontologische, stratigraphische und sedimentologische Untersuchungen des Salvatoredolomits (Mitteltrias) der Tessiner Kalkalgen. *Schweiz paläont Abh* 91:1–90
- Zorn H (1972) Mikrofazielle Analyse eines mitteltriadischen Rif-fkomplexes in den Tessiner Kalkalpen. *Mitt Ges Geol Bergbaustud Österr* 21:123–142
- Zühlke R (2000) Fazies, hochauflösende Sequenzstratigraphie und Beckenentwicklung im Anis (Mittlere Trias) der Dolomiten (Südalpin, Italien). *Gaea heidelbergensis* 6, CD-ROM
- Zühlke R, Bechstät T, Brack P, Mundil R, Rieber H (2000) Die Latemar-Kontroverse: neue Daten zur Geometrie, zeitlichen Entwicklung und Interpretation lagunärer Zyklen. *Mitt Ges Geol Bergbaustud Österr* 43:154
- Zühlke R, Bechstät T, Mundil R (2003) Sub-Milankovitch and Milankovitch forcing on a model Mesozoic carbonate platform - the Latemar (Middle Triassic, Italy). *Terra Nova* 15:69–80