

CRUSTOSE CORALLINE ALGAL PAVEMENTS FROM LATE EOCENE COLLI BERICI OF NORTHERN ITALY

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Riassunto. L'Eocene superiore del Veneto registra la prima fase di sviluppo delle Coralline crostose del Cenozoico del Mediterraneo. Nei Colli Berici (Vicenza) la formazione Marne di Priabona è caratterizzata da varie facies a Corallinaceae, attualmente oggetto di ricerche paleoecologiche. In questo lavoro sono esposti i primi risultati di uno studio riguardante un corpo affiorante presso Barbarano Vicentino ("le Scudellette"). Esso è caratterizzato da un bindstone a Coralline crostose spesso circa 6 m, al cui tetto sono stati riconosciuti livelli francamente marnosi.

Le Corallinaceae sono associate a briozoi, macroforaminiferi (*Nummulites*, *Discocyclina*, *Operculina*, *Asterocyclina*, *Spiroclypeus*, *Gypsina*, *Pellatispira*, *Biplanispira*), Echinidi, Serpulidi, spicole di Spugne e microforaminiferi bentonici. Le Coralline crostose sono rappresentate dai generi *Lithothamnion*, *Sporolithon*, *Mesophyllum* e frammenti di *Lithoporella* e *Spongites*. In considerazione della presenza prevalente e costante del genere *Lithothamnion*, l'associazione è stata denominata "Associazione a *Lithothamnion*".

Sulla base della morfologia costruzionale dei talli, sono state evidenziate due facies. Una inferiore è caratterizzata dalla prevalenza di piccoli rodoliti, alcuni costituiti da un sottile tallo incrostante un nucleo di grandi dimensioni e altri con vari episodi d'incrostazione. Sono presenti inoltre lenti tempestiche costituite prevalentemente da macroforaminiferi e da Briozoi (i rodoliti sono assenti). L'altra facies, propria della parte superiore dell'unità, è invece costituita da rodoliti di grandi dimensioni, ellissoidali, con struttura interna più complessa e da sottili croste laminari che formano pacchetti di talli spessi almeno un centimetro. Sia i tipi morfologici presenti che l'associazione algale sono caratteristiche di biotopi attuali presenti a profondità compresa tra i 50 e i 100 m. Il contesto nel quale i rodoliti e le croste algali si svilupparono era quello di un ambiente di piattaforma aperta (shallow circalittoral) su fondali situati al di sotto della normale azione delle onde, ma influenzati occasionalmente dalle tempeste.

Abstract. The Eocene from the Prealpine region records the first phase of the crustose coralline algae flourishing in the Cenozoic. These algae are very frequent in the Marne di Priabona Formation (Late Eocene). This palaeoecological research involves outcrop at Barbarano Vicentino (Vicenza) in the Colli Berici which is well known for its Paleogene stratigraphy.

The coralline unit consists of a floatstone bank 6 m thick with rhodoliths and laminar crusts; it lies between macroforaminifer dominated limestone (Middle Eocene) and coral-algal massive limestone (earliest Oligocene). *Lithothamnion*, *Sporolithon*, *Mesophyllum*, and some *Lithoporella* and *Spongites* have been recognized. Bryozoans, large foraminifera, bivalves, echinoids, serpulids, benthic and rare planktic forams also occur. The large foraminifera are represented by *Nummulites*, *Discocyclina*, *Operculina*, *Asterocyclina*, *Spiroclypeus*, *Gypsina*, *Pellatispira*, *Biplanispira*.

The coralline association is dominated by *Lithothamnion*. A lower and an upper facies have been recognized. Small rhodoliths made up of thin crusts around a large core, or several encrusting stages characterise the lower part of the unit; big rhodoliths (4-10 cm in size) with a complex inner structure and several thin delicate laminar crusts occur in the upper part; groups of laminar crusts, parallel to the depositional surface, are frequent too. Bioclastic lenses rich in large foraminifera and bryozoans, without rhodoliths, occur in the lower part of the unit.

The Priabonian algal community built a "Crustose Pavement" on the open shelf (shallow circalittoral) below the wave base at 50-100 m in depth, occasionally influenced by storms. The morphology of the thalli suggests a decrease in hydrodynamic energy or an increase in depth from the bottom to the top of the unit.

Introduction.

Coralline algae (Rhodophyta, Corallinaceae) are common fossils in the stratigraphic units of the Late Eocene, making up the Colli Berici (Vicenza, Northern Italy), south-eastern margin of the *Lessini Shelf*, where they were identified for the first time by Fabiani (1908), using the term "nullipore". He ascribed these units, recognized throughout the Veneto, to the Priabonian-Oligocene transition (Fabiani, 1915). The Priabonian coralline units were indicated as "calcari marnosi, marne, calcari nulliporici con *Nummulites fabianii*, Ortoframmine, Echinidi e bivalvi"; "calcari marnosi e nulliporici a *Nummulites vasca*, Ortoframmine e Briozoi" were ascribed to the Early Oligocene.

During the survey for the New Italian Geological Map, the Colli Berici fossiliferous associations were the subject of chronostratigraphic studies (Ungaro & Bosellini, 1965; Bosellini et al., 1967; Ungaro, 1969; Ungaro, 1978).

Corallinaceae were also studied for this purpose, with a detailed study of a Colli Berici stratigraphic section (I.G.M., Foglio 50 "Padova", III, SW, 1966) situated near Barbarano Vicentino, including the units of the Eocene-Oligocene boundary (Francavilla et al., 1970).

Palaeoecological research of the Corallinaceae, which has developed very recently, has not previously

involved the Paleogene species. A research programme was started with two fundamental purposes: one to address the relations between thallus morphology, bathymetry and climate, while the other addressed the community composition for a comparison with those of the Neogene. The programme also involves the study of the associations in relation to the sequence stratigraphy.

The research started with the study of the Priabonian strata with Corallinaceae which crop out near Barbarano Vicentino (Fig. 1) in the Colli Berici (VI, Northern Italy), at "le Scudellette", which is part of the section already examined by Francavilla et al. (1970) from a biostratigraphic point of view. The data obtained from this study are the object for this paper.

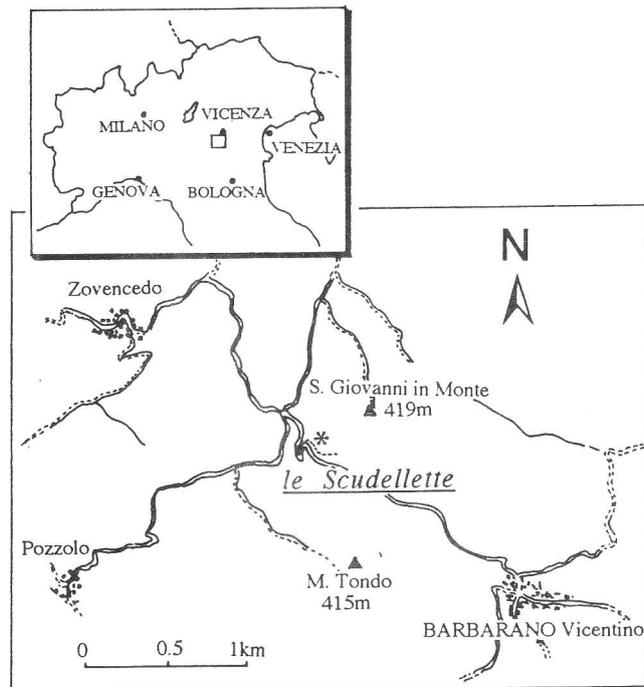


Fig. 1 - Geographical location of the fossiliferous site "le Scudellette" (southern margin of the Colli Berici; Vicenza, Northern Italy).

Methods.

Three samples from the bottom (MPB1), the middle (MPB2), and the top (MPB3) of the unit were picked. From each sample, weighing about 2 kg (2600 cm³ about), dry-peels (mean surface 45 cm²) and thin sections, perpendicular and parallel to the surface of the layer were made. The technique, to make dry-peels, involves treating a prepared surface with acid, applying a sheet of cellulose acetate, allowing the film of plastic material to dry, then removing the peel, from the acid-treated surface.

The identification of the taxa was based on the classification proposed by Braga et al. (1993), in which the identification criteria are provided by SEM observation of particular cell characteristics, cell arrangement,

and the type of conceptacles. These anatomical characters, if preserved in the fossils, permit the identification of the known fossil Cenozoic coralline algae using similar criteria to those used for modern corallines (Woelkerling, 1988). The implications of these studies are that many fossil corallines have to be re-assigned to different genera. This is the case for the species ascribed in the literature to *Archaeolithothamnium* Rothpletz 1891 now are *Sporolithon* Heydrich 1897 (Moussavian & Kuss, 1990; Verheij, 1993); *Lithothamnium* Philippi 1837 is named *Lithothamnion* Heydrich 1897 (Woelkerling, 1988); some species previously misidentified as *Lithophyllum* Philippi 1837 can be now assigned to *Mesophyllum* Lemoine 1923, *Spongites* Kützing 1841 or *Neogoniolithon* Setchell & Mason 1943 (Braga et al., 1993). Miscellaneous features considered of potential importance by Johansen (1976) for delimiting genera of nongeniculate Corallinaceae, unfortunately are not recognizable in fossils, and those present are insufficiently described in the literature. The status of the species already identified in the Colli Berici must also be checked according to the ICBN (International Code of Botanic Nomenclature). We use an open nomenclature for the species recognized at this stage of the research focused on palaeoecological purposes. When one of these species revealed some correspondence with a species in the literature, the latter has been considered a provisional synonym.

The algal community has been characterized by coverage percentages of 6 categories: 1) *Lithothamnion*, 2) *Mesophyllum*, 3) *Sporolithon*, 4) Macroforaminifers (without the distinction of genera), 5) Bryozoans, and 6) matrix (including all the loose bioclasts, the microforaminifers, and the micrite). *Lithoporella*, occurring in loose fragments and as small thalli on other algae, and *Spongites* have not been considered in the covering percentage because of their rarity.

The linear method was used to measure the abundance of each category occurring along the two diagonals of a 4 cm square. The linear method was chosen after some comparison tests with the areal method, in which it turned out to be similarly reliable and more practical in its application.

The morphology and algal thallus sizes were also studied along the stratigraphic series (from the bottom to the top of the outcrop). A statistical study of the distribution of the mean diameter (D) of the rhodoliths along this series was also made.

Coralline algal beds of the Marne di Priabona.

Stratigraphic notes. The levels richest in crustose coralline in the Colli Berici belong to the Marne di Priabona Formation and are characterized, according to Bosellini et al. (1967), by a massive limestone, often in the upper part of the formation, with *Num-*

mulites, *Discocyclusina*, and nulliporic limestone lenses. The Marne di Priabona lie between the "Nummulitic Limestones" of the Middle Eocene and the Calcareni di Castelgomberto of the Oligocene, rich in corals and Rhodophyceae.

The outcrop area is located on sheet 50 (Padova, III, SW, tavoletta "Barbarano Vicentino", I.G.M., 1966). The coralline unit of the "le Scudellette" (Barbarano Vicentino) is made up of a white massive, lenticular body with grey and yellow spots. Its maximum exposed thickness is 6 m as measured along the gravel road "le Scudellette".

The vegetation partly covers the rest of the succession of the massive algal and large foraminifera limestones of the Early Oligocene up to the top of the Priabonian bank. The stratigraphic units below the Priabonian coralline algal beds are not visible because of the rich vegetation. About 500 m in the direction to Barbarano, calcarenites with large *Nummulites* of the Middle Eocene crop out.

In the unit studied, the top of which is marked by marly layers without algae, rhodoliths and laminar

Lithothamnion Community.

Composition. Bryozoans occur in branched and encrusting forms.

The large foraminifera are represented by several genera: *Nummulites*, *Discocyclusina*, *Pellatispira*, *Biplanispira*, *Asterocyclusina*, *Operculina*, *Spiroclypeus*, *Gypsina*. *Nummulites* and *Discocyclusina* are very small in relation to those of the Lutetian stratigraphic units below (Middle Eocene; Ungaro, 1969). Among the echinoids, *Echinolampas* and small clypeasterids are recognized. In the field, in thin sections and in the dry-peels, some serpulids were identified, while in a marl sample taken from the upper part of the outcrop, sponge spiculas were found.

According to the classifications of Conti (1950), Maslov (1962), Johnson (1965), and Mastrorilli (1968), Francavilla et al. (1970) identified in this locality the listed species in Tab. 1. According to the classification of Braga et al. (1993) and on the basis of the illustrations given of the mentioned species by Francavilla et al. (1970), some genus and some species of our specimens have been reviewed and assigned again (Tab. 1).

FRANCAVILLA ET AL., 1970		THIS PAPER
<i>Lithothamnium</i>	<i>aesitante</i> Conti, 1949	<i>Lithothamnion</i> sp. 1
"	<i>moreti</i> Lemoine, 1927	<i>Lithothamnion</i> sp. 2
"	<i>roveretoi</i> Airoidi, 1932	—
<i>Dermatholithon</i>	sp. Foslie, 1899	—
<i>Lithophyllum</i>	<i>simplex</i> Lemoine, 1927	<i>Mesophyllum</i> sp. 1
"	<i>symetricum</i> Lemoine, 1927	" "
"	cf. <i>perrandoi</i> Airoidi, 1932	—
"	<i>quadrangulum</i> Lemoine, 1934	—
"	cf. <i>kampteneri</i> Mastrorilli, 1968	—
"	<i>heteromorphum</i> Mastrorilli, 1968	—
"	<i>giammarini</i> Mastrorilli, 1968	<i>Mesophyllum</i> sp. 2
<i>Mesophyllum</i>	cf. <i>rigidum</i> Mastrorilli, 1968	" "
"	cf. <i>roveretoi</i> Conti, 1943	—
"	<i>obsitum</i> Airoidi, 1932	—
<i>Archaeolithoth.</i>	cf. <i>varium</i> Mastrorilli, 1958	<i>Sporolithon</i> sp.
"	<i>praeerithraeum</i> Airoidi, 1932	" "
"	sp. n. Francavilla et al., 1970	—
—	—	<i>Spongites</i> sp.
—	—	<i>Lithoporella melobesoides</i> (Foslie) Foslie, 1909

Tab. 1 - Identified species by Francavilla et al. (1970) compared to the species described in this paper.

algal crusts parallel to the depositional surface are recognizable. The rhodoliths are mainly elliptical and discoidal in shape, with smooth outer surfaces or incipient ramifications. Thin laminar crusts occur isolated or grouped in packets. The algae (both branched and laminar) are the main encrusting and binding agents of the other components of the association. During sedimentation, they overgrew bryozoans, large foraminifera, echinoids, serpulid worm tubes, sponge spiculas, benthonic and rare planktonic forams, forming therefore a bindstone.

Regarding *Lithothamnium*, it has not been possible to compare the examples of samples of Francavilla et al. (1970) with those studied by us because there is only one illustration of the conceptacles of *Lithothamnium aesitante*.

In the sample MPB1 (bottom of the outcrop), the prevailing algal genus is *Sporolithon* (20%), while *Lithothamnion* and *Mesophyllum* occur in lower covering percentages, 14% and 2% respectively. The large foraminifera constitute a 6%, bryozoans are a 10% and the matrix the remaining 48% (Fig. 2).

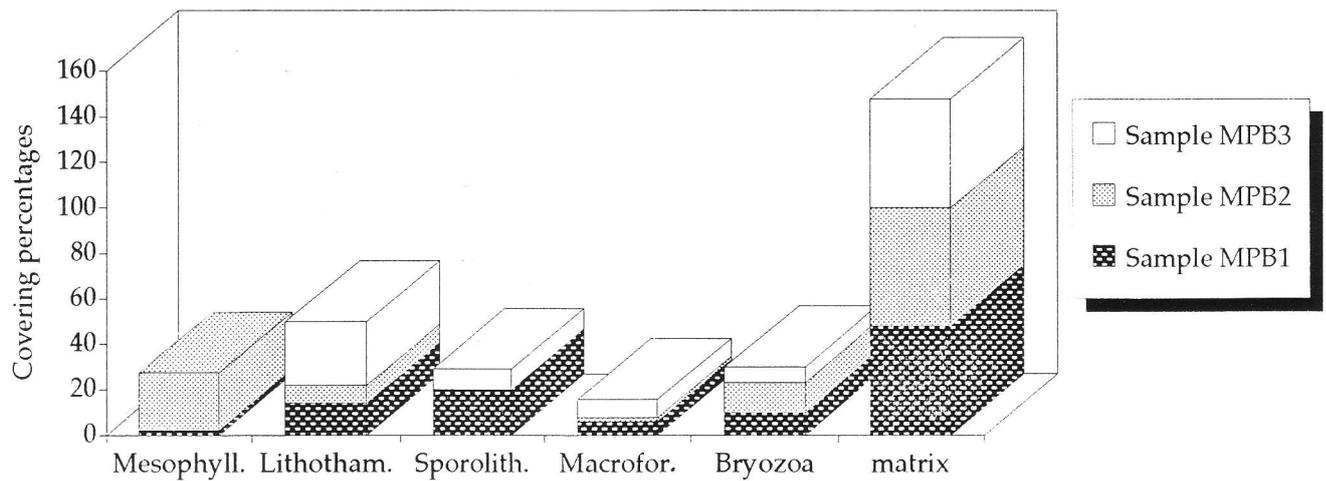


Fig. 2 - Histogram of the covering percentages in the three samples. The percentages of each category are related in the text. See the stratigraphic log (Fig. 7) where the samples are from.

In the sample MPB2 (middle part of the outcrop), *Mesophyllum* covers a 25.3%, *Lithothamnion* 8% and *Sporolithon* has not been recognized. Macroforaminifers, bryozoans and the matrix represent 1.7%, 13% and 52% respectively (Fig. 2).

In the sample MPB3 (top of the outcrop), *Mesophyllum* does not occur, while *Lithothamnion* represents 28%, *Sporolithon* 9%, large foraminifera 8%, bryozoans 7%, and the matrix 48% (Fig. 2).

Lithothamnion, bryozoans, and large foraminifera are the three constant components of the association. This palaeoenvironmental unit is defined as a "*Lithothamnion* Community".

Morphologies and growth conditions of the coralline algae.

Growth morphologies of the coralline algae. Four main growth morphologies have been distinguished:

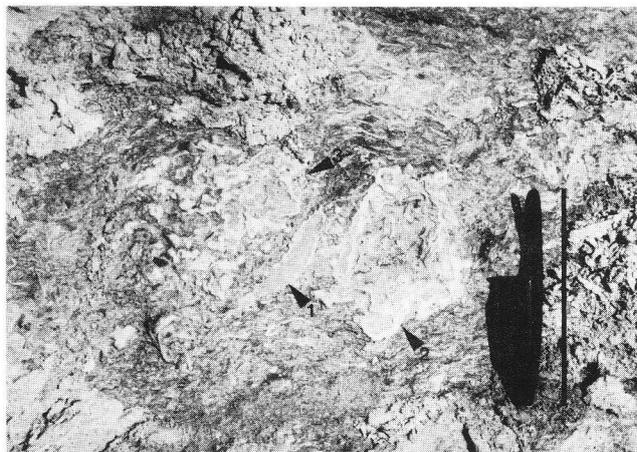


Fig. 3 - Field view of the small massive rhodolith (arrow 1) and small rhodoliths (arrows 2 and 3) made up of several generations of encrusting thalli (bottom of the outcrop). The scale bar is 5.7 cm long.

- Small compact rhodoliths (Fig. 3): 1-3 cm in diameter, made up of a core (\varnothing mean 8 mm) bigger than the encrusting algal cover (2.2 cm thick in average). The plants cover the core in several quite compact layers with a very low volume of structural voids. The outer surface is smooth. The core is generally made up of micrite, algal fragments, macroforaminifer and bryozoan fragments.

- Small loose rhodoliths with a small core and a thick algal cover (Fig. 3): the length of the largest axis is 1-4 cm. The organisation of the crusts (0.7 mm thick on average) is very complex and they often include small foraminifers, bryozoans, crustose coralline and micrite fragments. The void percentage is higher than in the rhodoliths previously described.

- Big rhodoliths made up of several crust generations (Fig. 4): 4-10 cm in length along the greatest axis. The structure of these rhodoliths is similar to the smaller and more compact ones. The thickness of the thalli is on average 1.3 mm. The rhodolith surface

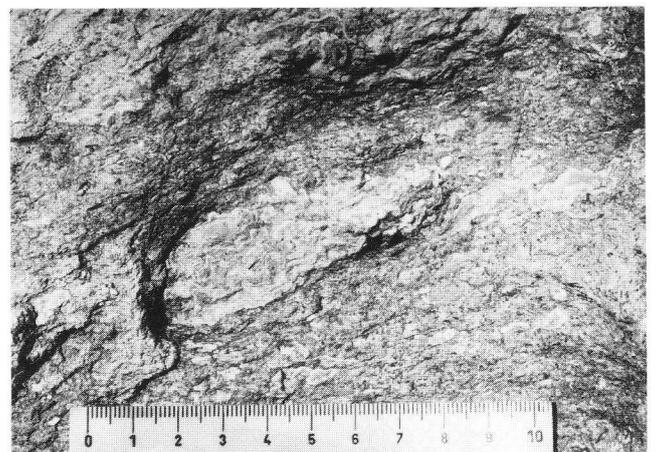


Fig. 4 - Field view of a big ellipsoidal rhodolith showing the irregular outer surface with small protuberances (top of the outcrop).

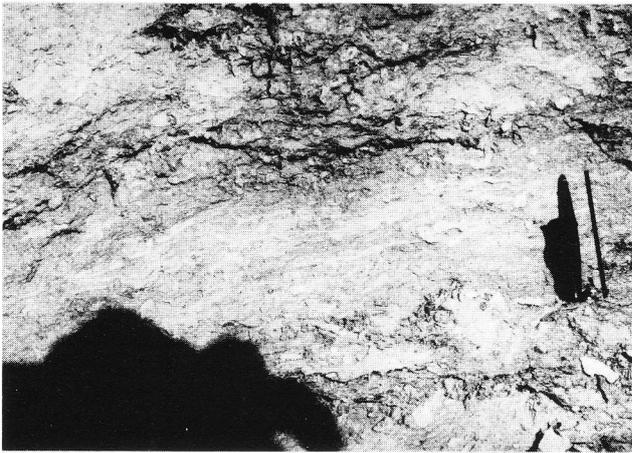


Fig. 5 - Field view of a packet of several delicate laminar crusts (top of the outcrop). The scale bar is 5.7 cm long.

shows wide protuberances some millimetres high, resulting from the laminar thalli covering the thin algal branches during successive growth stages.

- Thin laminar crusts (Fig. 5): generally 0.5-1 mm thick (mean thickness is 0.58 mm) mostly parallel to the plane of stratification, make up packets of thalli thicker than 1 cm.

Mesophyllum sp. 1 is always present as thin laminar crusts and as small branch fragments, while the thin thalli of *Mesophyllum* sp. 2 usually make up rhodoliths. *Lithothamnion* and *Sporolithon* show all the morphological types described. *Lithoporella* encrusts other coralline and it is frequently associated with *Lithothamnion*. *Spongites* is present as thinnest laminar crusts.

Many rhodoliths show eroded surfaces, caused by bio-erosion and/or reworking due to fragmentation. Several growth phases can be distinguished within all types of rhodoliths, represented by erosional surfaces and by bioclastic sediment incorporated between the algal laminae. This sediment also occurs as intraclasts, which occasionally may be the core of some rhodoliths.

In the field, a variation of the forms has been recognized, from the bottom to the top, which provides the first distinction of two facies: one, identified at the base of the outcrop with small rhodoliths, which merges gradually into the other, with big rhodoliths at the top of the unit. The distribution has been verified by the measurements of 127 mean diameters (D) (Bosellini & Ginsburg, 1971) of the rhodoliths on the surface unit of a square mesh. Two groups have been identified (Fig. 6): one with mean diameter D of about 1-3.5 cm, and the other with diameter D= 3.5-8 cm, in the lower and upper part of the outcrop respectively.

The lower facies is also characterized by abundant small rhodoliths, rare laminar crusts and sporadic concentrations of finer material rich in large foraminifera without algal components. In the upper facies, big rhodoliths and wide laminar crusts, sometimes grouped in packets, prevail.

Palaeoenvironmental implications: Crustose *Lithothamnion* Pavement.

The algal associations and the loose crustose coralline fragments of the Priabonian of "le Scudellette"

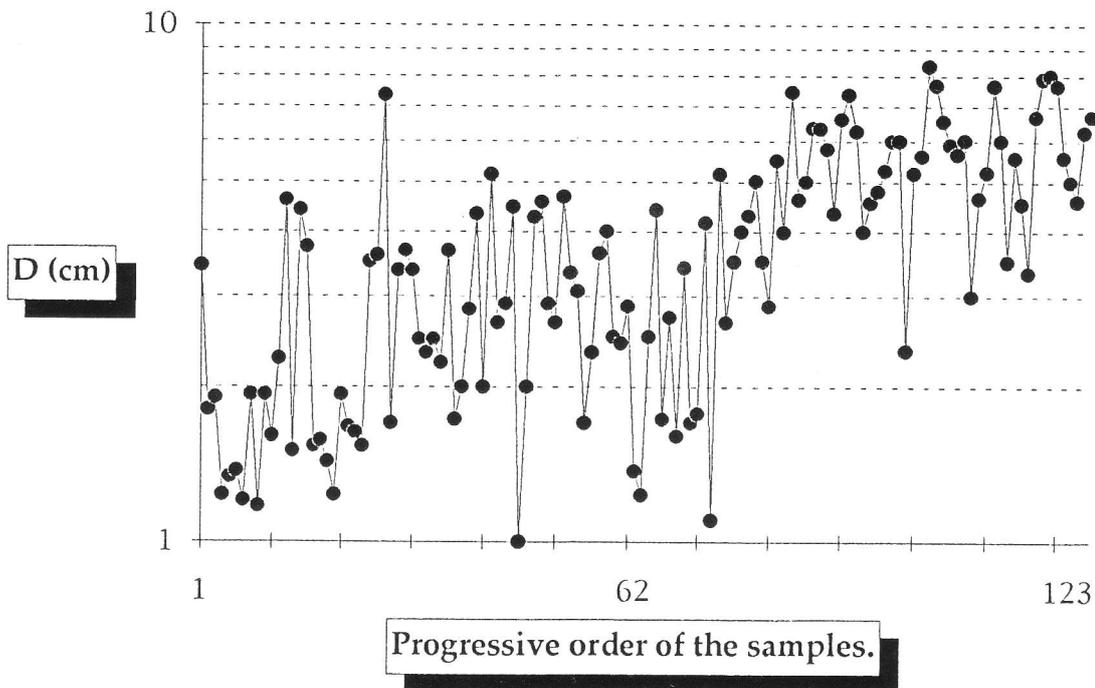


Fig. 6 - Semilogarithmic diagram showing the distribution of the mean diameter (D, in cm; ordinates axis) from the bottom (sample 1) to the top (sample 127) of the outcrop. The mean diameter is $D = (s+I+L)/3$, where s, I, and L are the shortest, intermediate, and longest diameter respectively, according to Bosellini & Ginsburg (1971).

in the Colli Berici are dominated by genera of the subfamily Melobesioideae Lemoine 1939. Two genera of the subfamily Mastophoroideae Setchell 1943 also occur.

This coralline flora is considered to be characteristic of present-day environments below the normal-wave base in tropical and subtropical areas (Adey & McIntyre, 1973; Adey, 1979; Martín et al., 1993). Comparable fossil associations have been recognized in the Neogene of several places (Bosence & Pedley, 1982; Bosence, 1983, 1985, 1991; Buchbinder, 1977; Braga & Martín, 1988; Carannante et al., 1988; Martín & Braga, 1993).

Many other components of the Priabonian association of Vicenza are to be found in the Neogene

coralline associations, particularly in the Miocene, but with a few exceptions: *Discocyclusina*, *Asterocyclusina*, *Pellatispira*, *Biplanispira*, *Spiroclypeus*. These forms became extinct in the Late Eocene, except *Spiroclypeus* which reached the Early Miocene.

The percentage relationships of *Lithothamnion* (47%), *Sporolithon* (27%) and *Mesophyllum* (26%) and the occurrence of *Lithoporella* and *Spongites* are very similar to those found by Adey (1979) in recent coralline associations at 70 m in depth in the Hawaiian Islands and the Caribbean; *Lithothamnion* and *Mesophyllum* dominate the coralline floras from 30 to 80 m in depth on the shelves of the Indo-Pacific region (Adey, 1979); the same algae associated with encrusting foraminifers occur in the Flower Garden Banks (northwestern Gulf

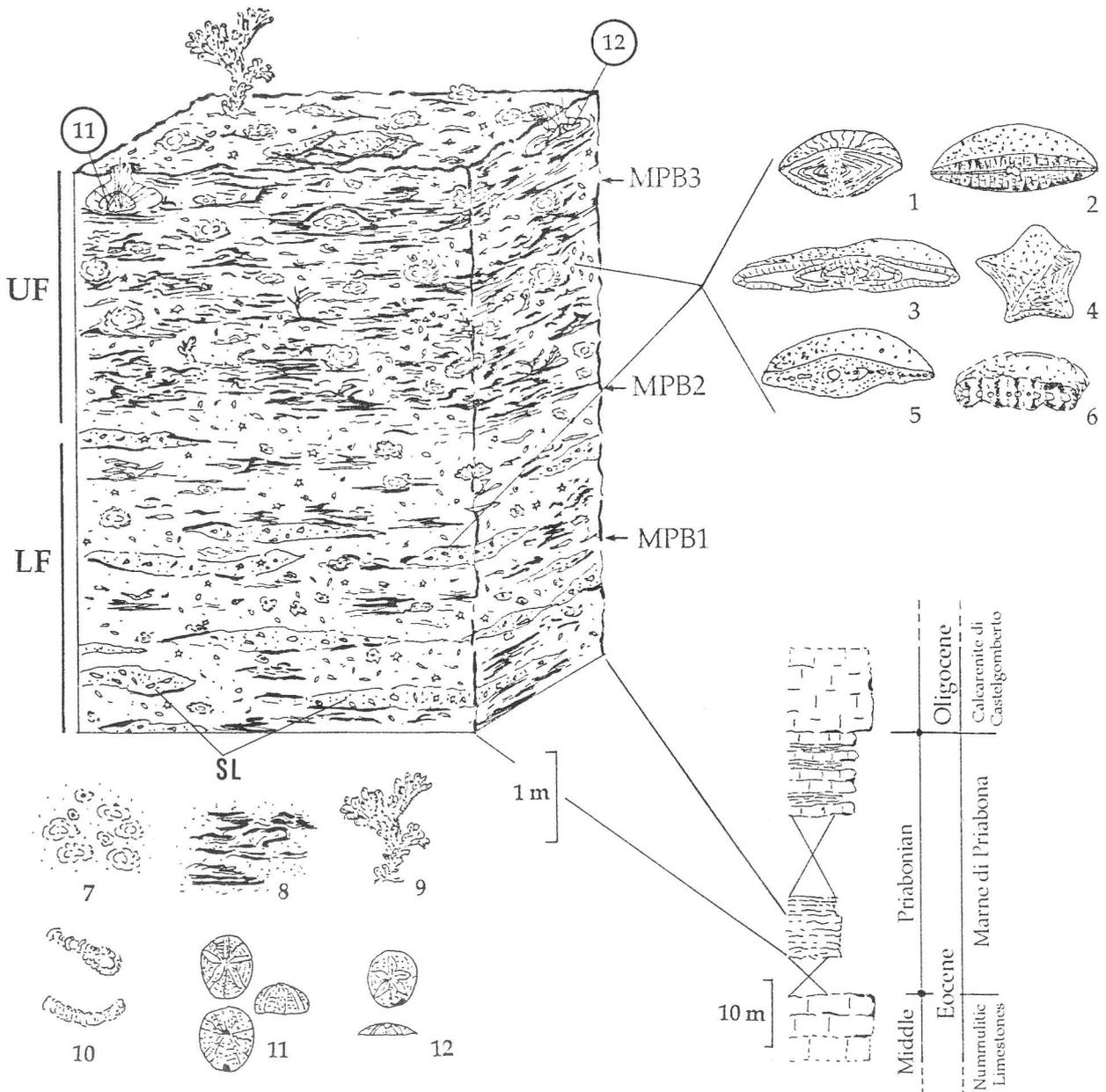


Fig. 7 - Sketch of the vertical succession of the two algal facies of the "Crustose *Lithothamnion* Pavement" with the sample locations (MPB1, MPB2, MPB3) and stratigraphic log. LF= Lower Facies. UF= Upper Facies. SL= Storm layers.

1) *Nummulites*; 2) *Discocyclusina*; 3) *Operculina*; 4) *Asterocyclusina*; 5) *Spiroclypeus*; 6) *Pellatispira*; 7) rhodoliths; 8) laminar crusts; 9) bryozoans; 10) serpulid worm tubes; 11) *Echinolampas*; 12) clypeasterids. (For further details, see text)

of Mexico; Minnery, 1990). In the Mediterranean similar associations have been located at 30-110 m in depth (Pérès & Picard, 1964; Bosence, 1985; Carannante et al., 1988). Thin laminar crusts dominate in the deep-water rhodoliths (Braga & Martín, 1988; Martín & Braga, 1993) and are especially characteristic of open shelf environments.

Therefore, evidence from both the coralline association and the algal morphology points to an open-platform setting for the "le Scudellette" facies. The palaeobathymetry can be estimated as being some tens of metres, presumably 50-100 m, which is well below the normal-wave base, but within the reach of storms. The southern Australian shelf has storm action down to 90-110 m in depth (James & MacIntyre, 1985).

Presumably the layers without rhodoliths (storm layers) occurring in Barbarano and characterizing the bottom of the outcrop were produced by the reworking action of the storms: high energy reworked the bottom thus winnowing the rhodoliths with respect to the rest of the sediments made up mainly by large foraminifera and bryozoans. In contrast, during fair weather conditions micrite and bioclasts were deposited on the bottom where the rhodoliths grew (Martín et al., 1993; Braga & Martín, 1988). Sporadic concentrations of finer sediment without rhodoliths, which can be found at the bottom of the outcrop of "le Scudellette", show that these events were of high hydrodynamic energy. Intermittent storms may also be responsible for the abrasion and the different concentration of bryozoa and algae (Bosence & Pedley, 1982).

The two facies recognized on the basis of the algal morphology, may indicate two different hydrodynamic regimes: the lower facies is related to moderate energy conditions (the rhodoliths were frequently moved with interruptions in their growth), while lower energy, and undisturbed growth of the rhodoliths and laminar crusts, would have prevailed in the upper facies (Fig. 7). This situation would favour the development of thin laminar crust growths (sometimes covering small branches) in fair weather and their reworking and partial destruction during storms (Bosence & Pedley, 1982; Burgess & Anderson, 1983; Martín et al., 1993). Small and big rhodoliths coexist in the lower facies. The typical occurrence of the largest ones associated with laminar crusts (which were not affected by movement or rolling) gives information about the low energy level of the environment which was therefore the deepest one.

In the Barbarano unit there are many similarities to the Crustose Pavement described by Bosence & Pedley (1982) from the Maltese Islands. Therefore, the Priabonian facies is defined as a "Crustose *Lithothamnion* Pavement". As in Malta, this framework is leafy and mainly constructed by *Lithothamnion*, *Mesophyllum*, and

Sporolithon, with encrusting *Lithoporella melobesioides*. The crusts build up the framework by foliaceous growth combined with various modes of crust fusion and rhodolith fusion. The framework supports a varied epifauna of bryozoans, serpulids, large foraminifera and echinoids. The top of the "le Scudellette" unit is marked by marly layers without algae, containing planktonic forams.

Systematic appendix

We keep an open nomenclature for the identification of the algal species occurring at Barbarano, as a result of the classification problems previously described. For some species described, a provisional synonymy is provided (Tab. 1), because the type species, indicated by Francavilla et al. (1970), of each genus have not been reviewed yet. The studied specimens were compared, in this study, only to the types described by Francavilla et al. (1970).

Division **R h o d o p h y t a** Wettstein, 1901

Class **Rhodophyceae** Rabenhorst, 1863

Order **Corallinales** Silva & Johansen, 1986

Family **Corallinaceae** Lamouroux, 1812

Subfamily **Melobesioidae** Lemoine, 1939

Genus *Lithothamnion* Heydrich, 1897

Lithothamnion sp. 1

Pl. 1, fig. 1, 2

Horizon and locality. Upper part of the Marne di Priabona Formation, Priabonian (Late Eocene), "le Scudellette", near Barbarano Vicentino, Colli Berici (Vicenza, Veneto, Northern Italy).

Material. Thin sections and dry-peels, MPB 1, 2, 3, stored in the Museo di Paleontologia del Dipartimento di Scienze Geologiche e Paleontologiche dell'Università degli Studi di Ferrara. The institutional acronym of this museum is: MPDSGPUF.

Description. Plumose hypothallium (335 μm mean thickness, 325-345 μm) with rectangular cells measuring 25-35 μm (mean 30 μm , s.d. 3.5) long and 10-28 μm (mean 19 μm , s.d. 4) wide. Perithallium made up of large and differentiated cells; multiporate conceptacles are present (452-520 μm , mean 485 μm , s.d. 6, long; 180-220 μm , mean 200 μm , s.d. 4.7, in diameter). Fusions between cells of contiguous filaments are present in the perithallium and in the hypothallium.

Lithothamnion sp. 1 shows all the described morphological types.

Observations. The plumose hypothallium and the multiporate conceptacles ascribe our samples to the

genus *Lithothamnion*. *Lithothamnion* sp. 1 is probably assignable to *Lithothamnium aesitante* but there is only one illustration of this latter species showing the multiporate conceptacles in Francavilla et al. (1970). As there are no illustrations of the hypothallium and perithallium, the description provided by these authors does not allow an immediate comparison, although it was specified that the perithallium is very thick and made up of ordered cells arranged in linear rows, as in *Lithothamnion* sp. 1.

Lithothamnion sp. 2

Pl. 1, fig. 3

Horizon and locality. Upper part of the Marne di Priabona Formation, Priabonian (Late Eocene), "le Scudellette", near Barbarano Vicentino, Colli Berici (Vicenza, Veneto, Northern Italy).

Material. Thin sections and dry-peels, MPB 1, 2, 3, stored in the MPDSGPUF.

Description. Plumose hypothallium (380 μm mean thickness, 360-400 μm) with cells measuring 13-23 μm (mean 18 μm ; s.d. 2) long and 7-11 μm (mean 9 μm ; s.d. 3) wide. Perithallium made up of small cells (12-18.5 μm , mean 15 μm , s.d. 2.4, long and 7-11 μm , mean 9 μm , s.d. 0.8, in diameter) arranged according to a irregular grid. Rare multiporate conceptacles (417-503 μm , mean 460 μm , s.d. 12, long; 65-115 μm , mean 90 μm , s.d. 8, in diameter).

Lithothamnion sp. 2 may develop all the described morphology.

Observations. Francavilla et al. (1970) described *Lithothamnium moreti* e *Lithothamnium roveretoi* without illustrations. According to their description, both species have "...a very thin hypothallium which normally cannot be seen or is absent. The perithallium is made up of small cells arranged in a continuous but confused succession and sometimes with alternate septa". The two species differ in the size of their multiporate conceptacles: 120x600-900 μm for the first one, and 90-120x300-330 μm for the second. On the basis of

the sizes of the conceptacles, *Lithothamnion* sp. 2 is equivalent to *Lithothamnium moreti* of Francavilla et al. (1970).

Genus *Mesophyllum* Lemoine, 1923

Mesophyllum sp. 1

Pl. 1, fig. 4; Text-fig. 8 A

Horizon and locality. Upper part of the Marne di Priabona Formation, Priabonian (Late Eocene), "le Scudellette", near Barbarano Vicentino, Colli Berici (Vicenza, Veneto, Northern Italy).

Material. Thin sections and dry-peels, MPB 1 and 2, stored in the MPDSGPUF.

Description. Coaxial hypothallium well-developed and 180-220 μm (mean 200 μm) thick; the hypothallial cells measure 21-33 μm (mean 27 μm ; s.d. 6) long and 15-19 μm (mean 17 μm ; s.d. 3) wide. The perithallium is thin or missing in many samples; in most samples it is micritized, hindering measurement of cell dimensions. There are no conceptacles. Fusions between cells of contiguous filaments are common in the hypothallium (Pl. 1, fig. 4; Fig. 8 A).

It is always present in thin laminar crusts and in small branch fragments.

Observations. The occurrence of the coaxial hypothallium, the multiporate conceptacles and the cell fusions ascribes our samples to the genus *Mesophyllum*.

The samples studied in this work show the characteristics of the plants described and illustrated in Francavilla et al. (1970) as *Lithophyllum simplex* and *Lithophyllum symmetricum* coming from the same locality.

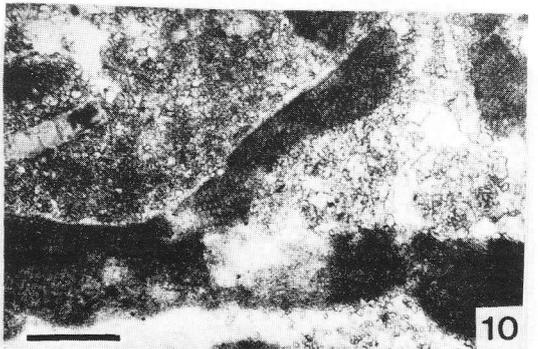
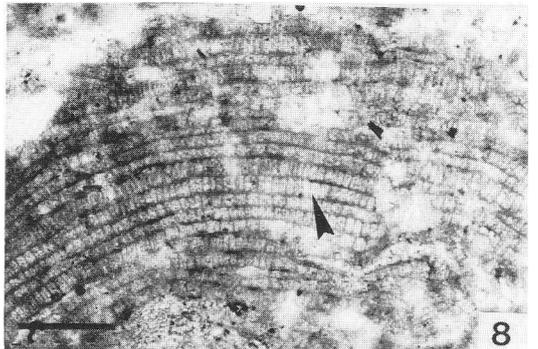
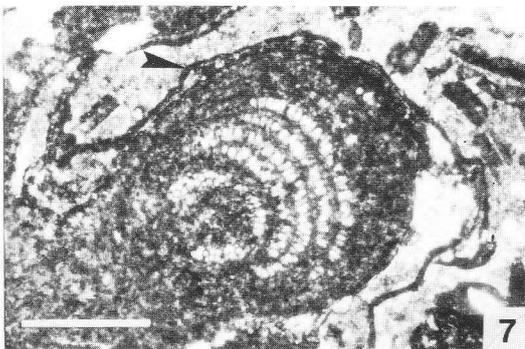
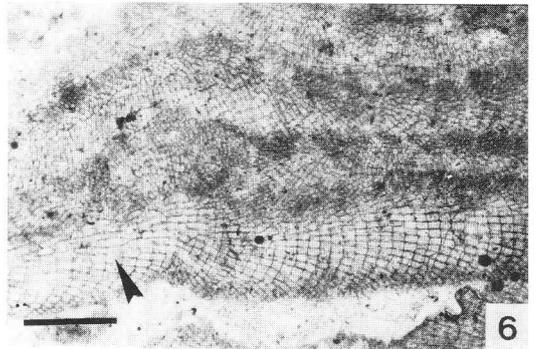
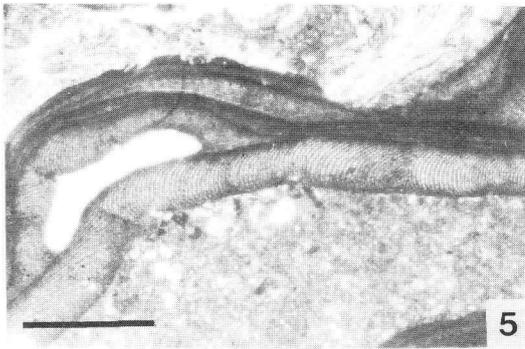
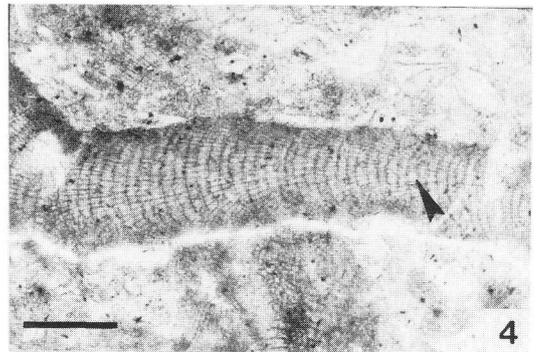
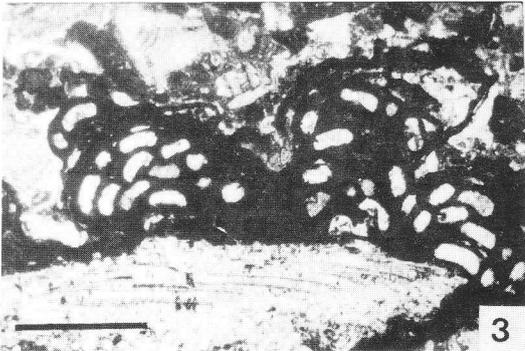
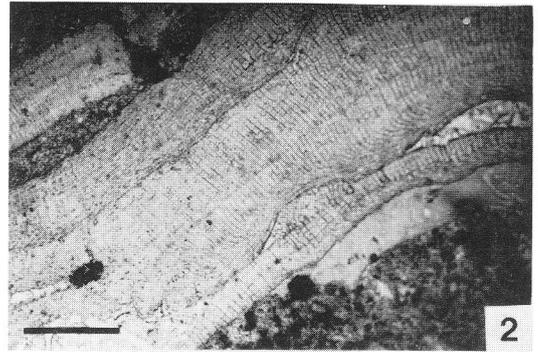
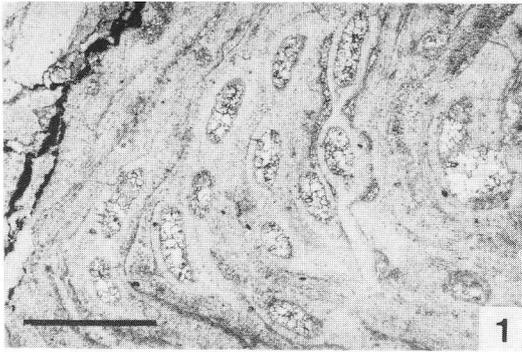
Francavilla et al. (1970) described *Lithophyllum simplex* as being made up by of slightly undulating strings of sterile thalli. The perithallium was made up by small cells ("considered to be the continuation of the hypothallial cells").

Lithophyllum symmetricum of the same authors was only identified on the basis of some hypothallial fragments; conceptacles were not identified.

PLATE 1

Thin section photomicrographs of different coralline algae.

- Fig. 1 - *Lithothamnion* sp. 1. (Dry-peel photomicrograph). Section showing perithallium and multiporate conceptacles (Scale bar = 200 μm).
 Fig. 2 - *Lithothamnion* sp. 1. (Dry-peel photomicrograph). Hypothallium and perithallium (Scale bar = 150 μm).
 Fig. 3 - Small protuberances with conceptacles of *Lithothamnion* sp. 2 encrusting a *Discocyclusina* (Scale bar = 1 cm).
 Fig. 4 - *Mesophyllum* sp. 1. Section of a thick coaxial hypothallium (Scale bar = 200 μm). Note the cell fusions (arrowed).
 Fig. 5 - Framework construction of leafy overgrowths of *Mesophyllum* sp. 2 (Scale bar = 1 cm).
 Fig. 6 - *Mesophyllum* sp. 2. Section showing basal coaxial hypothallium and perithallium; note the cell fusions (arrowed) (Scale bar = 200 μm).
 Fig. 7 - *Sporolithon* sp. Section of a knobby branch showing perithallium with sori. Arrow indicates a thin encrusting thallus of *Lithoporella melobesioides* (Foslie) Foslie (Scale bar = 1 cm).
 Fig. 8 - *Lithoporella melobesioides* (Foslie) Foslie. Section of agglomerate branches and several superimposed thalli (Scale bar = 200 μm). Arrow indicates some fusions between cells of contiguous filaments.
 Fig. 9 - *Spongites* sp. Framework construction of leafy overgrowths. Shown also numerous differently oriented sections of the uniporate conceptacles: lower right part represents oblique section; upper right and upper left parts represent axial sections (Scale bar = 500 μm).
 Fig. 10 - *Spongites* sp. Detail of the fig. 9, showing hypothallium and uniporate conceptacle (Scale bar = 150 μm).



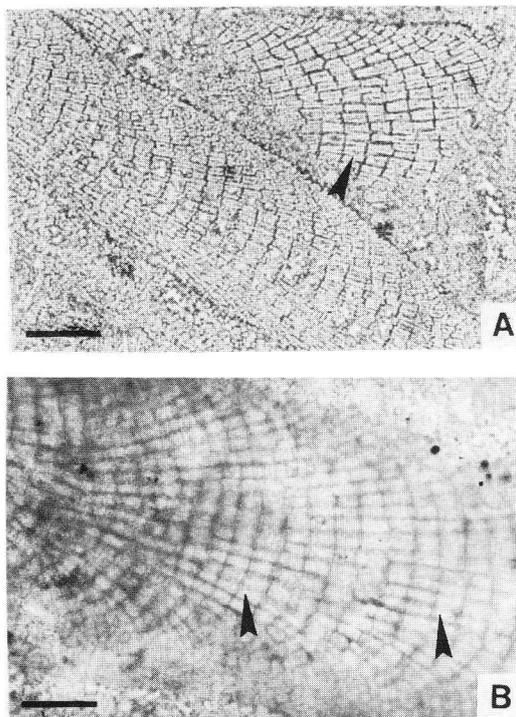


Fig. 8 - Longitudinal sections of hypothallia showing the cell fusions (arrowed). A) *Mesophyllum* sp. 1: peel replica (Scale bar = 100 μm). B) *Mesophyllum* sp. 2: thin section (Scale bar = 60 μm).

Therefore both species were determined on the basis of the morphological appearance and the hypothallial cell size: characters not sufficient to determine the genus (Wray, 1977; Braga et al., 1993). The occurrence of the cell fusions further is a character to assign our samples to *Mesophyllum* and not to *Lithophyllum* (Braga et al., 1993).

Mesophyllum sp. 2

Pl. 1, fig. 5,6; Text-fig. 8 B

Horizon and locality. Upper part of the Marne di Priabona Formation, Priabonian (Late Eocene), "le Scudellette", near Barbarano Vicentino, Colli Berici (Vicenza, Veneto, Northern Italy).

Material. Thin sections and dry-peels, MPB 1 and 2, stored in the MPDSGPUF.

Description. Coaxial hypothallium (281-339 μm , 310 μm mean thickness) with rectangular cells measuring 25-28 μm (mean 27 μm ; s.d. 1.5) long and 11-23 μm (mean 17 μm ; s.d. 4) wide. Thick perithallium made up of cells measuring 20-43 μm (mean 31 μm ; s.d. 4) long and 12-25 μm (mean 19 μm ; s.d. 2) wide, where several multiporate conceptacles occur 300-572 μm (mean 436 μm ; s.d. 3.4) long, and 110-278 μm (mean 194 μm ; s.d. 3) in diameter arranged in rows. Cell fusions present both in hypothallium (Fig. 8 B) and in perithallium (Pl. 1, fig. 5). Usually it makes up rhodoliths.

Observations. *Mesophyllum* sp. 2 differs from *Mesophyllum* sp. 1 in having smaller conceptacles and thicker perithallium.

According to the descriptions of *Mesophyllum* cf. *rigidum* and *Lithophyllum giammarini* (considered a junior synonym of *Lithophyllum contii* Mastrorilli, Fravega & Vannucci, 1987) given by Francavilla et al. (1970) both species show a coaxial hypothallium without conceptacles. In absence of conceptacles it is not possible (Woelkerling, 1988) to assign the two types of hypothallium to two different genera.

The samples of Francavilla et al. (1970), identified as *Mesophyllum* cf. *rigidum*, show the coaxial hypothallium thicker than the perithallium (often zoned); the conceptacles were not described.

"*Lithophyllum giammarini*" is characterized by a "medullar hypothallium" on the side of which there is a growth of perithallium; the conceptacles were not described.

The two species have been included in *Mesophyllum* sp. 2 because having the same hypothallial and perithallial characteristics and showing multiporate conceptacles. Further, cell fusions are distinctive of *Mesophyllum* and not of *Lithophyllum* (Braga et al., 1993).

Genus *Sporolithon* Heydrich, 1897

Sporolithon sp.

Pl. 1, fig. 7

Horizon and locality. Upper part of the Marne di Priabona Formation, Priabonian (Late Eocene), "le Scudellette", near Barbarano Vicentino, Colli Berici (Vicenza, Veneto, Northern Italy).

Material. Thin sections and dry-peels, MPB 1 and 3, stored in the MPDSGPUF.

Description. Plumose hypothallium (98-292 μm , 195 μm mean thickness) with cells measuring 11-49 μm long (mean 30 μm ; s.d. 2) and 5-27 μm (mean 16 μm ; s.d. 1.5) in diameter. Thick perithallium with rows of tetrasporangia in sori (53-87 μm , 70 μm mean length; 28-62 μm , 45 μm mean height) located along the cell rows which, when there are some protuberances, are arched and sometimes zoned. The perithallial cells measure 20-24 μm long (mean 22 μm ; s.d. 1) and 13-17 μm (mean 15 μm ; s.d. 3) in diameter.

It shows all the previously described morphological growth types.

Observations. According to Woelkerling (1988), Moussavian & Kuss (1990), and Braga et al. (1993), *Sporolithon* is the correct name for algae formerly named *Archaeolithothamnium*. The occurrence of the plumose hypothallium and the tetrasporangia in sori ascribes our samples to the genus *Sporolithon*.

According to Francavilla et al. (1970) both *Archaeolithothamnium* cf. *varium* and *Archaeolithothamnium praeerithraeum* have the same characters for both the hypothallium and the perithallium. The outer morphological shape is similar for both species; however this character does not have any systematic value.

From the descriptions given of the two species, the only discriminant character is the size of the sori, which for *Archaeolithothamnium* cf. *varium* are 30-50 μm in length ("the height was not measured as there were no suitable oriented sections") and for *Archaeolithothamnium praeerithraeum* are 35x60-70 μm . This difference in size of the sori is very low. According to Verheij (1993) it is not possible to distinguish between two species on the basis of such small size differences and therefore it is not possible to ascribe the specimens of Francavilla et al. (1970) to two different species. *Sporolithon* sp., therefore, encompasses the plants ascribed by Francavilla et al. (1970) to *Archaeolithothamnium* cf. *varium* and *Archaeolithothamnium praeerithraeum*.

Subfamily *Mastophoroideae* Setchell, 1943
Genus *Lithoporella* Foslie, 1909

***Lithoporella melobesioides* (Foslie) Foslie, 1909**

Pl. 1, fig. 8

1983 *Lithoporella melobesioides* - Bosence, pp. 165-166, pl. 18, fig. 1; text-fig. 11.

Horizon and locality. Upper part of the Marne di Priabona Formation, Priabonian (Late Eocene), "le Scudelletto", near Barbarano Vicentino, Colli Berici (Vicenza, Veneto, Northern Italy).

Material. Thin sections and dry-peels, MPB 1, 2, 3, stored in the MPDSGPUF.

Description. Successive layers of monostromatic plants forming very thin crusts. Each thallus consists of a single layer of large and high cells (16-22 μm , 18.9 μm mean height; 25-34 μm , 29.4 μm mean length). Fusions between cells of contiguous filaments occur in the hypothallium (Pl. 1, fig. 8). There are no conceptacles.

Observations. The occurrence of a thin thallus (1 cell thick) and the multiple overgrowths of large hypothallial cells ascribes to genus *Lithoporella* and, according to Buchbinder (1977) and Bosence (1983), to species *Lithoporella melobesioides*. Francavilla et al. (1970) did not record the occurrence of this genus.

It occurs rarely as thin, laminar crusts within rhodoliths from all facies. There are sometimes some very small fragments, made up generally of a single row of cells.

Genus *Spongites* Kützing, 1841

***Spongites* sp.**

Pl. 1, fig. 9, 10

Horizon and locality. Upper part of the Marne di Priabona Formation, Priabonian (Late Eocene), "le Scudelletto", near Barbarano Vicentino, Colli Berici (Vicenza, Veneto, Northern Italy).

Material. Thin sections and dry-peels, MPB 1 and 2, stored in the MPDSGPUF.

Description. Thalli monomerous, forming crusts up to 1.5 mm thick, that give rise to branching protuberances 2-3 mm in diameter and up to 2 mm in height. Plumose hypothallium 87-107 μm thick. Hypothallial cells very irregularly shaped, 26-29 μm (mean 27.4 μm , s.d. 0.7) long and 10-16 μm (mean 12.4 μm , s.d. 1.2) in diameter. Perithallial cells form a thin zoned, irregular grid due to cell fusions. Cells in this part of the thallus have variable sizes and shapes. Cells are 14-23 μm (mean 17.9 μm , s.d. 1) long and 10-15 μm (mean 13 μm , s.d. 0.6) in diameter. Only uniporate conceptacles are present. They are flask-shaped, measuring 430-521 μm (mean 470.9 μm , s.d. 14) in diameter and 219-269 μm (mean 244 μm , s.d. 14) in height from the floor to the roof (not including the pore) of the conceptacle. Only one conceptacle pore has been found (Pl. 1, fig. 10). It measures 122 μm in diameter and 148 μm in height.

Observations. The crustose coralline showed in Francavilla et al. (1970, pl. 86, fig. 2) considered by the authors to be of analogous shape to "*Lithophyllum giammarini*" Mastrorilli. In that figure the conceptacle does not show the pore because the section is not axial to it. Francavilla et al. (1970) did not describe the conceptacles and the hypothallium arrangement. On the contrary, our samples show the conceptacle pore, the plumose hypothallium and the cell fusions. According to Braga et al. (1993), these characteristics are peculiar of *Spongites*.

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R E F E R E N C E S

- Adey W.H. (1979) - Crustose coralline algae as microenvironmental indicators in the Tertiary. In Gray J. & Boucot A.J. (Eds.) - Historical Biogeography, Plate Tectonics and the Changing Environment. *Oregon State Univ. Press*, pp. 459-464, Corvallis.
- Adey W.H. & McIntyre I.G. (1973) - Crustose coralline algae: a re-evaluation in the geological sciences. *Bull. Geol. Soc. Am.*, v. 84, pp. 883-903, Boulder.
- Bosellini A., Carraro F., Corsi M., De Vecchi G.P., Gatto G.O., Malaroda R., Sturani C., Ungaro S. & Zannetin B. (1967) - Note illustrative della Carta geologica d'Italia-

- Foglio 49, "Verona". *Serv. Geol. Italia*, Nuova Tecnica Grafica (Eds.), Roma.
- Bosellini A. & Ginsburg R.N. (1971) - Form and internal structure of Recent algal nodules (rhodolites) from Bermuda. *Journ. Geol.*, v. 79, pp. 669-682, Chicago.
- Bosence D.W.J. (1983) - Coralline algae from the Miocene of Malta. *Palaeontology*, v. 26, pp. 147-173, London.
- Bosence D.W.J. (1985) - The "Coralligène" of the Mediterranean - A recent analog for the Tertiary coralline algal limestone. In Toomey D.F. & Nitecki M.H. (Eds.) - *Palaeoalgology: Contemporary Research and Applications*, pp. 216-225, Springer-Verlag, Berlin.
- Bosence D.W.J. (1991) - Coralline Algae: Mineralisation, Taxonomy, and Palaeoecology. In Riding R. (Eds.) - *Calcareous Algae and Stromatolites*, pp. 98-113, Springer-Verlag, Berlin.
- Bosence D.W.J. & Pedley H.M. (1982) - Sedimentology and palaeoecology of a Miocene coralline algal biostrome from the Maltese Islands. *Palaeogeogr., Palaeoclimat., Palaeoecol.*, v. 38, pp. 9-43, Amsterdam.
- Braga J.C., Bosence D.W.J. & Steneck R.S. (1993) - New anatomical characters in fossil coralline algae and their taxonomic implications. *Palaeontology*, v. 36, pt. 3, pp. 535-547, London.
- Braga J.C. & Martín J.M. (1988) - Neogene coralline-algal growth-forms and their palaeoenvironments in the Almanzora river valley. *Palaeogeogr., Palaeoclimat., Palaeoecol.*, n. 67, pp. 285-303, Amsterdam.
- Buchbinder B. (1977) - Systematic and palaeoenvironment of the calcareous algae from the Miocene (Tortonian) Ziq-lag Formation, Israel. *Micropaleont.*, v. 23, pp. 415-435, New York.
- Burgess C.J. & Anderson J.M. (1983) - Rhodoids in Temperate Carbonates from the Cenozoic of New Zealand. In Peryt T.M. (Ed.) - *Coated Grains*, pp. 243-258, Springer-Verlag, Berlin.
- Carannante G., Esteban M., Milliman J.D. & Simone L. (1988) - Carbonate lithofacies as palaeoaltitude indicators: problems and limitations. *Sediment. Geol.*, v. 60, pp. 333-346, Amsterdam.
- Conti S. (1950) - Alghe Corallinacee Fossili. *Pubbl. Ist. Geol. Univ. Genova*, n. 4, s. A, Paleontologia, pp. 1-156, Genova.
- Fabiani R. (1908) - Paleontologia dei Colli Berici. *Mem. Soc. Ital. Sc.*, s. 3, v. 15, pp. 45-248, Roma.
- Fabiani R. (1915) - Il Paleogene Veneto. *Mem. Ist. Geol. R. Univ. Padova*, v. 3, pp. 1-336, Padova.
- Francavilla F., Frascari Ritondale Spano F. & Zecchi R. (1970) - Alghe e macroforaminiferi al limite Eocene-Oligocene presso Barbarano (Vicenza). *Giorn. Geol.*, s. 2, v. 36 (1968), pp. 653-686, Bologna.
- Fravega P. & Vannucci G. (1987) - *Lithophyllum giammarinoi* sinonimo più recente di *Lithophyllum contii* dell'Oligocene ligure-piemontese. *Riv. It. Paleont. Strat.*, v. 93, n. 2, pp. 225-236, Milano.
- James N.P. & MacIntyre I.G. (1985) - Carbonate depositional environments, modern and ancient. Pt. 1. Reefs: zonation, depositional facies, diagenesis. *Colorado School Mines Quat.*, v. 80 (3), pp. 1-70, Golden.
- Johansen H.W. (1976) - Current status of generic concepts in coralline algae (Rhodophyta). *Phycologia*, v. 15, pp. 221-244, Oxford.
- Johnson J.H. (1965) - Coralline Algae from the Cretaceous and Early Tertiary of Greece. *Journ. Paleont.*, v. 39, pp. 802-814, Tulsa.
- Martín J.M. & Braga J.C. (1993) - Eocene to Pliocene coralline algae in the Queensland Plateau (northeastern Australia). In Davies P.J., McKenzie J.A., Palmer-Julson A. et al. - *Proc. ODP, Scientific Results*, v. 133, pp. 67-74, College Station, TX, USA.
- Martín J.M., Braga J.C., Konishi K. & Pigram C.J. (1993) - A model for the development of rhodoliths on platforms influenced by storms: the Middle-Miocene carbonates of the Marion Plateau (Northeastern Australia). In McKenzie J.A., Davies P.J., Palmer-Julson A. et al. - *Proc. ODP, Scientific Results*, v. 133, pp. 455-460, College Station, TX, USA.
- Maslov V.P. (1962) - Fossil red algae of the USSR and their relation to facies. *Trud. Geol. Inst.*, v. 53, pp. 1-222, Moskva.
- Mastrorilli V.I. (1968) - Nuovo contributo allo studio delle Corallinacee dell'Oligocene Ligure-Piemontese: i reperti della tavoletta Ponzone. *Atti Ist. Geol. Univ. Genova*, v. 5, n. 2, pp. 153-406, Genova.
- Minnery G.A. (1990) - Crustose coralline algae from the Flower Garden Banks, Northwestern Gulf of Mexico: controls on distribution and growth morphology. *Journ. Sedim. Petrol.*, v. 60, pp. 992-1007, Tulsa.
- Moussavian E. & Kuss J. (1990) - Typification and status of *Lithothamnium aschersoni* Schwager, 1883 (Corallinaceae, Rhodophyta) from Paleocene limestone of Egypt. A contribution to synonymy and priority of genere *Archaeolithothamnium* Rothpletz and *Sporolithon* Heydrich. *Berliner Geowiss. Abh. Reihe A, Geol. Palaeont.*, v. 120.2, pp. 929-942, Berlin.
- Pérès J.M. & Picard J. (1964) - Nouveau manuel de bionomie benthique de la Mer Méditerranée. *Rac. Trav. Stat. Marine Endoume*, Bull. 31, n. 47, pp. 1-137, Marseille.
- Ungaro S. (1969) - Étude micropaléontologique et stratigraphique de l'Eocène supérieur (Priabonien) de Mosano (Colli Berici). *Coll. Eocène*, v. 3. *Mém. B.R.G.M.*, n. 69, pp. 267-280, Paris.
- Ungaro S. (1978) - L'Oligocene dei Colli Berici. *Riv. It. Paleont. Strat.*, v. 84, n. 1, pp. 199-278, Milano.
- Ungaro S. & Bosellini A. (1965) - Studio micropaleontologico e stratigrafico sul limite Eocene-Oligocene nei Colli Berici Occidentali. *Ann. Univ. Ferrara*, n.s., sez. 9, Sc. Geol. Min., v. 3, pp. 157-183, Ferrara.
- Verheij E. (1993) - The genus *Sporolithon* (Sporolithaceae fam. nov., Corallinales, Rhodophyta) from the Spermonde Archipelago, Indonesia. *Phycologia*, v. 32 (3), pp. 184-196, Oxford.
- Woelkerling Wm. J. (1988) - The Coralline Red Algae: An Analysis of the Genera and Subfamilies of Nongeniculate Corallinaceae. V. of 268 pp., Oxford Un. Press, Oxford.
- Wray J.L. (1977) - Calcareous algae. V. of 185 pp., Elsevier, Amsterdam.