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Dasycladaleans and Depositional Environments of the Upper Triassic-Liassic Carbonate Platform of the Gran Sasso (Central Apennines, Italy)

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KEYWORDS: FACIES ANALYSIS - MICROPALAEONTOLOGY (DASYCLADALES, NEW TAXA) - PALAEOECOLOGY - CARBONATE PLATFORM - CENTRAL APENNINE (ITALY) - UPPER TRIASSIC-LOWER JURASSIC

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SUMMARY

Sedimentological and paleontological studies carried out on the Upper Triassic Dolomia Principale and on the Lower Liassic Calcare Massiccio carbonate platform successions of the Gran Sasso area (Central Apennine, Italy) allowed to recognize several microfacies types arranged in three different types of high frequency cycles, subtidal, peritidal and diagenetic. The cycles can be attributed to high frequency sea-level oscillations on a fifth and fourth order scale.

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Five algal assemblages have been identified: 1. *Gyroporella vesiculifera*, 2. *Griphoporella curvata*, 3. *Palaeodasycladus* spp., 4. *Palaeodasycladus* and *Thaumatoporella*, and 5. *Tersella genoti* and *Fanesella sokaci* assemblage. In this latter assemblage two new species (*Tersella genoti* n.sp. and *Fanesella sokaci* n.sp.) are described, both from Liassic beds. *Tersella genoti* differs from the other *Tersella* species for a less 'differentiated' club shaped thallus, the shape of secondary branches and size. *Fanesella sokaci* differs from other species of the same genus in shape and size of the branches, size of the thallus and degree of calcification.

A re-evaluation of the genus *Tersella* MORELLET considers Morellet's original diagnosis to be apter than the subsequent emendations. A discussion on several "Terselliform" taxa (*Dissocladella cretica*, *Linoporella lucasi*, *Dissocladella iberica* and *Dissocladella ebroensis*) is supplied.

Some comments on the genus *Fanesella* CROS & LEMOINE and *Palaeodasycladus gracilis* CROS & LEMOINE are given.

Several facies units have been identified on the basis of frequency and distribution of algal assemblages and type of cycle, each unit recording a different depositional paleo-environment.

In the Dolomia Principale Formation two main depositional environments have been recognized:

- a shelf lagoon facies characterized by subtidal and peritidal cycles dominated by the *Gyroporella vesiculifera* algal assemblage;
- a backmargin facies marked by peritidal and diagenetic cycles in which the *Griphoporella curvata* algal assemblage is widespread.

In the Calcare Massiccio Formation the following depositional environments have been recognized:

- a back-margin facies characterized by diagenetic cycles with high energy subtidal units and the *Palaeodasycladus* spp. algal assemblage. The presence of the *Palaeodasycladus* and *Thaumatoporella* algal assemblage indicates a local transition to a more protected open lagoon environment.

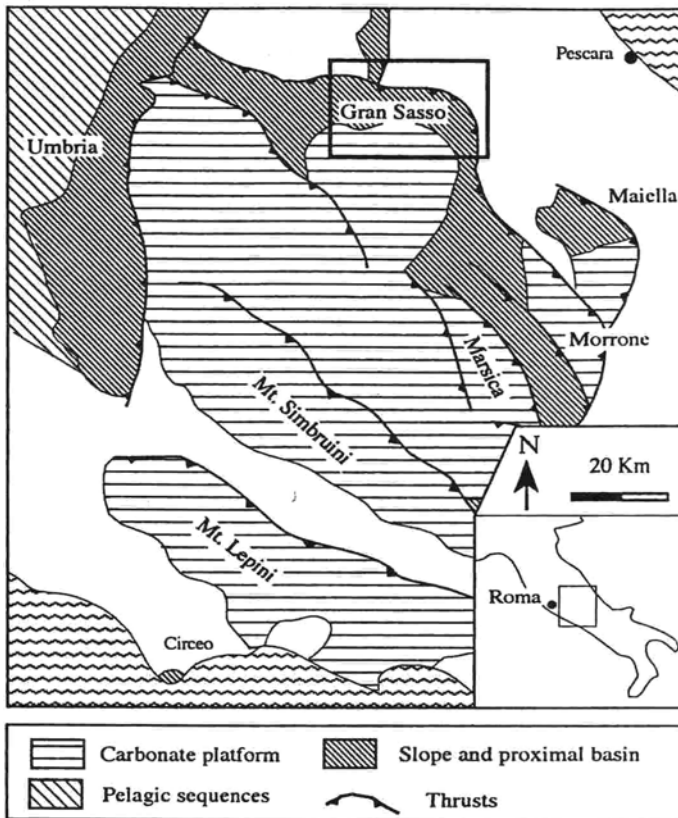


Fig. 1. Facies distribution map of central Apennines showing the location of the studied area.

- a margin facies characterized by oolites and bioclastic sandy shoals, with minor contributions of reef-building organisms, and by a very poor cyclothemic organization. This facies is marked by the widespread occurrence of the *Tersella genoti* and *Fanesella sokaci* algal assemblage

The environmental distribution of subtidal, peritidal and diagenetic cycles within the facies units were probably controlled more by the relative position to the margin than by the amplitude of the high frequency sea level fluctuations.

The distribution of facies units allowed the reconstruction of the paleoenvironmental evolution of the shallow water facies in this area during the Late Triassic-Early Liassic interval.

In the Late Triassic a shallow water carbonate facies (from lagoonal to backmargin) extended in the western and southern parts of the Gran Sasso area. In the Early Liassic the platform facies retrograded, and the margin moved back to the west and south of the Gran Sasso area. In the Middle Liassic, extensional tectonics fragmented the Calcare Massiccio platform. Large platform areas were drowned, and shallow water sedimentation retreated to the South of the Gran Sasso range.

RIASSUNTO

E' stata condotta un'analisi sedimentologica e micropaleontologica sulle successioni di piattaforma carbonatica della Dolomia Principale (Trias superiore) e

del Calcare Massiccio (Lias inferiore) dell'area del Gran Sasso (Appennino centrale, Italia), al fine di precisarne l'assetto stratigrafico, il contenuto algale, la distribuzione delle facies e dei paleoambienti.

Lo studio paleontologico ha messo in luce un ricco contenuto algale rappresentato da 5 associazioni ad alghe verdi dasicladali tra le quali sono state riconosciute due nuove specie, entrambe del Lias *Tersella genoti* n.sp. e *Fanesella sokaci* n.sp. *Tersella genoti* differisce dalle altre specie affini per un tallo claviforme meno "differenziato", per la forma dei rami secondari e le dimensioni delle varie parti del tallo. *Fanesella sokaci* differisce dalle altre *Faneselle* per la forma e le dimensioni dei rami, per le dimensioni del tallo nonché per l'andamento ed il grado di calcificazione. Vengono fornite, inoltre, osservazioni sui generi *Tersella* MORELLET in MORELLET & TERS 1951 e *Fanesella* CROS & LEMOINE 1966 ex GRANIER & DELOFFRE 1993.

L'analisi sedimentologica ha evidenziato una notevole varietà di microfacies sia nella Dolomia Principale che nel Calcare Massiccio la cui distribuzione verticale definisce quasi sempre un assetto ciclico con ciclicità ad alta frequenza di quarto e quinto ordine. Tre diversi tipi di cicli, subtidali, diagenetici e peritidali sono stati identificati. I cicli appaiono controllati da oscillazioni eustatiche ad alta frequenza.

La distribuzione e la frequenza delle microfacies, dei tipi di cicli e delle associazioni algali presenti, identificano varie facies deposizionali indicanti differenti paleoambienti.

Nella Dolomia Principale sono stati riconosciuti due ambienti deposizionali;

- facies di laguna occasionalmente a circolazione ristretta, caratterizzata dalla presenza di cicli a carattere subtidale e peritidale e dalla predominanza dell'associazione algale a *Gyroporella vesiculifera*.

- facies di retromargine, caratterizzata da cicli peritidali e diagenetici e dall'associazione algale a *Griphoporella curvata*.

Nel Calcare Massiccio sono stati invece riconosciuti i seguenti ambienti deposizionali:

- facies di retromargine, caratterizzata da cicli diagenetici con intervallo subtidale di alta energia e dalla associazione algale a *Paleodasycladus* spp. La presenza occasionale in questa facies della associazione algale a *Paleodasycladus* e *Thaumatoporella* indica la transizione ad un ambiente relativamente più protetto di laguna aperta.

- facies di margine, caratterizzata da barre oolitico-bioclastiche con modesti contributi di organismi costruttori che probabilmente formavano piccoli *patch reefs* in prossimità dell'area marginale. La facies si caratterizza inoltre per la scarsa organizzazione ciclica e per la dominanza dell'associazione algale a *Tersella genoti* e *Fanesella sokaci*.

La distribuzione dei cicli (cicli subtidali, peritidali e diagenetici) nei paleoambienti deposizionali appare principalmente controllata da differenze nel rilievo topografico

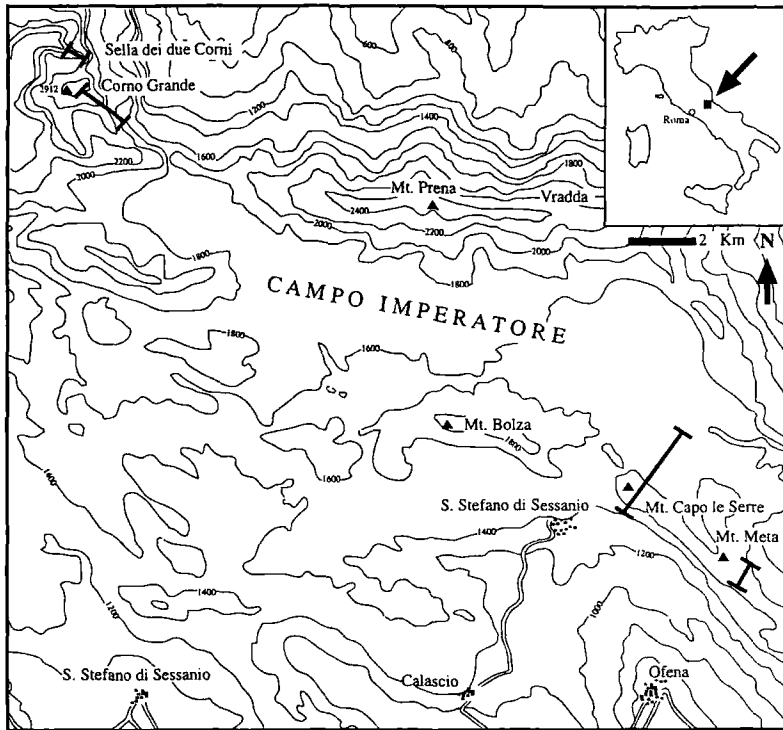


Fig. 2. Topographic sketch of the Gran Sasso area (Central Italy), showing the position of the main stratigraphic sections which Upper Triassic- Lower Liassic dasycladalean come from.

degli stessi, piuttosto che dalla ampiezza delle oscillazioni eustatiche ad alta frequenza.

La distribuzione delle facies nel tempo, ha inoltre consentito di ricostruire l'evoluzione paleoambientale dell'area.

Nel Trias superiore facies carbonatiche di mare sottile si deponavano nella porzione occidentale della catena del Gran Sasso e a Sud di essa (Campo Imperatore), in un ambiente variabile da lagunare ristretto al retromargine.

Nel Lias inferiore le facies di piattaforma arretrarono e facies di margine si stabilirono al Corno Grande e immediatamente a Sud della catena del Gran Sasso.

Nel Lias medio, in seguito ad un importante fase estensionale, la piattaforma del Calcare Massiccio annegò in tutta l'area del Gran Sasso.

1 INTRODUCTION

The Late Triassic-Early Liassic of the Gran Sasso area is characterized by carbonate sediments, of platform and basinal facies (BIGOZZI, 1987; DURANTI, 1987; ADAMOLI et al., 1990; Bigozzi et al., 1992). The shallow water facies are represented by the Norian-Raethian Dolomia Principale Fm. and by the Lower Liassic Calcare Massiccio Fm. They outcrop widely along the western part of the Gran Sasso range and southwards in the Mt. Meta-Capo le Serre-Ofena area. The basinal facies are represented by "Norian Bituminous Dolomites passing upwards to thin bedded dolomites" (Raethian p.p.), "Spotted Limestones and Cherty Limestones with scattered turbiditic calcarenites" (lower Lias). These basinal facies spread out in the eastern sector

of the Gran Sasso range (GHISETTI et al., 1990; BIGOZZI 1994).

On account of the strong late dolomitization extensively affecting the Dolomia Principale (D.P.) and partially the Calcare Massiccio (C. M.), the Gran Sasso area had not been object of detailed biostratigraphical and sedimentological studies up now. Even the fossil content (especially algae) is known only in part (BENEÒ, 1941; CHIOCCHINI, 1977; CHIOCCHINI & MANCINELLI, 1978).

The purpose of the present paper is to supply further data concerning facies types, algal biota and paleogeographic setting of the shallow water sediments of the Gran Sasso area during the Late Triassic - Early Liassic.

The sedimentological and micropaleontological analysis allow to discuss the facies distribution and paleoenvironmental reconstructions. The rich dasycladalean assemblages supply also some interesting biostratigraphical data.

2 LOCATION AND GEOLOGICAL SETTING

The Gran Sasso area is located at the northern margin of the Latium-Abruzzi carbonate platform, a large sedimentary body, about 200 km wide, which constitutes the core of the Central Apennine mountain range (Fig. 1). The Latium-Abruzzi platform consists of a thick sequence of shallow-water carbonates, deposited along the Southern margin of Tethys, from the Late Triassic to Miocene (COLACICCHI, 1987).

The geologic history of the Gran Sasso area, as most of the Italian peninsula, records the evolution of this margin which has been interpreted as a promontory of the African continental margin or as an isolated microplate known as Adria (CHANNEL et al. 1979; DERCOURT et al. 1986, STAMPLI & PILLEVUIT, 1993).

During the Late Triassic the western Mediterranean region, that was still part of an undifferentiated continental block formed by Europe, Africa and North America, underwent crustal extension due to the progressive westward opening of the Neotethys ocean (ZIEGLER 1988; Marcoux et al. 1993). The extensional regime determined the transgressions of shallow seas over part of this continent and the development of wide carbonate platforms (ZAPPATERA 1990).

During the Norian, evaporitic to peritidal carbonates sedimented over much of the Italian peninsula; local euxinic troughs developed as pull apart basins, related to transcurrent movements associated with the rifting phase (ZAPPATERA, 1990).

At this time in the Gran Sasso area, two depositional environments were differentiated: a carbonate platform, in which the shallow water facies of the Dolomia Principale

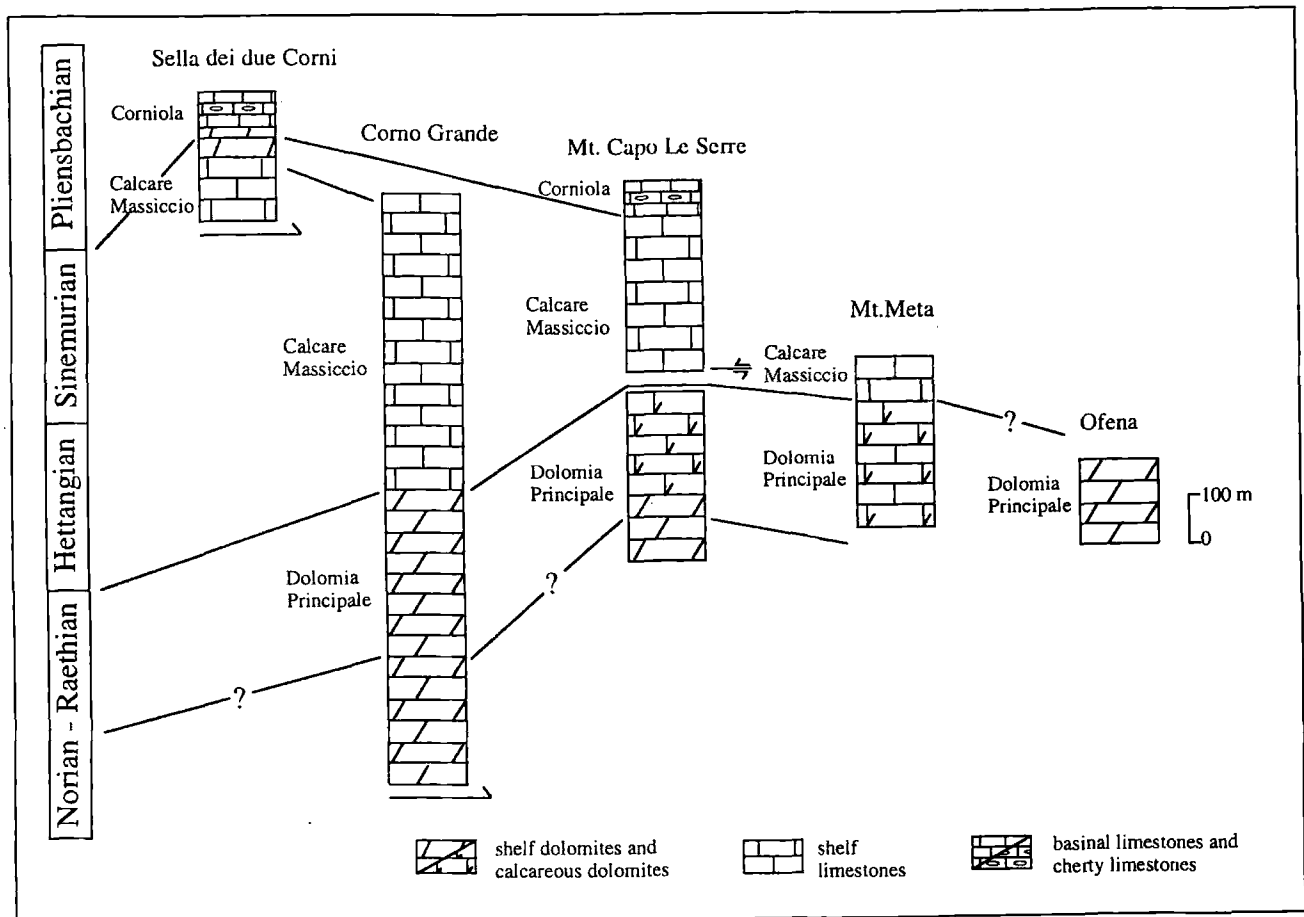


Fig. 3. Chronostratigraphic correlation of the Upper Triassic-Lower Liassic investigated successions (Gran Sasso area, Central Italy).

sedimented, and an euxinic trough, the Gran Sasso basin, in which bituminous dolomites deposited (ADAMOLI et al., 1990; BIGOZZI et al., 1992; BIGOZZI, 1994).

In the Early Jurassic new extensional phases affected the whole Italian region causing the opening of new rifting basins and the fragmentation and progressive drowning of some platforms (BASSOLLET et al., 1993; WINTERER & BOSELLINI, 1981; SARTI et al., 1992).

During the early Liassic this extensional regime determined the expansion of the Gran Sasso basin, which was connected to the Ionian and Belluno basins, and in the middle Liassic the break up and successive drowning of the Calcare Massiccio carbonate platform (ZAPPATERRA, 1990; ADAMOLI et al., 1978; BIGOZZI, 1993; 1994).

The Italian paleogeographic situation was substantially modified at the end of the middle Liassic; platform areas were strongly reduced and the pelagic domain extended from the Southern Alps to the Northern Apennine, even up to the Adriatic region. Shallow water sedimentation however continued in the Central and Southern Apennine, in the Latium-Abruzzi platform, which arose in this period as a distinct paleogeographic unit.

Starting from the middle Liassic, the Gran Sasso became a transition zone between the newly formed Umbria-Marchean pelagic basin and the Latium-Abruzzi platform (ADAMOLI et al., 1982 a): slope to proximal basin sedimentation resulted in the deposition of cherty limestones with abundant megabreccias and calcareous turbidites.

The rifting phase in central Italy ended in the middle Jurassic with the opening of the Ligurid ocean (ZIEGLER, 1988; ABBATE et al., 1992; ENAY et al., 1993). The Gran Sasso area then became part of the African passive margin which existed until the Oligocene when it was incorporated in the Apennine fold and thrust belt.

3 PREVIOUS WORKS

The Upper Triassic-Lower Liassic sequences of the Gran Sasso area have been almost completely ignored for a long time. This fact is partially justified by the strong late dolomitization that affects these successions.

A certain interest, for its mining value, is manifested in the first half part of this century for the "Scisti Bituminosi", a bituminous dolomitic succession, which outcrops in the eastern side of the Gran Sasso range, and that is doubtfully assigned to the Late Triassic by BENEVO (1941). Significant stratigraphic data on the region are given by several authors, especially on occasion of the geological mapping at scale 1:100,000 of the Sheets Sulmona and Teramo respectively (MANFREDINI, 1958, 1959; SCARSELLA 1953, 1954, 1955 a, 1955 b, 1958, 1959). These authors recognize Upper Triassic platform facies only in the Ofena area, but they misunderstand all the other Triassic outcrops of the Gran Sasso area attributing them to the lower Liassic Calcare Massiccio Fm. However in their tentative palaeogeographic reconstruction the Gran Sasso area is correctly

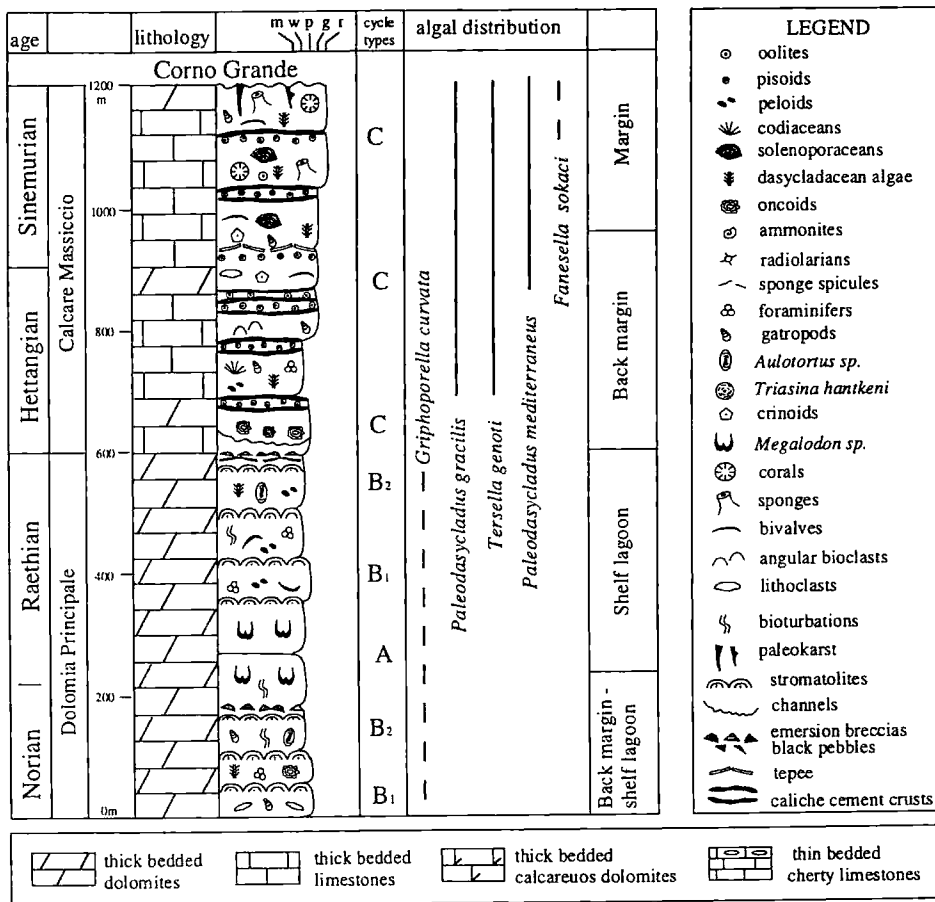


Fig. 4. Stratigraphic sketch of Corno Grande succession (Gran Sasso area, Central Italy) showing lithology, sedimentary cycles, dasycladacean algae and depositional paleoenvironments distribution.

A, subtidal cycles;
B1, incomplete peritidal cycles;
B2, complete peritidal cycles;
C, diagenetic cycles.

interpreted as a transitional zone between the Latium-Abruzzi carbonate platform and the Umbria-Marchean pelagic basin (Fig. 1).

The earliest significant paleontological data on the Triassic terrains are provided by ALESSANDRI et al. (1968). The fossils documented the presence of Upper Triassic platform facies in the western side of Corno Grande.

ADAMOLI et al. (1978, 1982a, 1982b, 1984), CHIOCCHINI (1977) and CHIOCCHINI & MANCINELLI (1978), carried out new stratigraphic and micropaleontological studies of the Triassic-Jurassic successions. They recognize the presence of Triassic shallow-water facies in the Mt. Meta-Mt. Capo Le Serre area, at the base of Mt. Preña and doubtfully at Vradda (eastern side of the Gran Sasso range). They also provide a paleogeographic reconstruction with a wide Late Triassic-Early Lias carbonate platform, which is fragmented and drowned in the Middle Liassic by an important extensional phase.

Recent contributions by BIGOZZI (1987), DURANTI (1987), ADAMOLI et al. (1990) and BIGOZZI et al. (1992) give further data on stratigraphy and palaeogeography of this area. The presence of carbonate platform and basinal facies is recognized and the detailed distribution of Upper Triassic-lower Liassic terrains along the Gran Sasso range is worked out on the basis of micropaleontological and sedimentological data. BIGOZZI et al. (1992) describe the following three successions:

- Valle dell' Inferno-Corno Grande succession which is entirely characterized by carbonate platform facies;

- Canala-Mt. Preña succession which is characterized by a platform to basin transition at the base and by platform facies in the upper part;

- Vradda sequence which is entirely characterized by basinal facies from the Late Triassic up to Late Jurassic.

BIGOZZI (1990) has carried out a study on the cyclicity of the Corno Grande Late Triassic-early Liassic platform succession, documenting the probable presence of orbitally forcing cyclicity referable to the precessional-eccentricity variations. BIGOZZI (1993, 1994) described the sequential evolution of the Gran Sasso area in the Late Triassic-Early Liassic interval, while GHISETTI et al. (1990) and VEZZANI et al. (1993) provided new geological maps of the Gran Sasso area at the scale 1:25,000 and 1:100,000.

4 INVESTIGATED SUCCESSIONS

Five Upper Triassic-lower Liassic shallow-water successions have been investigated: Corno Grande, Sella dei due Corni, Mt. Meta, Mt. Capo le Serre and Ofena (Figs. 2-3). These successions belong to the same tectonic unit so that the original palaeogeographic relations among these successions are roughly preserved (VEZZANI et al., 1993).

Corno Grande succession

The Corno Grande succession (Fig. 4), located at the eastern slope of this relief along the Valle dell' Inferno in the western side of the Gran Sasso range, is 1,200 m thick. It rests on the hanging wall of a splay thrust (GHISETTI et al.,

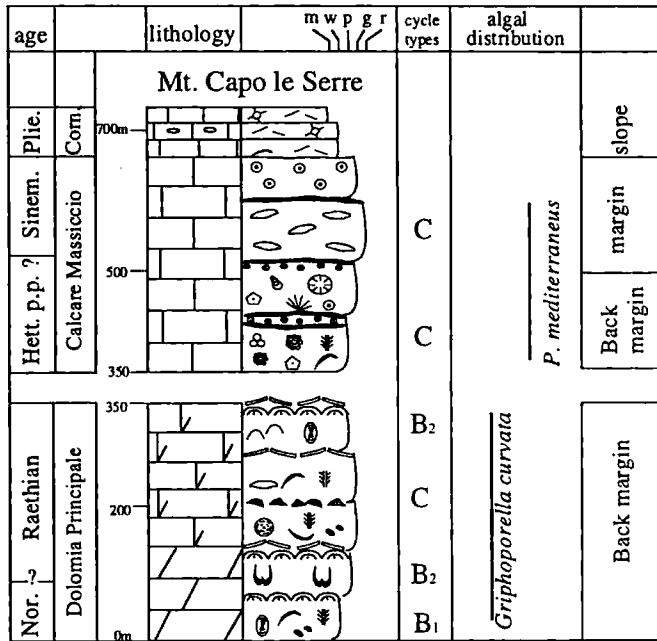


Fig. 5. Stratigraphic sketch of Mt. Capo le Serre succession (Gran Sasso area, Central Italy) showing lithology, sedimentary cycles and dasycladalean algae distribution, and the depositional paleoenvironments (for symbols see Fig. 4).

1990) and is composed of 600 m of Dolomia Principale followed by 600 m of Calcare Massiccio. About 300 samples have been collected, but only in the Calcare Massiccio formation well-preserved dasycladacean algae have been found. The Dolomia Principale contains a poor assemblage, represented quite exclusively by highly dolomitized dasycladaceans (probably *Griphoporella curvata*). The top of the succession is truncated by the splay thrust which superimposes the Sella dei due Corni sequence upon it.

Mt. Capo Le Serre succession

The Mt. Capo Le Serre succession (Fig. 5) is located at the South-East side of Campo Imperatore. It is composed of about 350 m of Dolomia Pricipale and of 300 m of Calcare Massiccio, separated by a normal fault. The sequence is limited downwards and upwards by normal faults. About 70 samples with a frequent dasyclad content have been collected.

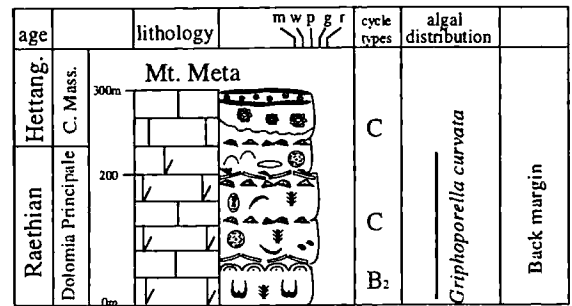


Fig. 6. Stratigraphic sketch of Mt. Meta succession (Gran Sasso area, Central Italy) showing lithology, sedimentary cycles and dasycladalean algae distribution, and the depositional paleoenvironments (for symbols see Fig. 4).

Mt. Meta succession

The Mt. Meta succession (Fig. 6) has been sampled along the southern slope, corresponding to the South-East side of Campo Imperatore. It is composed of about 200 m. of Dolomia Pricipale cut at the base by a normal fault. About 120 samples have been collected frequently showing a rich dasyclad assemblage.

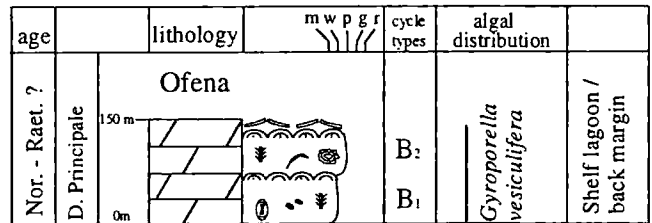


Fig. 7. Stratigraphic sketch of Ofena succession (Gran Sasso area, Central Italy) showing lithology, sedimentary cycles and dasycladalean algae distribution, and the depositional paleoenvironments (explanation of symbols in Fig. 4).

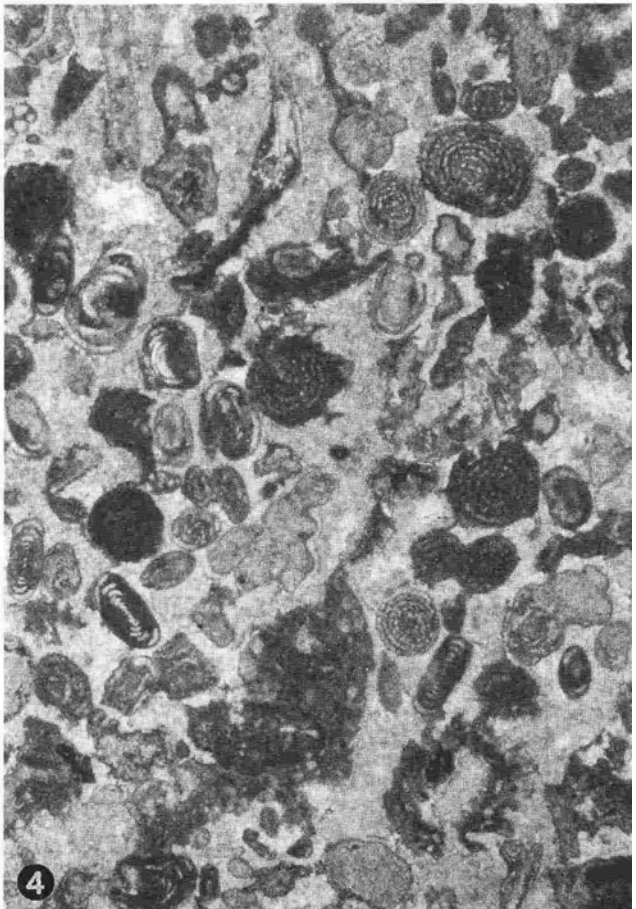
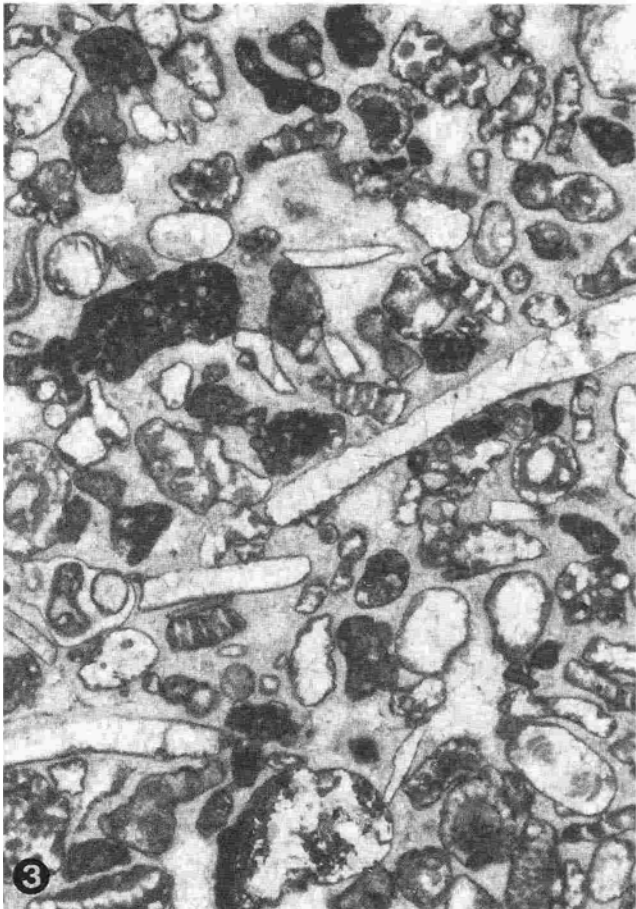
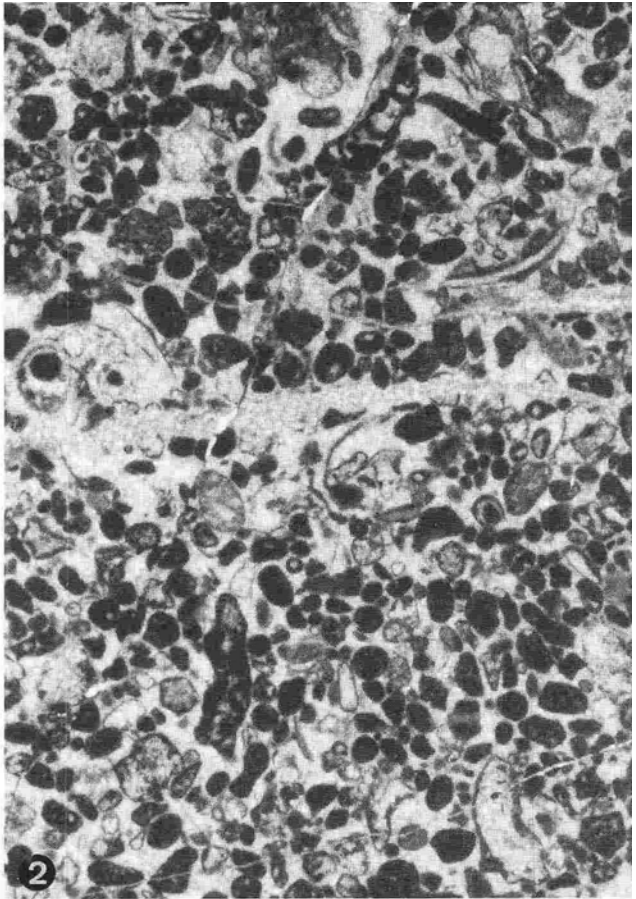
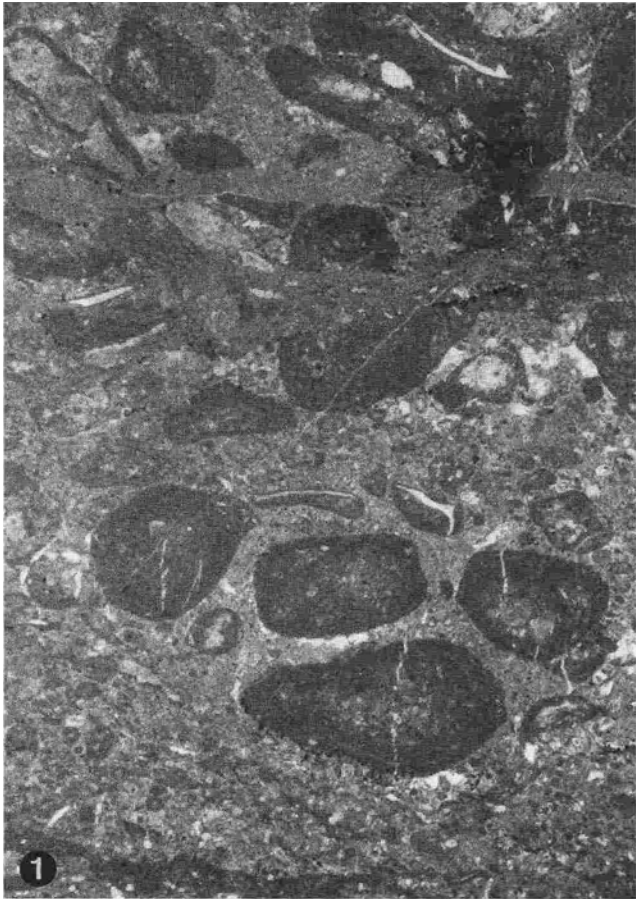
Ofena succession

The Ofena succession (Fig. 7), exposed north of Ofena village, consists of about 150 m of Dolomia Principale limited downwards and upwards by normal faults. 55 samples have been collected in this sequence.

Sella dei due Corni succession

The Sella dei due Corni succession (Fig. 8) is located between the Corno Grande and the Corno Piccolo mountains, on the hanging wall of the splay thrusts which overlies

- Fig. 1. Oncolitic packstone (DP6). Oncolites can reach several millimeters in length. Their nuclei are made both of lithoclasts and bioclasts. The muddy matrix contains peloids and small bioclasts (mainly shell fragments). In the upper portion stylolites, enriched in siltitic residual material with scattered crystals of pyrite, are visible. Monte Meta. TA105.b. x 8.3
- Fig. 2. Peloidal-bioclastic grainstone (DP9). In the assemblage lithoclasts, textulariid forams, pelecypod shell fragments and gastropods can be observed. Monte Capo le Serre; thin section CS3. x 13.3
- Fig. 3. Bioclastic grainstone (DP9). Particles are micritized fragments of mollusc shells, *Griphoporella curvata* and other dasycladaleans, in addition to *Aulotortus* sp. and other foraminifers, and small lithoclasts. The grains have been variously abraded and rounded. Monte Meta; thin section CM6. x 13.3
- Fig. 4. Foraminiferal grainstone (DP8). In the microfacies *Triasina hantkeni*, *Aulotortus* sp. and lithoclasts; in the assemblage, but not in the figure, gastropods and small irregular thalli of thaumatoporellaleans. Monte Meta; thin section CM2. x 13.3



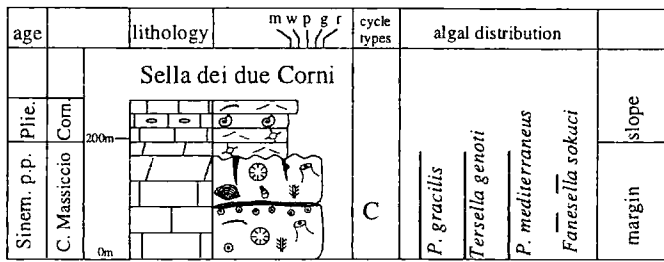


Fig. 8. Stratigraphic sketch of Sella dei due Corni succession (Gran Sasso area, Central Italy) showing lithology, sedimentary cycles and dasycladalean algae distribution, and the depositional paleoenvironments. (explanation of symbols in Fig. 4).

the Corno Grande sequence. The section is 100 thick and is composed of 50 m of Calcare Massiccio followed by 70 m of Pliensbachian basinal cherty limestones belonging to the Corniola Formation. The boundary between this two Formations has been affected by late dolomitization that partially masks the originally stratigraphic relations between the Calcare Massiccio and the Corniola. In this area Bigozzi (1992) recognized traces of a prolonged subaerial exposure at the top of the Calcare Massiccio. From this formation about 20 samples, frequently containing dasycladaleans, have been collected.

5 DOLOMIA PRINCIPALE

In the Gran Sasso area the Dolomia Principale Fm. (D.P.) outcrops at Corno Grande, Mt. Brancastello, Mt. Infornace, Mt. Prena, Fornaca, Mt. Meta, Mt. Capo le Serre and Ofena areas (VEZZANI et al. 1993). The D.P. has a maximum thickness of 600 m. At Mt. Prena (ADAMOLI et al. 1984) and Fornaca overlies basinal euxinic facies represented by bituminous dolomites ("Dolomie Bituminose", ADAMOLI et al., 1990). At Corno Grande and Mt. Capo le Serre the D.P. is overlain by the Calcare Massiccio Fm., while near Fornaca it is overlain by lower Liassic basinal facies (BIGOZZI, 1994; VEZZANI et al., 1993).

Two main depositional facies can be distinguished: a cyclothem and a massive facies (BIGOZZI, 1993; 1994).

The first facies crops out at Corno Grande, Mt. Brancastello, Mt. Infornace, Mt. Meta, Mt. Capo le Serre and Ofena and in the upper part of the Mt. Prena succession, over the massive facies. It is characterized by a cyclical sedimentation. The massive facies is known only at the base of Mt. Prena succession and in the Fornaca area. It has been referred to a marginal area (DURANTI, 1987; ADAMOLI et al., 1990; BIGOZZI et al., 1992). The margin was characterized by the presence of bioclastic sand shoals that were stabilized and colonized by encrusting and reef-

building organism e.g. calcareous sponges, and by foraminifers, algae, *incertae sedis* organisms and dasycladaleans. This facies is extremely dolomitized and is not subject to the present paper, as no algae have found.

The sedimentological and biostratigraphical analyses mainly focus on the cyclothem facies of the Corno Grande, Mt. Meta, Mt. Capo le Serre and Ofena successions, that turn out to be better preserved from late dolomitization.

5.1 Microfacies

13 microfacies types, related to different subenvironments, have been identified in the D.P. cyclothem facies on the basis of grains, textures and biota:

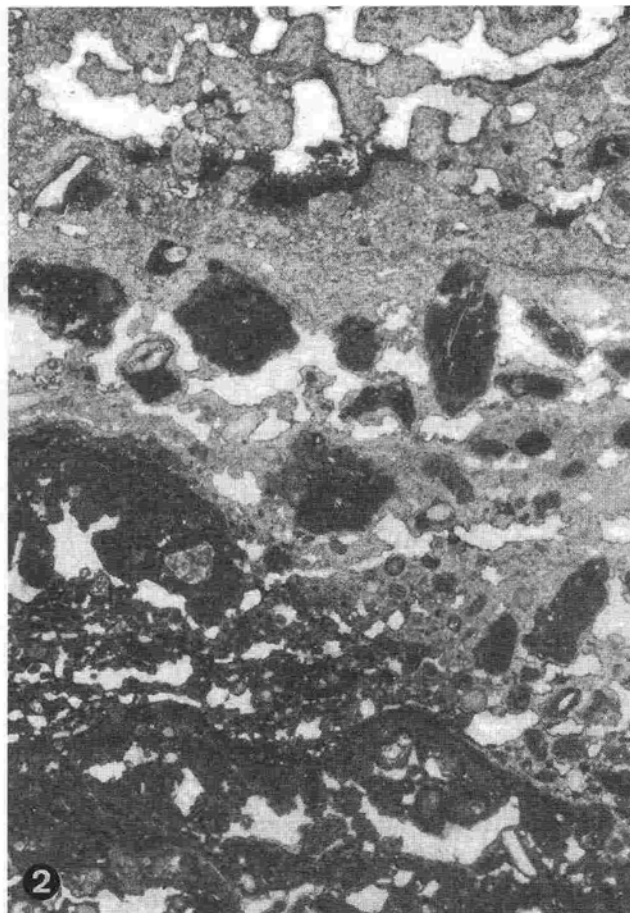
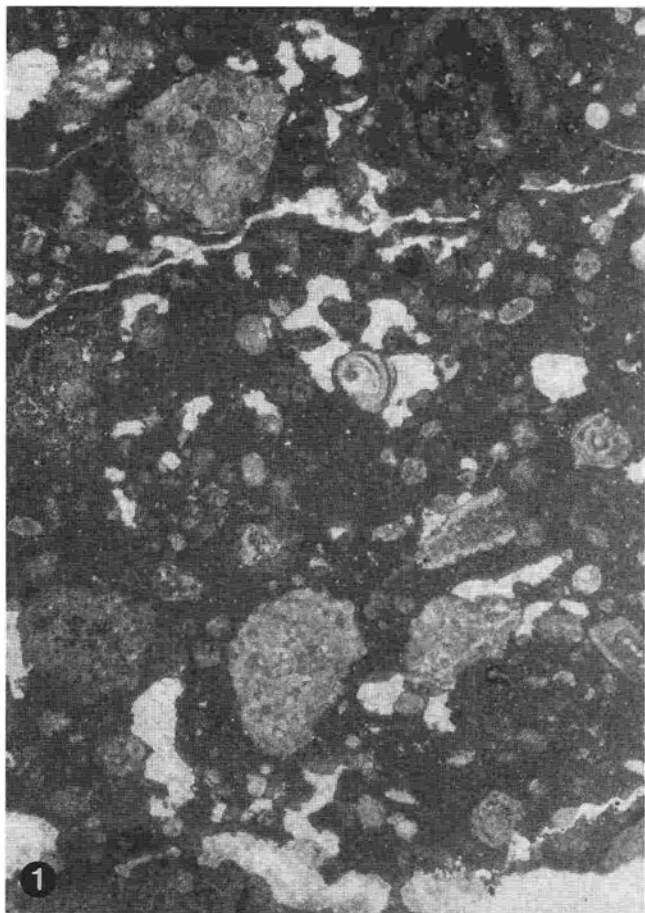
- DP1 - bioclastic wackestone
- DP2 - peloidal wackestone-packstone
- DP3 - megalodon wackestone
- DP4 - bioclastic packstone
- DP5 - lithoclastic packstone
- DP6 - oncolitic packstone-grainstone
- DP7 - aggregate lumps packstone-grainstone
- DP8 - foraminiferal grainstone
- DP9 - bioclastic grainstone
- DP10 - algal bindstone
- DP11 - loferite
- DP12 - pisolithic dolostone
- DP13 - dolomitic breccia

DP1 - bioclastic wackestone. Allochems consist mainly of small bioclasts composed of pelecypod shells, gastropods, dasycladalean algae and peloids. The microfacies are characterized mainly by the *Griphoporella curvata* algal assemblage and the *Gyroporella vesiculifera* algal assemblage. The depositional environment is a restricted lagoon.

DP2 - peloidal wackestone-packstone. It is characteristically composed of peloids in a muddy matrix. Other allochems are represented by green algae (thaumato-porellaleans), rare foraminifers and gastropods. This

Plate 40 Upper Triassic microfacies (Dolomia Principale; Gran Sasso, Central Italy).

- Fig. 1. Lithoclastic wackestone-packstone (DP5), with *Aulotortus* sp. and other forams, and dasycladalean algae in a muddy peloidal matrix. Lithoclasts are composed of bioclastic packstones. Part of the grains are oxidized. Fenestral cavities are present. Monte Meta; thin section TA37.a. x 11
- Fig. 2. Loferite (DP11) with laminoid fenestrae probably enlarged by dissolution. Notice the large specimen of *Aulotortus* sp. in the middle left. Monte Meta; thin section M4. x 6.7
- Fig. 3. Dolomitic breccia (DP13). Lithoclasts are composed of algal bindstones and by lithoclastic-bioclastic packstone. They are bordered by dog tooth cements. Cavities are completely filled by vadose silt. Ofena; thin section OF43. x 5.3



microfacies is the product of a shallow subtidal deposition in a low-energy environment, probably a restricted lagoon, as suggested by the low-diversity biota .

DP3 - Megalodon wackestone. It is characterized by large megalodontid shells in life position. The matrix consists of mud, often intensely bioturbated, with peloids and rare bioclasts. The microfacies describes a subtidal environment under moderate water movements in a lagoonal to a back margin area.

DP4 - bioclastic packstone (Pl. 42/2). Allochems are usually composed of shell fragments, dasycladaceans, foraminifers and lithoclasts. Often a distinct type of biogenic allochem is dominant. The matrix consists of mud, fine-grained bioclasts and/or peloids.

Like in DP1 the *Griphoporella curvata* algal assemblage and the *Gyroporella vesiculifera* algal assemblage are equally represented in this microfacies type interpreted as a deposit of shallow subtidal environment proximal to the shelf edge, under a moderate to intense water-energy.

DP5 - lithoclastic packstone (Pl. 40/1). The microfacies is composed of angular lithoclasts (\varnothing 0.5-5 mm) consisting of peloidal or bioclastic packstones; black pebbles and oxidated lithoclasts have been observed as well. The elements are immersed in a muddy peloidal matrix. Sometimes fenestral fabrics are recorded.

The microfacies is an intertidal to shallow subtidal transgressive lag deposit. Black pebbles and oxidated lithoclasts probably come from an earlier cemented substrate which had undergone subaerial exposure.

DP6 - oncolite packstone-grainstone (Pl. 39/1). The oncolites, often up to 2 mm, of various shape, have fossils or rounded lithoclasts as nuclei. The lithoclasts are peloidal or bioclastic wackestones-packstones. Other allochems are represented by shell fragments. The matrix consists of fine-grained peloids or bioclasts. When the matrix is lacking, the grains are usually surrounded by thin envelopes of fibrous cements. Dissolution cavities can sometimes be present. The microfacies is interpreted as a deposit of a shallow subtidal environment under moderately high water-energy conditions, probably lagoonal channels or shoals. The lithoclasts were probably eroded from a weakly consolidated substrate or from the levees of the channels.

DP7 - aggregate lumps packstone-grainstone. Allochems are composed of aggregate lumps, 2-5 mm in size, sometimes with thin micritic envelopes. The grains come from mud or peloidal aggregations in a muddy matrix. Rims of fibrous cements sometimes surrounding the grains are interpreted as an effect of winnowing. Aggregate lumps were formed in a restricted lagoon under very modest water movement (Flügel, 1982). The microfacies is related

to a shallow subtidal setting, with moderate to intense circulation, proximal to the shelf edge, into which the lagoonal aggregate grains were transported.

DP8 - foraminiferal grainstone (Pl. 39/4). Foraminifers form up to the 60 % of the allochems. Other constituents are pelecypod and dasycladacean fragments (*Griphoporella curvata*) . Fossils are usually well-rounded, and well-sorted. The microfacies is related to a high energy shallow subtidal to intertidal environment, proximal to the shelf edge, where some lagoonal foraminifers were swept in.

DP9 - bioclastic grainstone (Pl. 39/3-4). Allochems are composed of dasycladaleans, bivalves, gastropods, foraminifers, echinoderms, with very rare lithoclasts. Usually one distinct group of organisms dominate and form up to 70% of the allochems. The grains are set in a sparry mosaic, or are surrounded by isopachous rims of fibrous "dirty" cements that suggest an early diagenesis in a marine environment. Late spar calcite fills the remaining interparticle porosity but intraparticle and vuggy porosity can be preserved. The algal content is represented mainly by the *Griphoporella curvata* assemblage.

This microfacies deposited in a shallow subtidal, high-energy environment, on tidal bars, shoals or beaches, with an active early diagenesis. Dasycladaleans and foraminifers where transported from adjacent lagoonal setting.

Occasionally this microfacies is found also in 10-20 cm thick layers inside the DP1 to DP4 microfacies. One distinct group of organisms, especially dasycladaleans, dominates in these layers interpreted as storm deposits.

DP10 - algal bindstone (Pl. 41/1). It is composed of stromatolitic layers, with either LLH or planar algal laminae, trapping mud or peloids. Laminoid fenestrae and evidence of dessiccation are observed. This microfacies is referred to an intertidal to supratidal deposit in a tidal flat environment.

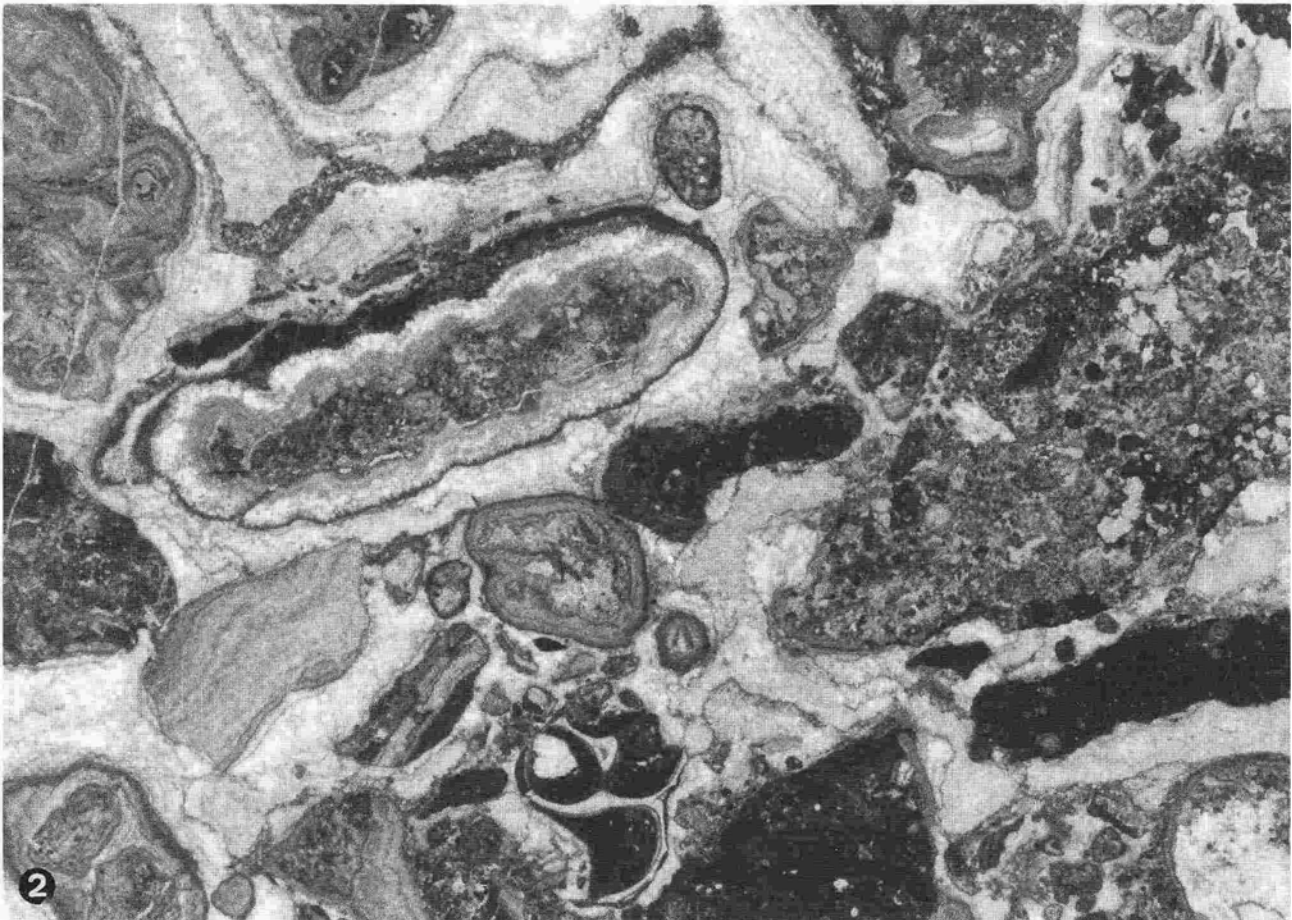
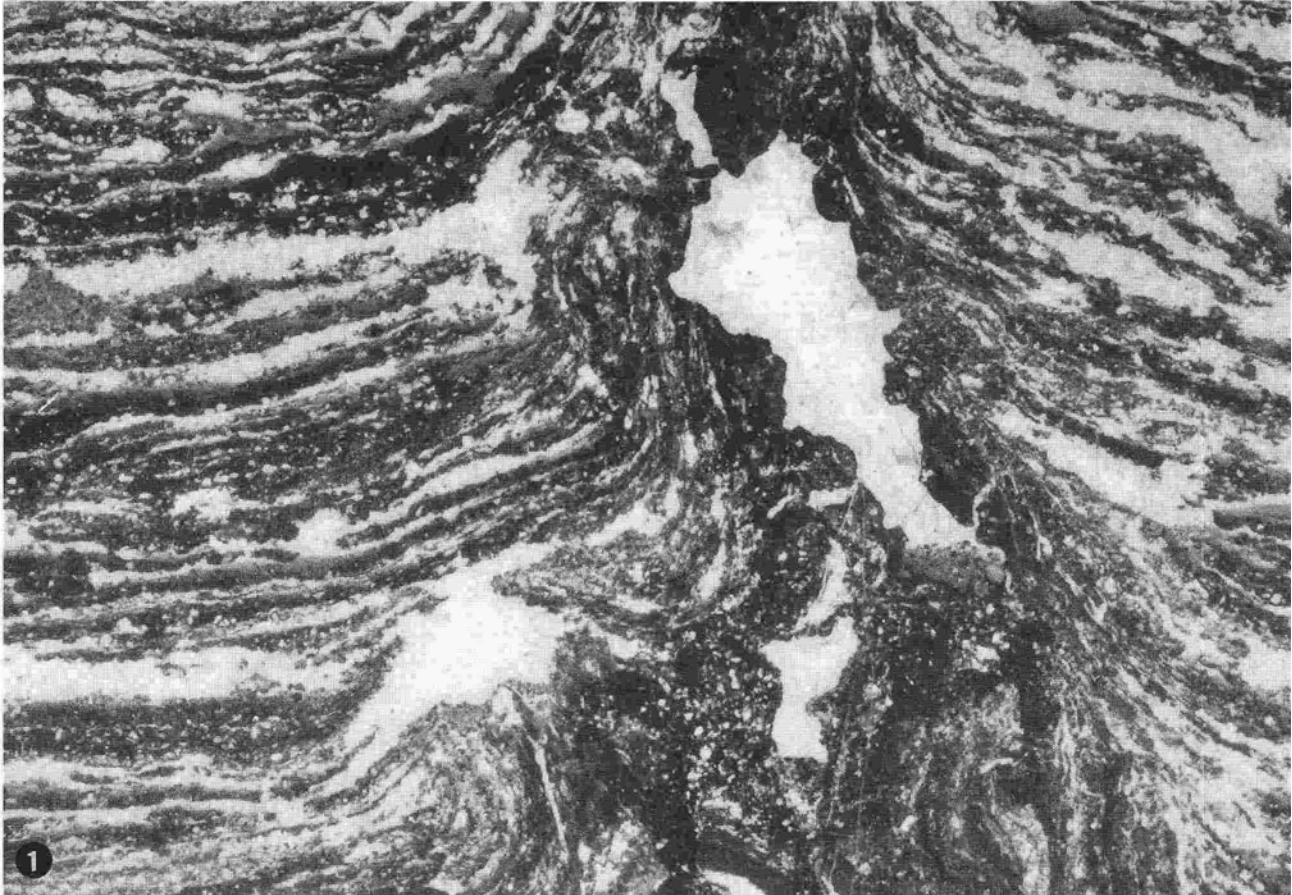
DP11 - loferite (Pl. 40/2). The lithofacies consists of peloidal packstone-grainstones, with birdseyes and fenestral fabrics. Other allochems are represented by rare foraminifers and gastropods. Plain bed laminae, 0.5-1.5 cm thick, of graded peloids can be present. The voids, sometimes enlarged by dissolution, are usually filled by late sparite. The lithofacies belongs to an intertidal to supratidal deposit on tidal flats.

DP12 - pisolitic dolostone (Pls. 41/2, 44/1). The microfacies is characterized by pisoids and thin cement crusts which can be indifferently superimposed on the preceding microfacies types. Fenestral fabric, birdseyes and/or dissolution cavities with geopetal textures are present. The microfacies is interpreted as the product of vadose diagenesis due to subaerial exposure.

Plate 41

Upper Triassic microfacies (Dolomia Principale; Gran Sasso, Central Italy).

- Fig. 1. Algal bindstone (DP10). Notice the tepee structures, in the center. Monte Meta; thin section MM7. x 6.8
 Fig. 2. Pisolitic dolostone (DP12). Vadose diagenesis has affected an original sediment composed of bioclastic-peloidal packstone. Monte Meta; thin section M3. x 8.3



Sedimentary Cycles from the Upper Triassic - Lower Jurassic in the Gran Sasso Area

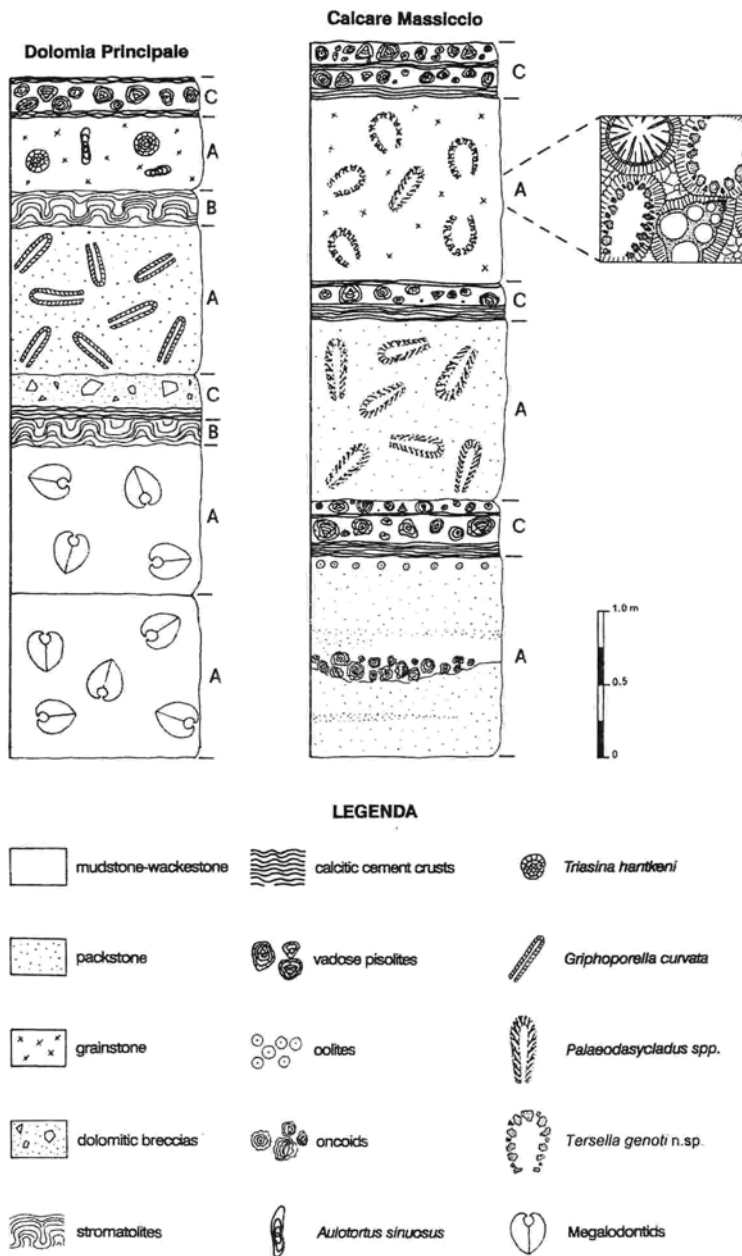


Fig. 9. Schematic column of sedimentary cycles from the Dolomia Principale (DP) and the Calcare Massiccio (CM) formations (Gran Sasso area, Central Apennines). A) subtidal interval, B) intersupratidal interval, C) supratidal interval. The Dolomia Principale Formation shows subtidal cycles (composed only by the A interval), peritidal cycles either complete or incomplete (respectively composed of A, B, C and A, B intervals) and diagenetic cycles (formed by A, C intervals). In the calcare Massiccio Formation diagenetic cycles prevail. Laterally the detail of the subtidal interval from a marginal facies is shown (microfacies type CM6).

5.2 Sedimentary cycles

In the studied area the microfacies are cyclically arranged (Fig. 9). The cycles are from 40 cm up to 3-5 m thick and generally exhibit a shallowing upwards character. Three main types of cycles have been identified:

- subtidal cycles, with only subtidal units (DP1, 2, 3): the upper boundary generally coincides with a maximum flooding surface;
- peritidal cycles, which can be complete or incomplete. In the first case they are composed of a subtidal basal unit (DP3-9), overlain by an intertidal unit (DP10, 11) and finally by a supratidal unit (DP12, 13); incomplete cycles lack the supratidal unit at the top of the cycle;
- diagenetic cycles (as defined by BOSELLINI & HARDIE, 1985), in which the supratidal interval (DP12, 13) is directly superimposed on the subtidal portion (DP3-9).

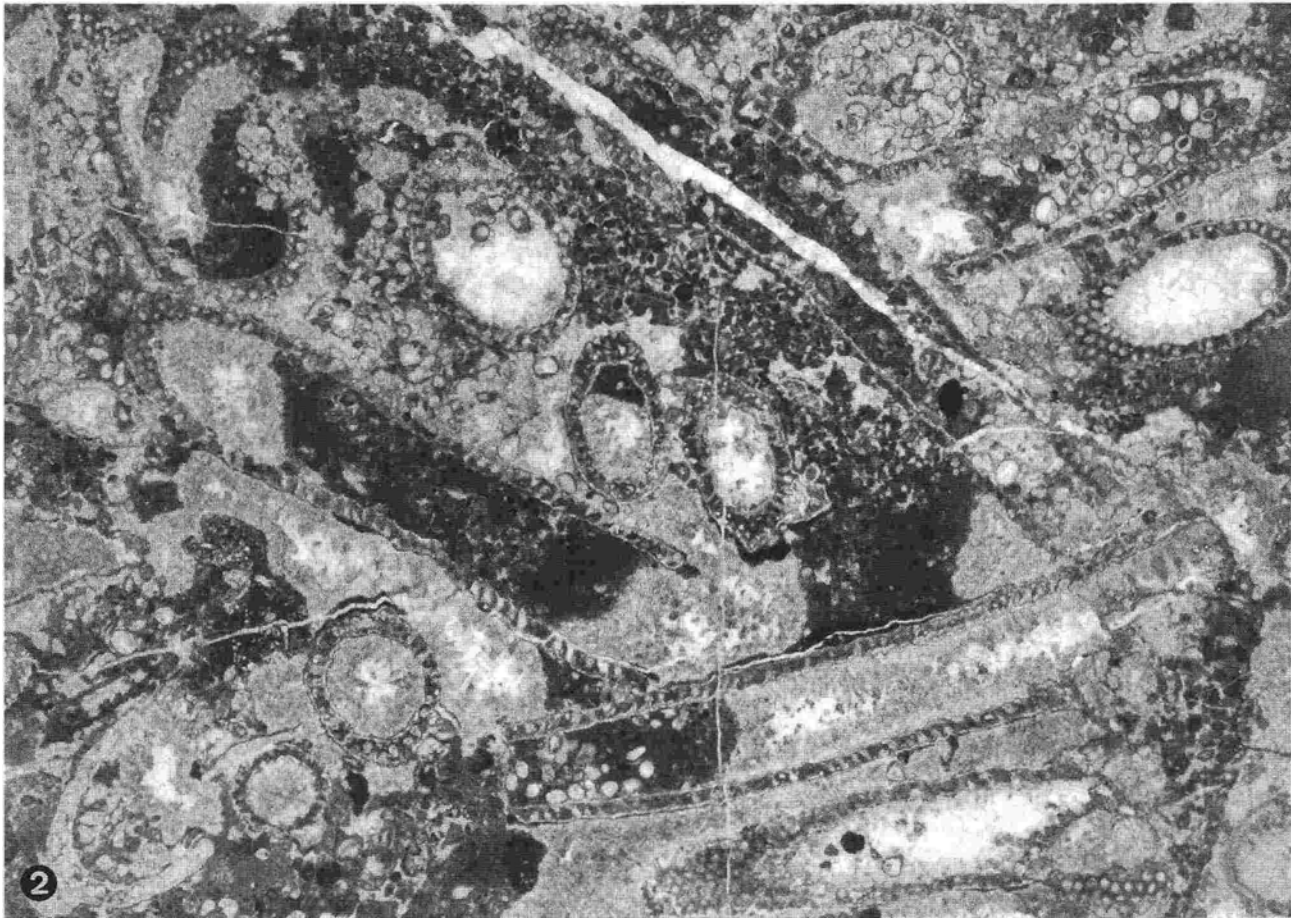
Cycles with partially deepening upwards characters are rare. These cycles have a basal intertidal transgressive interval represented by the DP11 microfacies type.

Lacking a good biostratigraphic resolution the duration of cycles can be only roughly estimated. BIGOZZI (1990) gave an average time span of 20-40 Kyr for the cycles of Corno Grande. This seems confirmed also for the other isochronous cyclothem sequences of the investigated area.

DP13 - dolomitic breccia (Pl. 40/3). It is composed of angular lithoclasts, in a green to yellowish coarse dolomite matrix. This lithofacies is interpreted as a collapse breccia due to subaerial exposure.

Plate 42 Upper Triassic microfacies (Dolomia Principale; Gran Sasso, Central Italy).

- Fig. 1. Pisolitic dolostone (DP12). The original sediment was probably represented by a *Gyroporella vesiculifera* (GÜMBEL) packstone-grainstone in a peloidal-bioclastic matrix. Notice the thick pisolitic envelopes around the grains which also trap part of the sediment. Fenestral cavities partially enlarged by dissolution. Ofena; thin section OF32.4 (= BA.594.4). x13.3
- Fig. 2. *Grifhoporella curvata* (GÜMBEL) packstone (DP4). Note the different size of calcareous thalli of this taxon in respect to those of the Fig. 1. Foraminifers (*Autotortus* sp.), gastropods and small lithoclasts are also present. Monte Meta; thin section TA16.3 (= BA.592.3). x 13.3



5.1.3 Origin of the cycles

Many authors have parallelized high-frequency, meter scale cycles of many shallow-water platform successions to orbitally forced sea-level variations with Milankovitch frequencies. The origin of meter scale cycles is still under discussion (see GOLDHAMMER et al., 1993 and DRUMMOND & WILKINSON, 1993, for a recent review). The controversial debate between autocyclic or allocyclic mechanisms, invoking progradation processes e.g. Ginsburg's autocycle (Ginsburg, 1971), or reversal high-frequency tectonic, is still open.

Peritidal cycles record the lateral progradation of a tidal flat environment over a subtidal shelf-lagoon but cannot rule out the possibility of an autocyclic mechanism. Simple progradation models cannot explain the presence of diagenetic caps, at the top of the cycles, which record a prolonged subaerial exposure, or the origin of diagenetic cycles which lack an intertidal interval at the top of the subtidal portion. Diagenetic cycles witness in fact sudden relative sea-level falls that should be controlled by either some allocyclic mechanism of high-frequency sea-level variations (with Milankovitch frequency) or reversal tectonic. Even the subtidal cycles, as suggested by ELRICK & READ (1991), need an allocyclic process for their explanation.

BIGOZZI (1990), on the basis of different types, distribution and organization of cycles, referred the cyclicity of the Late Triassic-Early Liassic Corno Grande succession to high-frequency sea-level variations on the Milankovitch band.

A similar interpretation seems to fit to all Dolomia Principale cyclothemic facies.

5.3 Algal assemblages

1. *Griphoporella curvata* assemblage (Pl. 42/2).

The assemblage is oligotypic, and the nominal taxon is always dominant. Foraminifers (*Triasina hantkeni* and *Aulotortus sinuosus*), thamatoporellaleans and rare mollusc shells can be present. The sediment consists of either bioclastic wackestone (microfacies DP1) or packstones and grainstones (microfacies DP4, DP9) where the alga may constitute the 70% of the allochems. This suggests

that the association probably occurred in restricted lagoon and in near-margin environments (BARATTOLO, 1991; Fig. 10/A), where the algae covered the shallow subtidal substrate by a more or less dense meadow. Very restricted conditions are recorded for this alga (MARTIN & DELGADO, 1980).

Griphoporella curvata is referred to the Norian-Rhaetian (BARATTOLO et al., 1993); the association with *Triasina hantkeni* and *Aulotortus sinuosus* (DE CASTRO, 1990a; MARCOUX et al., 1993) is typical for the late Norian-Rhaetian.

2. *Gyroporella vesiculifera* assemblage (Pl. 42/1).

The assemblage is oligotypic; calcareous skeletons of other undeterminable dasyclads occur seldom. The fauna consists commonly of gastropods and foraminifers (*Aulotortus* sp.). This algal assemblage is frequent in bioclastic wackestones-packstones (microfacies types: DP1, 4) where it can constitute the 100% of the fossil content. This assemblage is rarer than the preceding one. The two algal assemblages were presumably vicariant in quiet protected areas characterized by restricted circulation, as the relatively low diversity of associated biota suggests. *Gyroporella vesiculifera* assemblage most likely populated transitional areas between a restricted lagoon and a back margin (Fig. 10/A). In this environment *Griphoporella curvata*, if present, is always subordinate.

The algal assemblage is typical of the Norian-Rhaetian age even if *Gyroporella vesiculifera* is doubtfully known from younger strata (lower Liassic: CROS & LEMOINE, 1967; see also chapter 6).

5.4 Depositional environment

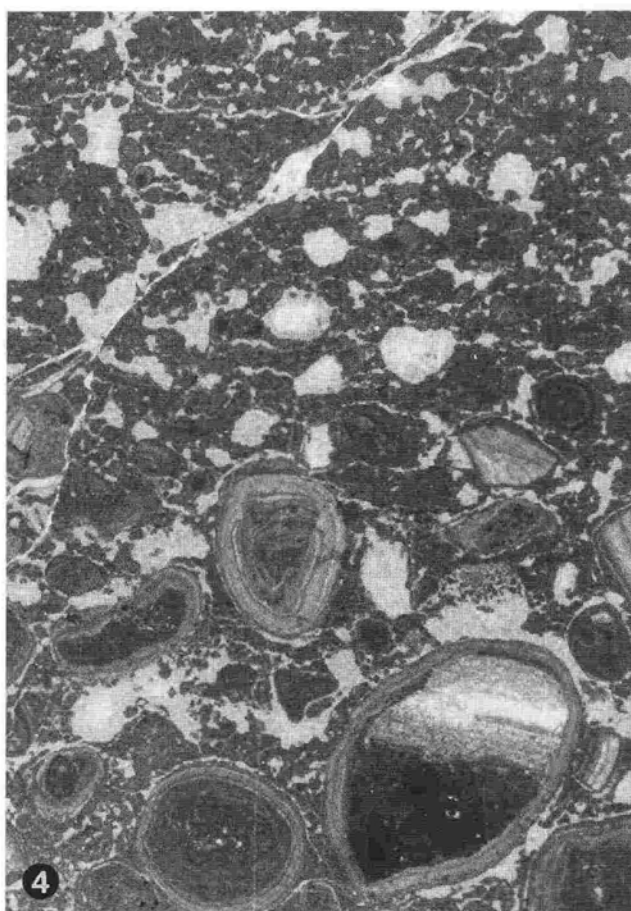
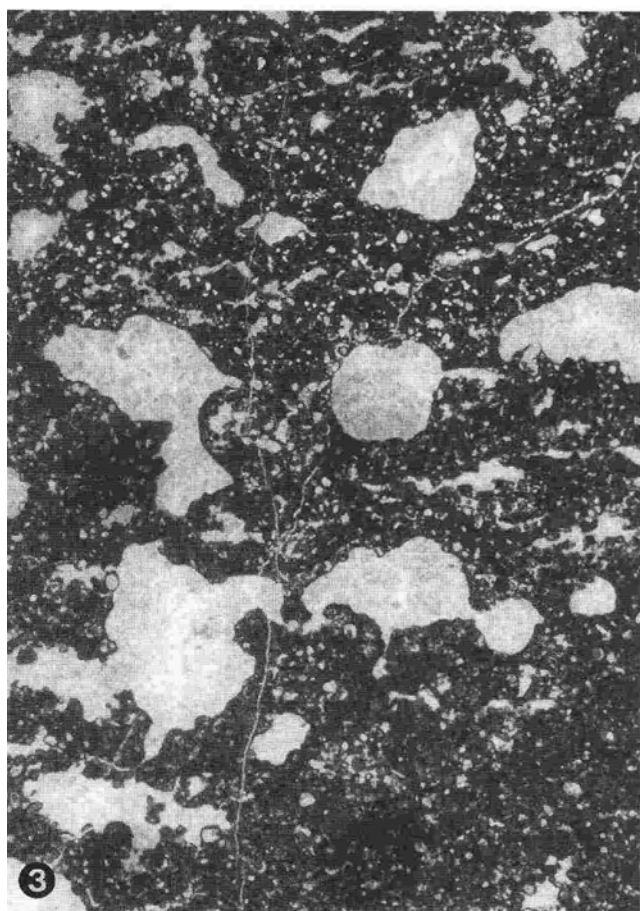
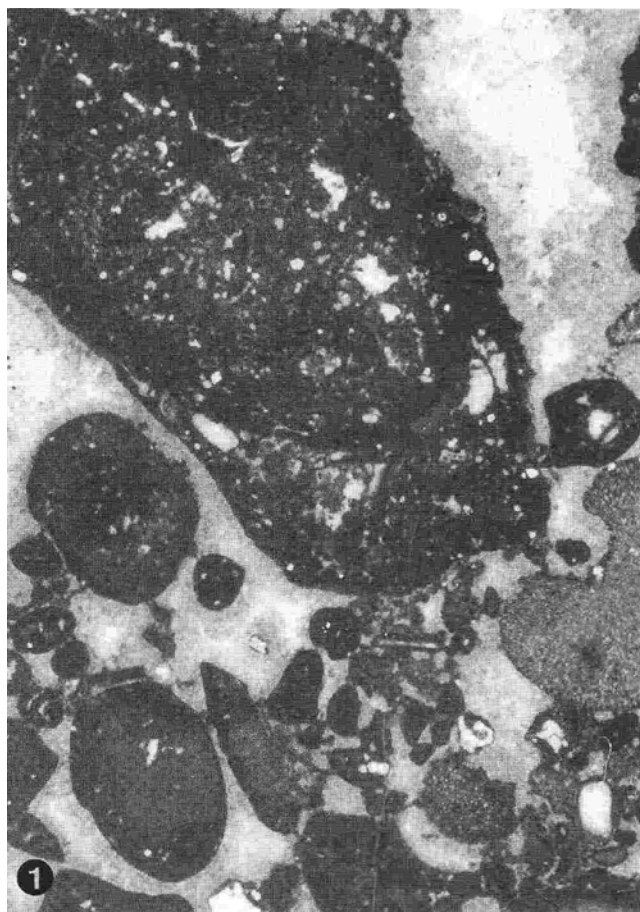
Two main facies can be differentiated based on type, distribution and frequency of microfacies, algal assemblage and cycle, each recording a particular depositional paleoenvironment:

- *shelf lagoon facies*. The prevailing microfacies are represented by bioclastic and peloidal wackestones (DP1, 2), megalodon wackestones (DP3), algal bindstones and loferites (DP10, 11) and rare bioclastic packstones (DP4). The *Gyroporella vesiculifera* algal assemblage dominates in respect to the *Griphoporella curvata* algal assemblage.

Plate 43

Lower Liassic microfacies (Calcare Massiccio Fm.; Gran Sasso, Central Italy).

- Fig. 1 Aggregate grains grainstone (CM5). *Cayeuxia*-like algae and shell fragments are present. The grains show thin envelopes of fibrous "dirty" cements. Remaining voids are filled by late spar calcite but some interparticle porosity is still preserved. Corno Grande; thin section PSC5. x 8.3
- Fig. 2. Corals framestone (CM9). Corals, in life positions, are partially recrystallized and encrusted by incertae sedis organisms, probable red algae. Intergranular space is filled by peloidal mudstone, containing scattered bioclasts, mainly composed of shell fragments. Corno Grande; thin section PSC11. x 10.4
- Fig. 3.. Birdseyes limestone (CM10). The original sediment is a peloidal packstone. Larger cavities enlarged by dissolution. Corno Grande; thin section BA7. x 10.4.
- Fig. 4. Pisolitic limestone (CM11). The original sediment is a peloidal packstone-grainstone. Reworked pisoids and the typical "drop" like structure, with downward growth of some pisoids (center). Geopetal structures within a pisoid can be also observed (lower left). Corno Grande; thin section BA2. x 10.4



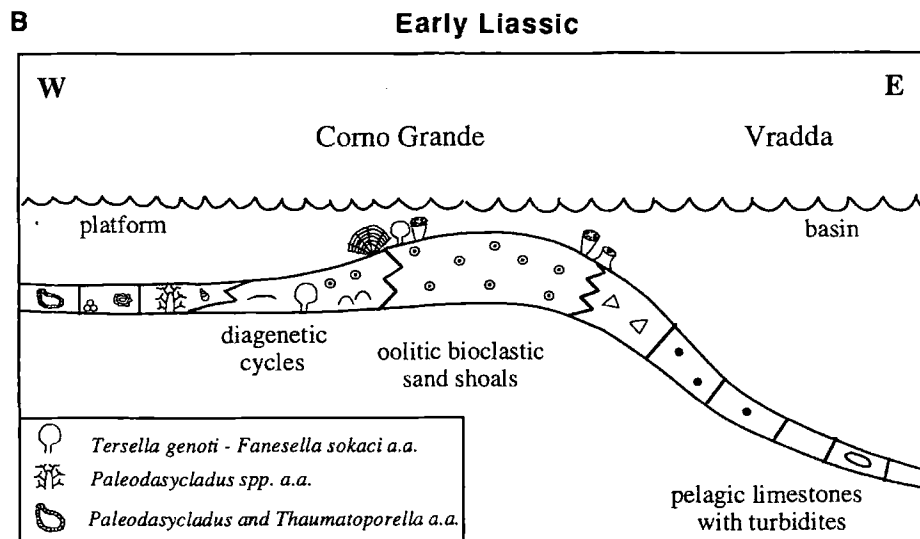
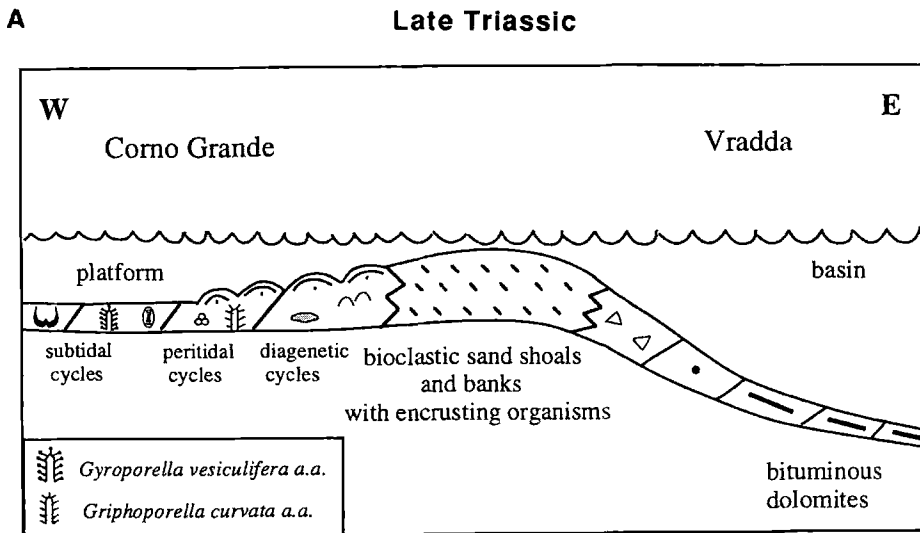


Fig. 10. Paleogeographic profiles showing the facies distribution in the Gran Sasso area in the Late Triassic (A) and in the early Liassic (B). The Corno Grande is characterized by outer lagoon facies during the Late Triassic and by marginal facies during the early Liassic (see also Fig. 11/A and Fig. 11/B). Note the occurrence of different type of cycles moving westward, from the margin to the lagoon (explanation of symbols in Fig. 4).

Shallowing upwards cycles (3 m thick in average) are usually observed in this facies. Subtidal and complete peritidal cycles, sharply prevail over complete peritidal cycles and diagenetic cycles (Figs. 4-10/A).

This facies, although largely dolomitized, is well-represented at the Corno Grande succession (middle-upper portion of the D.P terms) and in the Ofena area (Figs. 4-7).

The depositional environment is a protected lagoon characterized by modest to moderate water energy. The

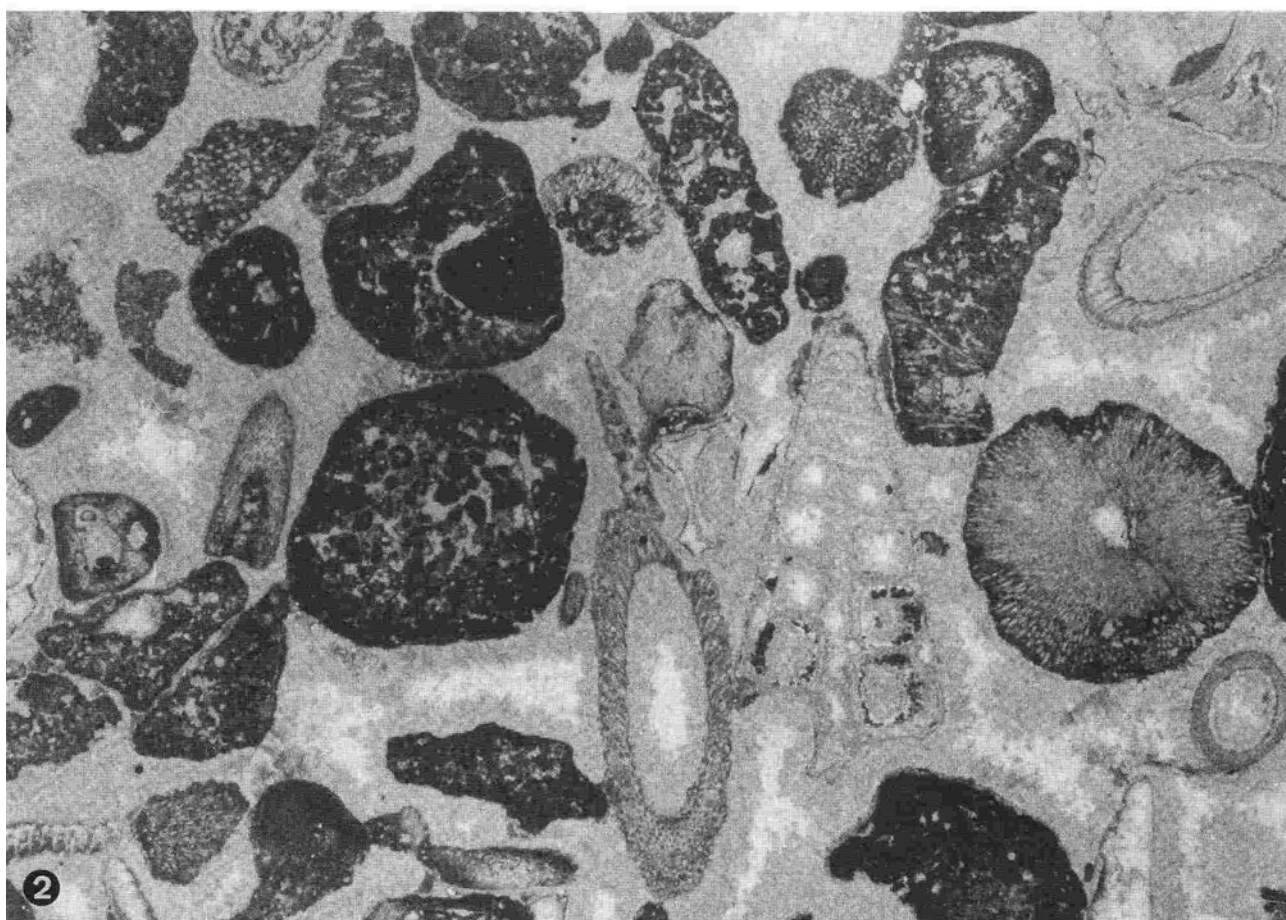
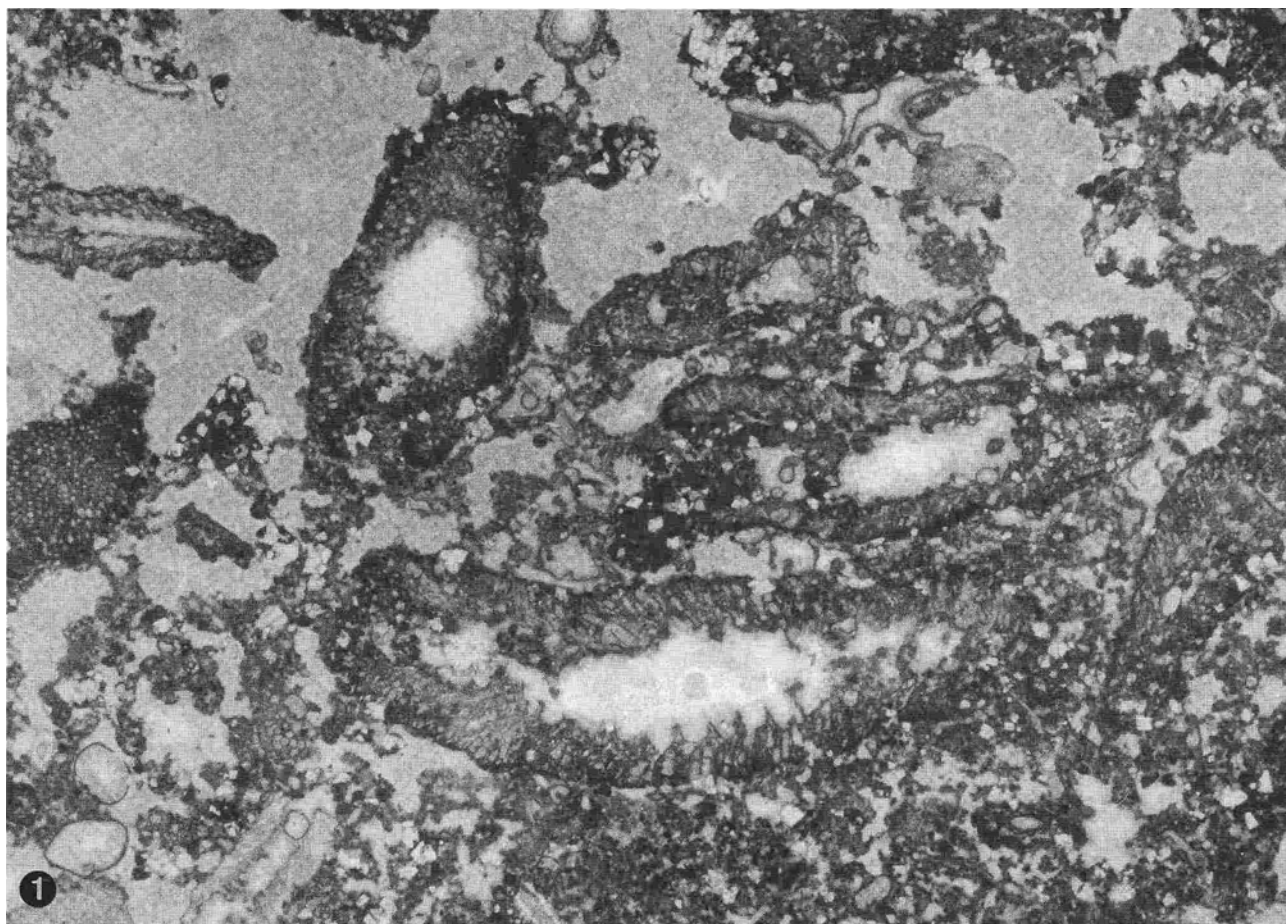
onset of restricted circulation is witnessed by the occasional occurrence of low diversity biota. Algal bindstones and loferites (DP10, 11) suggest the periodic development of tidal flats with cyanobacterians and stromatolites.

The cyclicity of this facies was mainly controlled by high frequency sea level oscillations which determined restriction in the circulation pattern inside the lagoon, progradation of peritidal facies over the subtidal lagoon and occasional temporary emersions. However the predominance of the subtidal and peritidal cycles over diagenetic

Plate 44 Lower Liassic microfacies (Calcare Massiccio Fm.; Gran Sasso, Central Italy).

Fig. 1. Bioclastic packstone (CM3) containing *Palaeodasycladus* and *Thaumtoporella* in a muddy peloidal-fine bioclastic matrix. Large dissolution cavities and scattered crystals of dolomite are present. Corno Grande; thin section D2.8 (= BA.588.8); x 10.4

Fig. 2. Lithoclastic-bioclastic rudstone (CM8). Lithoclasts are composed of peloidal and oncolitic packstone-grainstone and are rounded to subrounded. Bioclasts consist of *Palaeodasycladus* sp., gastropods, *Cayeuxia*-like algae, shell fragments and foraminifers. The grains are surrounded by isopachous fibrous cements. Remaining interparticle porosity is filled by late spar calcite. Corno Grande; thin section FC3.4 (= BA.598.3). x 8.3



ones indicates that the subtidal deposition prevailed over all other sub-environments and that the sea level variations were moderate.

- *back margin facies*: packstones and grainstones with bioclasts, foraminifera, oncolites, lithoclasts and aggregate lumps as well as algal bindstones and dolomitic breccias (DP3 to DP13 microfacies) mark this environment. The *Griphoporella curvata* algal assemblage and a cyclic organization are the most usual and striking elements of this facies.

Cycles, about 2.5 metres thick in average, exhibit a shallowing upwards pattern. Complete peritidal cycles as well as diagenetic cycles are recorded; subtidal cycles are absent (Fig. 10/A). This facies, more or less dolomitized, occurs at the Mt. Meta succession (Fig. 6) as well as at Mt. Capo le Serre (Fig. 5) and Corno Grande (lower interval of the Dolomia Principale, Fig. 4).

The depositional environment was characterized by a moderate to intense water movement. It was strongly influenced by high frequency sea level fluctuations and thus periodically evolved to high energy tidal flats where peloidal-bioclastic sands were accumulated and later trapped by cyanobacterial algal mats (Fig. 10/A).

The more frequent occurrence of diagenetic and of complete peritidal cycles within this back-margin area, in comparison to the lagoonal cycles, can be related to its higher morphological elevation. Indeed, topographically higher areas, like the margin and the back margin, often underwent a subaerial exposure in response to a sea level fall, compared to the inner and deeper lagoonal areas.

The occurrence of intertidal deposits over the subtidal interval depends on the rate and amplitude of sea level drop. A slow rate of sea-level fall (or minor sea level falls) produced a subaerial exposure only in marginal areas, while peritidal cycles formed in the backmargin area, and subtidal conditions developing corresponding cycles persisted in the shelf interior. A fast rate of sea level fall (or major sea level drops) resulted in sudden exposures of margin and backmargin area which yield widespread diagenetic cycles while tidal flat environments with peritidal cyclic sedimentation developed over lagoonal areas.

6 CALCARE MASSICCIO

The Calcare Massiccio Fm. is well represented in the Gran Sasso area. It is widely exposed at Pizzo Cefalone,

Corno Grande, Mt. Aquila, Mt. Capo le Serre and northward of Castel del Monte village. This Formation is locally affected by strong diagenetic alterations, which can limit the sedimentological and biostratigraphical analysis. Only the most continuous and best preserved sequences will be treated in the present paper: Corno Grande, Sella dei due Corni and Mt. Capo le Serre successions.

The Calcare Massiccio reaches a maximum thickness of 600 m. It overlies the Dolomia Principale Formation at Corno Grande and is overlain by the Corniola basinal formation at the Sella dei due Corni and Mt. Capo Le Serre.

6.1 Microfacies

The analysis of grains, sedimentary textures and biota allows to recognize the following microfacies each recording a depositional subenvironment in the Calcare Massiccio Formation:

- CM1 - bioclastic wackestone
- CM2 - peloidal packstone
- CM3 - bioclastic packstone
- CM4 - oncolitic packstone-grainstone
- CM5 - aggregate grain packstone-grainstone
- CM6 - oolitic grainstone
- CM7 - bioclastic grainstone-rudstone
- CM8 - lithoclastic grainstone-rudstone
- CM9 - coral framestone
- CM10 - birdseyes limestone
- CM11 - pisolitic limestone

CM1 - bioclastic wackestone. Allochems can form 30-40 % of the whole rock. They are represented by a great variety of grains (mainly fossils) among which dasycladaceans, *Cayeuxia*-like thalli, peloids, pelecypods, ostracods and gastropods. The *Palaeodasycladus-Thaumatoporella* algal assemblage is characteristic. The microfacies belongs to a subtidal setting with only modest to moderate water energy, presumably related to an open lagoon environment.

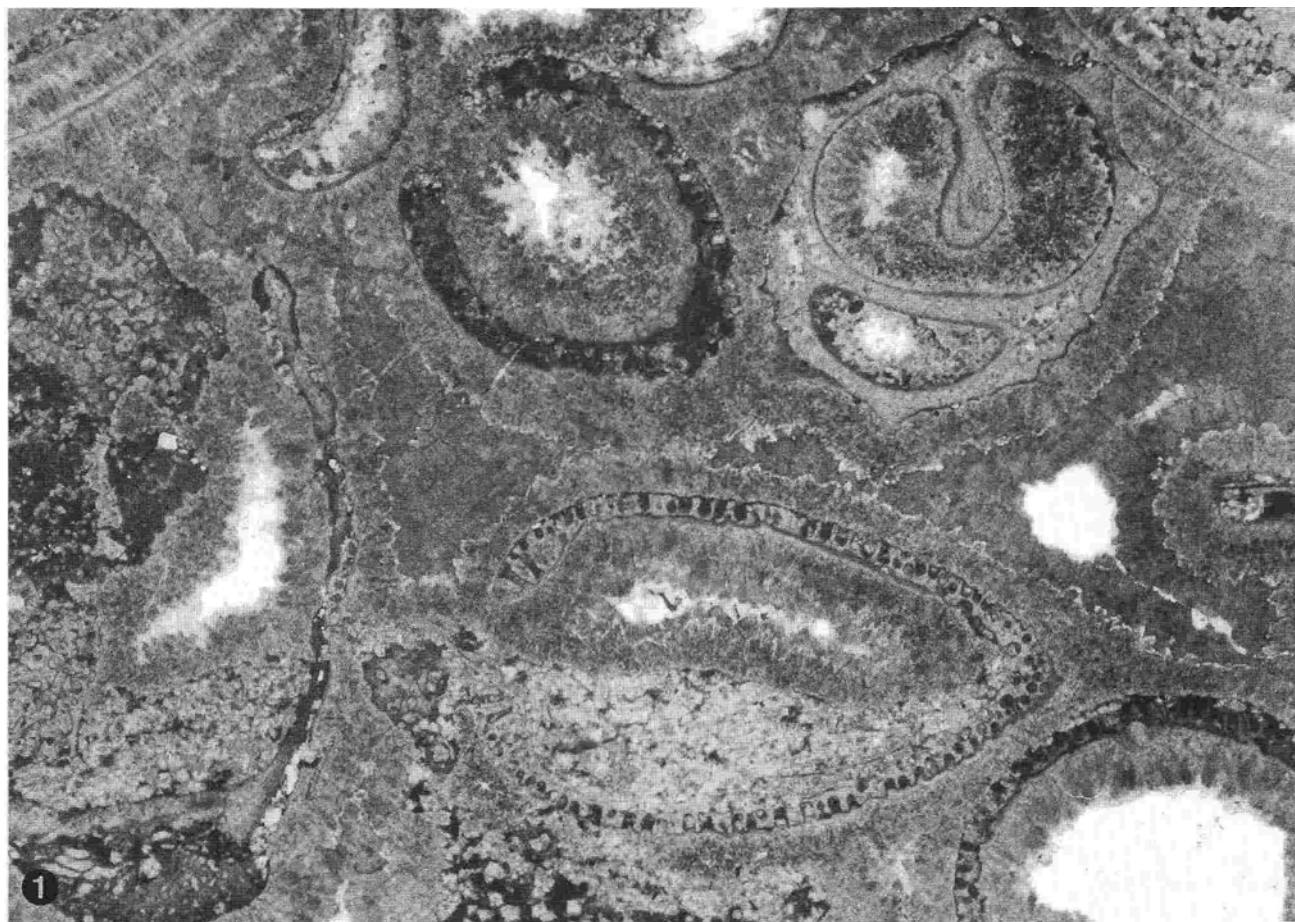
CM2 - peloidal packstone. It is characterized by the presence of peloids in a muddy matrix. *Thaumatoporellaceans*, foraminifers and gastropods can be present. This microfacies is interpreted as a shallow subtidal deposit in a moderate energy environment as a shelf lagoon, or a back margin tidal flat.

CM3 - bioclastic packstone (Pl. 44/1). Allochems are composed of pelecypods, gastropods, dasycladaceans (*Palaeodasycladus* spp.), *Cayeuxia*-like thalli, echinoderms,

Plate 45

Lower Liassic microfacies (Calcare Massiccio Fm.; Gran Sasso, Central Italy).

- Fig. 1. Dasycladalean rudstone (CM6). Grains are composed of dasycladacean algae (*Tersella genoti* n.sp.), gastropods and lithoclasts and are surrounded by one generation of isopachous fibrous cements. Remaining interparticle porosity is filled by late spar calcite, some intergranular and intragranular porosity is still preserved. Corno Grande; thin section FR13.4 (= BA591.4). x 6.7
- Fig. 2. Dasycladalean rudstone (*Tersella genoti* n.sp. and *Fanesella sokaci* n.sp.; CM6). Grains are surrounded by several generations of isopachous fibrous cements. Remaining interparticle porosity is filled by late spar calcite, some intergranular porosity is preserved. Corno Grande; thin section CG2.3 (= BA.598.3). x 6.7



foraminifers and lithoclasts. Rudite-sized shells, consisting of disarticulated valves of pelecypods immersed in a muddy detrital matrix, sometimes occur. These levels are interpreted as basal sediments of storm deposits.

The *Palaeodasycladus* spp. assemblage and the *Tersella genoti* - *Fanesella sokaci* assemblage are both well represented, although the first seems more widespread than the second. The microfacies is interpreted as a shallow subtidal deposit characterized by a moderately high water energy. An open lagoon proximal to the shelf edge can be inferred as depositional environment.

CM4 - oncolitic packstone-grainstone. Oncoids ($\varnothing < 2$ mm) form up to the 60% of the rock. Peloids and shell fragments occur. The interparticle space is filled by a peloidal muddy matrix or by sparry calcitic cement. The beds with this microfacies sometimes are limited downwards by an erosional boundary. The microfacies indicates a shallow subtidal setting with a moderately high water energy. A migrating lagoon channel, or a tidal bar or even a back-margin deposit is possible.

CM5 - aggregate grain packstone-grainstone (Pl. 43/1). Aggregate grains ($\varnothing 0.5$ to 5 mm) can compose over 60% of allochems. Peloids, mollusc shells (pelecypods and gastropods), dasycladaleans, solenoporaceans and solitary corals are also recorded. The grains sometimes exhibit envelopes of fibrous cements. Medium to coarse sized scattered dolomitic rhombs occur seldom inside the aggregate grains. The *Palaeodasycladus* spp. assemblage and the *Tersella genoti* - *Fanesella sokaci* assemblage are widely spread in this microfacies, especially the first one. Aggregate grains are referred to a restricted lagoon with moderate water movements (FLÜGEL, 1982). The composition of the aggregate grains, as well as the presence of high-energy organisms (corals, solenoporacean algae), suggests a shallow subtidal environment influenced by moderately high water energy conditions (e.g. a back margin lagoon).

CM6 - bioclastic grainstone-rudstone (Pl. 45/1-2). Allochems are composed of pelecypods, gastropods, solitary corals, calcareous sponges, dasycladaceans, solenoporaceans, echinoderms, foraminifers and lithoclasts. Dasycladaleans (*Tersella genoti*, *Fanesella sokaci* and *Palaeodasycladus* spp.) sometimes dominate forming up to 70% of allochems. Thin section analysis shows two different textures: 1) the grains show frequent grain-to-grain contacts and only one

thin generation of isopachous fibrous cement envelopes. The remaining interparticle cavities are partially filled by late spar calcite (Pl. 45/1). 2) the grains are less frequently in direct contact and are constantly surrounded by several generations of isopachous fibrous cements. The remaining interparticle voids are filled by late spar or part of the intraparticle and interparticle porosity is preserved.

The *Tersella genoti* - *Fanesella sokaci* assemblage is characteristic for this microfacies although the *Palaeodasycladus* spp. assemblage is also moderately frequent.

The microfacies belongs to a shallow subtidal high-energy setting with active early diagenesis, in a sandy shoal depositional environment next to the shelf edge. The first textural type mentioned above deposited in a more protected position within the margin, under a moderate water circulation; the latter deposited in an energetic foremargin environment, characterized by a more active early diagenesis, induced by a stronger water movement.

CM7 - oolitic grainstone. Allochems (up to 80%) are well-sorted tangential ooids with multiple coatings and rounded bioclasts (pelecypods and gastropods).

The depositional environment is a shallow subtidal setting with intense water movement, as on tidal bars or oolite shoals.

CM8 - lithoclastic breccia (Pl. 44/2). The elements are angular to subrounded, centimeter-size (1 cm to 15 cm) lithoclasts, consisting of bioclastic packstones-grainstones or oolitic grainstones, immersed in a sandy matrix. This microfacies shows lateral and vertical transition to CM6, CM7 or CM9 microfacies types.

The sediment is a breccia consisting of shelf margin material, deposited just in front of the shelf edge, at or just above the wave base.

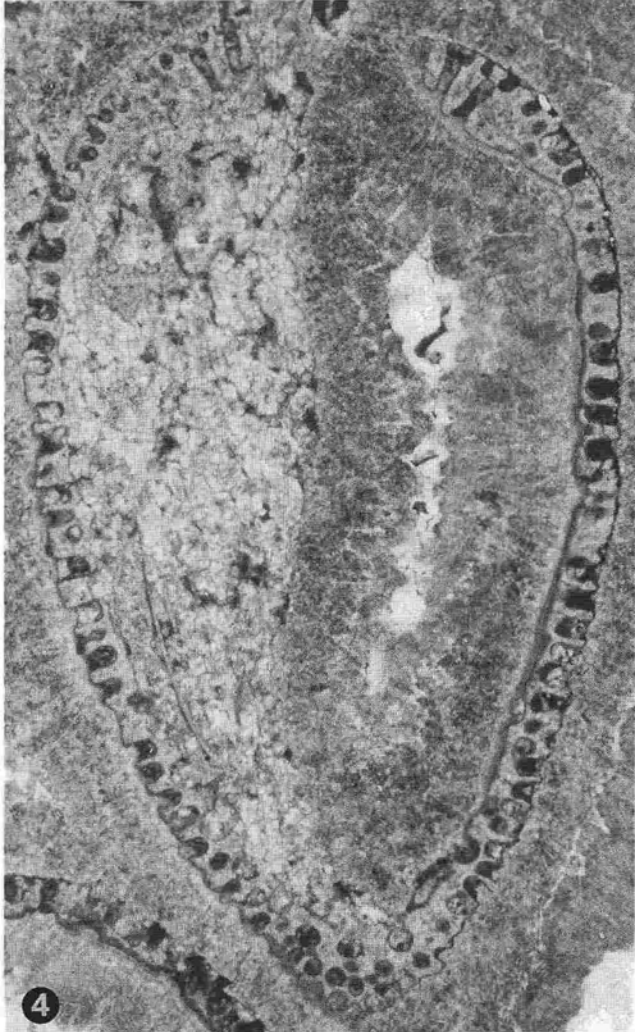
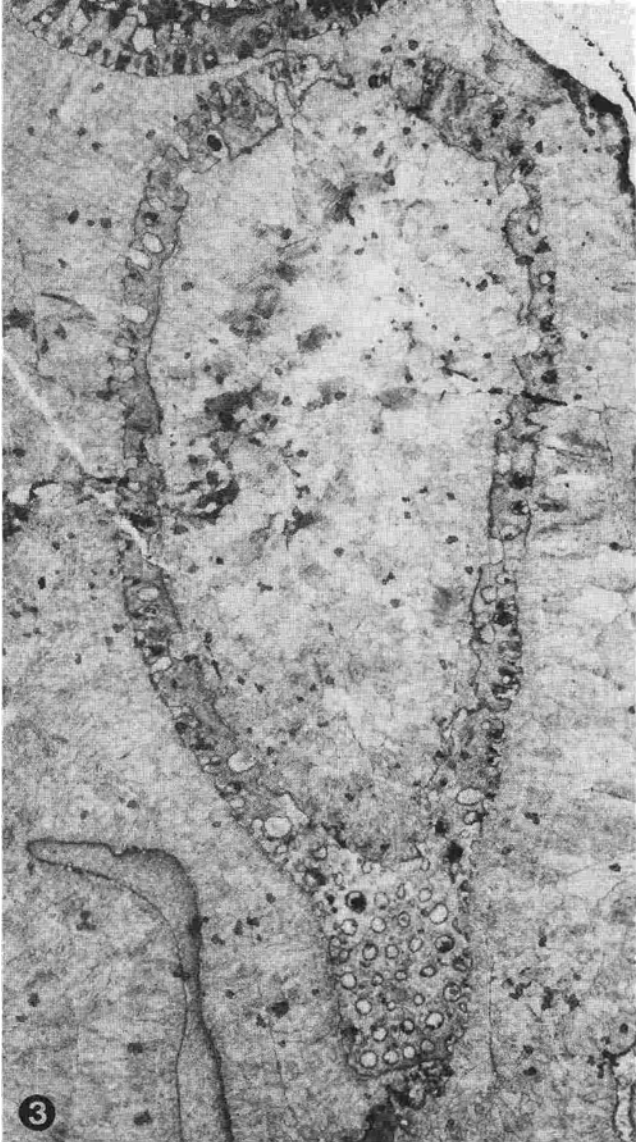
CM9 - coral framestone (Pl. 43/2). It consists of colonial corals in growth position. They can be encrusted by red algae. The intraparticle spaces are filled by mud or fine peloidal bioclastic sand. This microfacies belongs to a shallow subtidal high energy setting in front or just behind the platform margin.

CM10 - birdseyes limestones (Pl. 43/3). It is composed of oolitic and/or peloidal packstone-grainstones with birdseyes and fenestral fabrics and with thin algal laminae. The voids are usually filled with spar calcite. Birdseyes textures are typical for tidal flats, although when they occur in grainstones they are supposed to be deposited in a shallow subtidal

Plate 46 Liassic dasycladales from Calcare Massiccio Fm. (Gran Sasso, Central Italy): *Tersella genoti* n.sp.

Figs. 1, 3. Isotypes. Transversal-oblique sections probably cut between the stalk and the head part of the thallus; note the well defined swollen end of primary branches. Fig. 1: thin section BA.589.6, Fig. 3: thin section BA.589.5. Corno Grande. x 12

Figs. 2, 4-5. Isotypes. Transversal-oblique sections probably cut in the head part of the thallus; In section primary pores are represented as semicircles widely opened inward. Fig. 2: thin section BA.589.4, Fig. 4: thin section BA.589.11, Fig. 5: thin section BA.589.6. Corno Grande. x 12



environment (Shinn, 1982). The presence of algal lamination here is diagnostic for a peritidal setting.

CM11 - pisolitic limestone (Pl. 43/4). The presence of pisoids and thin cements crusts usually superimposed on the preceding CM1 to CM10 microfacies is typical. Fenestral fabrics, and/or dissolution cavities with geopetal textures can be present.

The lithofacies is the product of a vadose diagenesis due to subaerial exposure.

6.2 Sedimentary cycles

The vertical distribution of microfacies witnesses the cyclical organization of the Calcare Massiccio successions (Fig. 9). The cycles are generally composed of shallowing upwards diagenetic cycles formed of a basal subtidal interval (CM1-9) directly overlain by a supratidal interval (CM11). Peritidal cycles, although poorly spread, occur. They are characterized by an intertidal interval (CM11) that is interposed between a lower subtidal and an upper supratidal layer. Transgressive intertidal unit at the bottom of the subtidal unit are rare.

The diagenetic cycles of the Calcare Massiccio at Corno Grande have been interpreted by Bigozzi (1990) as allocycles controlled by high-frequency eustatic variations with Milankovitch characteristics (4th and 5th order). Based on the sedimentological data a similar interpretation could be extended to the C.M. cyclothemic facies investigated in the present paper.

5.2.3 Algal assemblages

Tersella genoti - *Fanesella sokaci* assemblage (Pl. 45/1-2). The assemblage is oligotypic. Besides the two index taxa, *Palaeodasycladus gracilis* CROS & LEMOINE occurs although less frequently. In addition, nodular *Cayeuxia*-like thalli and aggregate-grains have been observed (Pl. 43/1). The fauna is represented by bivalve shells. The presence of nerineids referable to the genus *Trochalia* is noteworthy.

This algal assemblage characterizes bioclastic grainstones (microfacies CM6), where it can represent the most important fossil group. The association populated shallow subtidal areas marked by open circulation conditions, with intense water movement and strong early diagenesis. It probably flourished in small patch reefs in front or just behind the shelf edge (Fig.10/B).

This assemblage is well represented at the Gran Sasso, where only lower Liassic members of the Calcare Massiccio occur.

Palaeodasycladus spp. assemblage (Pl. 44/2) It exhibits the highest diversity containing *Palaeodasycladus mediterraneus* (Pia), *Palaeodasycladus gracilis* CROS & LEMOINE, *Palaeodasycladus* sp., *Tersella genoti* n.sp. and *Petrascula ? heraki* SOKAC & NIKLER. Nodular *Cayeuxia*-like thalli are a common component. The fauna consists of bivalves, gastropods, echinoderms, calcareous sponges and corals. Among the gastropods, nerineids belonging to the genus *Pseudonerinea* (Pl. 44/2) occur. Foraminifers are represented by *Rectocyclammina* sp. (Pl. 44/2).

This algal assemblage is very frequent in bioclastic grainstones and packstones (microfacies type: CM2, CM6). It thrived on high energy, shallow subtidal settings, with clear water and open circulation which favoured the high floral and faunal diversity. The paleoenvironment was probably the backmargin area (Fig.10/B).

Palaeodasycladus and *Thaumatoporella* assemblage (Pl. 44/1). It is a moderately high diversity algal assemblage, even if its content never exceeds in richness the previous described one. *Palaeodasycladus* is represented by the species *P. mediterraneus* and *P. gracilis*. Other dasyclads (*Petrascula ? heraki* SOKAC & NIKLER) may occur, always less frequent. Mollusc shells and foraminifers (mainly siphonate valvulinids) are recorded in the faunal assemblage. *Thaumatoporellales* are represented by small globular to irregular thalli. Some of them, especially irregular ones, were encrusting skeletal grains and lithoclasts or are found inside skeletal cavities, others, mainly globular forms, were probably free rolling on the bottom (De Castro, 1990b).

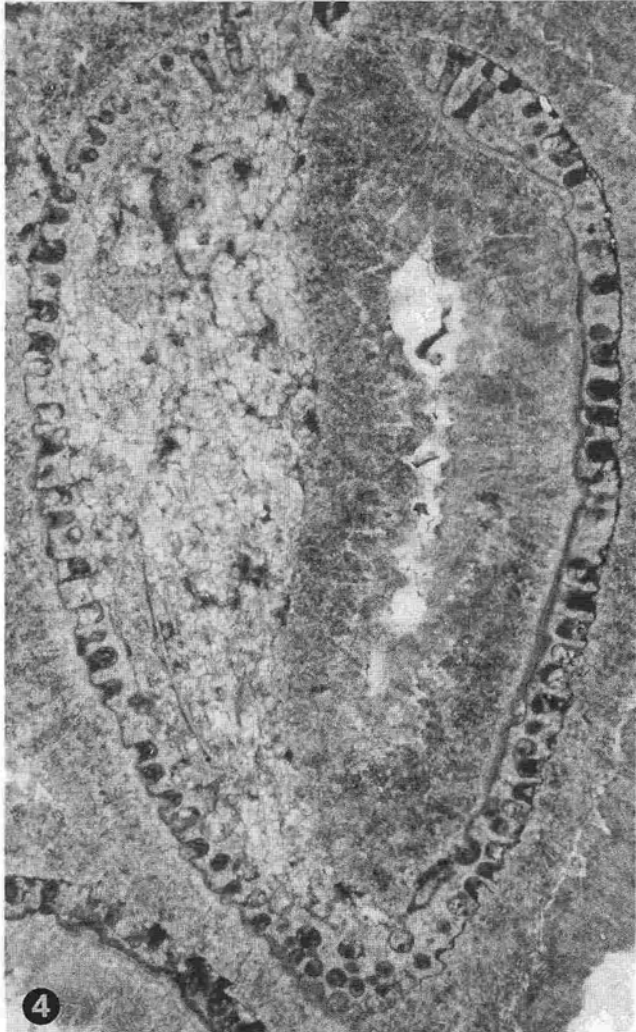
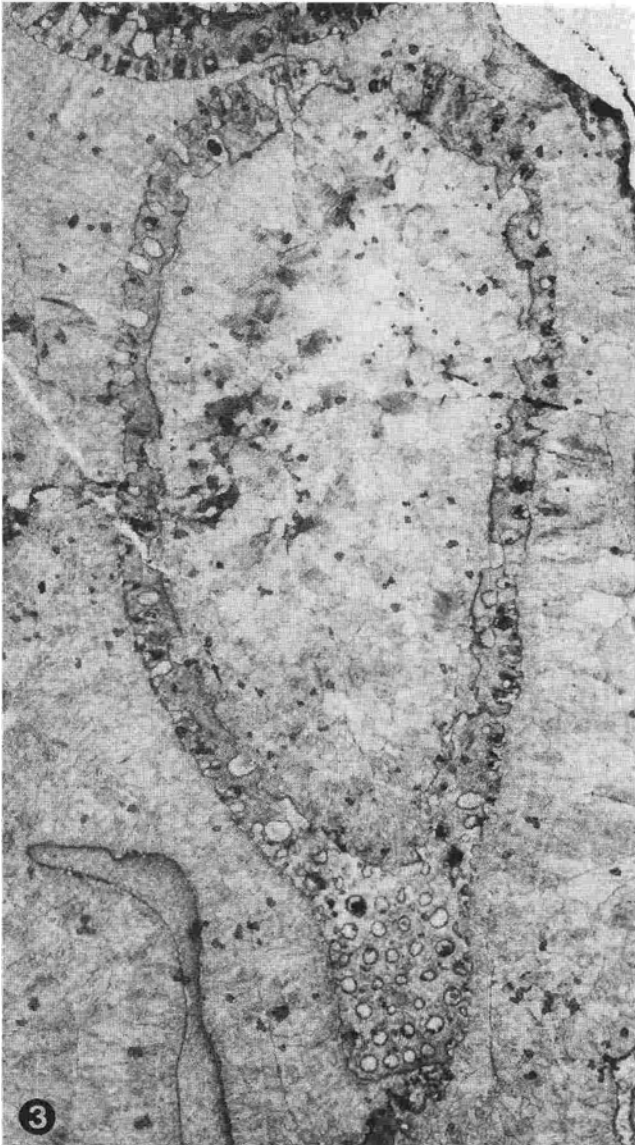
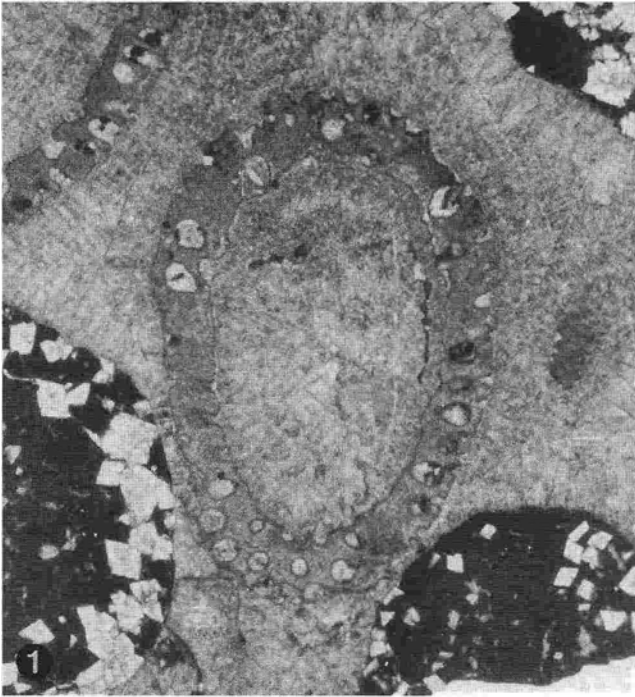
This algal assemblage is present in bioclastic wackestones and packstones (microfacies CM1). It occurs in shallow subtidal settings, in an open lagoon with open circulation and moderate water movement.

5.2.4 Depositional environment

Based on microfacies and algal assemblage distribution and their relative frequency two main paleoenvironmental facies can be identified:

- *backmargin facies*. It is characterized by diagenetic cycles with high-energy subtidal units (Fig. 10/B). The

- Plate 47 Liassic dasycladales from Calcare Massiccio Fm. (Gran Sasso, Central Italy): *Tersella genoti* n.sp.
- Figs. 1-2. Isotypes. Oblique sections probably across the stalk part of the thallus. Fig. 1: thin section BA.589.4, fig.2: thin section BA.589.5. Corno Grande. x 12
- Fig. 3. *Holotype*. Longitudinal-oblique section cutting the stalk and the head part of the thallus; the section crosses, although a little peripherally, the apical zone (top of figure). Thin section BA.589.11. Corno Grande. x 12
- Fig. 4. Isotype. Longitudinal-oblique section intersecting the head part of the thallus as well as the apex (see also Pl. 50/1). Thin section BA.591.4 (= FR13). Corno Grande. x 12



microfacies consist of packstones and grainstones with oncolites, bioclasts, aggregate lumps (microfacies CM3-5) and of pisolitic limestones (CM11). Less frequently peloidal packstones, bioclastic wackestones (CM1-2) and birdseyes limestones (CM10) occur.

The *Palaeodasycladus* spp. and *Petrascula ? heraki* algal assemblage dominate but, *Tersella genoti* - *Fanesella sokaci* algal assemblage can also be present, while the *Palaeodasycladus* and *Thaumatoporella* algal assemblage is rare.

Cycles have an average thickness of 2.5 m and a shallowing upwards character. Peritidal cycles as well as deepening upward cycles are almost completely absent. This facies occurs in the lower portion of the C. M. at Corno Grande and the lower portion of the C.M. at Mt. Capo Le Serre (Figs. 4-5).

The paleoenvironmental data suggest that the area was subject to intense water movement and conditions of open circulation, confirmed by the high-diverse biota. It was most likely intersected by migrating tidal channels where oncolitic packstones were deposited. Locally protected areas, probably representing transitional environments between backmargin and the lagoon, were populated by the *Palaeodasycladus* and *Thaumatoporella* algal assemblage and are characterized by peloidal bioclastic wackstones-packstones (CM1-2 microfacies). The depositional environment was strongly influenced by sea-level oscillations which caused the periodic exposure of the back margin and the formation of diagenetic cycles (BOSELLINI & HARDIE, 1985).

- *shelf edge facies*. The facies shows a less pronounced cyclicity with respect to the backmargin facies but diagenetic cycles can be still present (Fig. 10/B). The microfacies are characterized by grainstones and rudstones with oolites, bioclasts and lithoclasts, by coral framestones (CM6-9 microfacies) and by pisolitic limestone (CM11).

The *Tersella genoti* - *Fanesella sokaci* and *Palaeodasycladus* spp. algal assemblages dominate but *Palaeodasycladus* and *Thaumatoporella* algal assemblage can occasionally be found.

The present facies outcrops at Corno Grande (upper terms of the Calcare Massiccio Fm., Fig. 4), at the basal part of Sella dei due Corni succession (Fig. 8) and at Mt. Capo le Serre (upper part of C.M. Fm., Fig. 5).

The depositional environment was subject to an intense water movement and an early diagenesis. The margin was

formed of oolitic and bioclastic sand shoals, with some scarce contribution of reef building organisms, such as corals, sponges and solenoporacean algae. These organisms formed small patch-reefs behind or just in front of the platform margin where they found a more firm and stable substrate. Formation of a continuous barrier reef can be excluded.

Sea level changes strongly controlled the depositional environment, as suggested by the numerous evidences of subaerial exposure. However, the absence of a pronounced cyclical stacking pattern can be due to the erosion of the shelf edge either during low stand, or early transgressive phases, which could have reduced the preservation of a good eustatic signal.

According to the distribution of shelf, margin and slope facies in the Gran Sasso during the Late Triassic - middle Liassic it is possible to supply a tentative palaeogeographic map of the area (Fig. 11). In the early Liassic, the marginal facies becomes more widespread and migrates westward in respect to the Late Triassic scenery. In the middle Liassic most part of the studied area was drowned.

6 STRATIGRAPHICAL DISTRIBUTION OF ALGAE

Gyroporella vesiculifera has been observed in the Ofena succession (Fig. 7). In this series only *Aulotortus* sp. is present, the age can be generically assigned to the Norian-Rhaetian, that is also the stratigraphical distribution recognized for *Gyroporella vesiculifera*, if a doubtful Lower Jurassic record (CROS & LEMOINE, 1966) is neglected.

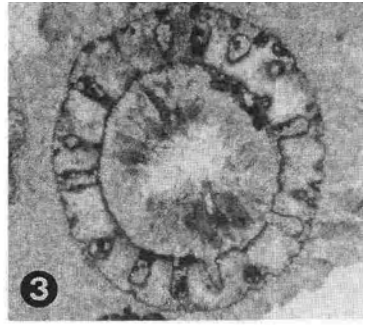
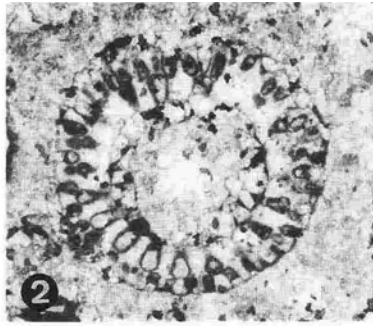
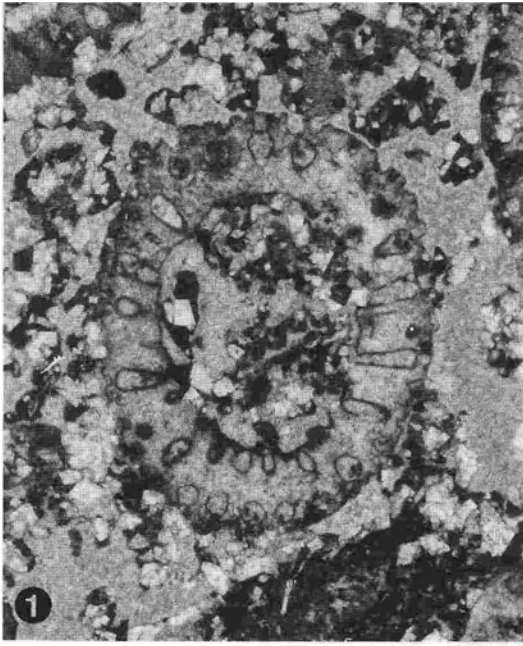
Griphoporella curvata has been found in the Dolomia Principale of Mt. Meta (Fig. 6), Mt. Capo le Serre (Fig. 5), as well as, but dolomitized, in the Dolomia Principale of Corno Grande (Fig. 4). In this last succession the alga is accompanied by *Aulotortus friedli*, both of them occurring during the whole formation. In the Mt. Capo le Serre the alga occurs in all the Dolomia Principale; it is associated at the base with *Aulotortus friedli*, while in the middle-upper part it occurs together with *Triasina hantkeni*. At Mt. Meta *Griphoporella curvata* is present throughout the Dolomia Principale, always with *T. hantkeni* and *A. friedli*. The Norian-Rhaetian age is generally accepted in literature.

Although the Calcare Massiccio (about 600-700 m complexively thick) is found in several profiles (Mt. Meta,

Plate 48

Liassic dasycladales from Calcare Massiccio Fm. (Gran Sasso, Central Italy): *Tersella genoti* n.sp.

- Figs. 1-3. Isotypes. Transversal-oblique sections cutting the stalk part of the thallus. Note the elongated primary and the small secondary branches. Fig. 1: thin section BA.597.2, Fig. 2: thin section BA.591.5 (= FR13); Fig. 3: thin section BA.598.6. Corno Grande. x 12
- Fig. 4. Isotype. Longitudinal-oblique section from a "poorly differentiated" thallus. Thin section BA.589.a.4 (= CG3). Corno Grande. x 12
- Fig. 5. Isotype. Longitudinal-oblique section cutting the stalk and the head part of the thallus as well as the apex. Thin section BA.591.3 (= FR13). Corno Grande. x 12



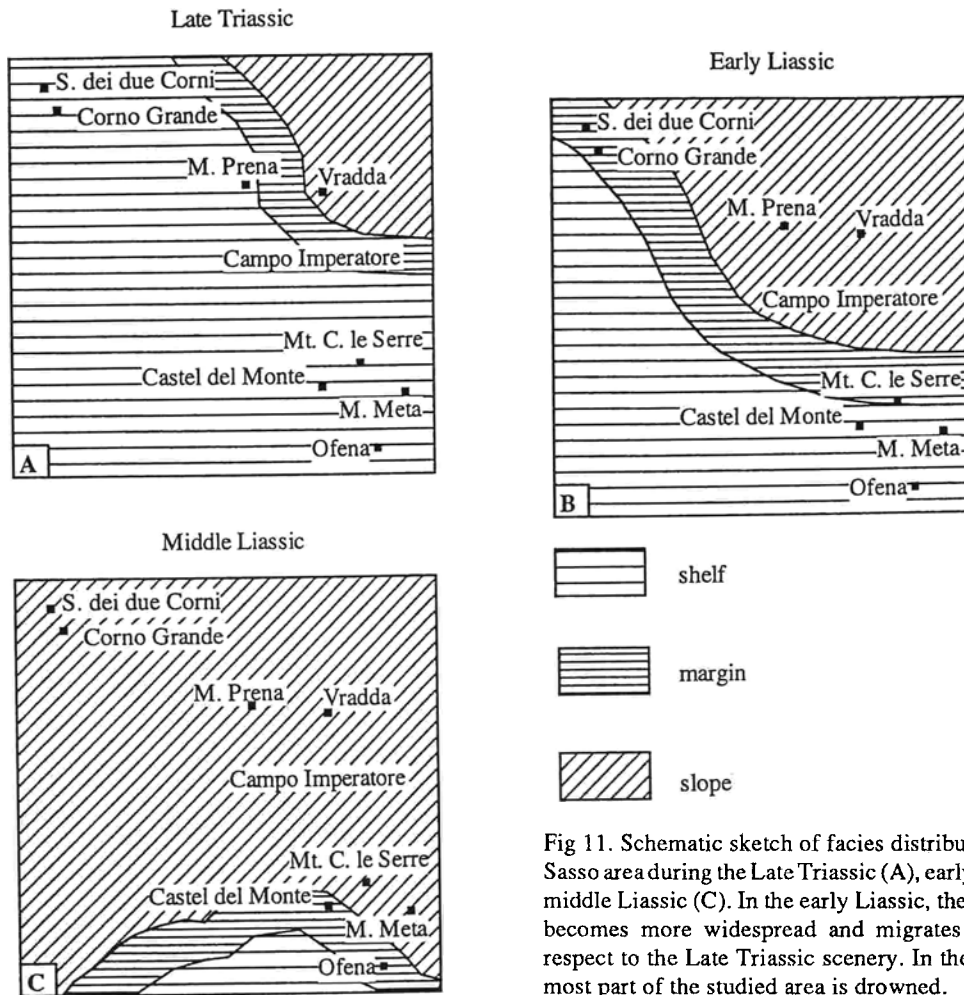


Fig 11. Schematic sketch of facies distribution in the Gran Sasso area during the Late Triassic (A), early Liassic (B) and middle Liassic (C). In the early Liassic, the marginal facies becomes more widespread and migrates westward with respect to the Late Triassic scenery. In the middle Liassic most part of the studied area is drowned.

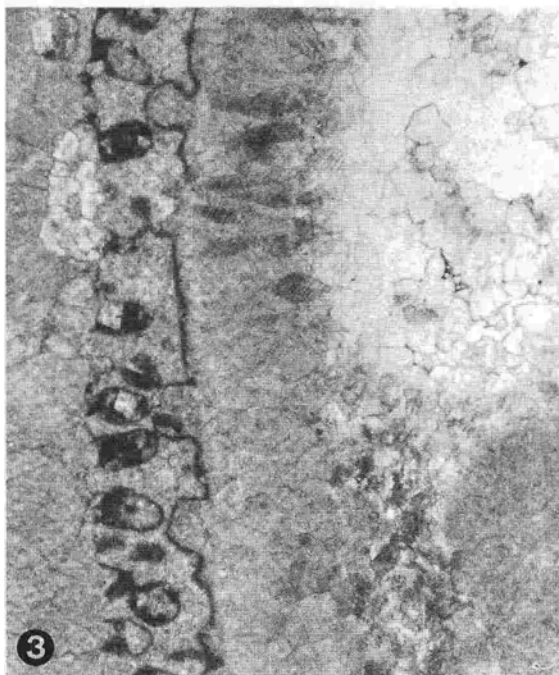
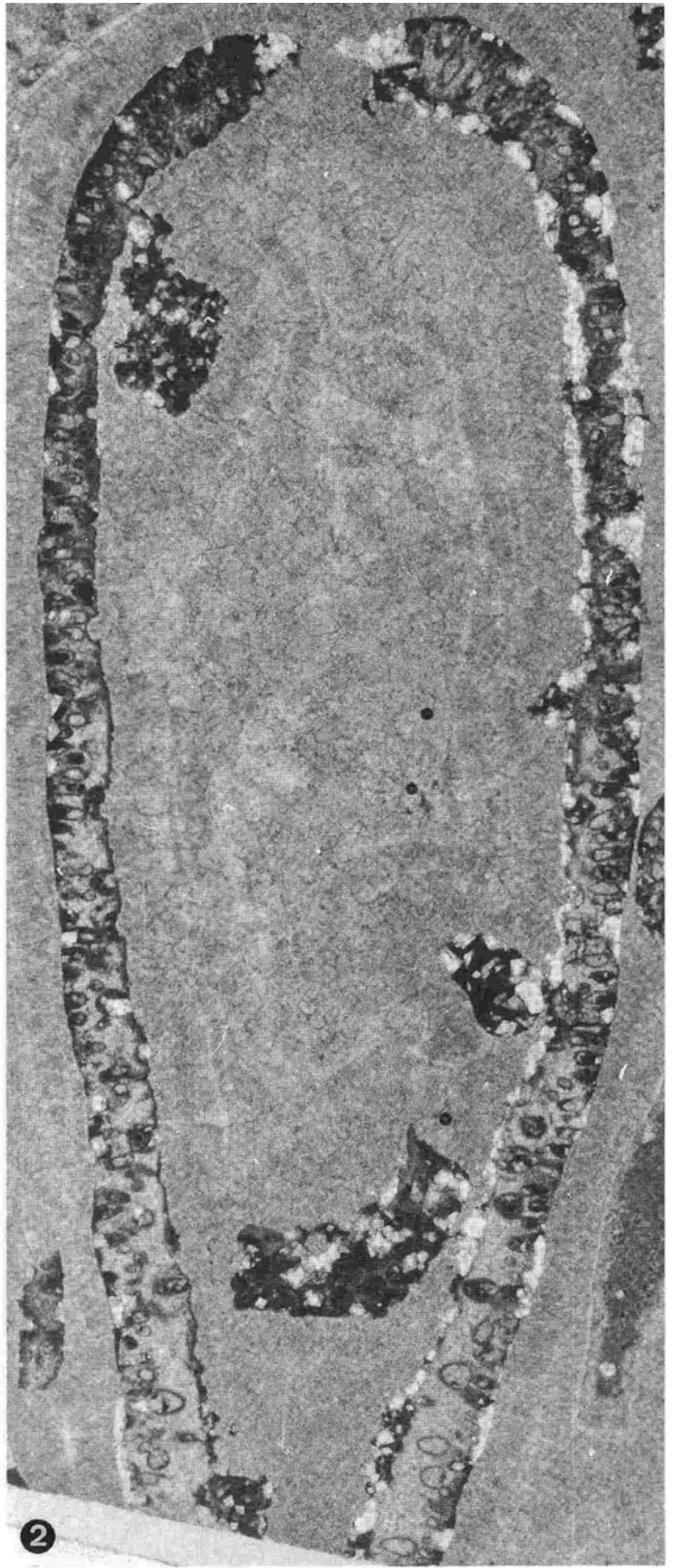
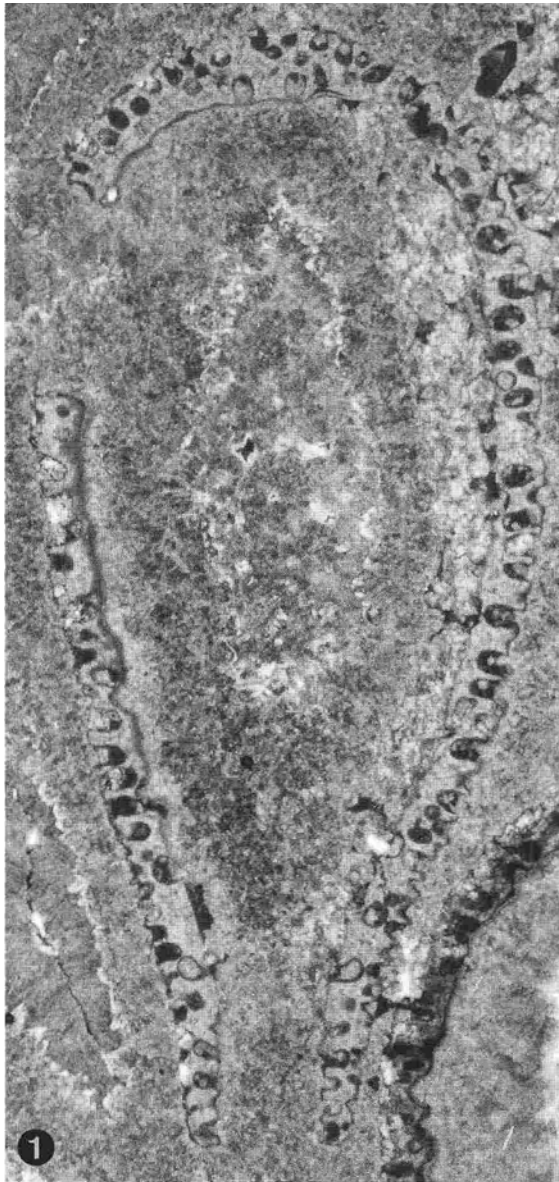
Fig. 6; Mt Capo le Serre, Fig. 5; Sella dei due Corni, Fig. 8) the only one rich in dasyclads and exhibiting the contact with the underlying formation is the Corno Grande succession (Fig. 4). Here the first dasyclads (*Palaeodasycladus gracilis* and *Tersella genoti* n.sp) appear about 100 m above the Dolomia Principale/Calcare Massiccio boundary, while *Palaeodasycladus mediterraneus* appears 150 m higher. *Fanesella sokaci* n.sp. is found in the last 100 m, i.e. 500 m above the boundary. This alga occurs also at Sella dei due Corni succession (Fig. 8) where it reaches the top of the Calcare Massiccio Fm. marked by an emersion surface and overlain by the Corniola Fm.. The global range of the Calcare Massiccio Fm. covers the Hettangian-Sinemurian interval. The lower limit corresponds to the disappearance of *Aulotortus friedli*, *Triasina hantkeni* and

Griphoporella curvata. The upper boundary can only be dated because of the overlying Corniola Fm, which contains Carixian nannofossils and Domerian ammonites (Prof. Venturi, pers. comm.). A Sinemurian age of the top of the Calcare Massiccio may be assumed because of the occurrence of characteristic Liassic algae and by the absence of typical middle Liassic foraminifera.

In the carbonatic sequences of the Central-Southern Apennines *Palaeodasycladus mediterraneus* appears 150-300 m over the last beds containing *Aulotortus sinuosus*, *Griphoporella curvata* and *Triasina hantkeni* (DE CASTRO, 1991; CHIOCCHINI et al. 1995), almost at the same time as *P. gracilis* (sub ?*Teutloporella elongatula*; CHIOCCHINI et al. 1995). According to De CASTRO (1987, 1991) the age of appearance is Hettangian p.p.- lowermost Sinemurian;

Plate 49 Liassic dasycladales from Calcare Massiccio Fm. (Gran Sasso, Central Italy): *Tersella genoti* n.sp.

- Figs.1-2 Isotypes. Longitudinal sections. Fig.1: thin section BA.597.1, fig.2: thin section BA.597.3 (= FC1). Corno Grande. x 12
- Fig. 3. Isotype. Detail of a longitudinal-oblique section that shows the shape of primary and secondary pores in the head part of the calcareous skeleton. Thin section BA.597.5 (= FC1). Corno Grande. x 20.9
- Fig. 4. Isotype. Detail of a transversal section that shows the shape of primary and secondary pores in the head part of the calcareous skeleton. Thin section BA.597.5 (= FC1). Corno Grande. x 20.9



according to CHIOCCHINI et al. (1995) it is a little older (upper Sinemurian). If we agree with De Castro the lower portion of the Calcare Massiccio before the appearance of *Palaodasycladus gracilis* has to be ascribed totally or partly to the Hettangian.

The stratigraphical distribution of the new algal taxa (*Tersella genoti* and *Fanesella sokaci*) can be inferred with reasonable confidence only from their first appearance because the top of the formation is cut by an emersion surface and covered by deep-water sediments. According to the stratigraphical data *Tersella genoti* n.sp. exhibits an Hettangian p.p.- Sinemurian interval, while *Fanesella sokaci* n.sp. seems to be limited to the Sinemurian.

8 PALEONTOLOGY

The most abundant fossil remains found in the studied area belong to green algae (dasycladales) and to molluscs (bivalves and gastropods). As a second, but occasionally abundant, important part of the fossil assemblage, foraminifers, cyanobacteria and thamatoporellaleans occur. Echinoderms, calcareous sponges and corals are rare. The following dasyclads are of special interest.

8.1 Genus *Tersella* MORELLET in MORELLET & TERS 1951

The genus *Tersella* was established by Jean MORELLET in 1951 (MORELLET & TERS, 1951) in a study on some dasyclad taxa from the Hettangian of Vendée (France). He supplied a comprehensive diagnosis for the genus and its type-species (*Tersella incompleta*). In MORELLET's opinion the alga is characterized by a club-shaped, thin calcareous skeleton, open at both ends. The lowest order branches are arranged in whorls but are calcified only at their distal end. Each branch ramifies into phloioporous branches of next higher order that show a subterminal narrowing before flaring out to form a sort of network of polygonal meshes at their distal end (most likely a cortex).

In 1967 CROS & LEMOINE established the species *Tersella alpina* from the Liassic of Northern Italy (Dolomites, Asiago Plateau). They agree with the MORELLET's diagno-

sis but propose a description (p. 249) stressing the differentiation of calcareous skeleton into a lower stalked part and an upper head. This character is evident only in some specimens of *T. alpina* but absent (never observed) in the type species (*T. incompleta*), where it was hypothetically assumed by CROS & LEMOINE (1967).

CUBAYNES & DELOFFRE (1984) established a new species, *Tersella quercyensis*, from the Toarcian of France (Central Massif). The authors emended the genus *Tersella* giving the following diagnosis: " *Le manchon calcaire se présente comme une tige cylindrique bien développée qui s'élargit pour donner un renflement en massue. Celle-ci est ouverte à son sommet pour permettre le passage de la continuation de la tige et la formation d'une nouvelle massue superposée. Les pores dans l'épaisseur du test indiquent l'existence de deux ordres successifs de ramifications.*"

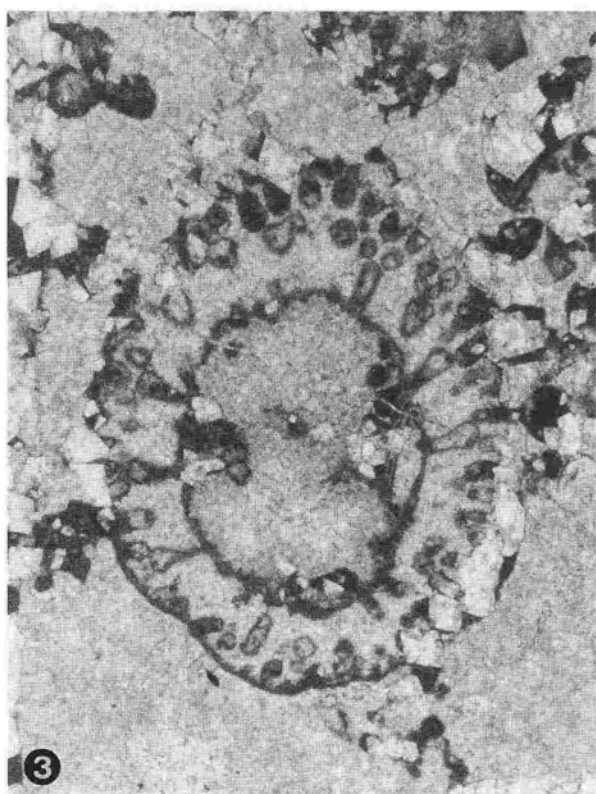
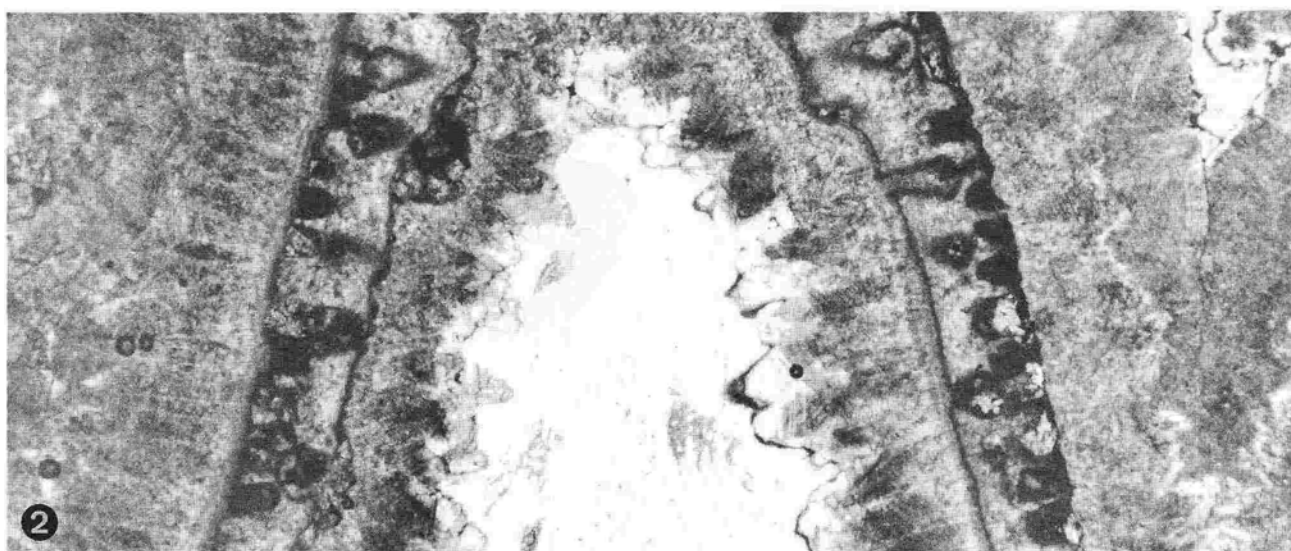
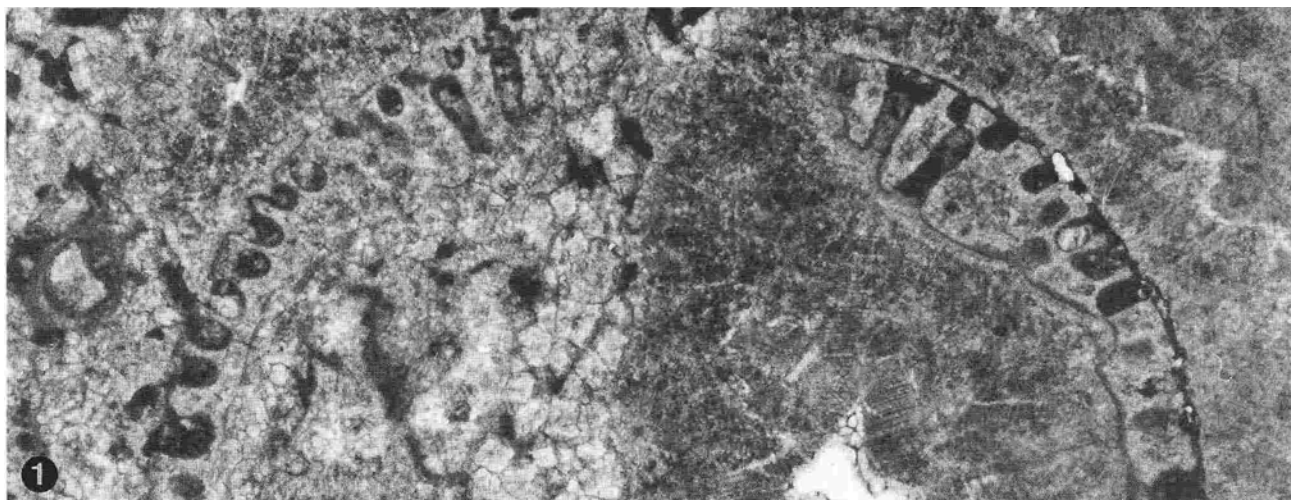
(The calcareous skeleton displays a well developed cylindrical stem that flares giving rise to a club-shaped swelling. This latter is open at the top in order to allow the stem to pass and make a new superimposed club-shaped unit. The pores inside the calcareous skeleton show the presence of two orders of branches.)

Which taxonomical weight should be attributed to the upper "opening" of the calcareous skeleton of *Tersella* is largely a matter of interpretation. If interpreted as the passage of the central stem, as in moniliform thalli (e.g. *Cymopolia*), then its taxonomical value must be high (generic level). This was first discussed by MORELLET (1951: p. 647). However he himself thought it to be unlikely because the articles of *Cymopolia* never show a well-rounded top and a tapered bottom as in *Tersella incompleta* (actually clavate articles were pointed out later: e.g. *Cymopolia inflataramosa* SEGONZAC). Afterwards the "moniliform hypotesis" was espoused by CUBAYNES & DELOFFRE (1984), which they founded their generic emendation on.

On the other hand if we explain the upper "opening" as a lack of calcification then its taxonomical value must be very low (below the specific level). In fact in several extant genera (e.g. *Bornetella*, *Neomeris*, *Cymopolia*) the apex, when it still holds hair-like branches, is uncalcified.

Plate 50 Liassic dasycladales from Calcare Massiccio Fm. (Gran Sasso, Central Italy): *Tersella genoti* n.sp.

- Fig. 1. Isotype. Detail of Pl. 47/4 showing the apical zone. Note the reduction in size of the secondary branches against the thickening of calcification and elongation of primary pores. Calcification stops just before the apex. Thin section BA.591.7. Corno Grande; x 20.9
- Fig. 2. Isotype. Detail of a longitudinal section between the stalk and head part of the calcareous skeleton in order to show the change in shape and/or size of primary and secondary pores. Notice how the calcareous skeleton becomes thinner and thinner upwards. Thin section BA.591.2 (= FR13). Corno Grande. x 20.9
- Fig. 3-4. Isotypes. Oblique sections in higher magnification showing the elongated primary branches in the stalk part of the thallus. Fig.4: the inner surface of the calcareous skeleton is regular and smooth *downwards* (probably because it touched the central stem) but irregular *upwards* (most likely because it departs from the central stem). Thin sections BA.597.6 and BA.597.8 (= FC1) respectively. Corno Grande. x 20.9



Actually, for the time being, no clear evidence exists that the type-species, and by reflex the genus, shows a moniliform thallus.

CROS & LEMOINE (1967) considered the presence of a stalked skeleton as a generic character in *Tersella*. This character seems to be too much restrictive, especially when such a shape can not be discerned in the type-species. On the other hand extant genera show a wide variability on this regard. The genus *Bornetella*, for example, includes both club-shaped and spherical species.

For these reasons it is, at the moment, better to stick to MORELLET'S original diagnosis.

Discussion on other comparable taxa. According to MORELLET'S diagnosis the characters of *Tersella* are rather close to *Dissocladella* PIA in RAO & PIA 1936. Also if the differences between the genera were not indicated by Morellet they are founded on the shape of the thallus and primary pores. The thallus is club-shaped, often differentiated in a stalk and an ovoid head in *Tersella*, cylindrical to slightly club-shaped in *Dissocladella*.

Primary branches are largely unknown in *Tersella* because uncalcified for the most extent, except their distal end. They are short and swollen outwards in *Dissocladella*, almost spherical in the type-species (*Dissocladella savitriae* PIA in RAO & PIA 1936).

The type-species of the two genera are not well known. A re-study on a richer material is necessary to judge the validity of the genus *Tersella* in respect to *Dissocladella*. Although a simple variation in the degree of calcification can not be used to differentiate the genera, at the present state of knowledge it seems better to keep separate the two genera. This fact will permit to give a generic status to a well defined group of species, sharing a more or less differentiated club-shaped thallus.

In the paleoalgal literature some Liassic species, currently ascribed to other genera, can be tentatively placed in the genus *Tersella*.

DRAGASTAN & TRAPPE (1986) described two new species (*Dissocladella iberica* and *D. ebroensis*) from a Liassic sequence of Iberian Chain (Spain) associated with some other specimens indicated as *Dissocladella lucasi* (CROS & LEMOINE), *Sestrosphaera liasina* PIA and *Gyroporella retica* (ZANIN BURI). The photographs and the descriptions supplied by the authors give the impression that all the taxa do

not differ significantly from each other and that they represent different sections of a single, slightly club-shaped, terselliform species.

Few years ago DELOFFRE & LAADILA (1990) attributed to *Palaeodasycladus mediterraneus* PIA some algae from the Lotharingian of Morocco. According to Barattolo *et al.* (1994) this taxon belongs to another species. Actually the Morocco species looks very similar to *Tersella genoti* n.sp. Only a somewhat bigger size of the calcareous skeleton and the smaller size of the primary branches do not allow a clear attribution to the new species.

More taxonomic uncertainty can arise for those species that show squat, finger-like, cylindrical to slightly club-shaped thalli exhibiting two order of branches and a distal calcification of primary branches (e.g. *Dissocladella cretica* OTT and *Linoporella lucasi* CROS & LEMOINE).

Dissocladella cretica was established by Ott in 1965 for some dasyclads coming from the Liassic of Crete (KOPP & OTT, 1977). I had the opportunity to see the type material during the Alpine Algae meeting (September 1993); although the state of preservation is rather poor most of the data supplied by OTT (1965) can be confirmed. The alga shows a slightly club-shaped calcareous skeleton, tapered and open at both ends. The central cavity is wide and the short swollen primary pores do not show, in their axial section, any inner narrowing referable to a junction point. Therefore the primary pores correspond to the calcified terminal part of primary branches as in *Tersella incompleta* and *T. genoti* n.sp. For this reason we propose here the new combination *Tersella cretica* (OTT).

Linoporella lucasi CROS & LEMOINE (1967) shows a cylindrical calcareous skeleton clearly tapered at the bottom where calcification becomes stronger (CROS & LEMOINE, 1967: pl. 1 fig. 5). The primary branches are calcified only at their distal end and are moderately thick. As affirmed by the authors, some sections look like those of *Tersella alpina* which occurs in the same assemblage. The shape of the thallus and the characters of the branches hardly permit a position in the genus *Linoporella* (see for example BARATTOLO, 1991b). This is why some authors questioned the attribution to *Linoporella* (BASSOULET *et al.*, 1978) and others proposed a transfer into the genus *Dissocladella* (DRAGASTAN & TRAPPE, 1986). The possibility that this taxon could represent a *Tersella* cannot be excluded.

Plate 51 Liassic dasycladales from Calcare Massiccio Fm. (Gran Sasso, Central Italy): *Fanesella sokaci* n.sp.

Figs. 1-4, 6. Isotypes. Transversal-oblique sections. Figs. 2-4 show a calcification that reaches the central stem. In Figs. 1, 4 calcification covers part of the primary branches up to quaternaries. Fig. 1: thin section BA.589.9, Fig. 2: thin section BA.589.8, Fig. 3: thin section BA.589.6, Fig. 4: thin section BA.589.8, Fig. 6: thin section BA.589.3. Corno Grande. x 15

Fig. 5. Isotype. Oblique section. Notice the narrow central stem and its weak calcification. Thin section BA.589.4. Corno Grande. x 15

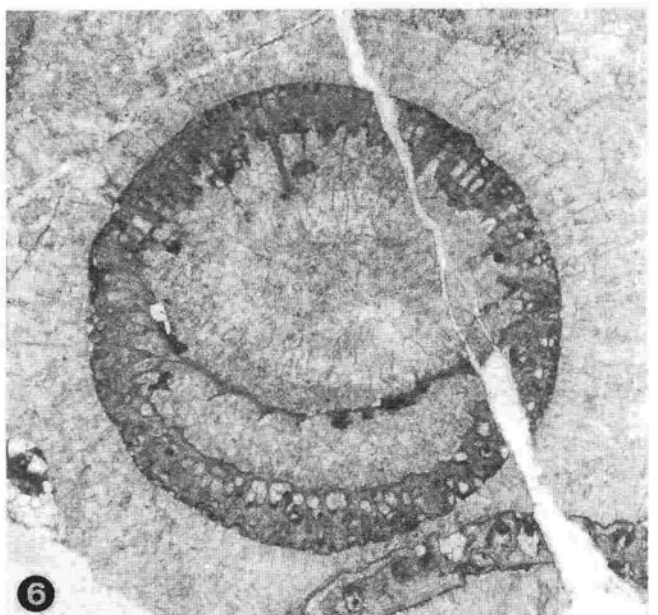
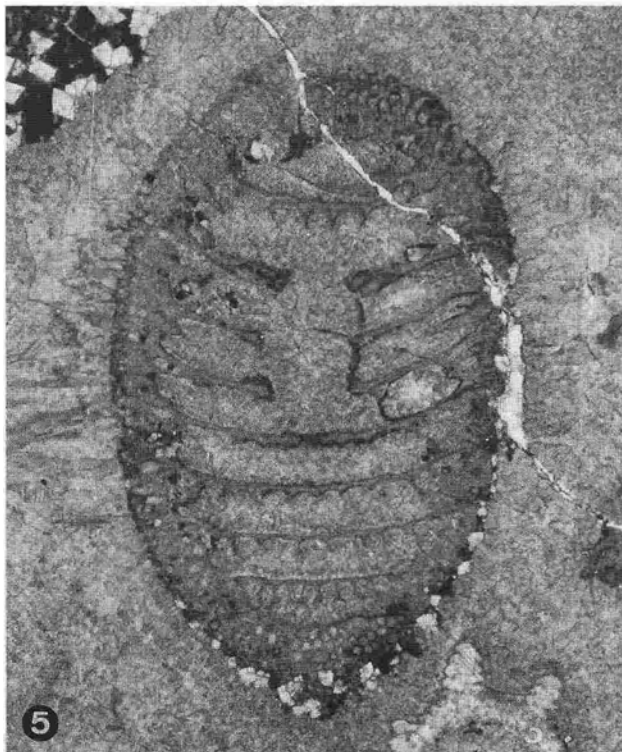
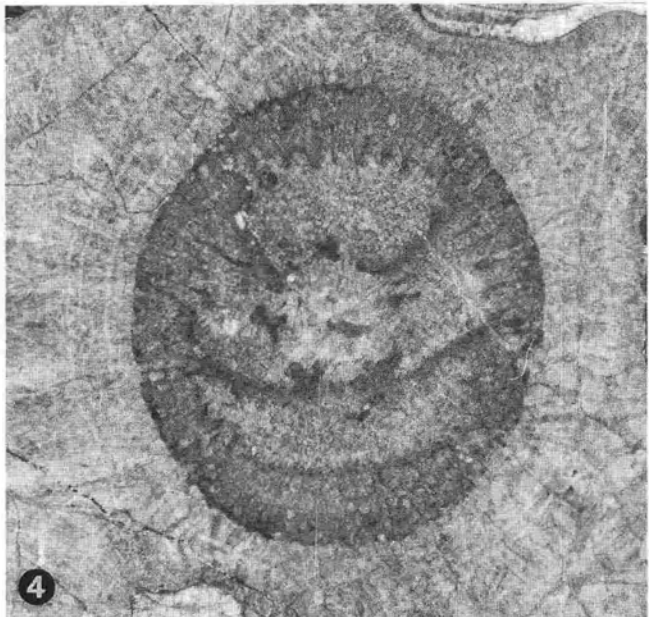
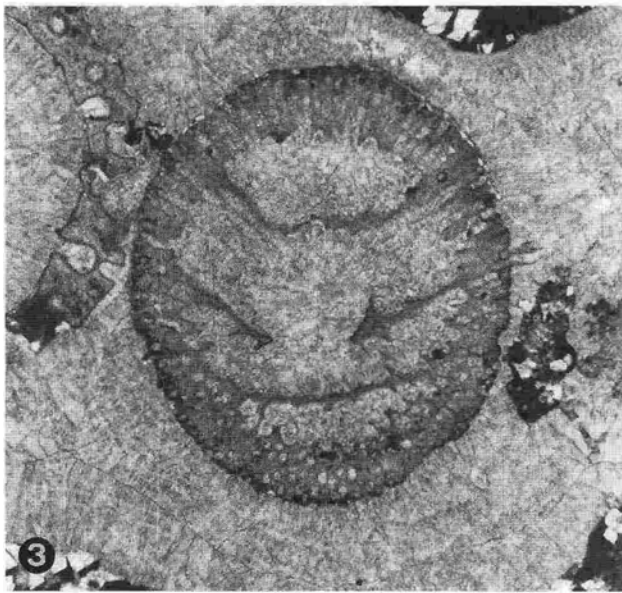
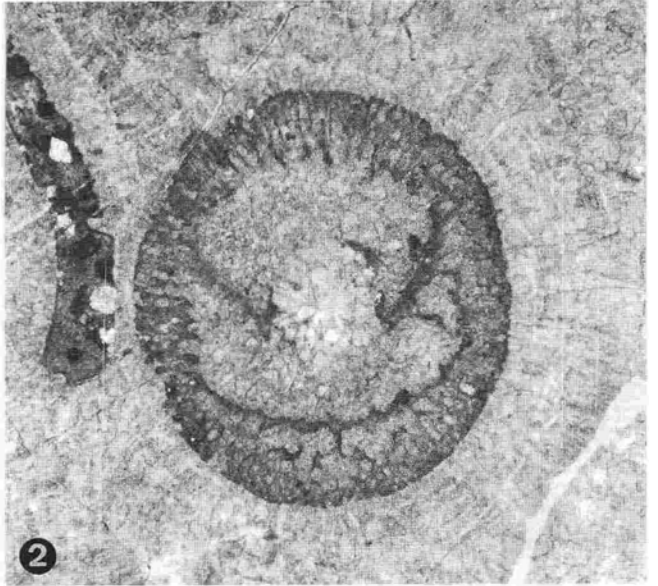
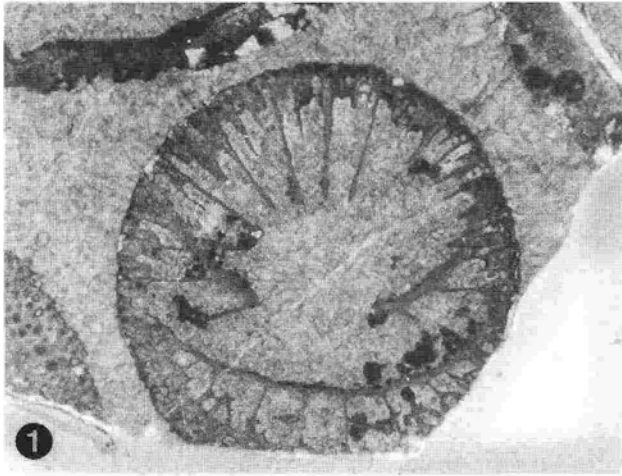




Fig. 12. Geographic setting of the type-locality of *Tersella genoti* n.sp. and *Fanesella sokaci* n.sp. The location of the sample BA.589 is indicated by an arrow.

8.1.1 *Tersella genoti* n.sp. (Pls. 45-50)

Origin of the name. The species is dedicated to the colleague Patrick Genot, Department of Earth Sciences, University of Nantes, for his contributions to knowledge of fossil algae.

Holotype. Specimens in longitudinal section figured in Pl. 47/3. Thin section BA.589.11.

Isotypes. Specimens of the sample BA.589 (= CG2 of the Bigozzi sampling): thin sections BA.589.1 - BA.589.11. Other material is represented by the samples BA.589.a (= CG3), BA.591 (= FR13), BA.597 (= FC1) and BA.598 (FC3).

Type-locality. Northern slope of Corno Grande (Gran Sasso, Central Italy), at about 2700 metres of altitude (Fig.12).

Type-level. Thick bedded white bioclastic packstones (see microfacies CM3).

Depository. The material is deposited at the Department of Palaeontology, University of Naples Federico II (Barattolo collection).

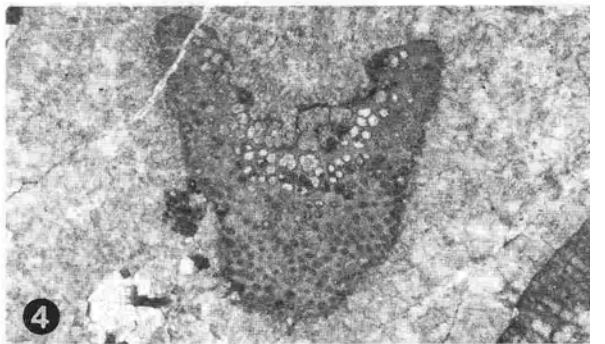
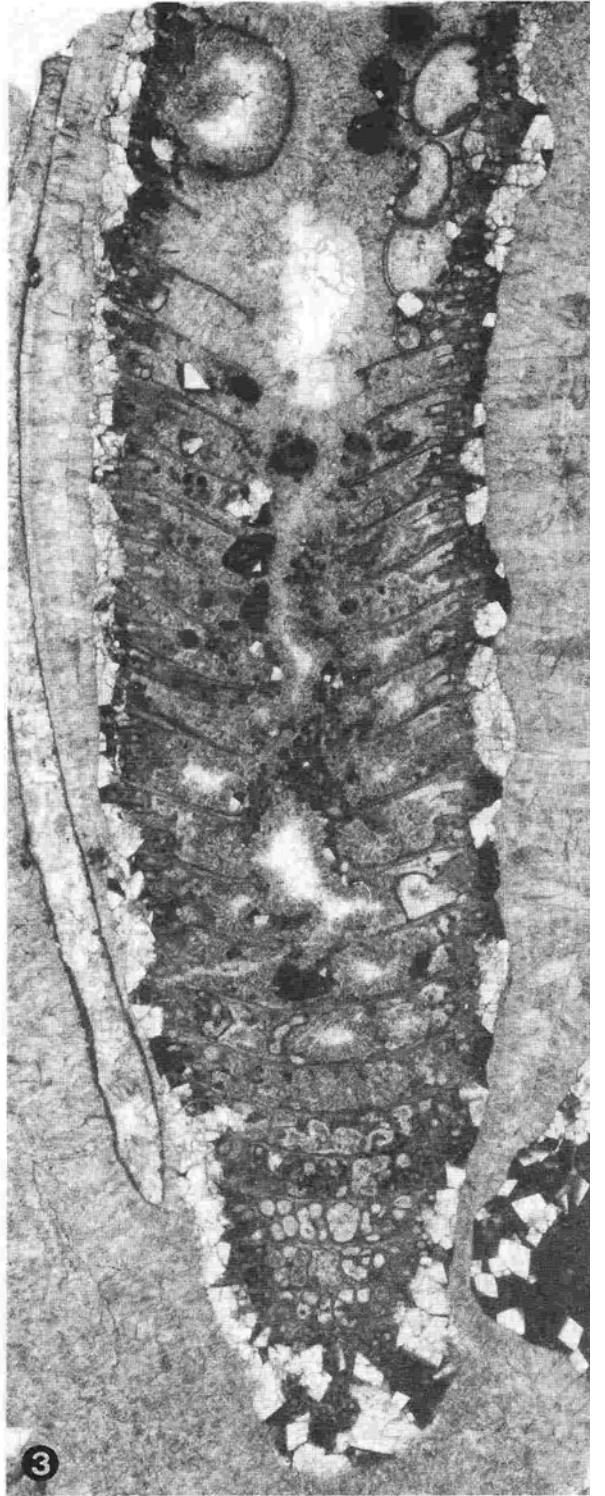
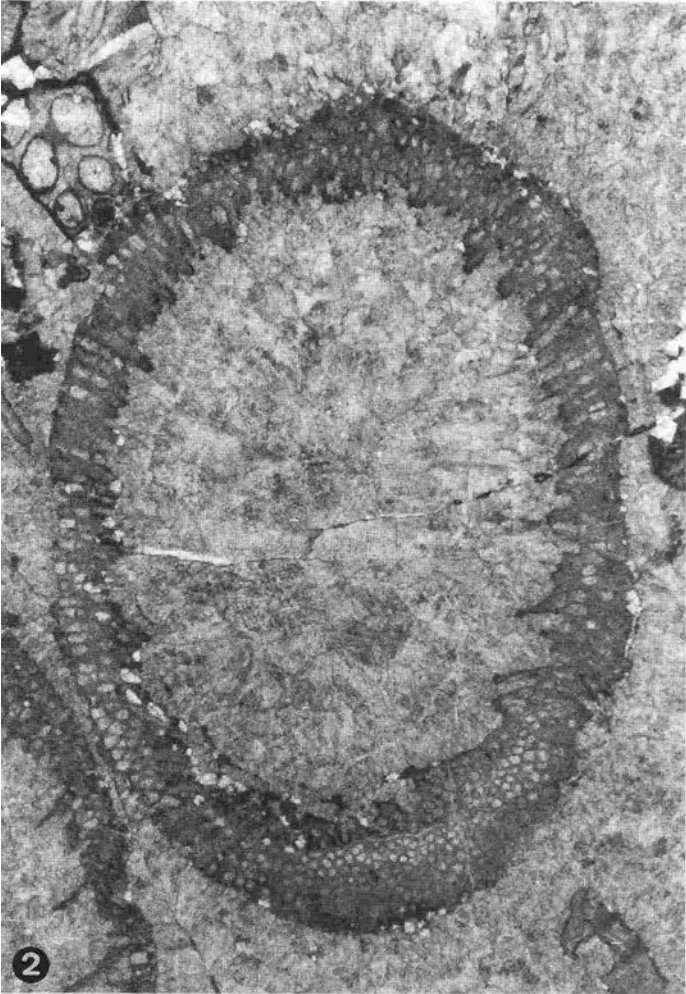
Diagnosis. Club-shaped simple thallus with a moderate differentiation into a subcylindrical lower part (the stalk) and an enlarged ellipsoidal upper head. Primary branches arranged in close verticils and alternating in the following ones. They are set almost perpendicularly to the main axis. However, moving to the top of the thallus, primary branches bend more and more upwards so that they are set vertically near the apex. Primary branches of the stalk are moderately long and widened outwards, with a circular cross section. Only distal ends of primary branches calcify in the head of the thallus, resulting in globular primary pores. Secondary branches, 4-5 per tuft, roughly keep the same inclination as the primaries. In their calcified part they are short and slightly widened outwards. They probably were phloio-

Plate 52 Liassic dasycladales from Calcare Massiccio Fm. (Gran Sasso, Central Italy): *Fanesella sokaci* n.sp.

Figs. 1, 3. Isotypes. Oblique sections showing a calcification mainly restricted to secondary-quaternary branches. Fig. 1: thin section BA.589.10, Fig. 3: thin section BA.589.10. Corno Grande. x 15

Fig. 2. **Holotype.** Longitudinal-oblique section. Notice the strong primary branches and the fact that calcification becomes weaker upwards enveloping only the branches of higher order. Thin section BA.589.7. Corno Grande. x 15

Fig. 4. Isotype. Tangential-oblique section showing secondary branches, tufts of three-four tertiary branches and a peripheral zone with crowded pores most likely corresponding to quaternary branches. Thin section BA.589.3. Corno Grande. x 15



Spec.	Thin section	Part	D	d	D-d/2	pi	pd	l	w	h	p'	l'
1	BA.589.8	S/H	4.4	3.4	0.50		0.38	0.36	22		0.26	0.30
2	BA.589.8	S	2.7	1.5	0.58		0.23	0.47	17		0.21	0.22
3	BA.589.8	H	4.9	3.7	0.60	0.20	0.47	0.66	25		0.20	0.27
4	BA.589.8	H	5.4	4.3	0.55		0.44	0.42	19		0.27	0.17
5	BA.589.9	H	5.8	4.6	0.57		0.37	0.22	29		0.22	0.32
6	BA.589.9	H	5.1	3.9	0.60		0.37	0.42	25	0.81	0.17	0.30
7	BA.589.9	H	6.0	5.0	0.52		0.39	0.27	31	0.64	0.25	0.34
8	BA.589.7	H	7.5	6.3	0.60		0.37	0.30	27		0.25	0.42
9	BA.589.7	S	1.7	0.94	0.40	0.10	0.20	0.32			0.10	0.17
10	BA.589.7	H	5.5	4.8	0.35			0.12			0.23	0.34
11	BA.589.6	S/H	4.3	3.2	0.55	0.25	0.37	0.47	21		0.22	0.22
12	BA.589.6	H	7.0	6.0	0.52		0.49	0.21	24		0.27	0.39
13	BA.589.6	S	3.0	1.9	0.55		0.34	0.42		0.44	0.15	0.22
14	BA.589.6	S	2.1	1.1	0.47		0.27	0.27		0.59	0.21	0.22
15	BA.589.5	H	5.5	4.2	0.62		0.34	0.39	24		0.22	0.30
16	BA.589.5	H	6.1	5.0	0.55		0.34	0.15			0.27	0.42
17	BA.589.5	S/H	4.2	3.1	0.57		0.34	0.39	17	0.57	0.25	0.37
18	BA.589.5	H	6.0	5.0	0.48		0.39	0.20			0.28	0.39
19	BA.589.4	S/H	3.7	2.5	0.62		0.32	0.42	22	0.39	0.15	0.22
20	BA.589.4	H	6.4	5.1	0.63		0.44	0.30	20		0.22	0.44
21	BA.589.4	S	3.6	2.3	0.62	0.17	0.27	0.57	22		0.12	0.20
22	BA.589.4	H	4.9	3.8	0.55		0.37	0.16	23	0.37	0.22	0.42
23	BA.589.4	H	6.3	5.1	0.62		0.39		25		0.16	0.25
24	BA.589.4	S	3.9	2.5	0.69		0.32	0.44	24		0.15	0.25
25	BA.589.3	H	7.8	6.7	0.57		0.39	0.30	25		0.27	0.42
26	BA.589.3	H	6.9	5.9	0.55		0.47	0.25		0.74	0.25	0.39
27	BA.589.3	S	3.0	1.7	0.62	0.15	0.34	0.44	15	0.44	0.18	0.17
28	BA.589.3	H	6.7	5.9	0.42		0.34	0.47	29		0.25	0.32
29	BA.589.2	S	3.7	2.7	0.50		0.28	0.37	19		0.16	0.17
30	BA.589.2	H	7.5	5.7	0.89		0.37	0.27	27	0.54	0.22	0.32
31	BA.589.2	S	2.1	1.2	0.47	0.18	0.32	0.37	19	0.36	0.22	0.22
32	BA.589.1	H	5.1	4.2	0.47		0.42	0.25	20		0.23	0.34
33	BA.589.1	S/H	4.2	2.8	0.73	0.17	0.37	0.66	25	0.45	0.20	0.22
34	BA.589.1	H	5.8	5.0	0.42		0.46	0.27	19		0.30	0.32
35	BA.589.1	S+H	5.1	4.0	0.55		0.37	0.30		0.57	0.27	0.62
36	BA.589.1	S	3.3	2.0	0.64	0.17	0.32	0.52	20		0.17	0.27
37	BA.589.10	H	7.6	6.5	0.55		0.37	0.17	28		0.22	0.34
38	BA.589.10	S/H	5.1	3.7	0.69		0.32	0.44		0.47	0.27	0.47
39	BA.589.11	H	5.6	4.5	0.56		0.44	0.25			0.20	0.42
40	BA.589.11	H	7.2	6.0	0.62		0.44	0.34	29		0.25	0.37
41	BA.589.11	S+H	5.3	4.1	0.60		0.37	0.20		0.52	0.17	0.32
42	BA.589.11	H	5.1	3.8	0.64		0.34	0.25		0.62	0.22	0.44
	Min.		1.7	0.94	0.35	0.10	0.20	0.12	15	0.36	0.10	0.17
	Max.		7.8	6.7	0.89	0.25	0.49	0.66	31	0.81	0.30	0.62
	Number		42	42	42	8	41	41	30	16	42	42
	Average		5.06865	3.93670	0.56597	0.17374	0.36540	0.34230	23.06667	0.53182	0.21642	0.31687
	St. Deviation		1.59441	1.57504	0.09557	0.04181	0.06309	0.13083	4.09317	0.12859	0.04619	0.09858

Table 1. Main biometric parameters of *Tersella genoti* n.sp. For each specimen is supplied the thin section number, the part of the thallus sectioned (S: stalk; H: head, S/H: intermediate part between S and H; S+H: section of both parts, measurements refer to H) and the dimensional values., The range (min. and max.), the number of measurements, the average and the standard deviation for each parameter are given at the bottom of the table. All size parameters are in millimeters. D: outer diameter of the calcareous skeleton; d: inner diameter of the calcareous skeleton; pi: inner width of primary branches; pd: distal width of primary branches; l: length of primary branches; w: number of primary branches per whorl; h: height between whorls; p': width of secondary branches; l': length of secondary branches.

phorous and constituted a distal cortex. No reproductive organs have been observed, they were placed most probably in the main stem or in the primary branches (endosporate-type or cladospore-type).

The calcareous skeleton is thicker along the stalk, where it envelopes almost entirely the primary and second-

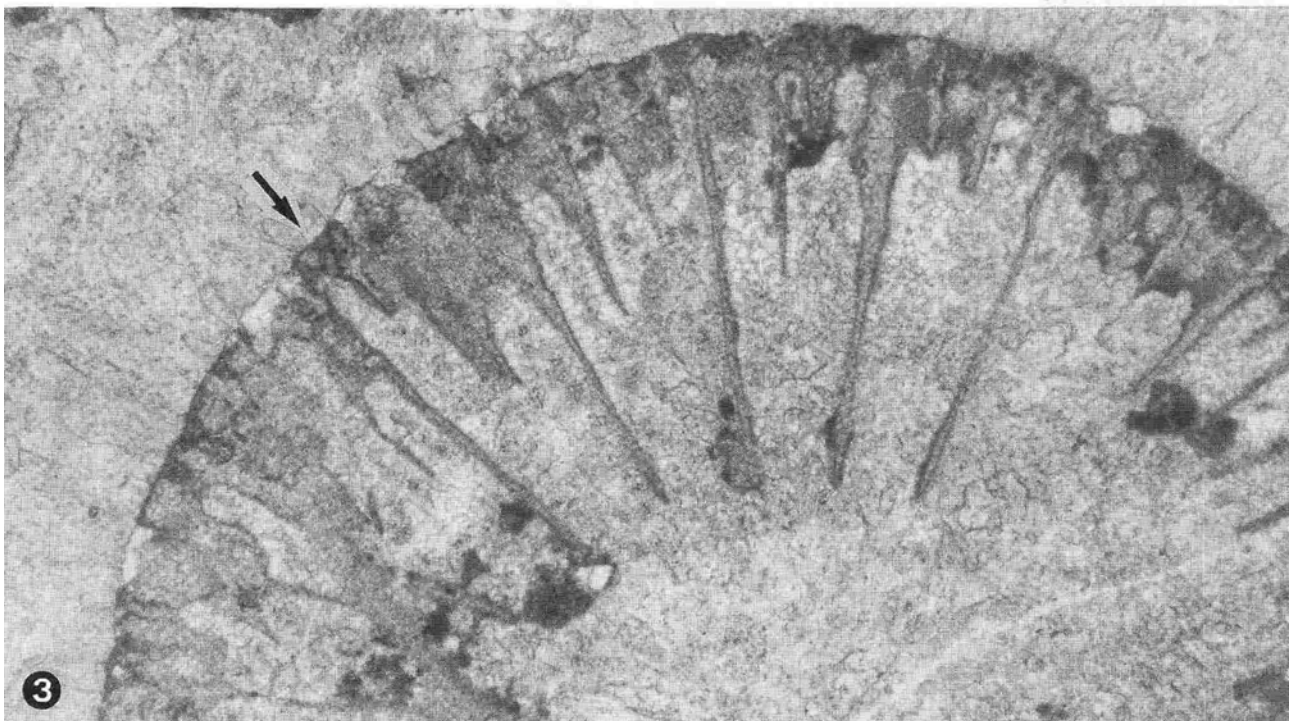
ary branches, while it is thinner around the head, where it envelopes the distal ends of the primary branches and the secondary branches.

The most significant biometric values, taken from a single sample (BA.589), are supplied in Tab. 1.

Plate 53

Liassic dasycladales from Calcare Massiccio Fm. (Gran Sasso, Central Italy): *Fanesella sokaci* n.sp.

- Fig. 1. Isotype. longitudinal-oblique. Thin section BA.589.9. Corno Grande. x 15
- Fig. 2. Holotype. Detail of Pl. 52/2. Primary, secondary and tertiary branches are clearly visible. Thin section BA.589.7. Corno Grande. x 48
- Fig. 3. Isotype. Detail of Pl. 51/1. Notice the weakly calcified primary and secondary branches and the tertiary branches. Very peripherally quaternary branches can be distinguished. Thin section BA.589.9. Corno Grande. x 48



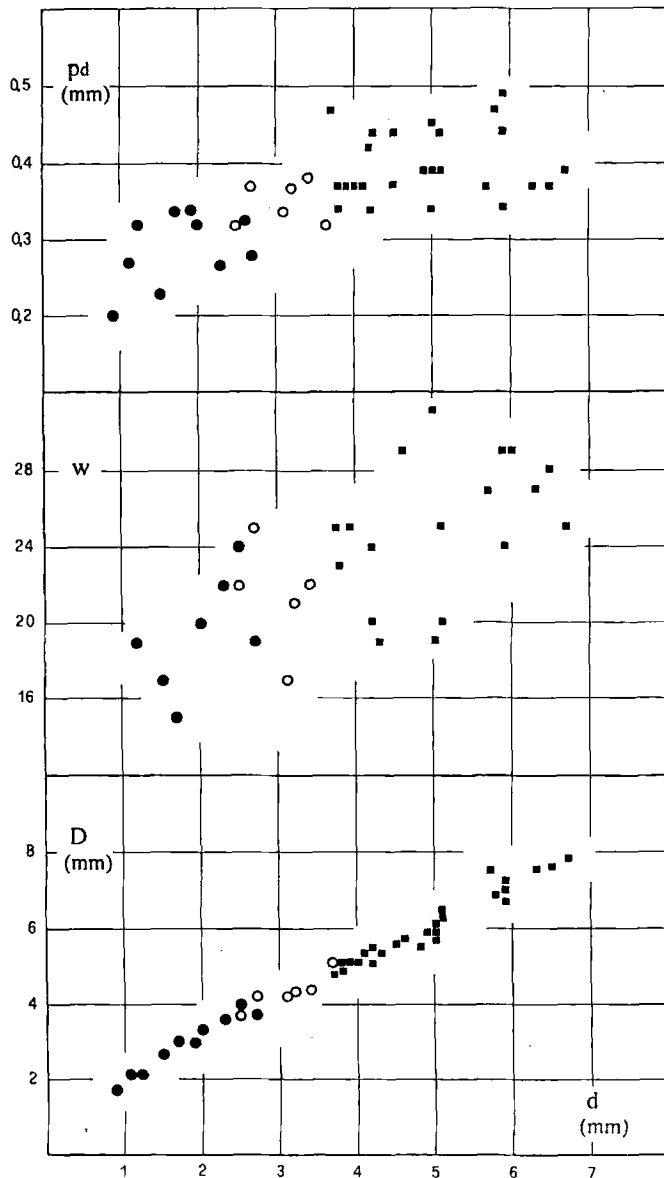


Fig. 13. *Tersella genoti* n.sp. Outer diameter of the calcareous skeleton (D, below), number of pores per whorl (w, centre) and distal width of primary pores (p_d , up) against the inner diameter of the calcareous skeleton (d). Specimens in thin section belonging to the stalk part of the calcareous skeleton (\bullet), the head (\blacksquare) and the intermediate part between the stalk and head (\circ) are specified.

General features of the calcareous skeleton. The calcareous skeleton is simple, continuous and without any trace of annulation or intusannulation. It exhibits a moderate differentiation into a subcylindrical lower part (the stalk) and an enlarged ellipsoidal upper part (the head). The head, when differentiated, represents in length 70-80% of the whole calcareous skeleton. The shape of the head is ellipsoidal to ovoidal, rather elongated - the outer diameter being 0.5-0.7 times the length - with the more tapered end directed downward. In the head the calcification is rather thin and envelops the distal end of primary pores and the secondary pores up to their distal swelling. Near the top its thickness increases enveloping thinner primary pores for a longer extent (Pl. 50/1). At the apex the calcification disappears leaving a cavity of 1.5-1.8 mm in diameter. The stalk is rather short, cylindrical to slightly cone-shaped. It usually shows a calcification thicker than in the head, enveloping the primary pores (thinner than in the head) for a longer extent and the secondary pores up to their distal swelling. Transversal and oblique sections, probably cutting the stalk portion, often exhibit a regular inner surface (Pl. 50/4 middle-lower part). This fact indicates that the calcareous skeleton was here very close the central stem or touched it.

Rarely the two parts (head and stalk) are undifferentiated or not well differentiated (Pl. 48/4). In this case the calcareous skeleton looks like an elongated club and the calcification shows almost the same thickness from the lower to the upper part of the thallus.

The calcareous skeleton was probably aragonitic, it appears always recrystallized in calcite or dolomitized.

The inner diameter is 0.9-3.7 mm in the stalk portion (ds) and 3.7-6.7 mm in the head portion (dh); the outer diameter is 1.7-5.1 mm in the stalk portion (Ds) and 4.9-7.8 mm in the head portion (Dh).

Primary pores. The primary pores are roughly perpendicular to the main axis along the greatest extent of the thallus; but, in the uppermost part of it, their inclination decreases until they stand vertically near the apex zone (Pl. 50/1).

The primary pores are arranged in simple whorls (euspondyle type; Pl. 48/1,5; Pl. 47/3). Subsequent whorls exhibit branches arranged in alternate position even if not properly regular (Pl. 47/3).

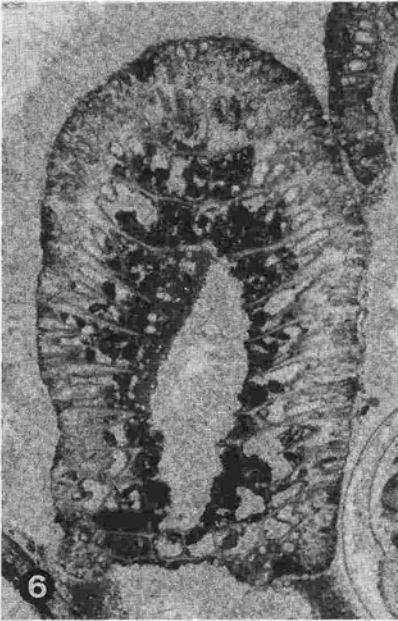
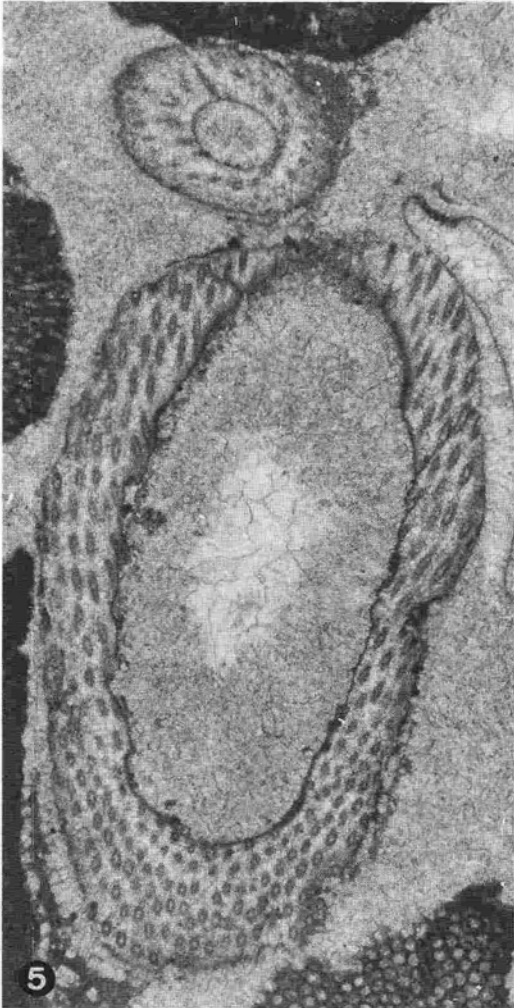
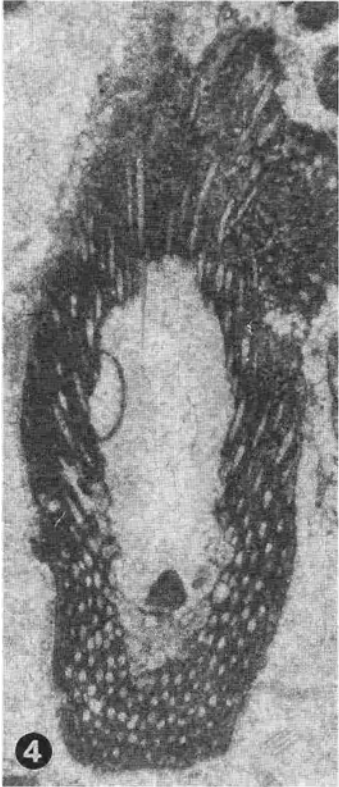
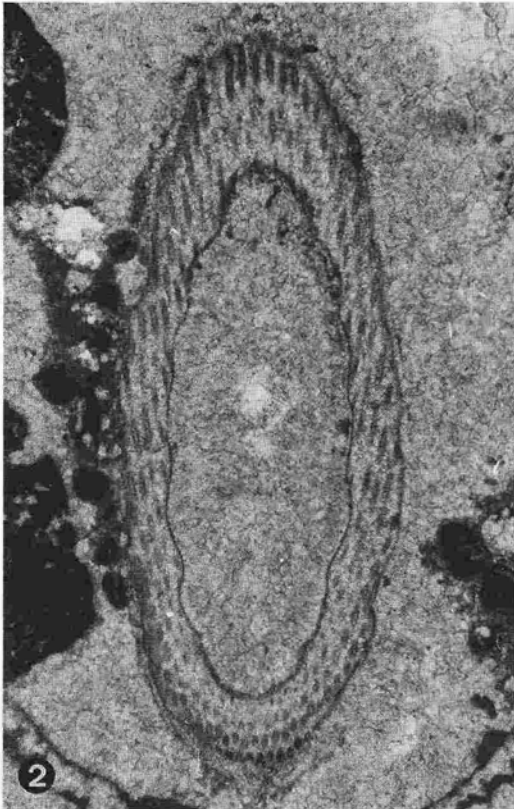
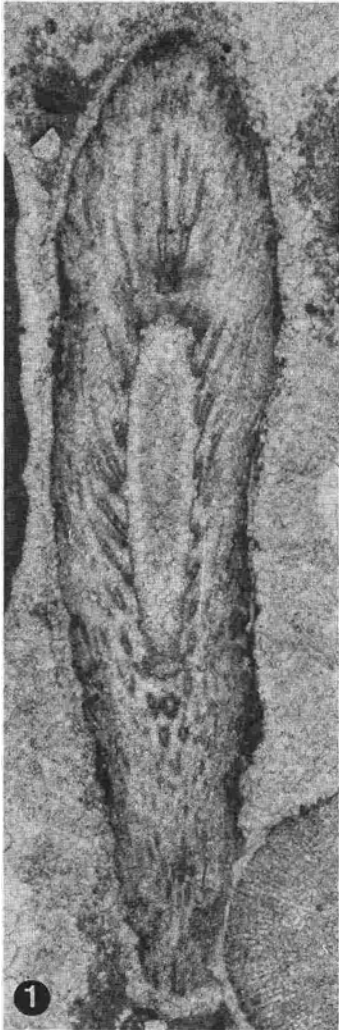
Plate 54

Liassic dasycladales from Calcare Massiccio Fm. (Gran Sasso, Central Italy)

Figs. 1-2, 4-5. *Palaeodasycladus gracilis* CROS & LEMOINE. Oblique sections. Small specimens (Fig.1; Fig.5, specimen at the top) exhibit a stronger calcification probably reaching the central stem and three order of branches. Medium to big sized specimens (figs. 2, 4-5) show a wider central cavity, their calcareous skeleton represents the calcification around the secondary and tertiary branches or around these last ones only. Thin sections: BA.598.5, BA.598.4, BA.598.7, BA.598.3 respectively. Corno Grande. x 30

Fig. 3. *Palaeodasycladus* sp. Oblique section. Thin section BA.598.2. Corno Grande. x 15

Figs. 6-7. *Petrascula ? heraki* SOKAC & NIKLER. Oblique sections. Thin sections: BA.598.7 and BA.598.4 respectively. Corno Grande. x 15



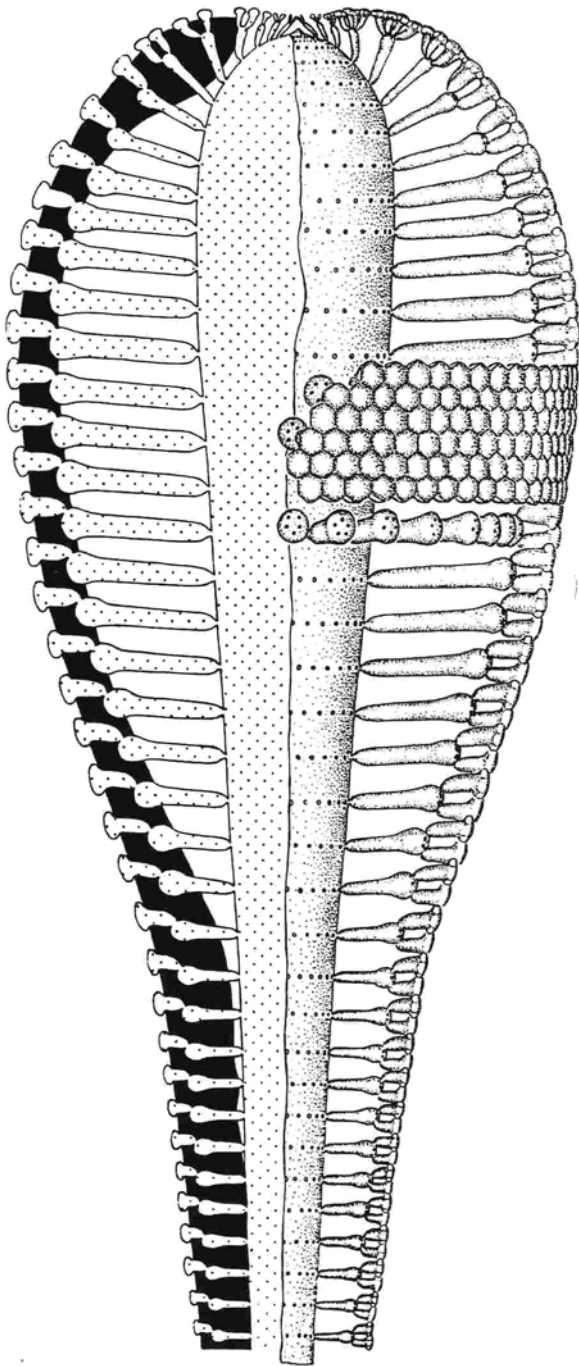


Fig 14. *Tersella genoti* n.sp. Reconstruction of the thallus in longitudinal view. *Left side*: primary branches, secondary branches and calcification (black) in axial section. *Right side*: longitudinal view of the branches without calcification and the central stem showing the junctions of primary branches; in the middle part a perspective view of the branches and the cortex is drawn. (x 12.7)

The height between whorls (h) is about 0.36-0.81 mm. The number of pores in a whorl (w) is about 14-31, but this parameter seems to increase slightly upwards, i.e. from the stalk to the apex.

The primary pores in the stalk are phloiophorous and club-shaped (Pl. 49/1; Pl. 50/3-4). They often show an inner portion, subcylindrical in shape, that is about 0.6-0.75 times the total length. This part is thinner than the

outer part that in turn usually exhibits a well-defined globular shape. It is rarely observed that the very proximal part is joined to the central stem (Pl. 50/4). The cross section of the pores is circular, its size 0.1-0.25 mm (p_{is}) and 0.20-0.34 mm (p_{ds}) in the inner and distal part respectively. The length of the primary pores in the stalk (l_s) is 0.27-0.51 mm.

The primary pores in the head are nearly globular. In thin section they appear sometimes as moderately big circles or semicircles widely opened inward (Pl. 46/1-2,4), sometimes as large arcs (Pl. 46/5). This can be explained as due to a calcification restricted to the distal globular part of primary branches. The diameter is 0.34-0.49 mm (p_{dh}).

In the uppermost part of the calcareous skeleton primary pores are club-shaped, decrease in size and are calcified for a great extent; practically they look like the ones of the lower part of the thallus. This indicates that the primary branches of the head were phloiophorous and club-shaped (for a farther reaching discussion see reconstruction, Fig. 14).

Secondary pores. Secondary pores are cylindrical or slightly widened outwards. In rare places they are seen closely packed at the outer surface of the calcareous skeleton (Pl. 47/4). This observation allows the assumption that the secondary branches flared in their distal part, usually uncalcified, and formed a cortex. The secondary pores originate from the distal part of primary branches, 3-5 per tuft. They increase in size from the stalk to the head of the thallus. In the stalk they are 0.08-0.21 mm wide (p'_s) and 0.06-0.42 mm long (l'_s) while in the head they are 0.17-0.29 mm wide (p'_h) and 0.25-0.58 mm long (l'_h).

Reproductive organs. No reproductive organs have been observed in the calcareous skeleton. However the primary branches are not particularly strong to infer a reproductive function. The greatest part of the primary branches of the head (usually the main fertile part of the thallus) was uncalcified, we therefore have few arguments to judge where the reproductive organs of *Tersella genoti* n.sp. were situated. A reproduction of endosporate-type or cladospore-type seems to be possible.

Reconstruction (Figs. 14, 15).

The uppermost part of the head and the stalk often show a calcification touching or very close to the central stem. Therefore for these two regions of the thallus we can take the inner diameter of the calcareous skeleton as a good proxy for the diameter of the axial stem. It comes out that in the uppermost part of the head the diameter of the axial stem is equal or a little wider than in the stalk. The stalk portion exhibits a slightly club shaped central stem. In our reconstruction we suppose that the central stem keeps this shape from the base to the apex of the thallus. Our interpretation is consistent with what said above for the stem diameter in the uppermost part of the head and is based on the assumption that primary branches becomes longer and longer in the head before getting shorter again toward the apex.

Some evidence indicates that the primary branches of

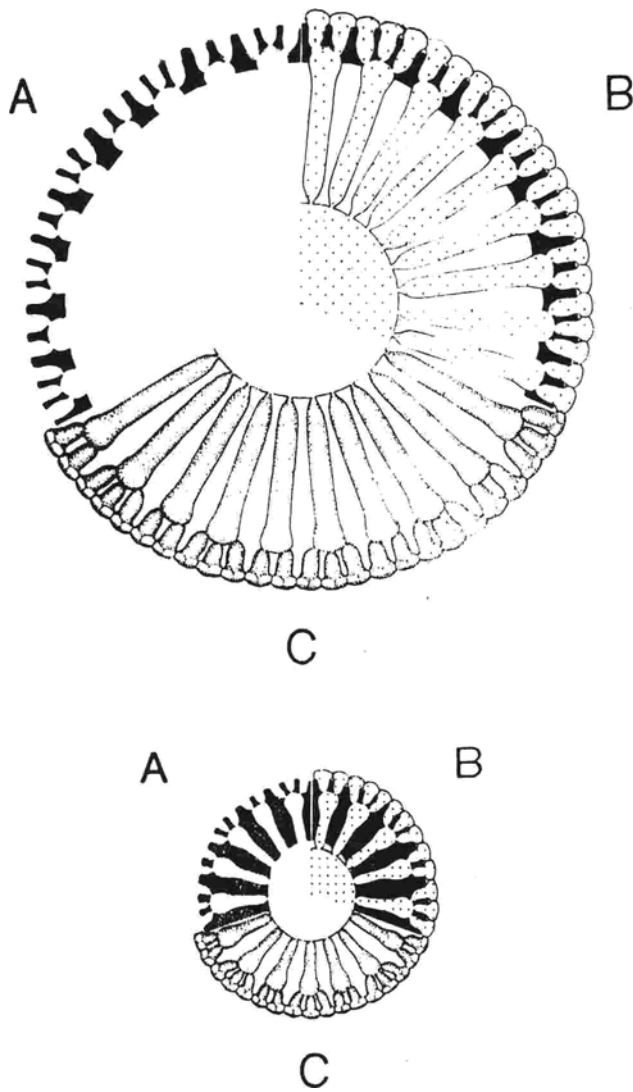


Fig 15. *Tersella genoti* n.sp. Reconstruction in transversal view of the stalked part (*below*) and the head (*up*) of the thallus.

A: transversal section at whorl level showing the calcareous skeleton. (x 12.7)

B: transversal section at whorl level showing primary and secondary branches and the calcification (*black*). C: central stem and branches in transversal view. (x 12.7)

the head had a shape similar to those of the stalk. Primary pores, if axially cut, are always broadly opened inward and nowhere (except in the stalk) a structure reliable to a junction point has been observed. Primary branches placed at both ends of the calcareous skeleton, stalk and top, are very similar. The thickness of calcification clearly and quickly decreases between stalk and head. Here the primary pores become shorter and shorter. The inner surface of the calcareous skeleton here gradually departs from the central stem leaving the akrophorous part of the branch uncalcified. The branches never show an appreciable increase in size that could be correlated to a specialization (e.g. reproductive; Pl. 50/2). Accordingly the primary branches have been drawn with equal shape but increasing in size upwards. They reduce their size and inclination again when approaching the top.

According to the shape and inclination of the branches close to the top of the calcareous skeleton, and based on what observed in club-shaped dasyclads with phloiophorous branches (e.g. *Neomeris*) the apical zone is considered to be constructed by branches closed together to form a sort of bud. It may be inferred that the bottom of the thallus was a rather short branchless stalk-like part of the siphon.

Comparisons.

Tersella genoti differs from the type species, *Tersella incompleta* MORELLET (Hettangian), in the presence of a moderately long stalk region, in the shape of the secondary pores (cylindrical or slightly widened outwards versus pores characterized by a subterminal narrowing just before the cortical swelling) and for a smaller number of pores in a whorl (14-31 versus 30-40).

The new species differs from *Tersella alpina* CROS & LEMOINE (Liassic) and *Tersella quercyensis* CUBAYNES & DELOFFRE (Toarcian) in a less "differentiated" club shaped skeleton; in addition the stalk portion is far less elongated. Moreover *Tersella genoti* is much smaller than *T. quercyensis* (4.9-7.8 mm versus 10-24 mm). *Tersella genoti* differs from *Tersella alpina* also in the larger size of primary pores (0.34-0.49 mm versus 0.25 mm), and in the shape of secondary pores (cylindrical or slightly widened outwards instead of swollen at the base and then regularly phloiophorous).

The new species differs from *Tersella lucasi* (CROS & LEMOINE) (Liassic) in the shape of the skeleton (club-shaped moderately stalked versus cylindrical) and in a generally larger calcareous skeleton (4.9-7.8 mm versus 2.4-3.1 mm).

T. genoti differs from *Tersella cretica* (OTT) (lower Liassic) for the shape of the calcareous skeleton (club-shaped moderately stalked versus cylindrical to club-shaped). Moreover in *T. cretica* the calcification never reaches the stem wall, and primary pores are globular and do not show a club shape. The primary and secondary pores are, in average, smaller than in *T. genoti* (0.22-0.42 mm versus 0.34-0.49 mm).

T. genoti differs from *Dissocladella iberica* DRAGASTAN & TRAPPE (and assembled allied forms; Liassic) for a general bigger size of the biometrical parameters.

7.2 Genus *Fanesella* CROS & LEMOINE 1966 ex GRANIER & DELOFFRE 1993

The genus *Fanesella*, and its type-species *Fanesella dolomitica*, were established by CROS & LEMOINE in 1966 when studying an algal-rich material from the Liassic of Northern Italy (Dolomites and Asiago Plateau). According to the two authors the genus is characterized by a cylindrical calcareous skeleton. Primary branches are swollen and laterally compressed, arranged in whorls. They are specialized for reproduction (cladosporate-type). Each primary branch divides into secondary branches without any narrowing at the junction. Tufts of tertiary and quaternary branches are present. These branches show narrowings at the junction point.

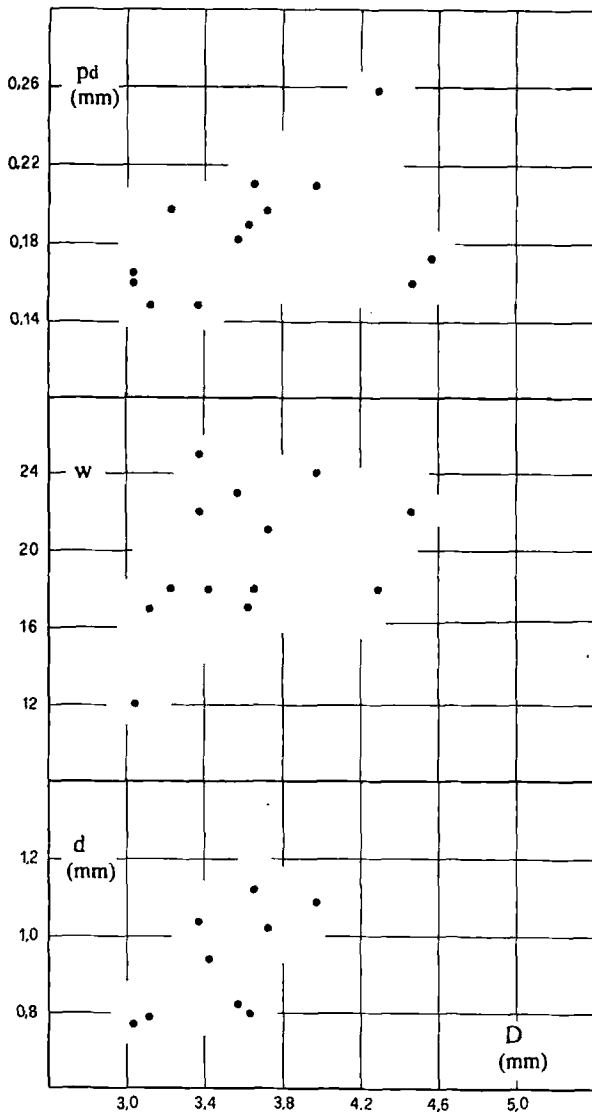


Fig. 16. *Fanesella sokaci* n.sp. Inner diameter of the calcareous skeleton (d, below), number of pores per whorl (w, centre) and distal width of primary pores (p_d , up) against the outer diameter of the calcareous skeleton (D).

BAKALOVA (1976) described the species *Fanesella ? urgonica* from the Lower Cretaceous of Bulgaria. According to this author the species shows three orders of ramifications; actually the occurrence of tertiary branches is highly questionable. The "secondary branches" figured by BAKALOVA (1976; pl.1 fig.4 = detail of the right side of pl.1 fig.3) can be interpreted as primary pores of the same whorl forming an annular cavity (a fact that is evident in the holotype: BAKALOVA 1976, pl.1, fig.1). On the left side of the same section (pl.1, fig.3), separated primary pores are visible. In agreement with the present interpretation the occurrence of strong primary branches and secondary branches can be inferred, therefore this species should be ascribed to another genus (tentatively to *Triploporella*) and will not be considered here.

SOKAC (1988) established *F. anae* from the lower Liassic of Croatia (Velebit Mts.). The species is characterized by bulbous primary branches that continue into 3-5 nipple-like projections and ramifications up to third or fourth

order, this depending whether nipple-like projection are considered as real ramifications or not. The fact that more than one nipple-like projection per primary branch occurs, and that each of them is the origin of a tuft of branches can lead to the conclusion that they represent proper secondary branches.

In the generic diagnosis CROS & LEMOINE (1966) remark the absence of a narrowing at the proximal end of secondary branches. However this can be due to the lack of calcification for the closely packed primary and secondary branches. A similar phenomenon frequently happens, for example, among the primary branches of a same whorl of *F. dolomitica* resulting in a lateral fusion of primary pores into a sort of annular channel (CROS & LEMOINE, 1966, pl.2 figs.4-5). This is confirmed by examples where the primary pores of the same whorl are separated one from each other (CROS & LEMOINE, 1966, pl.2 fig.3). The absence of narrowings at the inner end of secondary pores is of no taxonomic importance.

At the present state of knowledge the genus *Fanesella* differs from *Palaeodasycladus* PIA mainly in the presence of four orders of branches instead of three and secondly in the somewhat thicker primary branches. The type species of *Fanesella* lacks a segmentation in the pores of last order.

7.2.1 *Fanesella sokaci* n.sp. (Pl. 45/2; Pls. 51-53)

Origin of the name. The species is dedicated to the colleague Branko Sokac, Institut za Geoloska Istrazivanja of Zagreb (Croatia) for his contributions to knowledge of fossil algae.

Holotype. Specimens in longitudinal section figured in Pl. 52/3. Thin section BA.589.7.

Isotypes. Specimens of the sample BA.589 (= CG2 of the Bigozzi sampling): thin sections BA.589.1 - BA.589.11.

Type-locality. Northern slope of Corno Grande (Gran Sasso, Central Italy), at about 2700 metres of altitude (Fig. 12).

Type-level. Thick bedded white bioclastic packstones (see microfacies CM3). Same locality as *Tersella genoti* n.sp.

Depository. The material is deposited at the Department of Palaeontology, University of Naples Federico II (Barattolo collection)

Diagnosis. Cylindrical simple thallus. Primary branches arranged in close whorls and alternating in following ones. They are set at an angle of 70-90° to the central stem, and the branches of higher order tend to maintain the same inclination. Primary branches are very thick, phloiophorous. They can be straight or slightly curved upward or downward. In general the verticillar section increases gradually outward but the vertical section remains constant. The inner transversal section looks like a vertically elongated rectangle while the outer one is similar but wider. Secondary branches are akrophorous, moderately squat, 4-6 per tuft. They often are laterally compressed, especially in their inner part, with a subtriangular to subquadrangular

Spec.	Thin section	D	d	D-d/2	pwd	pvd	l	w	b	p'	l'	p''	l''	p'''	l'''
1	BA.589.1	3,4	0,94	1,24	0,39			18				0,111	0,27	0,086	0,25
2	BA.589.2	4,6				0,32				0,17		0,135	0,30	0,111	0,37
3	BA.589.3	4,3			0,44			18		0,26	0,54	0,123	0,32	0,098	0,25
4	BA.589.3					0,42				0,20		0,098		0,081	
5	BA.589.4	3,6	0,82	1,38		0,38	0,69	23		0,18	0,34	0,106	0,18	0,069	0,14
6	BA.589.4	4,2										0,123		0,098	
7	BA.589.5	3,0								0,16	0,32	0,098	0,25	0,086	0,11
8	BA.589.5	4,5			0,25			22		0,16		0,111	0,25	0,086	0,17
9	BA.589.6	3,4	1,04	1,17	0,25			25		0,15		0,098	0,30	0,074	0,10
10	BA.589.6	3,1	0,79	1,17		0,42		17	0,54	0,15		0,111			
11	BA.589.6	4,5										0,098			
12	BA.589.7	3,6	0,80	1,41	0,22	0,44	0,76	17	0,46	0,19	0,31	0,111	0,33	0,069	0,15
13	BA.589.7	5,0							0,70			0,111	0,42		
14	BA.589.8	3,7	1,02	1,35				21		0,20	0,27	0,086	0,15	0,062	0,12
15	BA.589.9	3,6	1,12	1,26	0,34			18		0,21	0,32	0,111	0,27	0,086	0,12
16	BA.589.9	3,0	0,77	1,13				12		0,16		0,111		0,062	
17	BA.589.9	4,0	1,09	1,44		0,49		24	0,54	0,21	0,31	0,123	0,33	0,111	0,12
18	BA.589.10	3,2			0,44			18		0,20		0,111	0,17	0,074	0,17
19	BA.589.10	3,3				0,62		22	0,62			0,123	0,42	0,062	0,10
20	BA.589.10	5,3										0,111		0,086	
21	BA.589.10	4,2										0,123		0,091	
<i>Min</i>		<i>3,0</i>	<i>0,77</i>	<i>1,13</i>	<i>0,22</i>	<i>0,32</i>	<i>0,69</i>	<i>12</i>	<i>0,46</i>	<i>0,15</i>	<i>0,27</i>	<i>0,086</i>	<i>0,15</i>	<i>0,062</i>	<i>0,10</i>
<i>Max</i>		<i>5,3</i>	<i>1,12</i>	<i>1,44</i>	<i>0,44</i>	<i>0,62</i>	<i>0,76</i>	<i>25</i>	<i>0,70</i>	<i>0,26</i>	<i>0,54</i>	<i>0,135</i>	<i>0,42</i>	<i>0,111</i>	<i>0,37</i>
<i>Number</i>		<i>20</i>	<i>9</i>	<i>9</i>	<i>7</i>	<i>7</i>	<i>2</i>	<i>13</i>	<i>5</i>	<i>14</i>	<i>7</i>	<i>21</i>	<i>14</i>	<i>18</i>	<i>13</i>
<i>Average</i>		<i>3,8713</i>	<i>0,9325</i>	<i>1,2822</i>	<i>0,3339</i>	<i>0,4407</i>	<i>0,7257</i>	<i>19,6154</i>	<i>0,5717</i>	<i>0,1850</i>	<i>0,3437</i>	<i>0,1111</i>	<i>0,2818</i>	<i>0,0828</i>	<i>0,1669</i>
<i>St. Deviation</i>		<i>0,65934</i>	<i>0,13861</i>	<i>0,11565</i>	<i>0,09618</i>	<i>0,09352</i>	<i>0,05218</i>	<i>3,59487</i>	<i>0,09076</i>	<i>0,02988</i>	<i>0,08943</i>	<i>0,01139</i>	<i>0,08174</i>	<i>0,01549</i>	<i>0,07790</i>

Table 2. Main biometric parameters of *Fanesella sokaci* n.sp.. For each specimen is supplied the thin section number and the dimensional values. The range (*min.* and *max.*), the number of measurements, the average and the standard deviation for each parameter are given in italics at the bottom of the table. All size parameters are in millimeters. *D*: outer diameter of the calcareous skeleton; *d*: inner diameter of the calcareous skeleton; *p_{wd}*: distal whorly width of primary branches; *p_{vd}*: distal vertical width of primary branches; *l*: length of primary branches; *w*: number of primary branches per whorl; *h*: height between whorls; *p'*: width of secondary branches; *l'*: length of secondary branches; *p''*: width of tertiary branches; *l''*: length of tertiary branches; *p'''*: width of quaternary branches; *l'''*: length of quaternary branches.

transversal section. Tertiary branches are rather thin, cylindrical in shape, 2-4 per tuft. Sometimes they show some cross partitions inside. The branches of highest order are thinner and shorter than the tertiaries, in tufts of 2-3. They probably were distally widened to form a cortex.

No reproductive organs have been observed in the plant, they were placed most likely in the primary branches (cladospore-type).

The calcareous skeleton is rather thick, it usually envelops the distal part of the primary branches up to the cortical quaternary branches. It rarely reaches inward to the main axis.

The most significant biometric data are summarized in Tab. 1. They have been taken from a single sample (BA.589).

General features of the calcareous skeleton. The calcareous skeleton is simple, cylindrical, continuous and without any trace of annulation or intusannulation. A great amount of sections exhibits a wide central cavity (Pl. 52/1-2); the calcification envelops the distal part of primary pores or the secondary pores up to the quaternary pores, probably just before their cortical swelling. Some sections shows a narrow central cavity with a stronger calcification that can touch the central stem (Pl. 51/3-5). In this case a certain degree of calcification occurs at both ends of primary pores and in the space between whorls, but almost never between the pores of the same whorl, probably because of the close packing of the primary pores that does not leave space enough for calcification. For this reason in oblique or tangential section the whorls are represented by con-

tinuous horizontal channels separated by scalloped calcified bands (Pl. 51/5; Pl. 53/1). These bands represent the interspace between whorls that sometimes can be recognized up to the zone with tertiary pores as a thin poreless band inside the calcareous skeleton (Pl. 52/3; Pl. 53/1). Some evidences from longitudinal sections (Pl. 52/3) show that calcification is thicker in the lower region of the thallus (from the central stem up to the quaternary pores) and becomes thinner in the upper region (from secondary to quaternary pores).

The inner diameter (*d*) is 0.77-1.1 mm and the outer diameter (*D*) is 3.0-5.3 mm.

Primary pores. Primary pores are generally set at 60-70° as to the main axis. Usually they bend downwards in the very inner part and then upward in the outer part (Pl. 53/2), sometimes downwards again in the very distal end (Pl. 53/1). The primary pores are arranged in close whorls (euspondyle type; Pl. 51/5). The height between whorls (*h*) is 0.46-0.70 mm. The number of pores in a whorl (*w*) is approx. 12-25.

The primary pores are phloiophorous (Pl. 51/1). The width of the vertical section (DE CASTRO, 1995) of the pores is nearly constant for most of the pore length (Pl. 53/2), while the width of the verticillar section increases radially (Pl. 53/3). The cross section of a pore is sub-quadrangular, passing outwards into a rounded vertical rectangle. The length (*l*) of the primary pores is 0.69-0.76 mm. The vertical (*p_v*) and the verticillar (*p_w*) width are 0.32-0.61 mm and 0.22-0.44 mm.

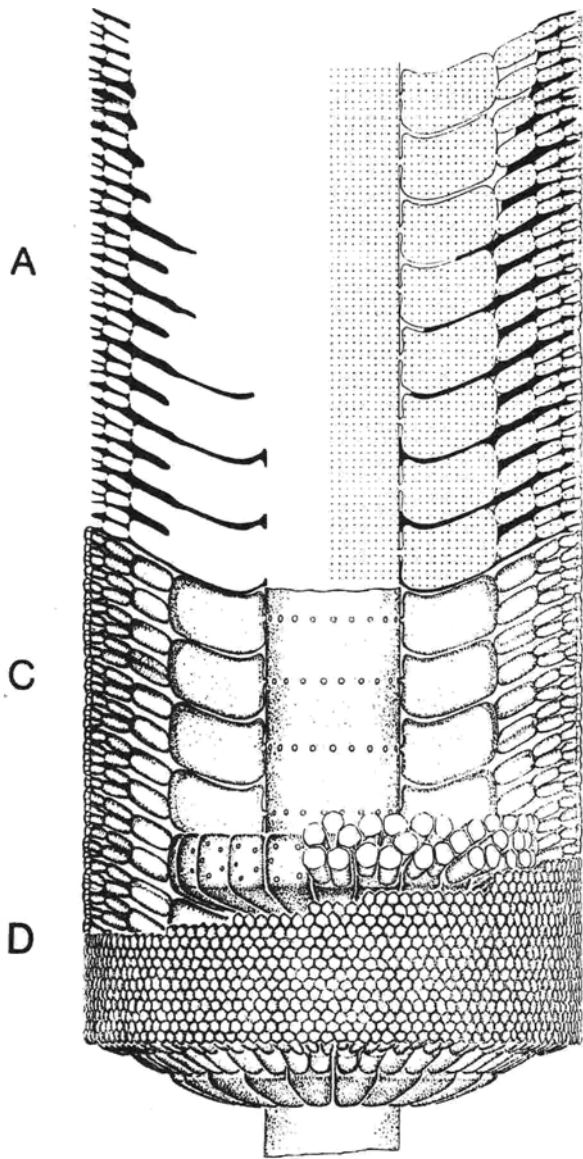


Fig 17. *Fanesella sokaci* n.sp. Reconstruction of the thallus in longitudinal view.

- A: calcareous skeleton in axial section.
 B: central stem, primary to quaternary branches and calcification (black) in axial section.
 C: longitudinal view of the thallus without calcification; the central stem shows the junctions of primary branches.
 D: perspective view of the branches and the cortex. (x 11.5)

Secondary pores. The secondary pores are roughly subcylindrical, more or less laterally compressed leading to oval to subquadrangular transversal shapes. In some oblique sections secondary pores seem to be slightly tapered outwards (Pl. 52/3 lower part; Pl. 53/3). It is difficult to judge if this fact is real or just a result of calcification. The secondary pores originate in the distal part of primary pores, 4-6, usually five per tuft. They are 0.15-0.26 mm wide (p') and 0.27-0.54 mm long (l').

Tertiary pores. At the distal end of the secondary pores a tuft of two or three tertiary pores originates. These pores are cylindrical and moderately long. Their transversal section is triangular to subpolygonal in the proximal part

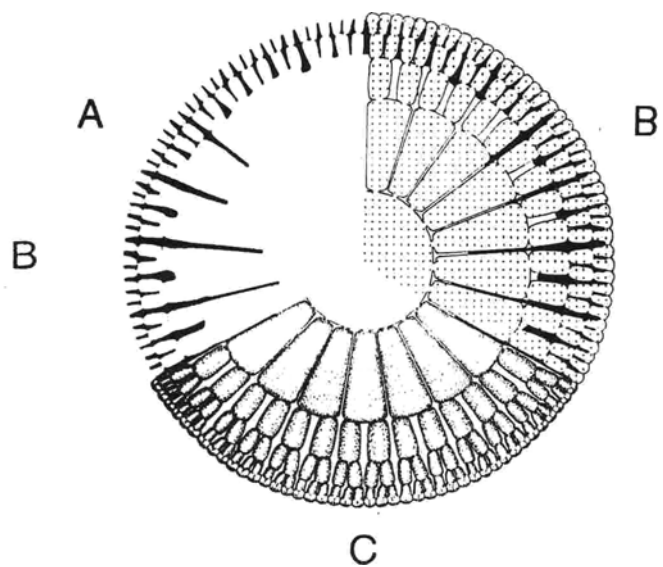


Fig 18. *Fanesella sokaci* n.sp. Reconstruction of the thallus in transversal view.

- A: transversal section at whorl level showing the calcareous skeleton.
 B: transversal section at whorl level showing primary to quaternary branches and the calcification (black).
 C: central stem and branches in transversal view. (x 11.5)

and becomes round in the distal one. Often 1-3 transversal septa are seen inside the pores. However they maintain their cylindrical shape and no remarkable constriction is combined with each septum (Pl. 53/2; Pl. 52/2). Tertiary pores are 0.09-0.13 mm wide (p'') and 0.15-0.42 mm long (l'').

Quaternary pores. The compaction of tertiary pores, the occurrence of cross partitions inside and the erosion or diagenetic damages (micritization and/or dolomitization) of the outer surface of the calcareous skeleton make it difficult to detect the presence of higher order pores. Some well preserved specimens reveal at least quaternary pores (Pl. 53/3). Quaternary pores are short, roughly cylindrical most of their length, slightly widening outwards at their distal end. Very probably two quaternary pores stem from each tertiary pore.

The close packing, the distal widening and some evidence of polygonal pores near the outer surface of the calcareous skeleton from specimens cut in tangential and oblique sections make it probable that quaternary pores form a cortex at their distal end.

Reproductive organs. No clear traces of reproductive organs have been observed in the calcareous skeleton. However primary branches appear strong enough for carrying a reproductive function. For this reason a reproduction of cladospore-type is highly probable.

Reconstruction (Figs. 17, 18). Unfossilized or questionable parts are considered here: i.e. the top and the bottom of the thallus.

According to observations in cylindrical dasyclads with phloiophorous branches (e.g. *Neomeris* and *Dasycladus*) the apical zone is considered to consist of branches form-

ing a bud. The basal part of the thallus was a rather short branchless stalk-like portion of the siphon.

Comparisons. *Fanesella sokaci* n.sp. can be differentiated from *F. dolomitica* CROS & LEMOINE by its weaker calcification. In *F. sokaci* calcification does not often reach the central stem but it is restricted from the outer parts of secondary to quaternary branches. The new species shows higher biometrical data of the thallus (e.g. D = 3.0-5.3 mm versus 2.6-3.3 mm; d = 0.77-1.1 mm instead of 0.4-1.0 mm). Even if the primary branches show comparable sizes, the secondary branches are usually longer (l' = 0.27-0.54 mm versus 0.15-0.30 mm) and larger in diameter (p' = 0.14-0.25 mm versus 0.15 mm). Tertiary branches are longer (l'' = 0.15-0.42 mm versus 0.15 mm) but show similar diameters (p'' = 0.086-0.13 mm versus 0.10 mm).

Fanesella sokaci n.sp. differs from *F. anae* SOKAC in a general bigger size (e.g. D = 3.0-5.3 mm versus 1.48-2.85 mm; d = 0.77-1.1 mm versus 0.35-0.48 mm) and a weaker calcification. The primary branches of *F. sokaci* are phloioiphorous with a constant vertical width while they are globular and much shorter in *F. anae*. The tertiary branches of *F. anae* are by far more slender than those of the new species.

8.3 Other taxa

8.3.1 *Palaeodasycladus mediterraneus* (P1A) (Pl. 44/1-2)

This taxon has recently been the object of a scientific debate involving its specific status and generic characterization (DELOFFRE & LAADILA, 1990; BARATTOLO et al., 1994).

This species is largely spread in lagoonal and shelf margin facies of the Liassic of the Tethys (BARATTOLO, 1991a). In the Gran Sasso area it is used to define two algal assemblages (*Palaeodasycladus* spp. algal assemblage and *Palaeodasycladus* and *Thaumatoporella* algal assemblage).

Dasyclads identifiable as *P. mediterraneus* are rather numerous in the studied area, although their morphology may differ from the type material (e.g. BARATTOLO et al., 1994). Two extreme morphologies occur. One shows a smaller size, thinner secondary branches, but last order branches distinctly phloioiphorous (Pl. 44/1-2). The second morphology exhibits rather stout and densely set secondary and tertiary branches. A continuous variety of intermediate morphologies is recorded, but only rarely two distinct morphologies are intermingled in the same sample.

Waiting for an accurate quantitative study and comparison of the several morphologies, these forms are considered as a single taxon.

8.3.2 *Palaeodasycladus gracilis* CROS & LEMOINE 1967 ex GRANIER & DELOFFRE 1993 (Pl. 54/1-2, 4-5; Pl. 44/2)

Palaeodasycladus gracilis (= *Palaeodasycladus mediterraneus* var. *elongatulus* PRATURLON) has been reinstated

for nomenclature reasons by GRANIER & DELOFFRE (1993), a taxonomic review is also given by BARATTOLO et al. (1994).

An analysis of the figured original material and of our specimens allows a new interpretation on some characters of the alga (thallus morphology, calcification and ramifications) partly differing from the description supplied by CROS & LEMOINE (1967).

Judging from Pl. 1/2 of CROS & LEMOINE (1967: Pl. 1/2), that is the lectotype (GRANIER & DELOFFRE, 1993), the thallus appears distinctly club-shaped and not cylindrical. Moreover, as already affirmed by CROS & LEMOINE (1967, p. 251), this specimen also shows that intusannulation is not anywhere present along the thallus; in fact it is lacking or undistinct in the lower part of the figure, contrary to the upper part where it is clearly visible. This might suggest that intusannulation has a regional range and is growth dependent, similarly to what happens in *Palaeodasycladus mediterraneus* (BARATTOLO et al., 1994).

CROS & LEMOINE (1967, p. 251) think that each intusannulation involves two or three whorls of primary branches whose distal ends continue into the calcareous skeleton (CROS & LEMOINE, 1967: fig.4). We suppose that the primary branches of CROS & LEMOINE are to be considered secondary branches. While Pl. 1/2 of CROS & LEMOINE (1967) shows continuous horizontal channels (i.e. intusannulations), Pl. 1/4 shows that those figures break downwards into single rows (i.e. one whorl) of moderately large pores (seemingly primary pores). In the Gran Sasso material this fact occurs too (Pl. 54/4). Regarding calcification *Palaeodasycladus gracilis* behaves like *Palaeodasycladus mediterraneus* (BARATTOLO et al., 1994: p.3). Problems will consequently arise in the discussion about the order of ramifications of *Palaeodasycladus gracilis* (four?, five?; see CROS & LEMOINE, 1967: fig.4).

The calcareous skeleton of the specimens from the Gran Sasso, which were originally aragonitic, usually are recrystallized in sparitic calcite and only rarely micritized (Pl. 39/4).

8.3.3 *Petrascula ? heraki* SOKAC & NIKLER (Pl. 54/6-7)

Some specimens from CM1, CM3 and CM5 microfacies are referred to this taxon. They occur in the *Palaeodasycladus* and *Thaumatoporella* algal assemblage, and *Palaeodasycladus* spp. algal assemblage.

The size of our specimens fits well to that of *P. ? heraki*. The characters of primary and secondary branches, as well as the number of secondaries per tuft, also fit the variability deduced from the Sokac & Nikler's photos and description.

However our specimens clearly show tertiary branches, which have not been observed in *P. ? heraki*, even if SOKAC & NIKLER (1969, p.111) do not exclude their occurrence. Although some photos (SOKAC & NIKLER, 1969: pl.2 figs 4-5) show traces of tertiary branches, the state of preservation of the original material does not allow farther reaching discussion. The attribution of our material to the taxon is given with some reservation.

In agreement with BASSOUILLET et al. (1978) the position

in the genus *Petrascula* is doubtful, but the taxon is not believed to be a junior synonym of *Fanesella dolomitica* CROS & LEMOINE as supposed by OTT (1974)

9 CONCLUSIONS

Sedimentological and paleontological analysis have been carried out in the Dolomia Principale and in the Calcare Massiccio shallow water carbonate successions from the Upper Triassic and lower Liassic of the Gran Sasso area (Central Apennine, Italy) in order to define stratigraphy, algal content, facies distribution and paleoenvironments.

The paleontological study has revealed a rich algal content in which five dasycladacean green algal assemblages have been recognized. They have been used both as biostratigraphical and paleoenvironmental indicators.

Two new algal species, *Tersella genoti* n.sp. and *Fanesella sokaci* n.sp., both from Liassic beds have been established. *Tersella genoti* differs from the other allied species in a less "differentiated" club shaped thallus, the shape of secondary branches and size. *Fanesella sokaci* differs from other species of the same genus in the shape and size of the branches, the size of the thallus and the degree of calcification.

The paleontological study has allowed some new observations on the genus *Tersella* MORELLET which lead to consider Morellet's original diagnosis more apt than the subsequent emendations. The description of *Tersella* as having a well-marked, stalked thallus proposed by Cros & Lemoine (1967) seems to be too much restrictive, especially when such a shape can not be discerned in the type-species. The assignment of a moniliform thallus, as suggested by CUBAYNES & DELOFFRE (1984), cannot be verified for the type-species, and the genus.

A discussion on several "terselliform" taxa (*Dissocladella cretica*, *Linoporella lucasi*, *Dissocladella iberica* and *Dissocladella ebroensis*) is supplied and some comments on the genus *Fanesella* CROS & LEMOINE and *Palaeodasycladus gracilis* CROS & LEMOINE are given.

The sedimentological analysis has allowed to point out a variety of microfacies in the Dolomia Principale and in the Calcare Massiccio Units defining a high frequency cyclic pattern. Three different types of cycles were observed: subtidal cycles composed only by a subtidal unit, peritidal cycles formed by a subtidal unit overlain by an intersupratidal unit and rarely by a supratidal unit (incomplete and complete peritidal cycles) and diagenetic cycles made of a subtidal unit directly overlain by a supratidal unit.

Microfacies, types of cycles and frequency and distribution of algal assemblages have been used to define facies patterns and depositional environments.

In the Dolomia Principale Fm. two main depositional environments were recognized:

- a shelf lagoon facies occasionally characterized by restricted circulation. In this facies subtidal and incomplete peritidal cycles are present and the *Gyroporella*

vesiculifera algal assemblage dominates;

- a backmargin facies marked by complete peritidal cycles and by diagenetic cycles. In this facies the *Griphoporella curvata* algal assemblage is present.

In the Calcare Massiccio Fm. the following depositional environments were recognized:

- a back-margin facies characterized by diagenetic cycles with high energy subtidal units and by the *Palaeodasycladus* spp. algal assemblage. In this area the presence of *Palaeodasycladus* and *Thaumatoporella* algal assemblage can be interpreted as a local transition to a more protected lagoonal environment.
- margin facies characterized by oolites and bioclastic sand shoals with minor contribution of reef-building organisms as corals, sponges, solenoporaceans and dasycladacean algae of the *Tersella genoti* and *Fanesella sokaci* algal assemblage. These organisms probably formed small patch-reefs in front and/or behind the shelf edge. The facies rarely shows a cyclothemic organization.

The cyclicity of the shallow water units is referred to high frequency sea level fluctuations. The distribution of subtidal, peritidal and diagenetic cycles within the facies units was mainly controlled by the topographic position of the depositional environment relative to the marginal area and less by the amplitude of high frequency sea level variations.

The facies distribution has allowed to construct a paleoenvironmental model for the Gran Sasso area.

In the Late Triassic shallow water platform facies extended in the western and southern parts of the Gran Sasso area, with a lagoonal to backmargin facies (Fig. 11/A). In the early Liassic the shallow water facies retrograded, and the marginal area moved back to the western and southern parts of the Gran Sasso area (Fig. 11/B). In the middle Liassic, after the break up of the Calcare Massiccio platform, large shelf areas were drowned, and shallow water sedimentation retreated to the South of the Gran Sasso range (Fig. 11/C).

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