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Triassic reefs and platform carbonates in the Northern Calcareous Alps

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Introduction

The Permian/Triassic–event at the end of the Paleozoic time has not only caused the extinction of a lot of Paleozoic taxa in generic or higher level but also the disappearance of reefs. From the lowermost Triassic time (Skythian) no bioconstructions are known until now. Within the Alpine region no reef organisms and calcareous algae have been recorded from this time so far. The present state of knowledge points to the existence of a global "reef gap" in the Early Triassic (fig. 1). The stratigraphic age of some reefs or reefal structures, known as Scythian from some localities in the world (China, Russia, Azerbaijan), should be scrutinized carefully.

In the following the present state of knowledge about Triassic reefs and platform carbonates as well as the biotic, especially algal composition of stratigraphic different Triassic reef types of the Alpine Mediterranean region in general and the Northern Calcareous Alps in detail are described briefly and furthermore some important references are given. Fig. 2 exhibits the characteristics of Triassic reefs in the Alps.

Anisian

I.Occurrences of reefs or platform carbonates

Starting with the Middle Triassic (Late Anisian) in the Northern part of the western Tethys the Anisian reefs, called Steinalm Reef Limestones ("SRL", fig. 1) and platform carbonates are known from the different localities in the Alpine realm (Northern Calcareous Alps, Southern Alps: Dolomites), Karawanks (Austria and Slovenia) and in Hungary. In the Northern Calcareous Alps the Anisian shallow-water carbonates are restricted to the western part (Tyrol) of this region (MILLER 1965, SARNTHEIM 1965). However, no detailed investigations are available from these areas. The best known Anisian reef limestones or platform carbonates are located in the Southern Alps, Dolomites (BECHSTÄDT & BRANDNER 1970, PISA et al. 1978, GAETANI et al. 1981, FOIS & GAETANI 1984, SENOWBARI–DARYAN et al. 1993). Most of the Anisian reefs are represented by allochthonous talus blocks of one to several cubicmeter size. Small autochthonous mounds of biostromal nature are extremely rare

II. Biotic composition

Olangocoelia otti (pl.1, fig. 1), a problematic organism (alga?), but first described as sphinctozoan sponge by BECHSTÄDT & BRANDNER (1970), is the most abundant organism within the Anisian reef boulders of the Southern Alps Dolomites (FOIS & GAETANI 1984, SENOWBARI–DARYAN et al.1993). *Celyphia zoldana* OTT, PISA & FARABEGOLI (1980), other thalamid sponges and a few inozoid sponges, followed by the bryozoan genus *Reptonodotrypa* and porostomate algae are the most common organisms in the Anisian reef limestones in Dolomites (SENOWBARI–DARYAN et al. 1993; see fig. 2). Scleractinian corals are known by 6 genera. They do not play an important role as frame builders. The Anisian reefs are characterized by minor importance of framework and framework porosity. Binding or encrusting organisms, like

Archaeolithoporella in Permian and some problematic encrusting organisms (spongiostromate cyanophyceans or sponges in Ladinian and Late Triassic reefs) are very rare (pl. 1, fig. 2). For more information about the facies, composition of biota and reef communities in Anisian reefs of the Southern Alps, see FOIS & GAETANI (1984) SENOWBARI-DARYAN et al.(1993).

III. Algae

The flora of the Anisian reefs and platform carbonates consists of green algae (dasycladaceans, codiaceans?), red algae (solenoporaceans), porostromate and spongiostromate cyanophyceans, as well as some problematic algae. Dasycladaceans occur predominantly in the lagoonal facies, the others usually in the buildups.

A. Green algae

1) Dasycladaceans

Recognizing the importance of the dasyclad green algae as facies and index fossils this group was studied for several years by PIA whose systematical, palaeoecological, stratigraphical, and facies analysis results are published in numerous papers (e. g. 1912, 1920, 1935, 1937a, 1937b, 1937c, 1942). Later, the Anisian dasycladaceans of Northern and Southern Alps were investigated mainly by FLÜGEL (1970), HERAK (1958, 1966), HURKA (1966), ZANINBURI (1965), FOIS (1979) and especially by OTT (1963, 1972a, 1972b, 1972c, 1974). The most abundant dasycladacean genera of the Anisian reefs or lagoonal sediments are *Physoporella, Oligoporella, Diplopora, Macroporella* and *Teutloporella*. Other genera are rare. Fig. 3 exhibits the stratigraphic range of the abundant dasycladacean genera and species in the stratigraphic different Triassic reefs and platform carbonates of the Northern Calcareous Alps. Within the Anisian lagoonal limestones SENOWBARI-DARYAN et al. (1983) have found two distinct different dasycladacean associations. The first one is characterized by the abundant occurrence of *Oligoporella* and subordinate *Macroporella* and *Teutloporella*, the second one by the dominance of *Diplopora* (*Diplopora annulatissima* PIA and *Diplopora annulata* PIA). The association mentioned first is typical for the time interval Early to Late Anisian (Aegean–Illyrian) while the second one indicates an age of Late Anisian (Illyrian).

2) Codiaceans

Sure codiacean algae have not been reported from the Anisian time interval. However, SENOWBARI-DARYAN et al. (1993: pl. 57, fig. 7) have reported structures of circular to oval or irregularly shaped thalli which could correspond to the perithallus of codiaceans or remains of some phylloid algae. The phylloid algae, abundant in Upper Permian reefs, have not been reported from Lower Triassic or Anisian limestones until now. However, we have found some phylloid algae in the Ladinian limestones exposed in the "Nordkette" (N Innsbruck). The detailed description of these algae is in preparation by SENOWBARI-DARYAN & FLÜGEL.

B. Red algae

The red algae are represented by the group of *solenoporaceans* with Solenopora and *Parachaetetes*. *Solenopora* seems to be abundant. A dome-shaped type of *Solenopora* (probably a new species) was found within the Anisian reef facies in association with

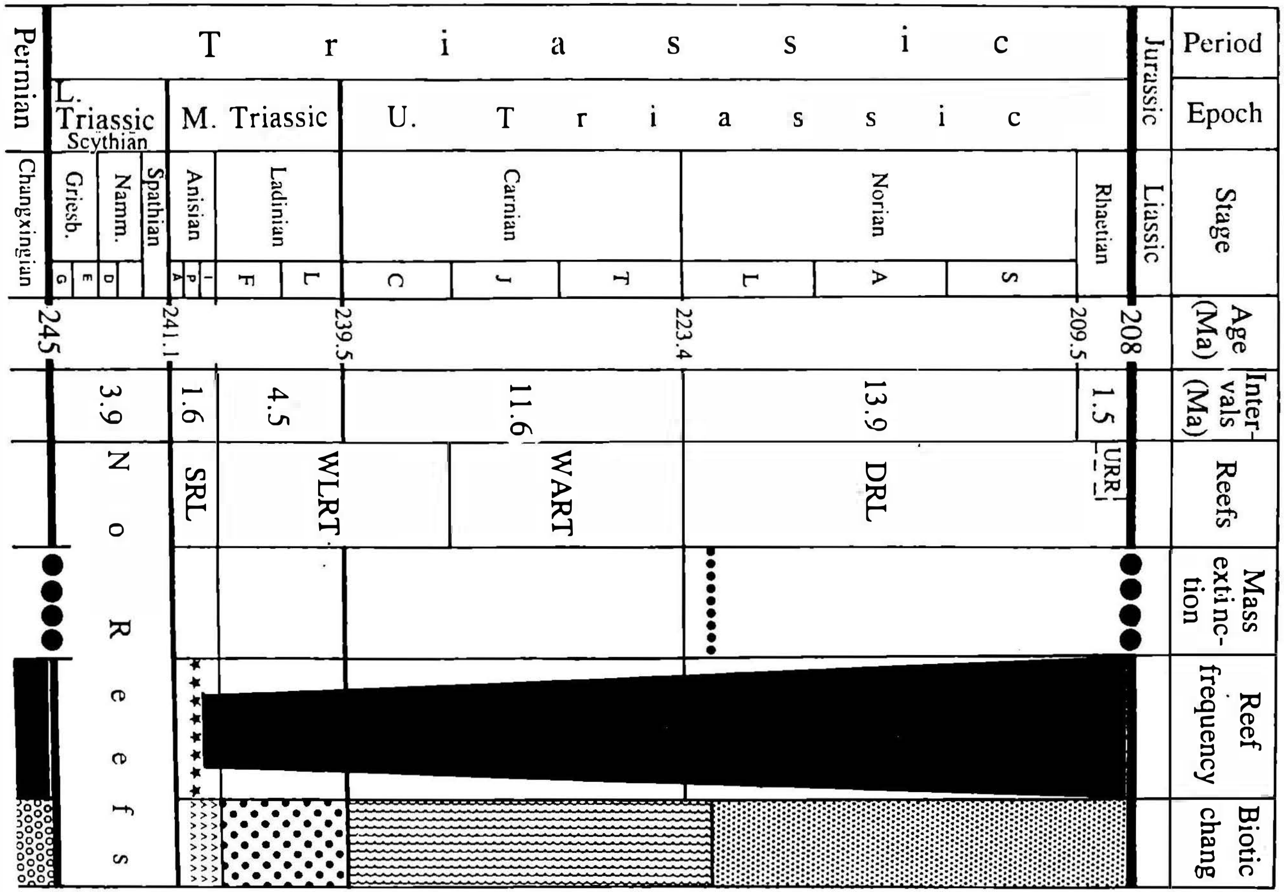

Fig. 1: Stratigraphic range of Triassic reefs in the Alps. SRL = Steinalm reef limestones, WLRT = Wetterstein reef limestones, WART= Waxeneck reef limestones, DRL = Dachstein reef limestones, URR= Upper Rhaetian reef limestones. Beginning and the end of the Triassic period are marked by mass extinctions. Some small extinctions can be recorded in the Triassic characterized by biotic changes.

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	Dimensions	Reefbuilder	Encrustations	Speciality	High-Mg-Calcite Sponges	Diversity + Biotic Changes	Biogeogr. Provinces	Cement
Jurassic								
Rhaetian	small large	Corals Sponges Algae	common	?	rare	very high	Yes ?	common
Norian	large	Sponges Corals Algae	common	Crusts	rare	very high	Yes	common
Carnian	small large	Sponges Algae Corals	common	"Tubiphy." Problem. Forams	common	high	No	common
Ladinian	large	Sponges Algae Corals	common	"Tubiphy." Codiaceans Cladogirv.	rare	high	No	common
Anisian	small	Sponges Algae Bryozoans	rare	Olangocoe.	absent	low	No	rare
Scythian								
Permian	large	Sponges	Archaeol.	plenty of	No	high	Yes	common

Fig. 2: Characterstics of Triassic reefs in the Alps.

some porostromate algae of *Ortonella*-type while the nodular solenoporaceans occur usually in the adjacent lagoonal facies (SENOWBARI-DARYAN et al.1993).

C. Cyanophyceans

1) Porostromate cyanophyceans

In the Anisian reefs porostromate cyanophyceans are more abundant and important than the red or green algae. They are of minor importance in the lagoonal facies. There are no detailed data about the systematic description and palecological importance of Anisian porostromate algae. However, FOIS & GAETANI (1984) and SENOWBARI-DARYAN et al. (1993) have described some porostromate algae as *Ortonella, Garwoodia* or *Hedstromia*. The most important porostromate alga is represented by the genus *Garwoodia* (FOIS & GAETANI 1984) or *Ortonella* sp. 1 by SENOWBARI-DARYAN et al. (1983). The genus *Brandneria*, with type-species *B. dolomitica* - is described by SENOWBARI-DARYAN et al. (1993) as new.

2) Spongiostromate cyanophyceans (pl. 1, fig. 2)

Being encrusting and stabilizing organisms in the reef environment the spongiostromate cyanophyceans, (important binders in Ladinian and Late Triassic reefs) are very rare or even absent in Anisian bioconstructions (SENOWBARI-DARYAN et al. 1993).

D. Problematic algae

"Tubiphytes", a problematic organisrn occuring as binder or baffler, is very common in Late Permian as well as in Ladinian and Carnian reefs but lacks or is extremely rare in Anisian buildups. GAETANI & GORZA (1989), however, *have reported the abundance of "Tubiphytes"* within the carbonate bank of the Camorelli Limestones in the Lombardy, Southern Alps. Some illustrated specimens by GAETANI & GORZA seem to be oncolitic in origin, some others described as *"Tubiphytes carinthiacus"* (FLÜGEL) should be placed to the genus *Plexoramea* MELLO, a superficially similar organism to *"Tubiphytes"*. *Plexoramea cerebriformis* MELLO is a relatively abundant organism in Anisian, Ladinian and Carnian reefs (FLÜGEL et al. 1988). Other problematic algae, like *Baccanella, Lithocodium* or *Bacinella* occur also in Anisian reef or platform carbonates but they are extremely rare.

Ladinian

I. Occurrence of reefs or platform carbonates

In comparison to the Anisian reefs distribution and frequency of Ladinian and Early Carnian (Cordevolian) biolithits called Wetterstein Reef Limestones ("WERL", fig. 1), and platform carbonates in the Alps and elsewhere are significantly larger than that of Anisian age. FLÜGEL (1982) gives an overview about the occurrence of Ladinian reefs in the world as well as in the Alps. From Northern Calcareous Alps the Ladinian reefs are described by BRANDNER (1978), BRANDNER & RESCH (1981), HENRICH (1982, 1983, 1984), OTT (1967, 1972d) and WOLF (1973).

II. Biotic composition

The biotic composition of Ladinian reefs is different from Anisian ones. The typically Anisian-type reef building organisms (*Olangocoelia, Celyphia zoldana* OTT et al., *Reptonodotrypa*, porostromate algae etc.) lack or are extremely rare in Ladinian reefs. The most abundant reef–constructing organisms in Ladinian bioconstructions are sphinctozoan sponges represented mainly by *Solenolmia manon* (MÜNSTER), unknown from Anisian reefs. Other sphinctozoans like *Vesicocaulis, Follicatena* etc. are also unknown from the Anisian. Sphinctozoan and in inozonan sponges with Mg–calcite mineralogy of the rigid skeleton (like *Uvanella, Alpinothalamia*) never found in Anisian reefs, may appear for the first time in Ladinian reefs. The frequency of individual genera of scleractinian corals and their role as framework constructors increase distincly in Ladinian time. The number of organisms and their diversity increase rapidly, too. In addition to the differences of the biotic composition also the submarine cements, the biogenic encrustations as well as total algal association differs distinctly from the Anisian counterpart.

III. Algae

A. Green algae

1) Dasycladaceans

Due to detailed studies, especially by PIA and OTT, the dasyclads are the best known group of algae in the Northern Calcareous Alps. As shown in fig. 3, the dasycladacean flora of Ladinian reefs and platform carbonates is characterized by taxa which appear mostly in the Late Anisian (*Avisianus* zone) and range up to the Ladinian /Carnian boundary. It is remarkable that the frequency of some taxa (for example *Diplopora annulata* PIA) of Ladinian limestones is higher than in Anisian carbonates. While a change of dasycladacean flora has taken place in the time from Early Illyrian (*Trinodosus zone*) to Later Illyrian (*Avisianus* zone), the Anisian / Ladinian boundary do not show any changes in dasycladacean associations. Most of Ladinian dasycladaceans have been found in lagoonal facies, only a few of them may occur in the reefal facies (e. g. *Teutloporella echinata* OTT 1975).

2) Codiaceans

There is no report about the occurrence of sure codiaceans from Anisian reefs or platform carbonates. The oldest Triassic codiaceans are reported by BRANDNER & RESCH (1980) as *Collarecodium oenipontanum* from the Ladinian–Cordevolian Wetterstein Limestones of "Innsbrucker Nordkette" near Innsbruck, Tyrol. This bush–like alga is characterized by multibranched thallus with annulation in irregularly distance and some collar–like elements. The description of some other codiaceans newly discovered in Ladinian reefs of the Southern Alps is in preparation by SENOWBARI–DARYAN & FLÜGEL.

B. Red algae

In Ladinian reefs solenoporaceans are much more abundant than in Anisian buildups. Columnar and branched solenoporaceans may build stromatolite–like domes of up to 30 cm in diameter with approximately the same height (BRANDNER & RESCH 1981, BRANDNER et al. 1991, WENDT 1993). In general the Ladinian solenoporaceans need further studies and detailed systematic descriptions of the individual taxa before a list of this group can be provided.

C. Cyanophyceans

1) Porostromate cyanophyceans

The porostromate cyanophyceans are relatively abundant within Ladinian reef complexes, especially in lagoonal facies-types. *Cayeuxia, Garwoodia, Ortonella, Bevocatria* and some other genera have been reported from different localities. Also the Ladinian porostromates should be studied more in detail.

2) Spongiostromate cyanophyceans
In comparison with the Anisian reef and shallow-water limestones the increase of spongiostromate cyanophyceans in Ladinian reefs is remarkable. Thin section investigations point out different types of encrustations (BRANDNER et al. 1991).
Biogenic crusts and submarine cementation of up to 15 cm thickness are the most common elements contributing to the formation of bindstones in Ladinian reefs (pl. 2). The crusts are also important for the formation of quite large (up to several cm in diameter) oncoids in the lagoonal facies. The Ladinian spongiostromate cyanophyceans are characterized by thin lamina around biogenic components (compare also crusts of Carnian reefs).

D. Problematic algae
There is a remarkable abundance of problematic organism-type *"Tubiphytes"* in Ladinian reefs (pl. 3). The most abundant type is represented by the dendroid and bush-like organism described as *"Tubiphytes multisiphonatus"* by SCHÄFER & SENOWBARI-DARYAN (1983). From Anisian? or Ladinian? reefs of Aggtelek area (BÜKK Mountains, Hungary) SCHLOZ (1970) described also an organism as *"Axopora aggtelekensis"* which most probably belong to the multibranched *"Tubiphytes"* occuring in Ladinian and Carnian reefs. The variety of Paleozoic *"Tubiphytes"* is discussed by SENOWBARI-DARYAN and FLÜGEL (1993) and the detailed investigations on Mesozoic *"Tubiphytes"* are still in progress. In addition to *"Tubiphytes"* also the frequency of other problematic algae increases in Ladinian reef complexes. Remarkable is the occurrence of the bush-like alga *Cladogirvanella cipitensis* OTT which may reach a length and diameter of more than 15 cm (pl. 4-6). Some problematic algae, like *Macrotubus babai* FOIS & GAETANI (1981), *Bacinella elongata* FOIS (1982), *Baccanella floriformis* PANTIC, *Plexoramea cerebriformis* MELLO, etc. have been also reported from Ladinian reef environments.

Carnian

I. Occurrences of reef or platform carbonates

Reports of Carnian reefs are known from numerous localities in the Alpine-Mediterranean region as well as in other areas in the world. FLÜGEL (1982) gives an overview about the worldwide occurrence of Carnian reefs. In the Northern Calcareous Alps the Ladinian Wetterstein reefs continue in several localities up to the Cordevolian (fig. 1). Cordevolian reefs of the Northern Calcareous Alps were studied by OTT (1967), BRANDNER & RESCH (1981), and HENRICH (1982, 1983). In addition numerous late Carnian reefs or reefal limestones are known from the Leckkogel beds (Cordevolien-Tuvalian), called generally "Tisovec Limestone" (LEIN 1972, 1980). However, the recent investigations of the the "Tisovec limestones" from the type locality by KRYSTIN et al. (1990) point to a Lower Norian age of these limestone. KRYSTIN et al. (1990) have proposed to use the new stratigraphic name "Waxeneck Limestone" for the Late Carnian reefs ("WART", fig. 1) and dasycladacean-bearing platform carbonates. Microfacies and palaeontology of some Carnian reefs in Northern Calcarous Alps are described by TOULA (1913), LEIN (1970, 1980), FLÜGEL et al. (1978), DULLO & LEIN (1980, 1982), DULLO et al. (1987), RIEDEL 1990, and KRYSTIN et al. (1990).

II. Biotic composition

Most of Ladinian reef organisms occur also in Carnian bioconstructions. Only a minor change of the biotic composition has taken place at the Ladinian/Carnian boundary. Furthermore the abundance and diversity of reef organisms increase during the Ladinian to Carnian (fig. 1). Among the sponges some "extinct" genera at the Permian/Triassic boundary, e.g. *Amblysiphonella* reappear in Carnian reefs (fig. 2). Both the diversity and frequency of sponges with high-Mg calcite skeleton increase further and new genera (e. g. *Jablonskyia, Leinia* etc.) characterize the sponge fauna of Carnian reefs. Contemporaneously the diversity of scleractinian corals increases distinctly.

An overview about the differences of Ladinian and Carnian as well as Carnian and Norian biota is given by RIEDEL (1990), of sphinctozoan and inozoan sponges by SENOWBARI-DARYAN (1990), and RIEDEL & SENOWBARI-DARYAN (1991). Not only the composition of frame-builders but also the other reef organisms of Carnian age differ from those of the Ladinian.

For example, the miliolid foraminifera (e. g. *Cucurbita* (= *Pseudocucurbita*), *Spiriamphorella, Urnulinella, Hydrania*) are typically Carnian microfossils and not known from Ladinian reef limestones. Also some microproblematic organisms (e. g. *Barbafera carnica* SENOWBARI-DARYAN) are typically Carnian microfossils and may be used to separate Carnian from Ladinian reef deposits.

III. Algae

A. Green algae

1) Dasycladaceans

The Ladinian/Carnian boundary is marked by the disappearance of almost all Ladinian dasyclad genera and by the appearance of new forms (e. g. *Poikiloporella duplicata*, *Clypeina*, etc. fig. 3) most of them are index fossils for the Carnian age. In contrast to well known Carnian dasycladaceans of the Carpathians (e. g BISTRICKY 1986) only some records exist about the Carnian dasycladaceans of the Northern Calcareous Alps (e. g. HOLZER 1967, DULLO 1980). The common dasyclad algae of Northern Alpine Carnian limestones are listed in fig. 2

2) Codiaceans

Just very few codiacean algae are known from Carnian deposits of the Northern Calcareous Alps. FLÜGEL et al. (1992) have described from the Carnian reef limestones of the BÜKK Mountains in Hungary a codiacean as *Egericodium hungaricum* which occurs also in Carnian reefs of the Southern Tethyan realm (Sicily, Hydra/Greece) and rarely in the Northern Calcareous Alps.

3) Red algae

The red algae in Carnian shallow water limestones of Northern Calcareous Alps are represented by the group of solenoporaceans and gymnocodiaceans. *Solenopora, Parachaetetes* and *Marinella* are the representatives of solenoporaceans known from different localities in the Northern Calcareous Alps. Gymnocodiaceans are not abundant and known only by the genus *Oligoplagia*, first described as a sponge by HERAK (1944). According to H. W. FLÜGEL (1971) *Oligoplagia* should be placed to the gymnocodiaceans. The occurrence of the genus *Dendronella* MOUSSAVIAN & SENOWBARI-DARYAN (1988),known from the Carnian limestones of the Cassian Formation in the Dolomites (Southern Alps), in Carnian buildups of the Northern Carcareous Alps is most probable.

C. Cyanophyceans

1) Porostromate cyanophyceans

Porostromate cyanophyceans of Carnian reefs in the Tethyan realm are poorly known (e. g. SCHÄFER & SENOWBARI-DARYAN 1983). *Cayeuxia*, *Orthonella*, *Heterotrichella*, *Garwoodia* and *Girvanella* are the abundant representatives of Northern Alpine Carnian porostromate cyanophyceans. This group of cyanophyceans generally occurs in lagoonal facies in association with some dasycladaceans, nodular red algae and involutinid and duostominid foraminifers. Some representatives are described by FLÜGEL et al. (1978) DULLO (1980), DULLO & LEIN (1980), and DULLO et al. (1987).

2) Spongiostromate cyanophyceans

Generelly two types of spongiostromate cyanophycean crusts can be distinguished in the Carnian reefs (pl. 7): The first type is similar to those crusts described from Ladinian reefs. This spongiostromate crust is represented by densely packed micritic laminae reaching usually a few mm to cm in thickness. (pl. 7, fig. 1). Most of the crusts occur around the reef-builders, some around cavities within the reef facies. Playing also the binding and stabilizing role the systematic affiliation of the second encrusting group is uncertain The crusts are composed of bubble-like "segments" with a dark micritic wall (pl. 7, fig. 2). Quite probably the wall is composed of high-Mg calcite with a granular microstructure. The interior of the bubbles are filled partly or totally with sediment or cement. This or similar types of crusts are described as the thalamid sponge *Uvanella ducta* by BOIKO (in BOIKO et al. 1991).

This group of spongiostromate cyanophyceans seem to be limited to the Carnian. Therefore they serve as important index fossils for this age. A detailed study of the crusts is in preparation.

D. Problematic algae

"*Tubiphytes*", occurring as small baffling or encrusting organisms, is the most abundant problematic algal form in the Carnian reefs. Several types can be distinguished. A similar problematic organism (alga ? or fungus ?), called *Plexoramea* MELLO, may also occur frequently in Carnian limestones (FLÜGEL et al. 1988). *Bacinella*, *Lithocodium*, *Thaumatoporella*, *Baccanella* are other problematic algae recorded from this time interval in Northern Calcareous Alps.

Norian – Rhaetian

I. Occurrence of reefs or platform carbonates

In the Northern Calcareous Alps as well as elsewhere in the world the Norian-Rhaetian reefs and shallow-water limestones show distinctly larger distribution than the Carnian or Ladinian reefal facies.

A list about the Norian–Rhaetian reef localities of the world is given by FLÜGEL (1982). Starting with WÄHNER (1903), VORTISCH (1926, 1927), SIEBER (1937) the Norian–Rhaetian Dachsteinkalk reefs ("DRL", fig. 1) and the Upper Rhaetian reefs ("URR", fig. 1) are the best studied and documented Upper Triassic reefs worldwide: "Numerous Late Triassic reefs in the Northern Calcareous Alps, Austria, and in Bavaria are among the most carefully documented reefs in the world, due in large part to the detailed work of the "Erlangen Reef Research Group" directed by Erik Flügel" (FAGERSTROM 1987: 402). Investigations of Norian–Rhatian Dachstein reefs in Northern Calcareous Alps have been carried out by ZAPFE (1960, 1962, 1967), FLÜGEL (1962), FLÜGEL–KAHLER (1963), ZANKL (1969), LOBITZER (1974), DULLO (1980b), SADATI (1981), and WURM (1982). Upper Rhaetian reefs have been studied by OHLEN (1959), ZAPFE (1963), FABRICIUS (1966), SCHÄFER (1979), SCHÄFER & SENOWBARI-DARYAN (1981), SENOWBARI-DARYAN (1980), PILLER (1981), PILLER & LOBITZER (1979), LOBITZER (1974, 1980), RIEDEL (1988), STANTON & FLÜGEL (1987, 1989).

A summary of microfacies types and the palaeontology of Late Triassic reefs of Northern Calcareous Alps is given by FLÜGEL (1981). Further references concerning Norian–Rhaetian reefs are given by STANTON & FLÜGEL (1989) and FLÜGEL & FLÜGEL–KAHLER (1992).

II. Biotic composition

At the Carnian/Norian boundary or during the Early Norian a relatively distinct mass extinction concerning reef organisms can be recognized. The Norian reefs document a change in reef organisms on the specific and generic level (fig.2). Most of the Carnian type organisms (e. g. sponges with high–Mg calcite, "typically" Carnian corals, some microproblematica) do not occur in the Norian reefs. The Norian–Rhaetian bioconstructions are characterized by a high diversity of new coral forms. In the Norian–Rhaetian reefs of the Northern Calcareous Alps the corals have almost the same importance than the reef–forming sponges in Middle Triassic and Carnian reefs (FLÜGEL 1981). The corals, especially the dendroid types (e. g. *Retiophyllia*) are the most important framework constructors in Upper-Rhaetian reefs and their percentage in these buildups is even higher than that of sponges. For more information about the diversity and frequency of frame–building organisms see FLÜGEL (1981)

III. Algae

Tab. 1 of chapter B2, shows a list of different algae known from the Norian–Rhaetian Dachsteinkalk reefs as well as from Late Rhaetian reefs of the Northern Calcareous Alps. The distributional pattern of different algae in Late Triassic reefs (Dachsteinkalk reefs as well as Late Rhaetian reefs) is shown in figs. 2a and 2b of the same chapter.

A. Green algae

The green algae of Norian–Rhaetian Dachstein reef complex are represented by dasycladaceans and a few codiaceans.

1) Dasycladaceans

As shown in fig. 3 the dasyclads of Norian–Rhaetian reef limestones are mainly represented by *Heteroporella* and the endosporid *Diplopora*. While *Heteroporella* occurs predominantly in the "oncoid–facies", *Diplopora* is mostly found in the reefal facies. As shown in fig. 3, just very few Carnian dasycladaceans pass rarely the Carnian/Norian boundary. Some dasycladacean species may be used to separate the Norian and Rhaetian part of a reef complex or shallow-water limestone respectively (fig.3). For example *Pentaporella rhaetica* SENOWBARI–DARYAN (1978a; pl. 9, figs. 1–3) or *Diplopora adnetensis* (FLÜGEL 1975; pl.10, fig. 4) have been found only in Late Rhaetian reefs. *Placklesia multipora* BILGÜTAY (pl. 11., figs. 3–4) seems to be limited to the Kössen Beds (SENOWBARI–DARYAN 1978b). The diversity of dasyclads of Norian–Rhaetian reef complexes is documented in pls. 8–10.

2) Codiaceans

Codiaceans are very rare in the Norian–Rhaetian reefs and shallow water limestones. The only recorded codiacean comes from the Gosaukamm: *Boueina hochstetteri liasica* (FLÜGEL 1981; compare FLÜGEL 1988).

3) Red algae

The red algae of Norian–Rhaetian reefs and shallow-water carbonates are documented by the representatives of sole- noporaceans and rarely gymnocodiaceans. *Solenopora* (pl. 11, fig. 1), and *Parachaetetes* are the representatives of solenoporaceans. *Solenopora* is much more abundant than *Parachaetetes* and occurs either in branched morphotypes in the reef facies or as nodular components in the lagoonal facies (compare chapter B2, figs.2a,b).

Abatea culleiformis SENOWBARI–DARYAN & SCHÄFER (1980) is the only gymnocodiacean representative known exclusively from Late Rhaetian reefs (pl. 11, fig. 2).

C. Cyanophyceans

1) Porostromate cyanophyceans

The porostromate cyanophyceans known from the Dachstein reef and bedded limestones as well as from the Upper Rhaetian reef complexes may be assigned to the genera *Cayeuxia*, *Garwoodia*, *Zonotrichites*, and *Ortonella*. The porostomate algae are found in association with dasycladaceans and involutinid and duostominid foraminifers in the "oncoid–" and "algal–foraminiferal facies". *Cayeuxia* seems to be the most abundant genus.

2) Spongiostromate cyanophyceans

Being useful index fossils the spongiostromate cyanophyceans of the Dachstein reef limestones and Late Rhaetian reefs are restricted to the central reef area (figs. 2a–2b in chapter B2). Reaching more than 10 cm thickness the crusts of this group are composed of micritic layers (organic precipitation) separated by microsparitic layers (inorganic precipitation?). The crusts occur in relatively low energy environment in the central reef areas around the frame–building organisms, in cavities or as large components (pl.12,fig 2).

D. Problematic algae

The most abundant problematic alga in Norian and Late Rhaetian reefs is represented by *Lithocodium* (=Proble- matikum 1, OHLEN 1959) and/or *Bacinella* (pl. 10, fig. 1–3). Occurring in the central reef area and in the "oncolite facies" both are responsible for the formation of oncolites (OHLEN 1959, SCHÄFER 1979, SENOWBARI–DARYAN 1980, FLÜGEL 1981). Also *Thaumatoporella* can be found predominantly in the oncolite-facies. Other algae of uncertain systematic position are usually restricted to the central reef area and are represented mainly by *Baccanella* and rarely *"Tubiphytes"*. The affiliation of *Pycnoporidium ?eomesozoicum* described by FLÜGEL (1970) to the algae is still questionable (pl. 12, fig. 1).

A1

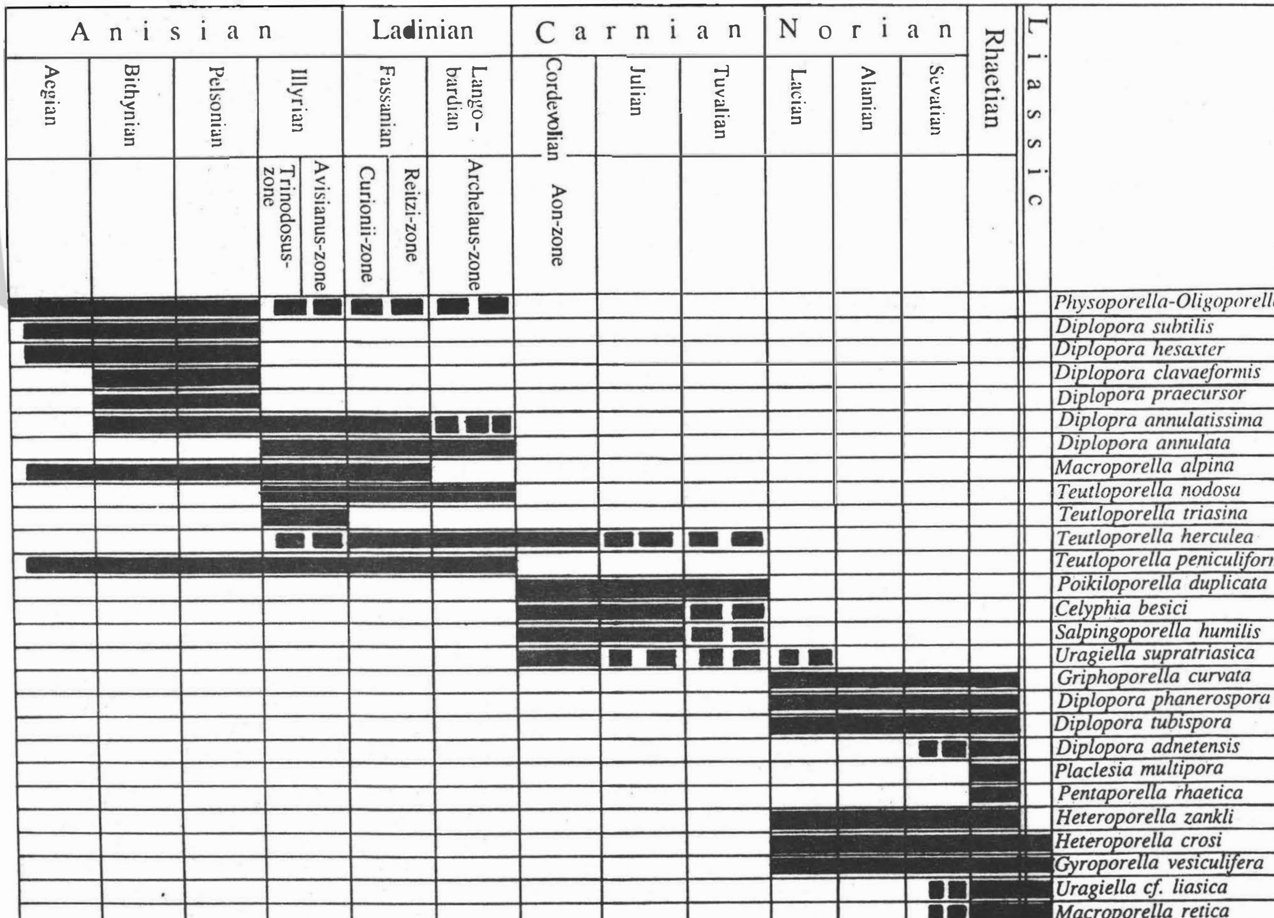

Fig. 3: Stratigraphic range of common dasycladacean algae in the Alps (modified from OTT 1984).

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Plate 1

Fig. 1:
Olangocoelia otti BECHSTÄDT & BRANDNER. Covering the sediment surface this enigmatic and very abundant fossil (sponge?, alga?) in Anisian reef boulders is composed of numerous small (less than 1 mm) spherical chambers. Anisian, Dolomites, Northern Italy, 5,6x.

Fig. 2:
Microbial crusts around a solitary (?) coral of Anisian reefs in Dolomites. The crusts are composed of very thin and dark laminae. Anisian, Dolomites, Northern Italy, 21x.

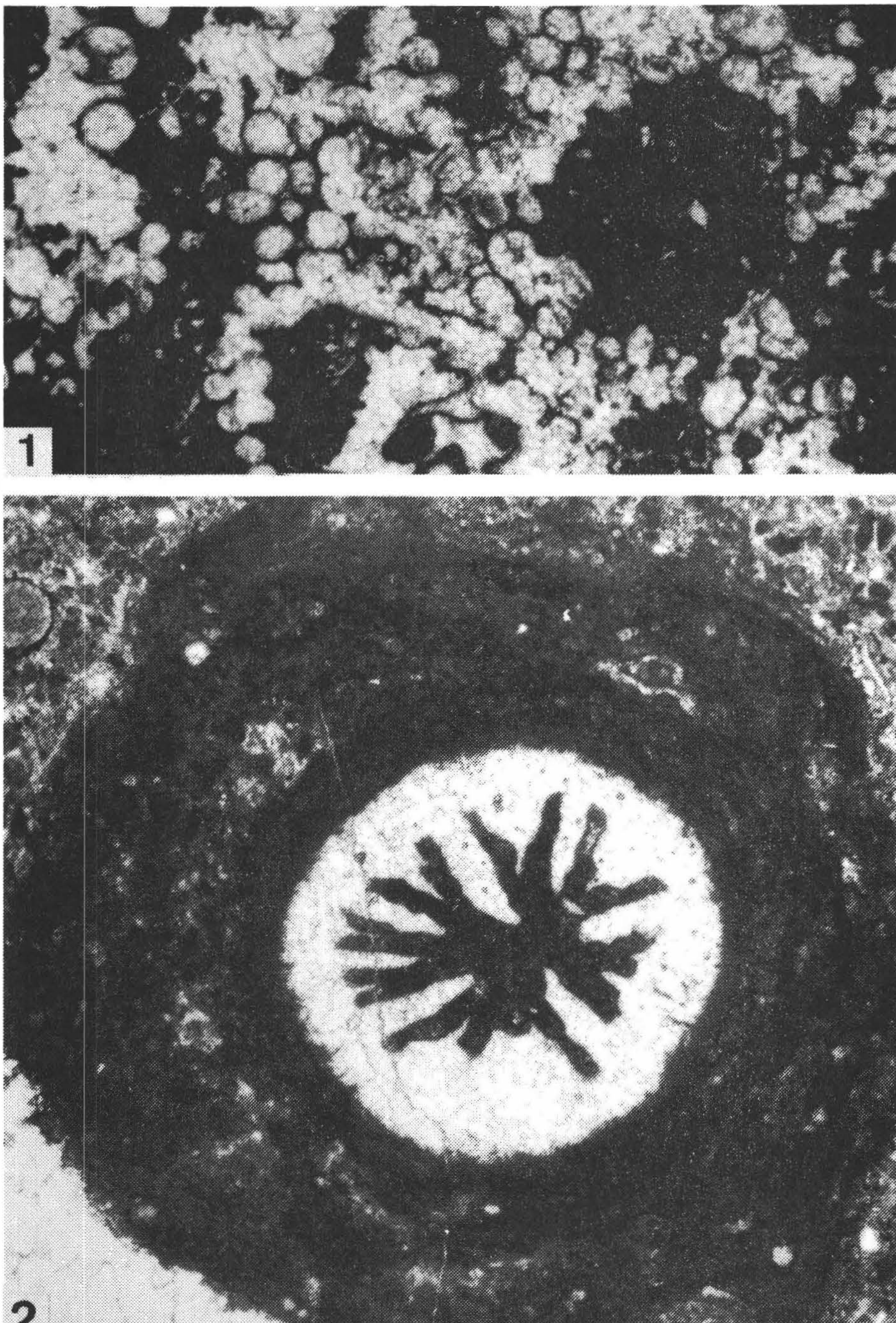
Plate 2

Ladinian microbial ("algal") spongiostromate cyanophyceans are characterized by irregular festoon-shaped crusts consisting of thin micritic laminae and thicker sparite areas. The micritic laminae exhibit a homogenous dense peloidal structure (relics of "algal" tubules). The sparite layers consist of long fibrous calcite forming druses and botryoidal cement. Ladinian reef boulders, Dolomites, Northern Italy, 7x.

Plate 3

This enigmatic fossil described as "*Tubiphytes multisiphonatus*" SCHÄFER & SENOWBARI-DARYAN is an abundant baffling or encrusting organism in Ladinian and Carnian reefs of the Tethyan realm. Ladinian reef boulder, Dolomites, Northern Italy, 7x.

A1



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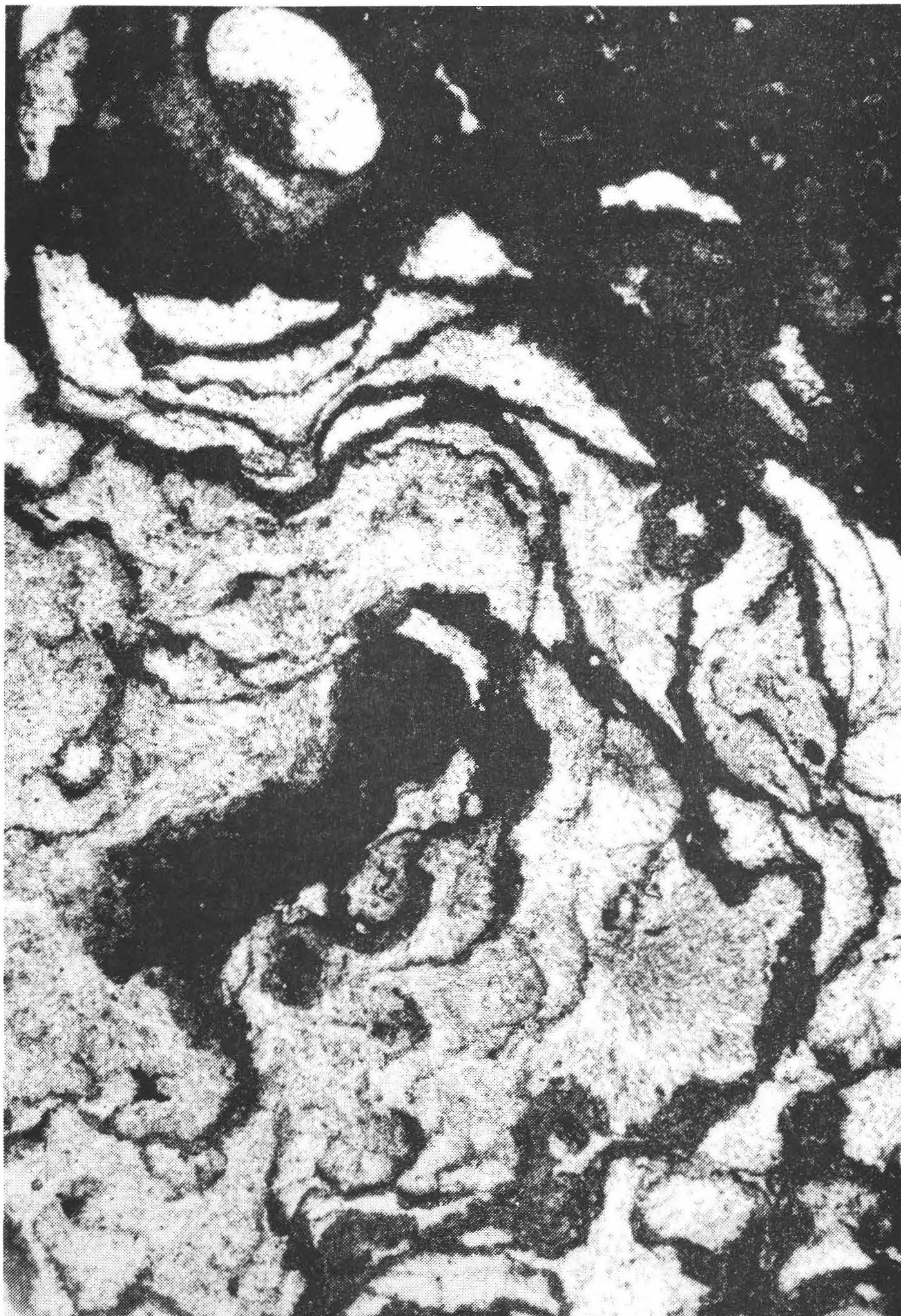

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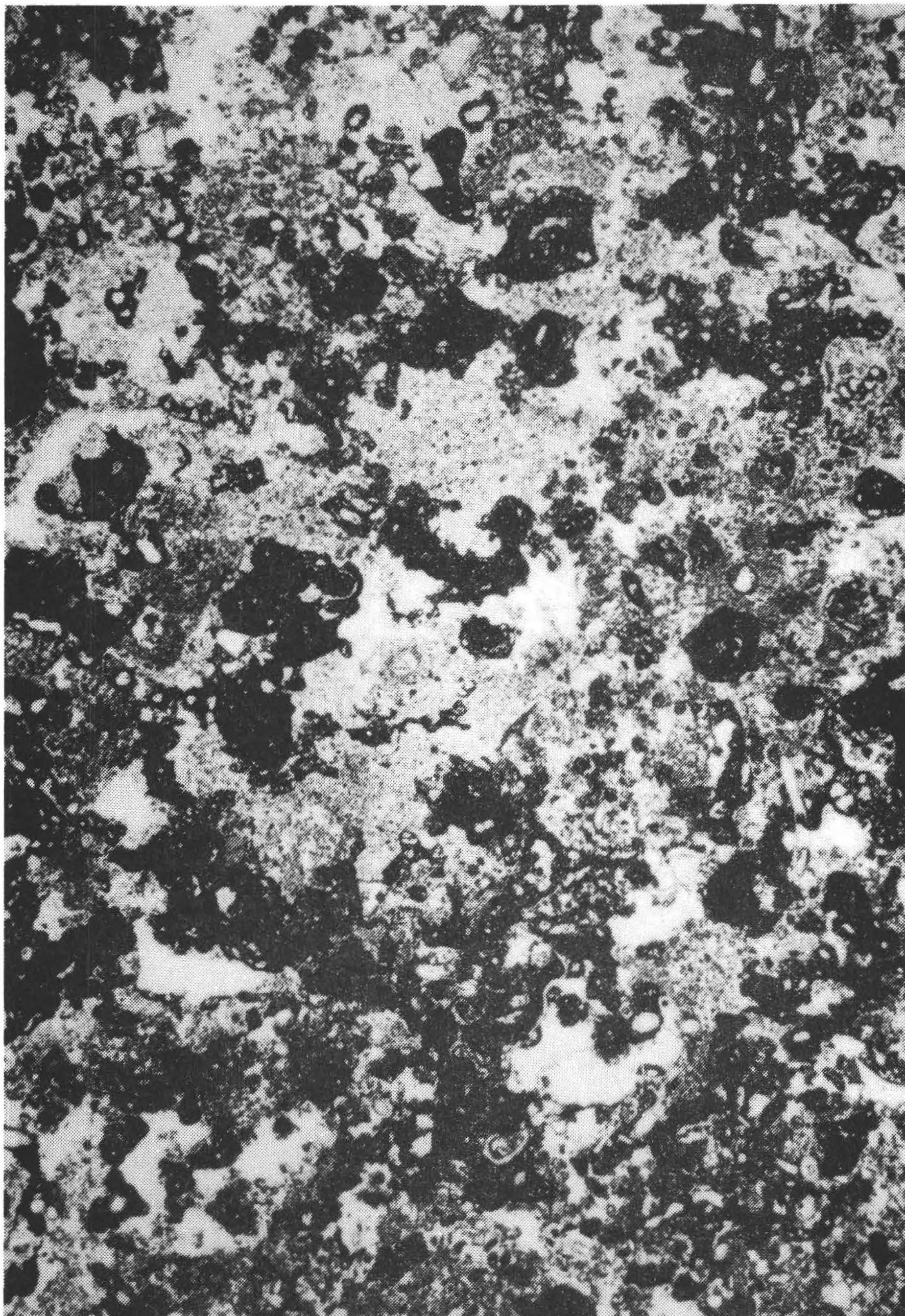

Plate 4

Cladogirvanella cipitensis, OTT is an abundant element in Ladinian reefs. The bush-like and multibranched alga reaches a length of more than 15 cm. For details see pls. 5-6. Ladinian reef boulders, Dolomites, Northern Italy, 3.5x.

Plate 5

REM-microphotograph of two branches of *Cladogirvanella cipitensis* OTT. The space between the branches is filled with sparry calcite cement. Ladinian, Dolomites, Northern Italy.

Plate 6

REM-microphotograph of *Cladogirvanella cipitensis* OTT. Magnification from pl. 4 showing the calcified cell walls of the alga and the sparry calcite cernent within the small cell tubes.

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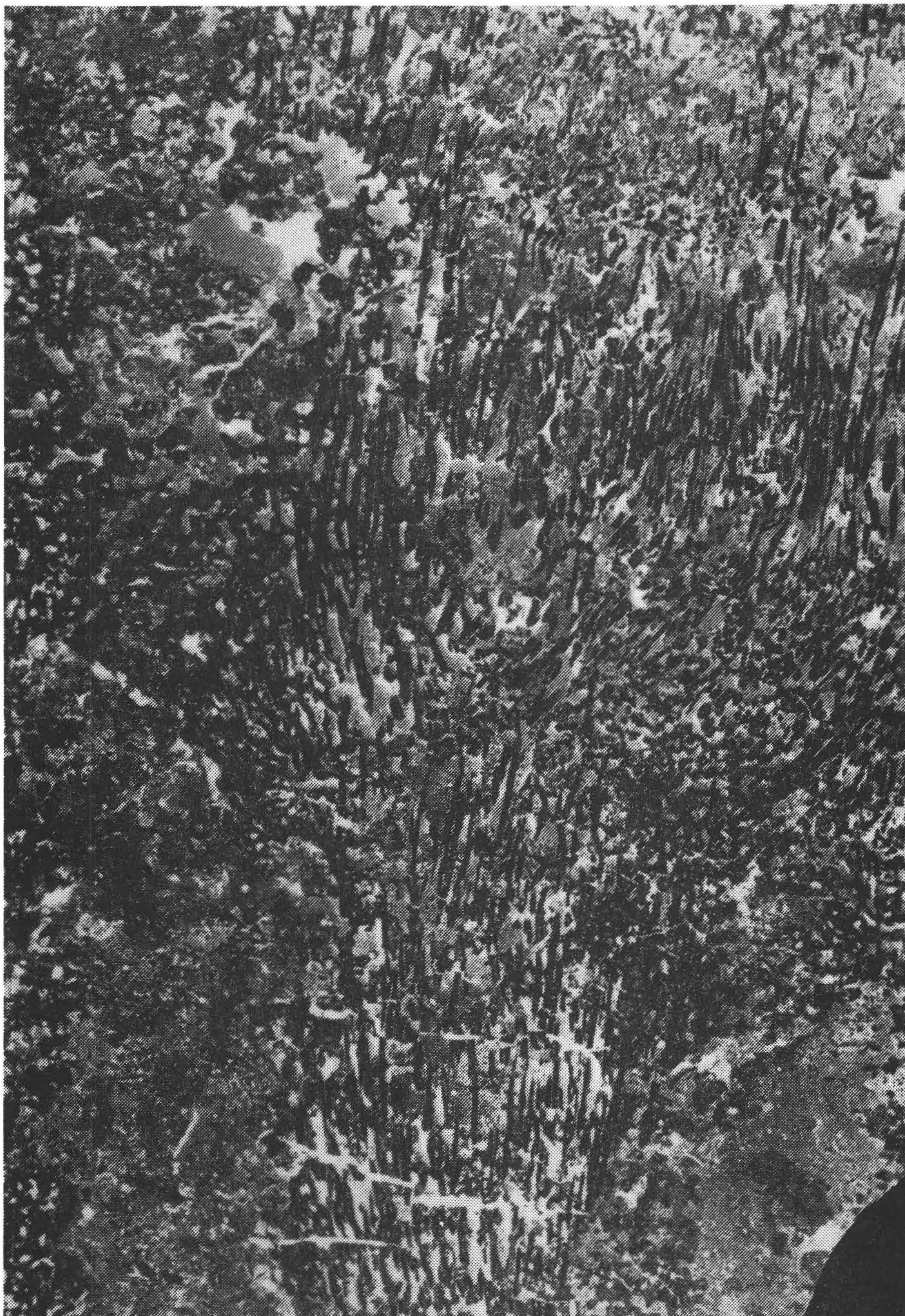

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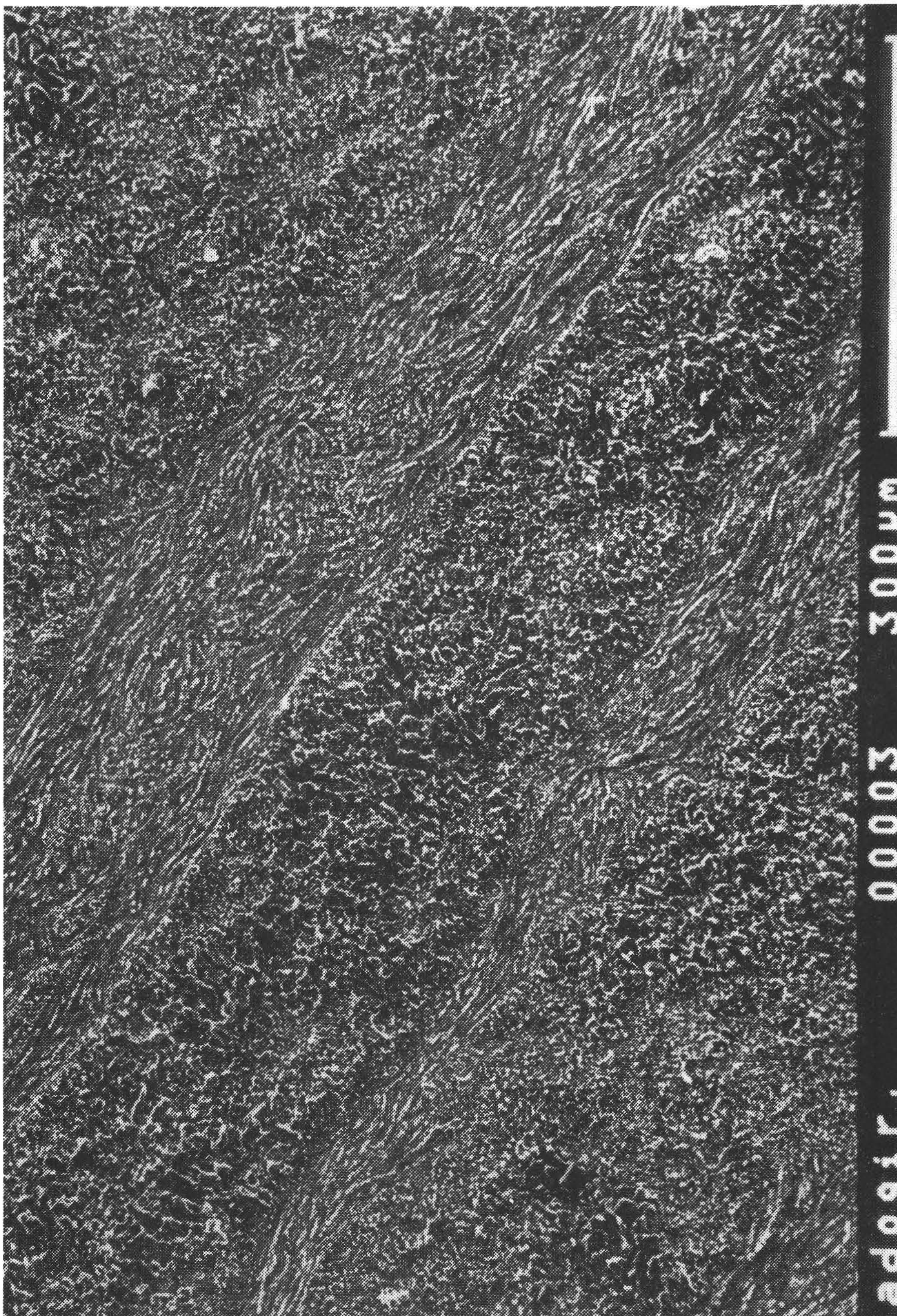

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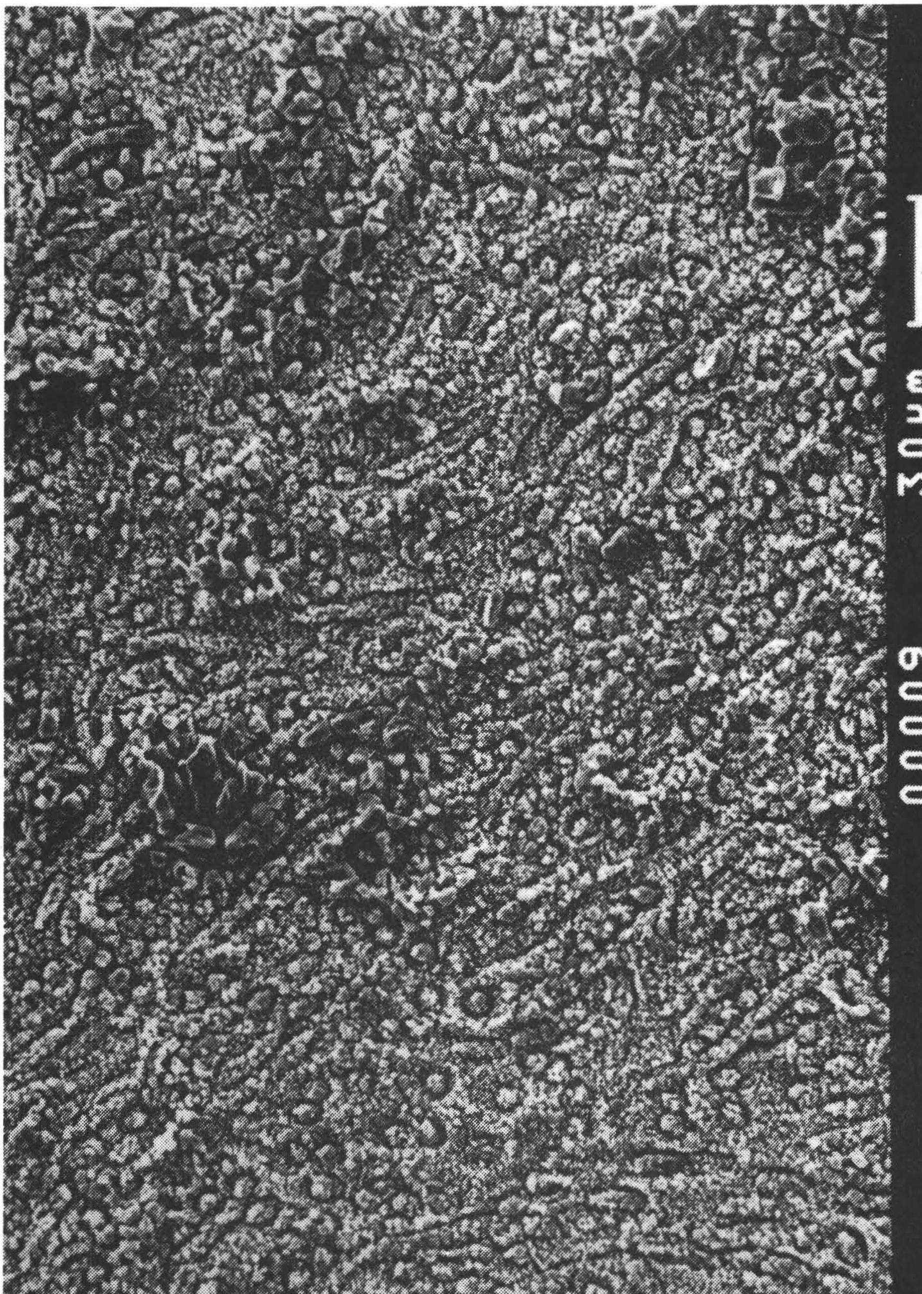


Plate 7

Fig 1:
Crusts (type 1) of Carnian reefs. The crusts are composed of dark micritic laminae similar to those of Ladinian age. Carnian, Slovenia; approximately 0.7x.

Fig. 2:
Crusts (type 2) of Carnian reefs. This type of crusts is composed of bubble like segments with dark micritic walls. The interior of the segments is filled with sparry calcite cement or with sediment. The systematic position of these crusts is uncertain (sponge? algae?). Carnian, Slovenia, 7x.

Plate 8

Fig. 1:
Cross and oblique section of *Diplopora* sp. from Upper Rhaetian reef of Feichtenstein near Hintersee, Salzburg. 10.5x.

Fig. 2:
Diplopora phanerospora PIA a relatively abundant dasycladacean in Upper Rhaetian reefs and shallow water limestones. Upper Rhaetian of Feichtenstein reef near Hintersee, Salzburg, 10.5x.

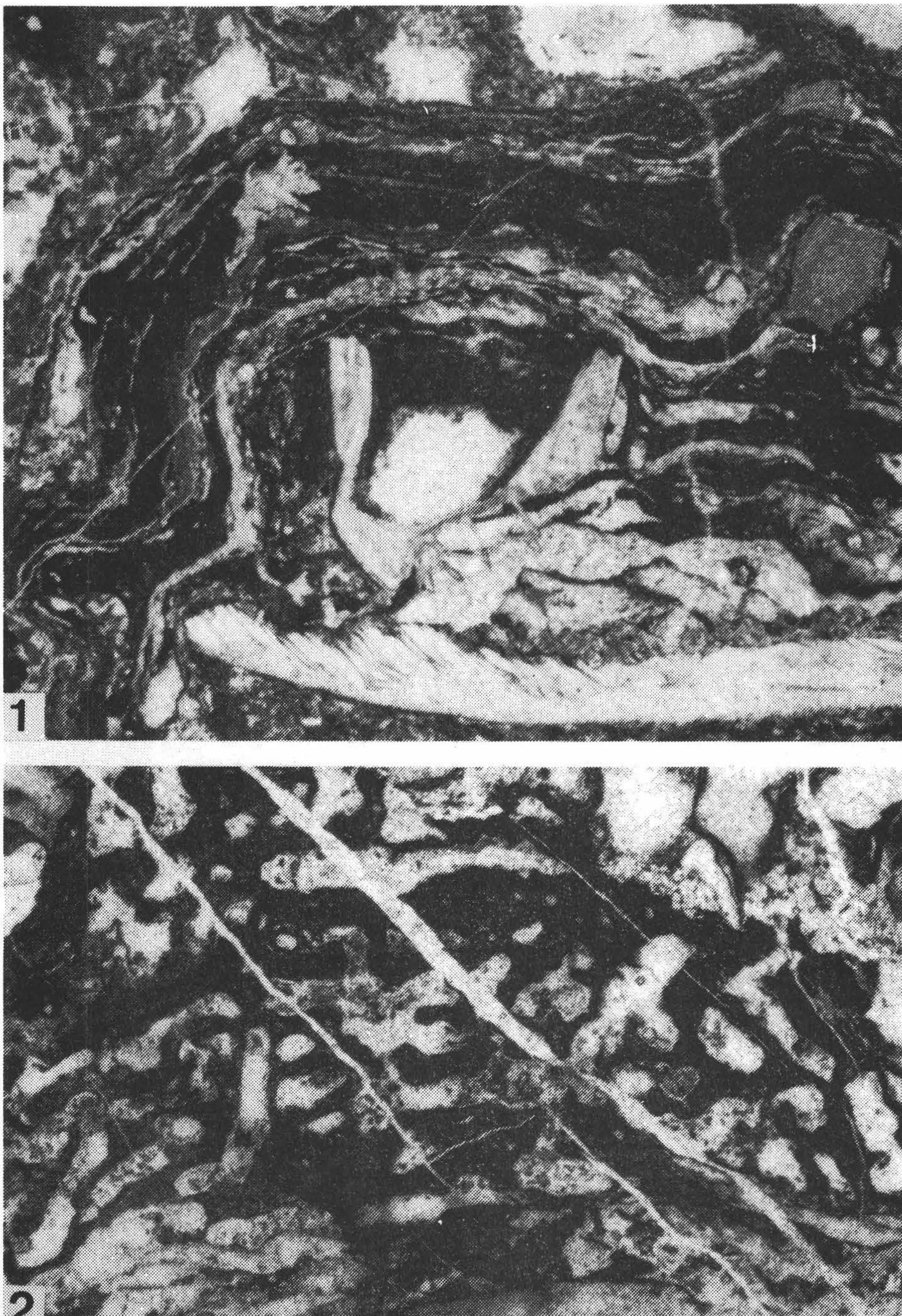
Fig. 3:
Diplopora tubispora OTT. Upper Rhaetian Feichenstein reef near Hintersee, Salzburg. 28x.

Fig. 4:
Griphoporella curvata (GÜMBEL). Cross section. Upper Rhaetian Gruber reef near Hintersee, Salzburg. 15.4x.

Plate 9

Figs. 1–3:
Pentaporella rhaetica SENOWBARI - DARYAN from Upper Rhaetian Gruber reef near Hintersee, Salzburg.
Fig. 1: 28x
Fig. 2. 28x.
Fig. 3: 63x.

Fig. 4:
Diplopora phanerospora PIA from Upper Rhaetian Feichtenstein reef near Hintersee, Salzburg. 25.9x.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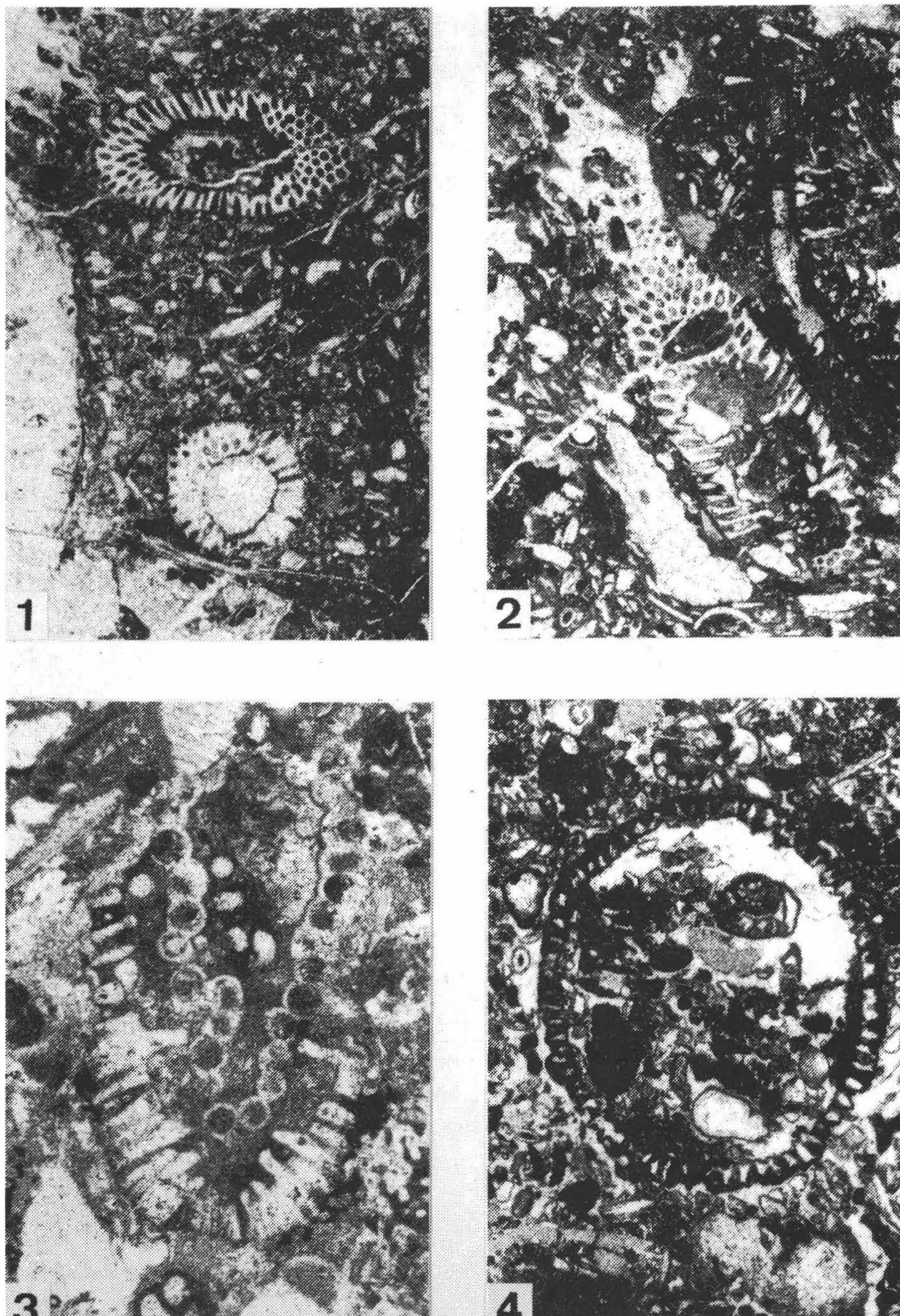
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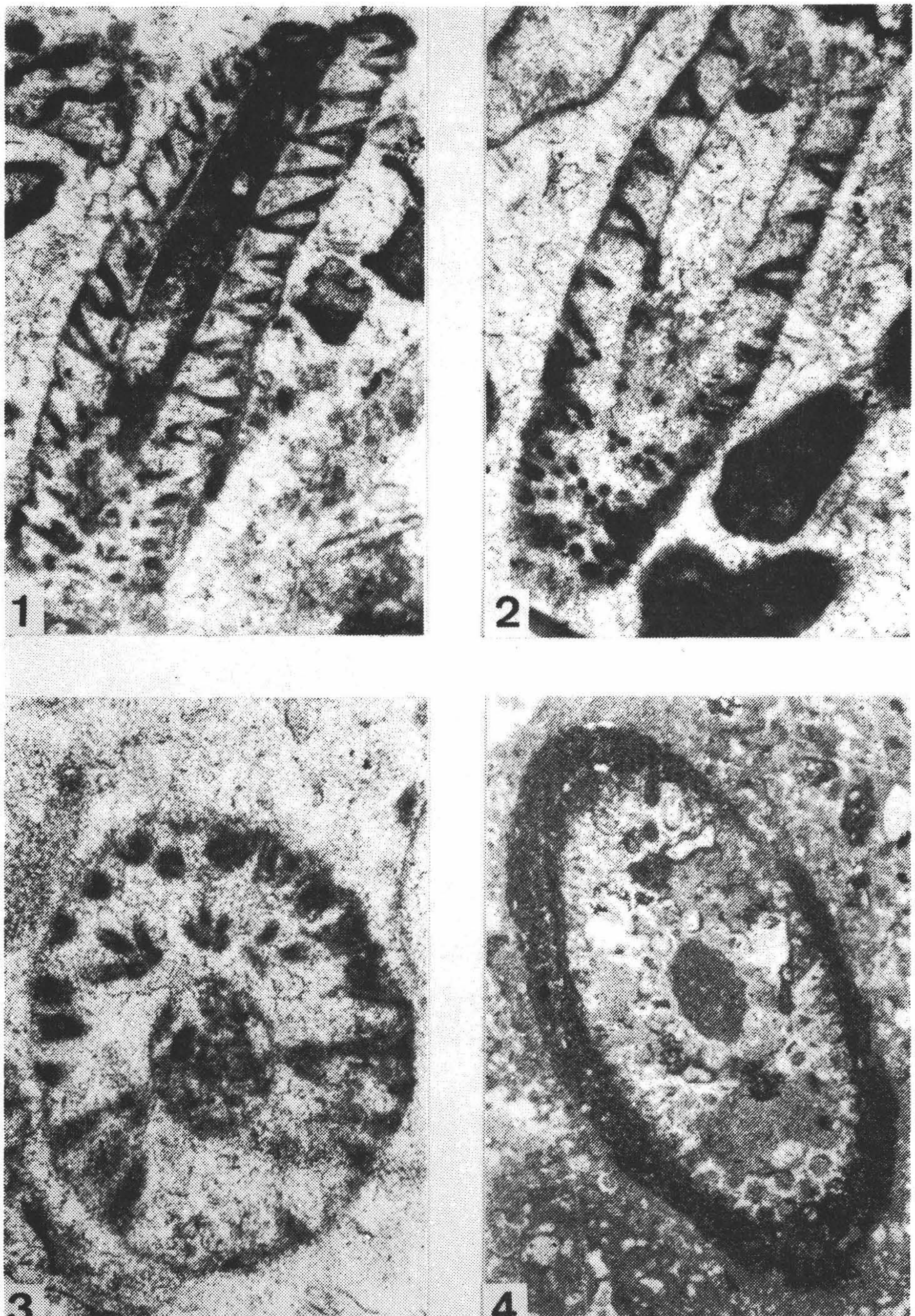

Plate 10

Fig. 1:
Oncolite facies of Upper Rhaetian reefs. Bioclasts of the dasycladacean alga *Heteroporella* serve as nuclei of oncoids encrusted by *Lithocodium/Bacinella*. Feichtenstein reef near Hintersee, Salzburg. Approximately 3.5x.

Fig. 2:
Different bioclasts are formed to a large "algal lump" by *Lithocodium/Bacinella*. Upper Rhaetian reef of Feichtenstein near Hintersee, Salzburg. 2.5x.

Fig. 3:
Lithocodium/Bacinella encrusting a coral. Also the interseptal space of the coral is filled by *Lithocodium/Bacinella* "tissue". Upper Rhaetian reef of Feichtenstein near Hintersee, Salzburg. 2.8x.

Fig. 4:
Diplopora adnetensis FLÜGEL, an abundant dasycladacean in the Upper Rhaetian reefs near Salzburg. Gruber reef near Hintersee. 5.3x.

Plate 11

Fig. 1:
Solenopora alcicornis OTT. The multibranched alga is relatively abundant in Norian/Rhaetian reef limestones.Upper Rhaetian Gruber reef near Hintersee,Salzburg. 2.1x

Fig. 2:
Abatea culleiformis SENOWBARI--DARYAN & SCHÄFER, a gymnocodiacean of Upper Rhaetian reefs. Upper Rhaetian Gruber reef near Hintersee, Salzburg. 7x.

Fig. 3–4:
Placklesia multipora BILGÜTAY found only in Kössen Beds. Both specimens are from Feichtenstein near Hintersee, Salzburg. 42x.

Plate 12

Fig. 1:
Pycnoporidium ?eomesozoicum FLÜGEL (around a shell) encrusting a sponge. The systematic position of this fossil is uncertain. Gosaukamm, approximately 4.2x.

Fig. 2:
Typically spongiostromate crusts of Norian/Rhaetian reefs are built by multilayered micritic laminae of usually several mm. Gosaukamm. 4.2x.

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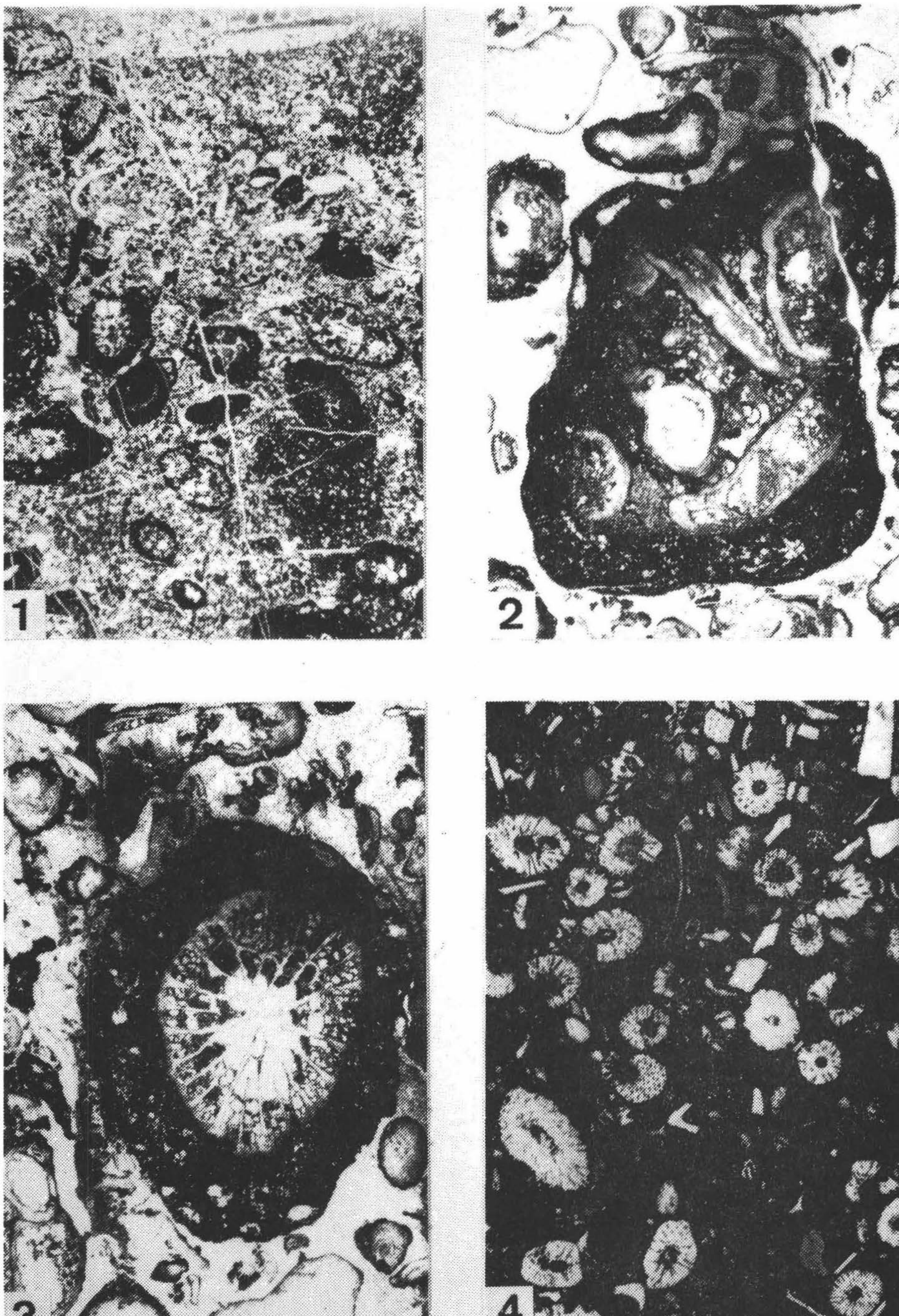

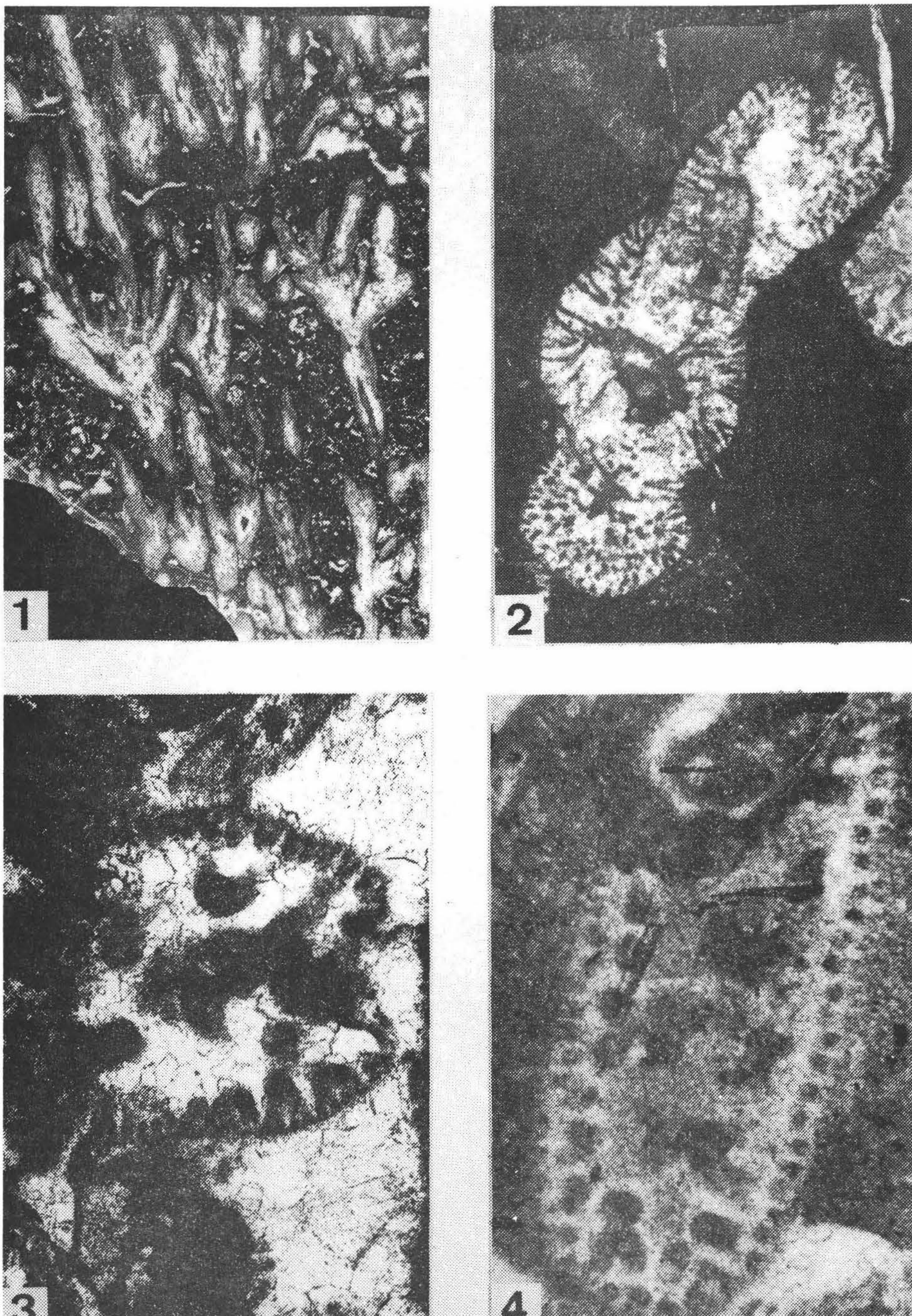
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