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OLIGOCENE CORAL AND ALGAL REEF AND RELATED FACIES OF VALZEMOLA (SAVONA, NW ITALY)*

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Riassunto. Vengono analizzati i sedimenti terrigeni e carbonatici appartenenti al ciclo trasgressivo oligocenico del Bacino Terziario del Piemonte, affioranti nell'area di Valzemola (Savona, Liguria occidentale, Italia nord-occidentale) e riferibili alla Formazione di Molare. Le sequenze terrigene sono rappresentate da brecce, conglomerati ed arenarie che ricoprono, in discordanza angolare, litotipi dolomitici o calcareo-dolomitici riferibili alla Formazione delle Dolomie di San Pietro dei Monti. Tali sequenze sono localmente caratterizzate da ricche associazioni ad Alghe Corallinacee e Coralli, che stabilizzando i fondali consentono lo sviluppo di un vero e proprio insediamento recifale. Successivamente la bioherma viene soffocata da una sedimentazione arenaceo-conglomeratica di derivazione fluviale da legarsi ad un intensificarsi degli apporti terrigeni nel bacino. Una progressiva superficializzazione porta infine all'instaurarsi di condizioni adatte alla deposizione di calcari di ambiente intertidale o supratidale.

L'analisi di questo insediamento recifale è stata compiuta esaminando sette sezioni stratigrafiche. Lo studio in chiave paleoecologica della corallofauna e della cenosi algale, caratterizzata quest'ultima da una significativa presenza sia del genere *Lithophyllum*, sia di *Lithothamnion*, ha consentito di avanzare alcune ipotesi sulle condizioni ambientali che caratterizzavano questo settore durante il tardo Oligocene. Si sono potute evidenziare nove differenti facies, delle quali sette direttamente connesse con il reef e due di ambiente marino prossimale e testimonianti una fase regressiva. Facies I: conglomeratico-arenacea, rappresenta una fase di colonizzazione in ambiente a dominante terrigena. Facies II: framestone a Coralli, rappresenta una fase di diversificazione ("inner reef front" vicino al "reef crest"). Facies III: bafflestone a Coralli, rappresenta una fase di colonizzazione in un "inner reef slope". Facies IV: bindstone a Coralli, rappresenta una fase di dominazione in ambiente di "reef crest". Facies V: bindstone a Coralli alternato a floatstone, testimonia una fase di colonizzazione in ambiente carbonatico. Facies VI: floatstone ad Alghe e Coralli, rappresenta una facies di accumulo di materiali smantellati dal reef. Facies VII: rudstone a Coralli, rappresenta una facies di accumulo confrontabile con la "rubble & pavement zone" del back reef. Facies VIII: conglomerati e sabbie di ambiente marino superficiale, rappresenta una sequenza regressiva. Facies IX: calcari massicci con strutture zonato-ondulate, rizoliti, vene di calcite e pisoidi, testimonia un ambiente intertidale o supratidale.

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Abstract. The terrigenous and carbonate sediments of the transgressive Oligocene cycle of the Tertiary Piedmont Basin outcropping in the area of Valzemola (Savona, western Liguria, Northwest Italy) and which are referable to the Molare Formation are analysed. The terrigenous sequence, represented by breccias, conglomerates and sandstones, overlies with an angular unconformity dolomitic or calcareous-dolomitic lithologies referable to the San Pietro dei Monti Dolomite Formation. These sequences are locally characterized by rich associations of coralline algae and corals, which by providing a stable substrate allowed the development of a true reef build up. Subsequently the bioherm was suffocated by fluvial sandstone and conglomerate. This may be associated with an intensification in the amount of terrigenous material being brought into the basin. A progressive shallowing continues until the introduction of conditions suitable for calcareous deposition in an intertidal or supratidal environment.

The analysis of this reef deposit was carried out by examining seven stratigraphic sections. The paleoecological study of the coral fauna and the algal assemblage, the latter characterized by the significant presence either of the genus *Lithophyllum*, or of *Lithothamnion*, allowed some hypothesis on the environmental conditions which characterized this sector during the Late Oligocene. Nine different facies could be shown, from those seven directly connected to the reef and two to nearshore environments proving a regressive phase. Facies I: conglomeratic-sandstone representing a stage of colonization in a dominantly terrigenous environment. Facies II: coral framestone, representing a stage of diversification ("an inner reef front" near to the "reef crest"). Facies III: coral bafflestone representing a colonization stage in an "inner reef slope". Facies IV: coral bindstone representing a stage of domination in a "reef crest" environment. Facies V: coral bindstone alternating with floatstone, gives evidence of a colonization stage in a carbonate environment. Facies VI: coral and algae floatstone, representing a facies of accumulated reef debris. Facies VII: coral rudstone, representing an accumulation facies comparable with that of the "rubble & pavement zone" of the back reef. Facies VIII: conglomerates and sands of a shallow marine environment, represent a regressive sequence. Facies IX: massive limestones with undulated-zoned structures, rhizoliths, calcite veins and pisoliths, evidence of an intertidal or supratidal environment.

Introduction and geological setting.

The present study examines the terrigenous and carbonate sediments belonging to the Oligocene transgressive cycle of the Tertiary Piedmont Basin (here afterwards abbreviated to T.P.B.) outcropping in the area of Valzemola (Savona, W Liguria, NW Italy). In this zone the transgression is developed on the internal margins of the Ligurian Briançonnais. For a more detailed picture of the geodynamic and geological events which characterize this area and more in general the T.P.B. refer to Giammarino (1984), and for a more detailed picture of the geological order of the studied area refer to Crispini et al. (1993). As previously stated this study examines the Valzemola area (Fig. 1, 2) where the base of the transgressive sequence is characterized by the presence of a coral and red algae reef.

Lorenz (1964, 1968) studied this area and described a "calcaire à Lithothamniées et Polypiers" ("calcaire de Valzemola") that overlies the rock of "Dolomia di San Pietro dei Monti" (San Pietro dei Monti Dolomite, Anisian-Ladinian). Lorenz (1968) ascribes the beginning of the transgression in this area to the "période de transition Stampien-Aquitanien". In particular, Lorenz (1964) reports the presence of *Miogypsinoides complanata* in the Valzemola area. This species, according to Drooger & Laagland (1986), is restricted to the Upper Chattian.

Aboveall, the finds of *Eulepidina dilatata* and of *Miogypsina* sp. respectively in the high-middle part (Molare Formation) and at the top (Rocchetta Formation) of a succession only hundreds of metres away from that studied here must be remembered;

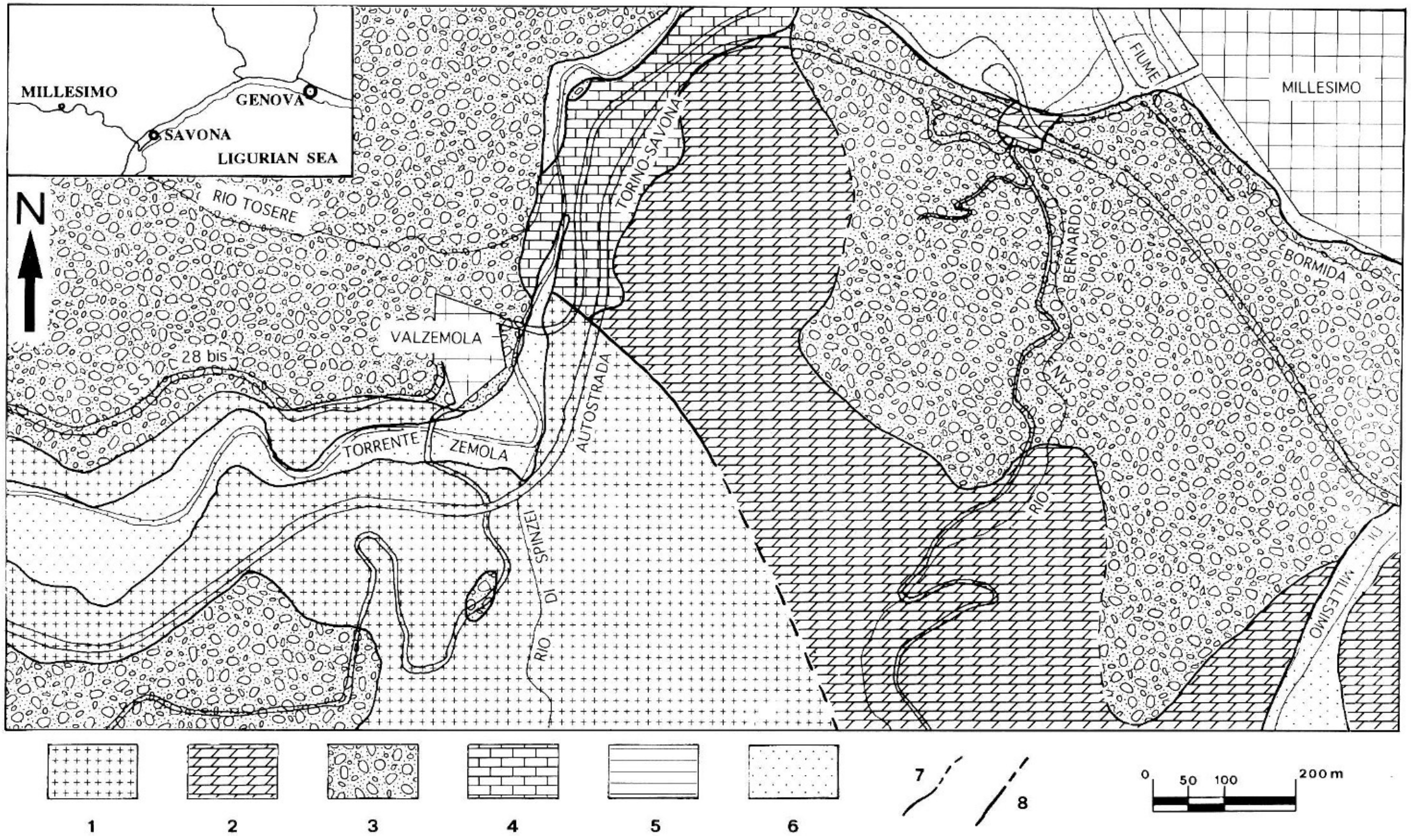
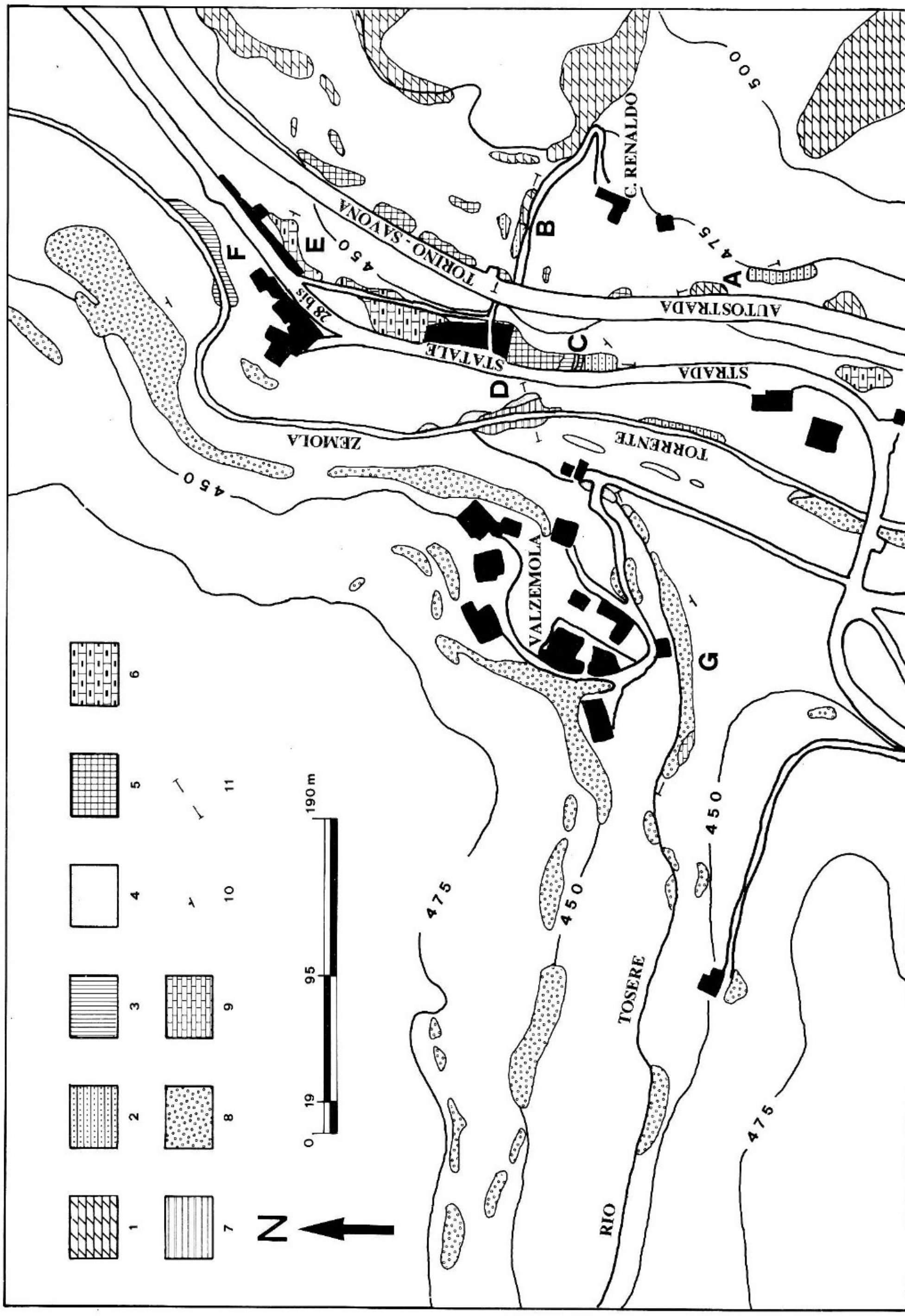


Fig. 1 - Geological sketch map of the investigated area and its geographical location. 1) Gneiss (Migmatiti di Nucetto, Upper Pre-Carboniferous); 2) dolomite and dolomitic limestones (Dolomia di San Pietro dei Monti, Anisian-Ladinian); 3) sandstones and conglomerates (Formazione di Molare, Chattian-Aquitanian?); 4) reefal facies (Formazione di Molare, Chattian), 5) hemipelagic pelites and turbidites, very thinly bedded (Formazione di Rocchetta, Upper Oligocene?-Lower Miocene); 6) recent alluvial deposits; 7) stratigraphic contacts and their probable continuation; 8) faults and their probable continuation.


C. RENALDO
AUTOSTRADA
TORINO - SAVONA
STRADA
STATALE
28 bis
TORRENTE
ZEMOLA
VALZEMOLA
RIO
TOSERE
A
B
C
D
E
F
G
500
475
450
1
2
3
4
5
6
7
8
9
10
11
0
19
95
190 m
N

this succession was referred to the Chattian passing to the Aquitanian with the first appearance of *Miogypsina* (Vannucci et al., 1993).

The succession distinguished by Lorenz (1964, 1968) as "calcaire de Valzemola" forms part of the basal portion of the Molare Formation (Upper Rupelian-Chattian), which is characterized by a great variety of facies which are laterally equivalent (Lorenz, 1968; Giammarino, 1984; Fravega et al., 1987; Fravega et al., 1988; Piazza, 1989). These diverse facies represent the various ways in which the Oligocene transgressive event was developed on the margins of the Ligurian Alps. The dominant facies is terrigenous and consists of conglomerate and arenaceous deposits; laterally equivalent to these are found biohermal bodies (similar to those of Valzemola), alluvial fans and beach deposits, etc. All of these facies, being laterally equivalent, pass upwards to a succession first of arenaceous-sands and then to silty-marl; the latter also are included in the Molare Formation. Overall, therefore, the Molare Formation is a fining upwards succession prevalently of terrigenous clastic sediments, followed by the Rocchetta Formation (Upper Oligocene-Lower Miocene), consisting of silty marls or argillaceous deposits of an epipelagic environment.

The material examined allowed a precise study of the algal associations, both of their morphostructural and taxonomic aspects. It is of note that the generic name *Archaeolithothamnium* is written within quotation marks because of its uncertain taxonomic position (see Woelkerling, 1988).

The corals from the Valzemola reef are generally strongly recrystallized, thus a precise taxonomic study is often impossible; therefore we have concentrated our attention on the study of the growth morphology of various individuals, which have been distinguished using the scheme outlined by James (1983, 1984).

Depositional, petrographical, paleontological, and paleoecological characters have allowed a paleoenvironmental reconstruction of this area of the T. P. B.

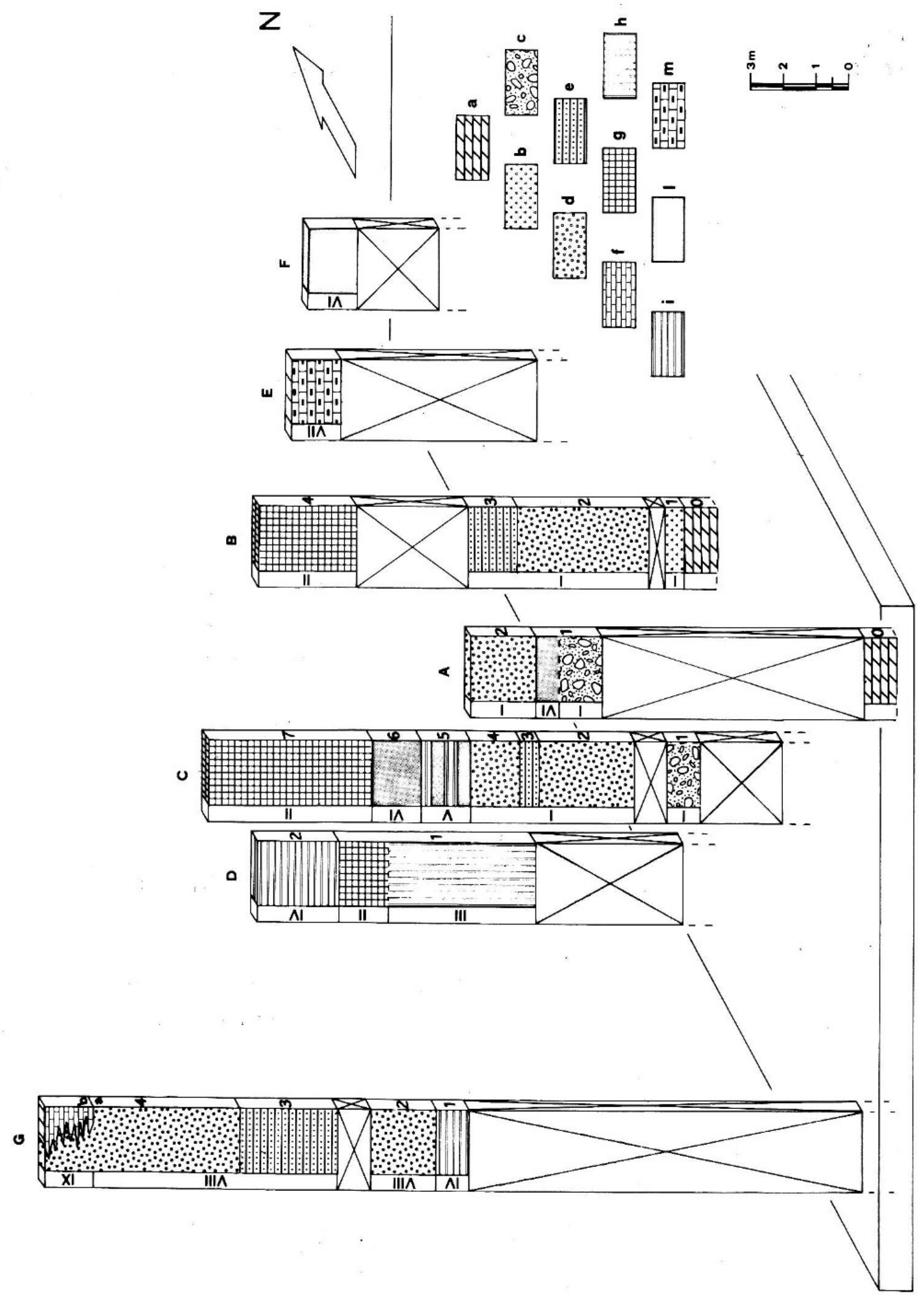
Description of sections.

All the sections described form part of the basal part of the Molare Formation.

Section A.

This section is situated about 70 m WSW of Casa Renaldo, starting from the Autostrada (Highway) Torino-Savona, at an altitude of between 460 and 475 m a.s.l. (Fig. 3; Tab. 1).

Fig. 2 - Facies map of Valzemola area. 1) Dolomite and dolomitic limestones; 2) sandstones and conglomerates with corals and/or coralline algae (Facies I); 3) floatstone (Facies VI and V pro parte); 4) bindstone (Facies IV and V pro parte); 5) framestone (Facies II); 6) rudstone (Facies VII); 7) bafflestone (Facies III); 8) regressive sandstones and conglomerates (Facies VIII); 9) limestones of intertidal or supratidal environment (Facies IX); 10) dipping between 18 and 20°; 11) location of stratigraphic sections.



Petrographic characters	type of clasts									sorting			roundness					interstitial	
Rock types and their occurrence (section / level)	d/dl	qzt	gn	phy	ccp	cfm	qz	wm	fld	w	m	p	va	a	sa	sr	r	sm	sc
fine conglomerate and coarse sandstone (A/2)	X	X	X	X								X				X		X	
coarse and medium conglomerate (A/1)	X	X	X	X								X			X	X		X	
fine sandstone (B/3)	X	X	X	X	X		X			X				X					X
fine conglomerate (B/2)	X	X					X				X					X		X	
breccia (B/1)	X					X						X	X					X	
medium conglomerate and coarse sandstone (C/4)	X	X					X	X	X			X		X	X	X			X
medium sandstone (C/3)	X	X					X	X	X			X		X					X
medium and fine conglomerate (C/2)	X	X	X	X			X					X					X	X	
coarse and medium conglomerate (C/1)	X	X	X	X			X					X					X	X	
fine and medium conglomerate (G/4a)	X											X					X		X
very coarse sandstone (G/3)	X	X					X				X						X	X	
fine conglomerate (G/2)	X	X					X				X						X	X	

Tab. 1 - Petrographic characters of the clastic rocks of the Valzemola area: d/dl) Dolomite and dolomitic limestone; qzt) quartzite; gn) gneiss; phy) phyllites; ccp) clay chips; cfm) coral fragments; qz) quartz; wm) white micas; fld) feldspars; w) well-sorted; m) moderatly sorted; p) poorly sorted; va) vary angular; a) angular; sa) sub-angular; sr) sub-rounded; r) rounded; sm) sand or sandstone matrix; sc) sparitic or microsparitic cement.

Top to bottom:

2) fine conglomerate grading upwards to coarse sandstone (total thickness: 2 m). Coral colonies are present; the morphologies represented are mainly domal or tabular and rarely robust branching (always found fragmented), or plate-like. Some colonies, belonging mostly to the latter morphology, are in living position; among which *Antiguastrea lucasiana* (De France, 1826) is present;

1) coarse to medium conglomerate grading upwards to coral floatstone (total thickness: 2 m). The conglomerate is poorly cemented and normally graded (clasts up to 50 cm in diameter at the bottom and up to 2 cm in diameter at the top). The pebbles sometimes show lithodomous borings. The floatstone is made of coral fragments, mostly of robust branching type (diameter between 2 and 4 cm), and with a wackestone matrix with bioclasts of coralline algae, bryozoans, echinoid spines and plates, bivalve fragments, and benthic foraminifera (miliolids, nodosariids, and small rotaliids).
The coralline algae content includes crustose or crustose-intumescent thalli, growing on coral fragments. The following species are identified:
Lithophyllum lemoinei Krivannè-Hutter, 1962
Lithoporella melobesioides (Foslie) Foslie, 1909
Lithothamnion cf. *crispithallus* Johnson, 1957
Mesophyllum vaughanii (Howe) Lemoine, 1928

Fig. 3 - Columnar sections of Valzemola area (locations according to Fig. 2) and their divisions according to facies. On the left side of each column the facies assigned to each level is indicated: I) conglomerate and sandstone transgressive facies; II) coral framestone facies; III) coral bafflestone facies; IV) coral bindstone facies; V) coral bindstone and floatstone facies; VI) coral and algal floatstone facies; VII) coral rudstone; VIII) conglomerate and sandstone regressive facies; IX) intertidal-supratidal limestone facies. On the right side the lithostratigraphic sequence is sketched: a) dolomite and dolomitic limestones; b) dolomite, dolomitic limestones and reef limestones breccia; c) very coarse to medium conglomerates; d) fine conglomerates and coarse sandstones; e) medium and fine sandstones; f) intertidal or supratidal limestones; g) framestone; h) bafflestone; i) bindstone; l) floatstone; m) rudstone.

"Archaeolithothamnium" oulianovii Pfender, 1926.
Several coral colonies are present in the conglomerates, some of them in living position. They have domal or tabular morphology, with dimensions up to 40 cm and often so highly recrystallized, that it has only been possible to identify *Favia subdenticulata* (Catullo, 1856), *Hexastrea* sp., and *Montastrea inaequalis* (Gümbel, 1861);

- poorly exposed (8 m);

0) Dolomia di San Pietro dei Monti: intraformational breccia with dark dolomite clasts of highly variable size (up to 20 cm) and a calcareous-dolomitic matrix.

Section B.

This section (Fig. 3; Tab. 1) is developed from the south towards the NW, about 50 m to the NNW of Casa Renaldo, at an altitude between 465 e 460 m a.s.l. until the boundary with the Autostrada Torino-Savona, along the latter the top level (4) is developed horizontally for about 100 m. Total thickness about 13 m, dip 30° NW.

Top to bottom:

4) strongly recrystallized pinky-white framestone (3 m) with interbedding of thin and discontinuous packstone layers. The framestone is made of coral colonies which are mostly large in size, prevalently encrusting and with subordinate domal morphology. Their width is between 15 and 80 cm. They are in living position and may be seen to have grown one above the other. Although they are badly preserved, it is possible to observe the prevalence of the genus *Antiguastrea* in the lower part of the sequence and subsequently its coexistence with the genera *Montastrea* and *Favia* (especially *Favia* cf. *subdenticulata*).
The fossil content includes bryozoans, coral and bivalve fragments, echinoid plates and spines, benthic foraminifera (among which are *Amphistegina* sp.), and small and badly preserved fragments of coralline algae (among which are rare intergenicula and crustose thalli of *Lithophyllum mengaudii* Lemoine, 1934);

- poorly exposed (3.4 m);

3) fine sandstone (1.5 m) with coralline algae, serpulids, bryozoans, corals, bivalve fragments, echinoid spines and plates, foraminifera (*Amphistegina* sp., *Operculina* sp., *Planorbulina* sp., *Sphaerogypsina* sp., nodosariids, small rotaliids, and textulariids), and rare ostracods. The coral colonies have chiefly plate-like and tabular morphology; less frequent is domal morphology, among which *Favia* sp. has been identified.
The coralline algae thalli grow on the sediment with crustose-laminar to crustose-intumescent morphologies; crustose growth morphology on coral fragments is rarer. Branching morphology and geniculate coralline fragments are of subordinate importance. The following species have been identified:
Lithophyllum lemoinei Krivannè-Hutter, 1962
Lithophyllum mengaudii Lemoine, 1934
Lithophyllum cf. *ligusticum* Airoldi, 1932
Lithoporella melobesioides (Foslie) Foslie, 1909
Lithothamnion ishigakiense Johnson, 1964b
Lithothamnion moretii Lemoine, 1927
Mesophyllum ingestum Conti, 1945
Jania nummulitica Lemoine, 1927.
The species *Lithothamnion ishigakiense* dominates the association;

2) fine conglomerate (4 m) slightly normally graded (grains generally measure between 2 and 5 mm in diameter). Abundant corals, rare bryozoans, and small rotaliids form the fossil content. The coral colonies (Fig. 4) have prevalent plate-like and tabular morphology and are up to 30 cm in width. Domal morphology is less frequent, being more common in the upper part of the level, that may reach, exceptionally, 40 cm in height. Some specimens are reworked and fragmented, others are in living position;
poorly exposed (0.5 m);

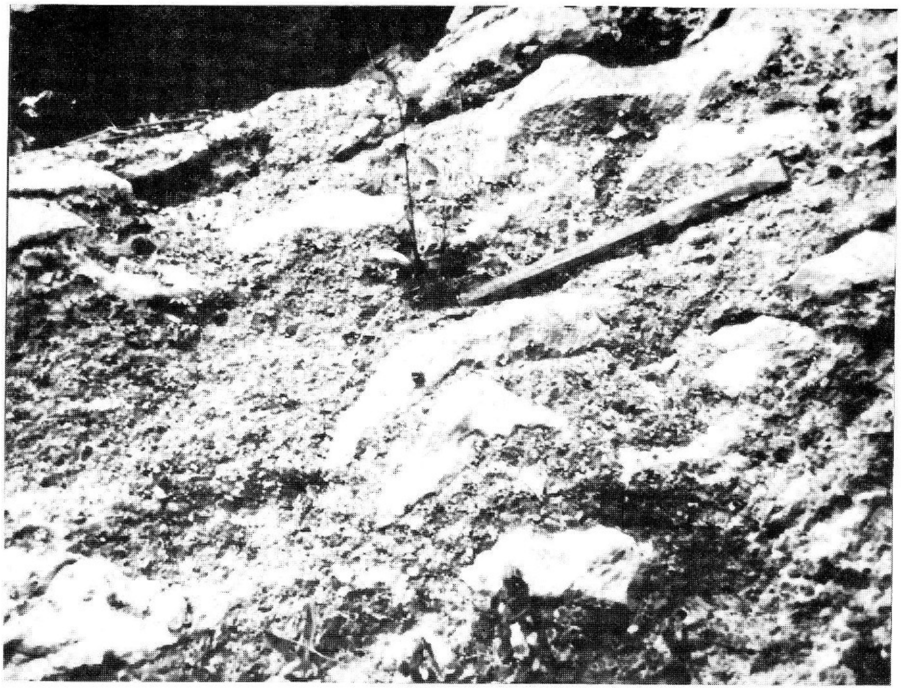


Fig. 4 - Laminar coral colonies in living position. Section B, level 2.

1) heterometric breccia (0.6 m) with very rare bivalve fragments and clasts with the major axis being as much as 10 cm;
0) Dolomia di San Pietro dei Monti: grey black dolomite and dolomitic limestones, strongly fractured.

Section C.

The section stretches, approximately, from south to north between the Strada Statale (State Road) 28 bis and the Autostrada Torino-Savona, ending at the side of a house at 438 m a.s.l. Total thickness about 15 m, dip 18° NW (Fig. 3; Tab. 1).

Top to bottom:

7) strongly recrystallized pinky-white framestone (5 m). The morphology of coral colonies varies from bottom to top: plate-like and tabular types dominate at the bottom, while encrusting and hemispherical types prevail on top. Sometimes there is interbedding of discontinuous layers of whitish packstone (a few cm thick). The very rich fossil content is strongly fragmented and includes coralline algae, bryozoans, bivalves, echinoid plates and spines, benthic foraminifera (*Heterostegina*, victoriellids, miliolids, and rotaliids). The algal content includes several small fragments of crustose or crustose-laminar thalli of coralline algae, mostly with coaxial hypothallus, and abundant intergenicula of articulate coralline. Because of the bad preservation of the thalli it has been possible to identify only the following species:
Lithophyllum intumescens Mastrorilli, 1968
Lithophyllum lemoinei Krivannè-Hutter, 1962;
6) floatstone (1.5 m) with small coral fragments. The abundant and fragmented fossil content includes coralline algae, corals, bryozoans, bivalves, echinoid plates and spines, benthic foraminifera (*Operculina*, lepidocyclinids, textulariids, victoriellids, miliolids, and small rotaliids). The algal content very often

includes fragmented specimens grown around coral fragments (Fig. 5), echinoid plates, and larger clasts. The nongeniculate coralline algae morphology varies from crustose-laminar to crustose; intergenicula of geniculate coralline algae are also present. The following species are identified:
Lithoporella melobesioides (Foslie) Foslie, 1909
Spongites albanensis (Lemoine) Braga, Bosence & Steneck, 1993
Mesophyllum vaughanii (Howe) Lemoine, 1928;

5) bindstone (1.5 m) made of corals with plate-like morphology, with a thickness of around 2-3 cm and diameters of usually between 20 and 30 cm. Grey coral floatstones (coral pebbles measure between 3 and 5 cm in diameter) with wackestone to packstone matrix are interbedded with the bindstone. The very abundant fossil content includes coralline algae, bryozoans, bivalves, echinoid plates and spines, benthic foraminifera (alveolinids and rotaliids). The rich coralline algae association is composed of several thalli encrusting coral fragments and having a crustose or crustose-intumescent morphology with small mamelons; crustose-laminar thalli are also present. The following species have been identified:
Lithophyllum intumescens Mastrorilli, 1968
Lithophyllum lemoinei Krivannè-Hutter, 1962
Lithoporella melobesioides (Foslie) Foslie, 1909
Lithothamnion moretii Lemoine, 1927
Mesophyllum vaughanii (Howe) Lemoine, 1928
"*Archaeolithothamnium*" *statiellense* Airoldi, 1932
"*Archaeolithothamnium*" *varium* Mastrorilli, 1958
"*Archaeolithothamnium*" cf. *statiellense* Airoldi, 1932
"*Archaeolithothamnium*" (among which "*Archaeolithothamnium*" *varium*, Pl. 3, fig. a) and *Lithoporella melobesioides* thalli are always well-developed;

4) medium conglomerate grading upward to very coarse sandstone (1.5 m). Coral colonies are common, some of them reworked, others in living position. They have a prevalent laminar morphology, both of tabular and plate-like types; the dimensions reach a diameter of 40 cm at the bottom level and 20 cm at the top. The poor fossil content includes coralline algae, bryozoans, bivalve fragments, echinoid plates and spines, and rare benthic foraminifera (*Operculina* and miliolids). Small and rare nodules made of crustose or crustose-laminar thalli of *Lithothamnion ishigakiense* Johnson, 1964b, form the algal content;

3) yellowish medium sandstone (0.6 m). The fossil content includes coralline algae, bryozoans, coral and bivalve fragments, echinoid plates and spines, benthic foraminifera (*Amphistegina* sp., *Trifarina* sp.,

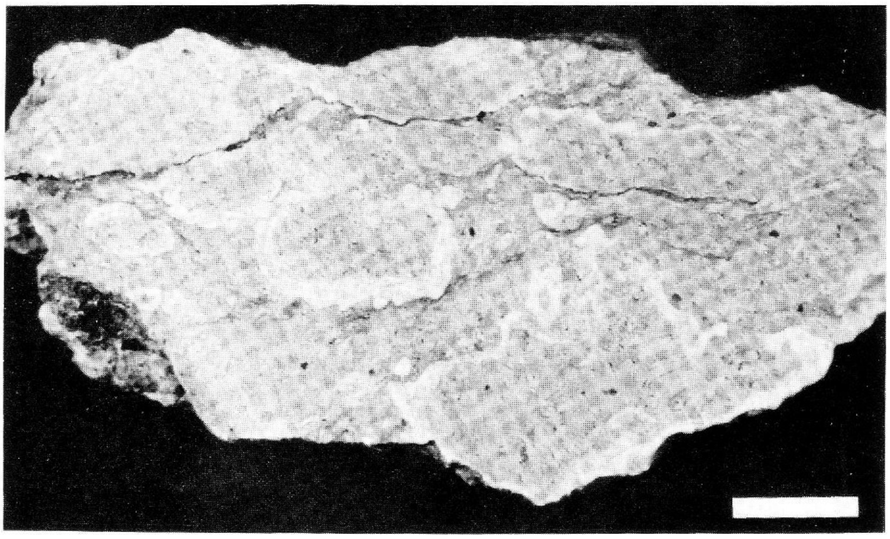


Fig. 5 - Coralline algae encrusting coral fragments (polished slab). Section C, level 6. Scale bar = 1 cm.

nodosariids, small rotaliids, and textulariids), and rare ostracods.

Crustose-laminar to crustose-intumescent thalli of coralline algae encrust the sediment; abundant geniculate coralline segments are also observed. The following species are present:

Lithophyllum intumescens Mastrorilli, 1968
Lithophyllum lemoinei Krivannè-Hutter, 1962
Spongites albanensis (Lemoine) Braga, Bosence & Steneck, 1993
Mesophyllum ingestum Conti, 1945
Mesophyllum obsitum Airoldi, 1932
Jania nummulitica Lemoine, 1927
Jania sp. 1 Mastrorilli, 1968
Corallina cossmannii Lemoine, 1917.

The geniculate coralline algae are very common, among which the genus *Jania* is the most abundant;

2) medium to fine conglomerate (3 m), in layers about 50 cm thick, slightly normally graded, and with load pockets at the lower joints. The fossil fraction consists of rare corals, some of which are in living position. Tabular morphology is the most common, but occasionally also domal and hemispherical specimens occur, especially at the top of the level;

\- poorly exposed (1 m);

1) coarse to medium matrix-supported conglomerate (1 m), slightly normally graded, with small and rare fragments of coral colonies.

Section D.

It is the only sequence (Fig. 3) which is formed entirely of reefal facies. It outcrops in the riverbed of Torrente (River) Zemola, in the section between the dam and the confluence with Rio (Stream) Tosere, between 430 and 435 m a.s.l.

Top to bottom:

2) coral bindstone (2.5 m) with tabular and encrusting coral colonies, with interbedded packstones with a fossil content that includes rare and small remains of nongeniculate coralline algae, bryozoans, coral and bivalve fragments, echinoid plates and spines, benthic foraminifera (*Amphistegina* sp., milioliids, rotaliids, and textulariids), and rare ostracods;

1) coral bafflestone infilled by grey-whitish wackestone and grading upwards to coral framestone (total thickness: 6 m). The bafflestone coral colonies have the following morphologies: a) robust branching: straight fan-shaped stems between 70 and 110 cm long and with an average diameter of 1.5 cm (Fig. 6), mostly identified as *Actinacis rollei* Reuss, 1864 and are very frequent at the bottom of the level; b) columnar (organ-pipe type): straight, parallel stems between 30 and 60 cm long and with a diameter of about 5 cm (Fig. 7), mostly identified as *Actinacis rollei* and are very common at the bottom of the level; c) hemispherical: diameter usually between 30 and 40 cm, exceptionally up to 50 cm (Fig. 6); the larger specimens may be ascribed to *Montastrea* sp. and are found at the bottom of the level; d) domal: diameters less than 30 cm and generally identified as *Antiguastrea lucasiana*. The coral framestone is made of massive colonies almost exclusively of domal type, generally identifiable as *Antiguastrea lucasiana*; hemispherical colonies are still present but their dimensions are smaller while the branching shapes are represented only by rare and small specimens (about 30 cm high) of columnar (organ-pipe type) morphology.

Calcareous red algae, bryozoans, coral fragments, bivalve fragments, echinoid plates and spines, foraminifera (nodosariids and small rotaliids), and rare ostracods are also present.

The algae are represented by very rare crustose-intumescent thalli encrusting the sediment or the coral fragments; the following species are identified:

Spongites albanensis (Lemoine) Braga, Bosence & Steneck, 1993
Peyssonnelia antiqua Johnson, 1964a.

Small lenses of coarse to very coarse grain-supported sandstones can also be seen, especially in the lower part of the level. The fossil content of these lenses includes bryozoans, coral and bivalve fragments, echinoid plates and spines, benthic foraminifera (*Pararotalia* sp., rare alveolinids, nodosariids, and small

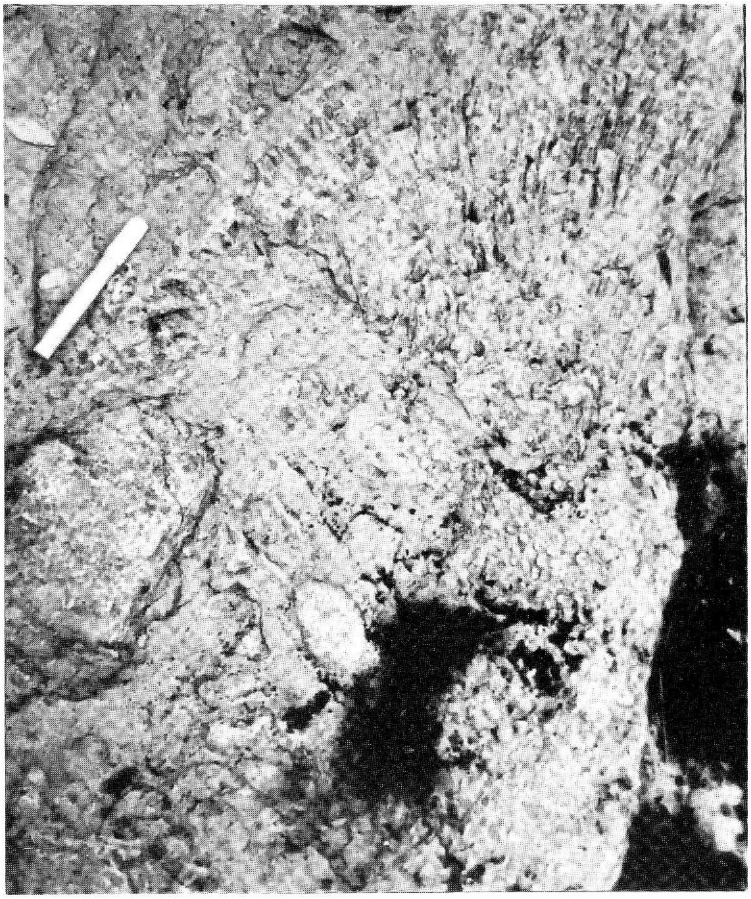


Fig. 6 - Large robust branching colony of *Actinacis rollei* Reuss and hemispherical colony of *Montastrea* sp. Section D, level 1.

rotaliids), and rare ostracods. Thin crustose thalli of coralline algae have overgrown small coral fragments; several shreds of thalli are also visible. The following species are present:
Lithophyllum lemoinei Krivannè-Hutter, 1962
Lithoporella melobesioides (Foslie) Foslie, 1909
Mesophyllum vaughanii (Howe) Lemoine, 1928
"*Archaeolithothamnium*" *varium* Mastrorilli, 1958.

Section E.

It stretches between the Strada Statale 28 bis and the Autostrada Torino-Savona, NNE of the house located at 438 m a.s.l. (Fig. 3).

The section consists of poorly bedded coral rudstone (1.5 m thick, dip 20° NW) with a wackestone matrix and very angular and highly recrystallized clasts (diameters between 5 and 30 cm) coming from massive or tabular coral colonies; some of which may be ascribed to *Stylocoenia* and *Hexastrea*. Bivalves, among which are oysters and pectinids, bioclasts, and very rare and scattered angular siliciclasts are also

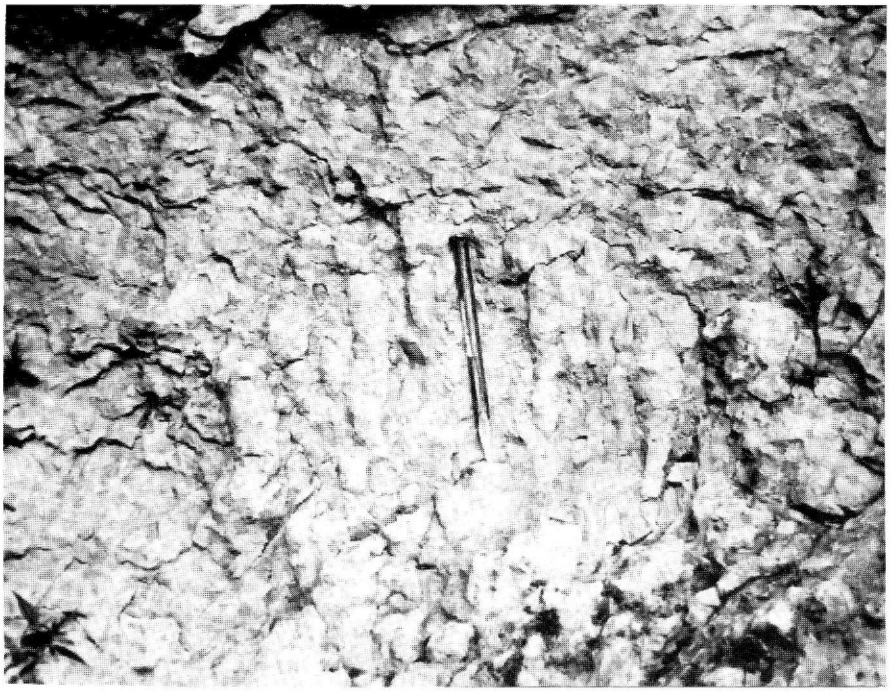


Fig. 7 - Columnar (organ-pipe type) colony of *Actinacis rollei* Reuss. Section D, level 1.

present. Coralline algae, serpulids, bryozoans, corals, bivalve fragments, echinoid plates and spines, foraminifera (*Amphistegina* sp., *Pararotalia* sp., and also nodosariids, small rotaliids, victoriellids, and rare globigerinids), and ostracods form the bioclastic content.

The coralline algae are represented by few thalli, generally crustose or crustose-intumescent, belonging to:

Lithophyllum lemoinei Krivannè-Hutter, 1962
Mesophyllum vaughanii (Howe) Lemoine, 1928
"*Archaeolithothamnium*" *oulianovii* Pfender, 1926.

Section F.

It may be seen in the Torrente Zemola riverbed (Fig. 3).

The section consists of a rhodolithic floatstone with a packstone matrix (1.5 m). The rhodoliths (Fig. 8) are spheroidal (diameter generally between 1 and 3 cm) or elliptical (with the major axis generally of 3 to 8 cm). The nucleus is formed of a coral fragment of the robust branching type and growth is prevalently laminar. Rare colonies of the hemispherical type (identified as *Montastrea*) and bivalves (pectinids) are also present. The packstone shows very rare angular siliciclasts and an abundant fossil content, that includes corals, bivalves, gastropods, serpulids, bryozoans, echinoid plates and spines, foraminifera (*Amphistegina* sp. is very common; *Eulepidina* sp., *Heterostegina* sp., *Operculina* sp., *Pararotalia* sp., *Pyrgo* sp., lepidocyclinids, miliolids, nodosariids, small rotaliids, victoriellids are common; globigerinids are rare), and coralline algae which encrust the sediment forming thin discontinuous laminar structures.

The algal flora found in the rhodoliths and those of the thin laminae on the sediment consist of the same species and generally are crustose or crustose-intumescent. The following species have been recognized:

Lithophyllum intumescens Mastrorilli, 1968

Fig. 8 - Floatstone with robust branching coral fragments encrusted by coralline algae. Section F.

Lithophyllum lemoinei Krivannè-Hutter, 1962
Lithophyllum cf. *ligusticum* Airoldi, 1932
Lithophyllum cf. *quadrangulum* Lemoine, 1934
Lithoporella melobesioides (Foslie) Foslie, 1909
Spongites albanensis (Lemoine) Braga, Bosence & Steneck, 1993
Lithothamnion ishigakiense Johnson, 1964b
Lithothamnion moretii Lemoine, 1927
Mesophyllum vaughanii (Howe) Lemoine, 1928
"*Archaeolithothamnium*" *oulianovii* Pfender, 1926.

Well-developed thalli of *Lithothamnion moretii* and *Lt. ishigakiense* (it is of note that a sexed specimen of the latter species has been found) dominate the association, but *Lithoporella melobesioides* is also very common.

Section G.

The section (Fig. 3; Tab. 1) crops out in the Rio Tosere riverbed from the small bridge of the road leading to Bric Lodola up to 440 m a.s.l. Total thickness about 14 m, dip 20° NW.

Top to bottom:

4) this level consists of two distinct lithotypes (4a e 4b) with clear heteropic relationships: a terrigenous clastic deposit (4a) is laterally replaced by carbonate sediments (4b);

4a) fine to medium, grain supported, strongly cemented conglomerate (maximum thickness 6 m); the fossil content includes only rare textulariids. In the lower part of this level, centimetric to decimetric sandy horizons are interbedded, in which fossils are not present;

4b) whitish to brown, very porous, and massive limestones (maximum thickness: 1.5 m), with very angular dark dolomite clasts (up to 6 cm) at the bottom. Four different types of structures can be identified: a) undulated-zoned structures (Pl. 1, fig. a) generally developing horizontally, made of alternating light and dark millimetric bands; b) prevalent vertical structures with centimetric dimensions, irregularly shaped and frequently branched (Pl. 1, fig. b); their color is generally brown, and sometimes they show a pseudocylindrical internal pocket; c) pisoids: white, spheroidal or ellipsoidal structures, with diameter or major axis up to 1 cm; d) veins infilled by clear calcite. Fossils are represented by massive and heavily recrystallized reworked coral colonies, and by rare gastropods;

3) very coarse sandstone (3 m) with rare centimetric pebbles and rare benthic foraminifera;

\- poorly exposed (1 m);

2) fine conglomerate (2 m) with coral fragments and rare miliolids;

1) coral bindstone (1 m) made of tabular colonies in a very fossiliferous packstone which includes worm tubes, bryozoans, small coral fragments, bivalve fragments, echinoid plates and spines, benthic foraminifera (*Amphistegina* sp., *Eulepidina* sp., *Operculina* sp., *Pararotalia* sp., and also miliolids and textulariids), and ostracods.

Biostratigraphy.

Foraminiferal associations which may be useful for a detailed biostratigraphy are quite rare and, when present, they are badly preserved (plankton) or contained (lepidocyclinids) in massive rocks which do not allow the necessary equatorial sections to be obtained. It was only possible to show: 1) the presence of lepidocyclinids, on which however, it was not possible to carry out a detailed study; 2) the absence of *Nummulites* and of *Miogypsina*.

On the basis of these scarse data, of the presence of *Miogypsinoides complanata* and *Eulepidina dilatata* mentioned previously and of the geological-stratigraphical setting of the area, it seems reasonable to attribute the studied succession to the Chattian, probably the Upper Chattian.

Facies description.

Nine different facies (two terrigenous and seven carbonate) occurring in one or more sections (Fig. 2; Fig. 3) have been recognized.

Facies I. Fossiliferous conglomerate and sandstone, with corals and/or coralline algae (section A level 1, excluding the top, and level 2; section B levels 1-3; section C levels 1-4). These terrigenous sediments, usually about ten meters thick, rest unconformably on the bedrock and underlie the carbonate reef facies. The corals (often in living position) have domal, hemispherical, tabular, robust branching and plate-like morphologies; the following genera have been recognised: *Antiguastrea*, *Favia*, and *Montastrea*. The algal association is dominated by *Lithothamnion* (even if the algal content of various levels referable to this facies are nonhomogeneous, this may be due to local variation in environment), the dominant morphology is crustose, subordinate morphology is crustose-laminar and crustose-intumescent. Furthermore accumulations of geniculate coralline algae are present. The presence of *Amphistegina* and *Operculina* among the larger foraminifera was also noted.

Facies II. Coral framestone with rare and thin fossiliferous packstone layers (section B level 4; section C level 7; section D top of level 1). Encrusting and hemispherical type colonies are prevalent with plate-like and tabular colonies being subordinate. It is possible to note a prevalence of *Antiguastrea* in the bottom part of the levels, followed by its coexistence with *Montastrea* (Fig. 6) and *Favia*, especially *Favia* cf. *subdenticulata*. The algal association is dominated by *Lithophyllum*, crustose and crustose-laminar morphologies are prevalent; furthermore geniculate coralline algae are abundant but indeterminate. The larger foraminifera are represented by *Amphistegina* and *Heterostegina*.

Facies III. Coral bafflestone with *Actinacis rollei* (Fig. 6; Fig. 7), wackestone matrix, and rare lenses of coarse sandstone (section D lower and medium part of level 1). The corals are in living positions and the prevalent morphologies are robust branching and columnar (organ-pipe type), the subordinate morphologies are hemispherical (*Montastrea*) and domal (*Antiguastrea lucasiana*). The algal association is characterized by a reduced number of individuals and increased differentiation. Therefore it is not possible to distinguish a clearly dominant genus; however it is possible to note a moderate prevalence of the genera that in warm water show a preference for sciaphilic ("*Archaeolithothamnium*") or deeper (*Mesophyllum*) conditions. The growth morphologies are essentially of the crustose-intumescent type. The alveolinids are the only larger foraminifera present.

Facies IV. Coral bindstone with tabular and encrusting corals in living position and a packstone matrix (section D level 2, section G level 1). This facies is completely lacking in algal flora, numerous larger foraminifera are however present and which are referable to the genera *Amphistegina*, *Operculina*, and *Eulepidina*.

Facies V. Coral bindstone and floatstone with plate-like corals and packstone or wackestone matrix (section C level 5). The coralline algae are well differentiated and the association is dominated by "*Archaeolithothamnium*", the large abundance of *Lithoporella* must also be noted; the dominant morphology types are crustose and crustose-intumescent. Rare alveolinids are also present.

Facies VI. Coral and algal floatstone with rhodoliths and wackestone or packstone matrix (section A level 1 uppermost part, section C level 6, section F). Coral fragments are mostly of robust branching type, encrusted by coralline algae and within a fine matrix. The coralline algae association is dominated by *Lithothamnion*, the genera *Lithoporella* e *Lithophyllum* are subordinate but however very abundant; crustose type morphology is distinctly prevalent, crustose-intumescent and crustose-laminar morphologies are subordinate. The larger foraminifera are rather abundant and diversified, the genera *Amphistegina* (very common), *Operculina*, *Heterostegina*, *Eulepidina* are present.

Facies VII. Coral rudstone with massive coral fragments and wackestone matrix (section E). The algal association is poor and shows a prevalence of the genera that in warm water prefer sciaphilic ("*Archaeolithothamnium*") or deep (*Mesophyllum*) conditions; crustose and crustose-intumescent type morphologies are dominant. The larger foraminifera are represented only by the genus *Amphistegina*.

Facies VIII. Very poorly fossiliferous conglomerate and sandstone without corals and coralline algae (section G levels 2-4a).

Facies IX. Massive limestone with undulated-zoned fabric, vertical structures, veins filled by clear calcite, and pisoids (section G level 4b). The zoned-undulated fabric is prevalently horizontally developed and consists of alternating light and dark undulating millimetric laminae. The microscopic analysis revealed that this structure consists of columnar calcite crystals which are developed perpendicularly to the laminae; each single crystal often traverses two or more laminae. The prevalent vertical structures are made of radial aggregates of columnar sparry calcite sometimes enveloped by micritic rings.

Paleoecological remarks on the faunal association.

The faunal association consists of sedentary anellids, bryozoans, corals, echinoids (small fragments), bivalves (pectinids and rare oysters), and benthic foraminifera.

The most important point to note in this faunal association is the presence of reef building corals. As is well known, these organisms are found today in clear tropical and subtropical waters, with optimum conditions at depths down to 20 m below sea level (Geister, 1979).

The larger foraminifera association is poor and difficult to determine, therefore it is not possible to carry out a detailed analysis. However, some considerations are possible and appropriate. The three genera most diffuse, ordered according to decreasing values of abundance, are: *Amphistegina*, *Operculina*, and *Heterostegina*; with these are associated sporadically the lepidocyclinids (among which is *Eulepidina*) or the alveolinids.

On the whole these taxa indicate normal marine salt water conditions with tropical or subtropical temperatures (20°-26° C) (Chaproniere, 1975; Murray, 1991). These indications fully agree with those limits imposed by the presence of a reef. Subsequent and more detailed paleoecological considerations on the faunal association will be given below, during the discussion of the facies.

Paleoecological remarks on the algal association.

The calcareous red algae association is present both in the carbonate sequence (section A top of level 1, section B level 4, section C level 5-6-7, section D level 1, section E, section F), and in the terrigenous one (section B level 3, section C levels 3-4) which generally preceeds the former (Tab. 2).

There is often a better diffusion of coralline algae in the terrigenous facies, which is conglomeratic-arenaceous (Facies I). The algal associations of the various carbonate facies are either well differentiated both qualitatively and quantitatively (e.g.: section C level 5, Facies V; section F, Facies VI), or with low differentiation or represented only by indeterminable fragments (e.g.: Facies IV).

Sections	A	B		C					D	E	F	Total
Species / Levels	t 1	3	4	3	4	5	6	7	lm 1			
Lp. cf. *ligusticum*		▪									ı	▬
Lp. mengaudii		▬	▪									▬
Lp. cf. *quadrangulum*											ı	ı
Lp. lemoinei	▬	▪		▪		▬		▪	▪	▪	▬	▬▬▬▬▬▬
Lp. intumescens				▬		▪		▪			ı	▬▬
Ltp. melobesioides	▬	▪				▬▬	▪		▪		▬▬	▬▬▬▬▬▬▬
S. albanensis				▬			ı		ı		ı	▬▬
Lt. moretii		▬▬				▪					▬▬	▬▬▬▬▬
Lt. cf. *crispithallus*	▬▬											▬▬
Lt. ishigakiense		▬▬▬			▬▬						▬▬	▬▬▬▬▬▬▬▬▬
Mp. vaughanii	ı					▬	▬		▬	▪	▪	▬▬▬▬▬
Mp. obsitum				ı								ı
Mp. ingestum		ı		▬								▬▬
"A." oulianovii	▪									▪	▪	▬▬
"A." statiellense						▪						▪
"A." cf. *statiellense*						▬						▬
"A." varium						▪			▪			▬
J. nummulitica		▬		▬								▬▬
J. sp.1 Mastrorilli				▬								▬
C. cossmannii				▪								▪
Psn. antiqua									▪			▪
Mostly as:	a	b/a	d	b	c	a	a	d	b/a	d	a/b	

Tab. 2 - Algal species distribution. The length of the line is proportional to the frequency. a) Encrusting on coral fragments; b) encrusting on sediment; c) nodules; d) fragments; t) uppermost part of the level; lm) lower and middle part of the level.

The Rhodophyceae association is formed almost exclusively of coralline algae (the Squamariaceae are occasionally represented by the species *Peyssonnelia antiqua*) and in particular of nongeniculate coralline algae which develop on the mobile bottom encrusting coral fragments (mainly "robust branching" types) or the sediment itself. Algal thalli directly encrusted on corals in living position have never been observed. The algal association (Fig. 9a, b; Tab. 2) is dominated by the genus *Lithothamnion*, but *Lithophyllum* is also common.

Only three species of *Lithothamnion*, represented by several well-developed crustose or crustose-intumescent thalli (29% of the total specimens), were found.

Five species (21% of the total specimens), mostly with crustose-laminar growth morphology, represent the genus *Lithophyllum*.

In order of decreasing abundance of specimens we encounter *Mesophyllum* (3 species present), *Lithoporella* (1 species), and *"Archaeolithothamnium"* (4 species); these three genera are on the basis of the number of specimens and their approximate equivalence quite significant in the association. The genus *Jania* is represented by 2 species and a reduced number of specimens (8% of the total specimens), therefore has a modest importance in the algal association. The genera *Spongites*, *Corallina*, and *Peyssonnelia* are extremely rare.

The association (Tab. 2) is clearly dominated by *Lithothamnion ishigakiense* (Pl. 2, fig. a), in fact a little less than 50% of the specimens collected are referred to the genus *Lithothamnion*. It is noteworthy that the thalli of this species are very well-

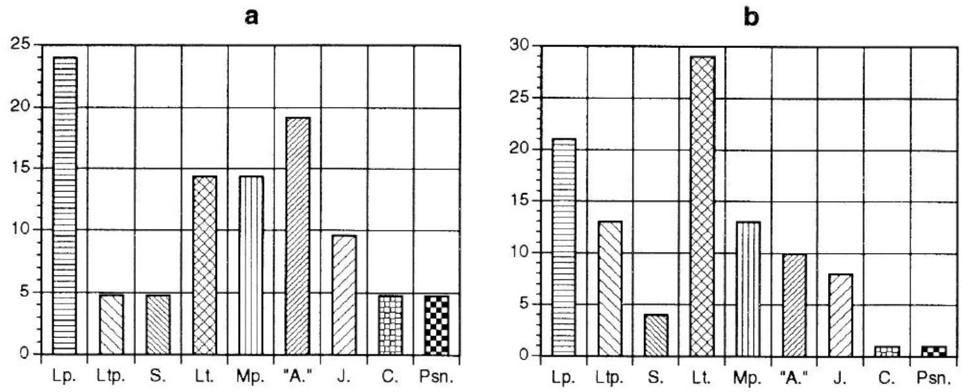


Fig. 9 - Composition of the algal association according to: a) percentage of species; b) percentage of specimens. Lp.) *Lithophyllum*, Ltp.) *Lithoporella*, S.) *Spongites*, Lt.) *Lithothamnion*, Mp.) *Mesophyllum*, "A.") "*Archaeolithothamnium*", J.) *Jania*, C.) *Corallina*, Psn.) *Peyssonnelia*.

developed and had grown on coral fragments as well as on the sandy sediment. In order of decreasing abundance of specimens follows the species *Lithoporella melobesioides* (Pl. 2, fig. b). Other co-dominant components of the association are *Lithophyllum lemoinei*, *Lithothamnion moretii* (Pl. 2, fig. b), and *Mesophyllum vaughanii* (Pl. 3, fig. b); they are represented by well-developed thalli. The species *Mp. vaughanii* represents about 70% of thalli referred to the genus *Mesophyllum* and it occurs exclusively in the calcareous horizons.

Lithophyllum intumescens, *Spongites albanensis*, *Lithothamnion* cf. *crispithallus*, and *Jania nummulitica* are accessory species while all the rest are occasionals.

On the basis of the composition of the algal association some general paleoecological considerations are possible, in particular we may observe that: the wide distribution of the genus *Lithoporella* suggests a generally warm tropical or subtropical climate (Lemoine, 1976; Wray, 1977); the strong distribution and the high diversity of *Lithophyllum* is a reflection of shallow waters, i.e.: Infralittoral Zone (Adey & Macintyre, 1973).

Further and more detailed paleoecological considerations on the algal association will be given later, during the discussion of the facies.

Facies discussion.

Facies I. The widespread presence of corals with tabular or plate-like morphologies allow a hypothesis of a mobile bottom conditions (Frost, 1981); the genera identified are characterized by a strong (*Favia* e *Montastrea*) or at least intermediate (*Antiguastrea*) sediment rejection potential and therefore a high rate of sedimentation may be presumed (Frost, 1981). The majority of the coral morphologies recognized and the prevalence of crustose type morphology among the coralline algae allow a hypothesis of low to moderate energy conditions (Frost, 1981; James, 1984; James & Macintyre, 1985; Poignant, 1976; Buchbinder, 1977; Minnery et al., 1985; Minnery, 1990). The sedimentological evidence (e.g.: lithodomous borings) suggests a depth referable to the shallower sector of the Infralittoral Zone; the dominance of *Lithothamnion* is characteristic of the shallow marine facies of the T.P.B. (Fravega et al., 1987; Fravega et al., 1988; Piazza, 1989) influenced by the strong influx of fresh water from the emerged land which locally alters the temperature, cooling the water and thus rendering it unfavourable for the genera typical of warm shallow water (i.e.: *Lithophyllum*).

Overall therefore we are dealing with a shallow facies (upper Infralittoral), strongly influenced by fluvial activity and a high rate of sedimentation, with a mobile bottom and a low to moderate water energy regimen. It to be considered as a colonization stage (according to James, 1984) in a dominantly terrigenous environment.

A hypothesis may be given for the repeated attempts of colonization by the corals which were suffocated from time to time by excessive influxes of sediment. The development of laminar corals, which are the first to stabilize themselves on the bottom, is probably favoured by the presence of nongeniculate coralline algae which harden the substrate (Fravega & Vannucci, 1987, with further references); subsequently the combined action of algae and laminar corals definitively stabilizes the substrate, thus making possible the development of massive and branching coral colonies.

The presence of geniculate coralline algae may be interpreted as a mechanical accumulation of flora from a more exposed sector.

Facies II. The variety of coral morphological growth types, among which the encrusting type form is prevalent, indicates a low rate of sedimentation with moderate to high energy conditions (James, 1984). The dominance of *Lithophyllum* and the abundance of geniculate coralline algae indicate conditions of limited depth and medium to high energy (Adey & Macintyre, 1973; Ghose, 1977; Minnery et al., 1985; Minnery, 1990). The coralline algae are almost exclusively of crustose or crustose-laminar morphology which indicates conditions of high energy and a depth within the first 45 m (Poignant, 1976; Buchbinder, 1977; Minnery et al., 1985; Minnery, 1990). The strong abundance of *Amphistegina* among the larger foraminifera indicates a depth probably not greater than 35 m and easily found between 5 and 20 m (Murray, 1973, 1991; Chaproniere, 1975).

Overall we are dealing with an environment with a low rate of sedimentation, medium to high energy, a depth within the first 20 m; comparing well with the diversification stage of James (1984) and placed in the inner reef front near to the reef crest, according to the scheme of James & Macintyre (1985).

Facies III. The presence of corals with ramose morphology indicates moderate energy and possible conditions of an increased rate of sedimentation (James, 1984), in fact branching morphologies are very resistant to high concentrations of sediment in suspension in as much as they offer to these a minimum surface of interception (Frost, 1981); crustose-intumescent is the prevalent morphological type among the coralline algae and this indicates moderate energy conditions (Poignant, 1976; Buchbinder, 1977; Minnery et al., 1985; Minnery, 1990). The coralline algae association is poor in number of specimens, well diversified (six genera), and dominated by "*Archaeolithotham-*

nium" & *Mesophyllum*. A similar composition may indicate a moderately deep environment very rich in microenvironments.

Overall it seems we are dealing with an environment of moderate depth, medium energy and a high rate of sedimentation. This facies may be interpreted as a colonization stage (sensu James, 1984) referable to an inner reef slope environment agreeing with that described by James & Macintyre (1985). This deduction is confirmed by the presence of corals either of branching or massive morphology and the coexistance of *Montastrea* (still living) with *Actinacis* (which may be easily compared with the living *Acropora*, *Goniopora* or *Porites*), and finally the presence of sandy horizons in the studied section, which are comparable with the sand trough described by James & Macintyre (1985). With these comparisons a depth within the first 30 m may be deduced (in agreement with James, 1984) or even more precisely around 25 m (in agreement with James & Macintyre, 1985).

With regard to the genus *Actinacis* with the branching form it must be remembered that it is prevalent in muddy calcareous sediments (Bosellini & Russo, 1988) and is considered among the corals to be more tolerant of extreme environmental stresses (Frost, 1977; Bosellini & Russo, 1988). As previously stated, the genus *Actinacis* is considered analagous to recent *Porites*, which, in the branching form, is characteristic of the last reefs of the Mediterranean. This form is, according to Esteban (1979) and Bossio et al. (1981), the result of very rapid growth on an unstable slope or an increased rate of sedimentation; the genus *Montastrea* also belongs to this Upper Miocene community of *Porites* but only as an accessory genus. Living *Porites* also have the capacity to survive in water with increased quantities of sediment in suspension; moreover, according to Geister (1979), living *Porites porites* has the capacity to adapt itself to mobile substrates by forming "colonies mobiles" for the regeneration of branches broken by storm waves.

Facies IV. The coral morphologies are exclusively tabular or encrusting and indicate moderate to strong energy conditions (James, 1984); the petrographical/paleontological characteristics (bindstone formed exclusively of corals and lacking in non-geniculate coralline algae and siliciclasts) indicate conditions of increased energy (James, 1984). On the whole the environment of formation may be interpreted as a reef crest (James, 1984; James & Macintyre, 1985), and referred to the domination stage of James (1984). The depth is reasonably presumed to be not greater than 10 m (in accordance with that schematized by James & Macintyre, 1985). In support of this hypothesis there is the fact that this facies is stratigraphically continuous with and overlies Facies II. As we are dealing with a succession through the body of a reef which has not been reworked, consequently its paleobathymetric position cannot be deeper with respect to Facies II which we have discussed above.

Facies V. The dominant coral morphology is the plate-like form which indicates conditions of a mobile bottom, a low energy regimen and a low rate of sedimentation (James, 1984); the dominance of "*Archaeolithothamnium*" suggests sciaphilic conditions (Adey & Macintyre, 1973; Wray, 1977), but probably due more to sheltered microenvironments than a marked and generalized characterization in that sense of the environment (i.e. strongly deep), because this would contrast with the high diversification of the coralline algae association; the significant diffusion of crustose-intumescent morphology suggests medium or low energy conditions (Poignant, 1976; Buchbinder, 1977; Minnery et al., 1985; Minnery, 1990).

Overall we are dealing therefore with a depositional environment with a mobile bottom, low rates of sedimentation and moderate to low energy levels. The facies is referable to the colonization stage (James, 1984) and may be considered as the calcareous counterpart of the previously discussed Facies I. In analogy with Facies I, we may suppose a succession of colonization attempts by the corals (bindstone) which are interrupted from time to time by coarse carbonate sediments (floatstone). Also in this case the development of laminar corals is probably favoured by the growth of nongeniculate coralline algae (among which *Lithoporella* is certainly of great importance) which stabilize the mobile substrate (Fravega & Vannucci, 1987, with further references). The diversification of the coralline algae association, which shows a good distribution of *Lithophyllum* and a contained frequency of *Lithothamnion*, indicates that in this case alterating thermal conditions are not shown (cited for Facies I). It is more difficult to give a precise definition of depth, we may suppose deeper conditions with respect to those proposed for Facies I (the deepest part of the upper Infralittoral?) because of the diffusion of "*Archaeolithothamnium*", and the significant presence of *Mesophyllum* and of *Lithophyllum*.

Facies VI. The sedimentological evidence suggests that we are dealing with an accumulation facies of reef material broken up during a storm event. The coral fragments thus produced are then colonized by coralline algae; in section F the colonization was found to be forced and true rhodoliths have been formed. The algal association is dominated by *Lithothamnion*; a strong diffusion of *Lithophyllum* and a subordinate but constant representation of "*Archaeolithothamnium*" are also seen. The form of the rhodoliths and the morphology of the constituent thalli indicate moderate to high energy conditions (Bosellini & Ginsburg, 1971; Bosence, 1983). Overall we may deduce bathymetric conditions analagous to those of Facies V, this implies a temporary and local deepening corresponding to the top of level 1 of section A. An interesting comparison may be made with the situation shown in the back-reef facies of James & Macintyre (1985, Barbados Pleistocene reefs), where a rhodolith zone has been distinguished with a composition analagous to that discussed here, positioned in the part of the back-reef nearest to the body of the reef. These indications would considerably reduce the possible depth.

Facies VII. The extreme disorganization and poor sorting of the sediments of this facies suggest very limited transport. The presence among the clasts of fragments only of massive or tabular corals indicates that the material only came from the shallowest part of the reef (reef crest). Overall this facies may be referred to a reef flat (sensu James, 1984) or to a "rubble & pavement zone" of the back reef (sensu James & Macintyre, 1985), that these authors have placed in very shallow waters (about 1-2 m according to James & Macintyre, 1985). On the basis of the presence of the crustose-intumescent form within the coralline algae association which indicates moderate energy conditions, and of the equivalent frequency of the genera sciaphilic (*"Archaeolithothamnium"*), deep (*Mesophyllum*), and heliophilic (*Lithophyllum*), it seems correct to suppose deeper bathymetric conditions with respect to those proposed in the literature. We suggest a steeper back reef which is an accumulation site of material from the reef crest, instead of a flat area like the more typical reef flat. The poorness of coralline algae association however, induces a note of caution with regard to our hypothesis.

Facies VIII. The extreme lack of marine fossil remains and the sedimentological evidences indicate that we are dealing with terrigenous deposition in a very shallow marine environment, with a sedimentation strongly controlled by river activity. The stratigraphic position of these sediments, overlying a reef facies and underlying or lateral with a supratidal or intertidal facies (refer to the discussion of Facies IX) allows them to be considered as the expression of a regressive event.

Facies IX. The colour alternation which characterizes the undulated-zoned structure may be due to diverse content of organic material (Love & Chafetz, 1988) or to impregnation of salts (Esteban & Klappa, 1983). Their formation may be linked to the action of Cyanobacters (and in particular to their photosynthetic processes) even if there is no evidence for an organic origin, which has possibly been obliterated by diagenetic processes, as shown by Love & Chafetz (1988) for Quaternary carbonates of this origin. We may presume, in agreement with the aforesaid authors, a primitive structure formed of alternations of two types of laminae: one formed of "tufts" of filamentous Cyanobacters each one surrounded by one or more sparry calcite crystals more or less elongated; the second type is formed of Cyanobacters isolated filaments encircled by smaller equidimensional micrite crystals. During diagenesis the sparite crystals enclosing the algal "tufts" grow upwards traversing the overlying laminae at the expense of the micrite crystals; the end result of the neomorphism is the formation of columnar crystals oriented perpendicular to the laminae. It must be noted that the columnar crystals grow across laminae which are richer in inclusions and incorporate them, thus maintaining the original aspect of the crust. The structures with a prevalent vertical trend may be interpreted as rhizolythes, that is organosedimentary structures linked to the roots of higher plants. According to the classification proposed by Esteban & Klappa (1983), they may be referred to "root molds": radial sparry calcite aggregates that fill the cylindrical holes left by the decomposition of the roots ; "root tubules": cylinders cemented around the root molds; "root petrifications": impregnation or substitution of the organogenic matter; "rhizocretions": concretional deposits of minerals around living roots.

This last phenomenon could be responsible for the deposition of the peripheral micritic rings that would therefore define the external border of the original organogenic structure. According to Heimann & Sass (1989), this "micritic envelope" seems to be too fragile and thin to be able to resist collapse and it is therefore necessary that it be reinforced by the associated radial sparry cement grown internally within them before the decomposition of the organic tissues. Sometimes, the sparite reinforcement has not been complete, as the presence of partially collapsed moulds show. The most internal and more irregular micritic rings, and in general the thin micritic depositions often without lateral continuity, could be evidence, according to Searl (1989), of "hiatus" in the growth of sparite crystals.

The high porosity of these limestones may be caused by the decomposition of organic tissues ("mouldic porosity"; Esteban & Klappa, 1983) and/or by the dissolution processes due to CO_2 production linked to root respiration or the oxidation of the organic matter.

The structures previously described (undulated-zoned, rhizolythes, pisoids, and calcite veins) are found in continental deposits, e.g.: caliche, travertine, flowstone, and cave facies.

Overall we may suppose an environment of formation for Facies IX linked to the highest part of the Intertidal Zone or to the Supratidal Zone; also in the upper part of the latter (spray zone) the presence of isolated pools may have allowed the proliferation of blue-green algae (Esteban & Klappa, 1983). In this environment, in which meteoric water plays an important role, a gastropod fauna, a flora of higher plants and Cyanobacters may have developed.

The high carbonate content necessary for the formation of the structures previously described was probably supplied by the nearby reef succession (situated a short distance away, as shown by the presence of reworked coral fragments in the continental carbonate deposits) and from the San Pietro dei Monti Dolomite Formation (or from breccia formed from clasts from this formation) certainly outcropping in the immediate vicinity, as shown by the presence of large angular dolomitic clasts at the base of the sequence.

Comparisons with other Oligocene Reefs.

The calcareous algae association and its associated coral fauna (Sassello sector and Lemme Valley), or the corals and the structure of the edifice they have formed (Cairo Montenotte and Acqui Terme sectors) have already been studied for some of the reefs present in the T.P.B..

Sassello - Ponte Prina (Fravega et al., 1987). The basal level of coral and algae conglomerate is comparable with Facies I studied here; the algal association found is characterized by the exclusive presence of the genus *Lithothamnion* and therefore, even if the species identified are diverse, they are fully analogous; furthermore notable similarities are present also between the morphologies of the coral fauna and on the part of its generic and specific composition. The terminal levels, characterized by alternating episodes of coral, algae and biocalcarenite, are comparable with Facies V studied here; analogies may be observed at the level of specific composition of the algal association, even if at Ponte Prina the genus *Lithophyllum* appears to be more diffuse (and in particular *Lp. contii* which assumes the role of preparing a hardened substratum). The tectonic-depositional dynamics of the Sassello sector allow however, only limited comparisons, in fact in the Ponte Prina sequence the first biohermal established on the metaophiolitic substrate, was suffocated by the terrigenous sediments which in the proposed model (marine transgression in a semigraben) are evidence of the evolution of the structural situation. The terrigenous sequence is effected by more or less evident colonization attempts by algae and corals, which are always suffocated by the resumption of gravelly-sandy deposition.

Val Lemme (Fravega et al., 1988). The succession is most comparable with Facies I described here. The coral fauna are analagous, even if it is found that those of the Val Lemme are more abundant and differentiated; the major analogy is between the composition of the algal association, which in both cases is dominated by *Lithothamnion*, even if there are only a few species present in both sites. The depositional dynamics of the Val Lemme sector allows limited comparisons because the coralline and coral episodes have a limited development on the distal part of fan-deltas reworked in a marine environment, and are evidence of situations linked to a quiescent phase during the progradation of the fan. The subsequent suffocation of the repeated colonizations are connected therefore to the depositional mechanics of the delta and subordinately to tectonic phenomena (instability of the margin).

Cairo Montenotte (Pfister, 1985). We are dealing with a fringing reef with reduced coral zonation, which is differentiated from the other reefs of the T.P.B. for its strong vertical development (40-60 m) and the presence of considerable lateral thinning. The analogies between the coral association of this reef and that of Valzemola are quite limited. Some of the facies distinguished by Pfister are comparable with those described here. In particular Facies B of the Cairo Montenotte sequence, dominant in the core reef and characterized by prevalently massive corals and by not very high specific differentiation, it is analogous to our Facies II. Also some similarities (i.e.: coral morphology and the hydrodynamics of the environment) are found with facies D, E and F distinguished by Pfister respectively with Facies III, IV and VII.

Acqui Terme - Cascine locality (Pfister, 1980). The small reef described is characterized by prevalent coral colonies of the branching type intercalated towards the top of the sequence with massive colonies, stabilized during a quiescence period by an abundant terrigenous deposition. The dominance of corals with branching morphology allow a generic comparison with Facies III described here.

Other Oligocene reefs of the western Tethys area have been analysed by various authors. Studies on Northern Italy have been carried out by Frost (1981) and for Southern Italy (Salento Peninsula) by Bosellini & Russo (1992). They deal with observations and reconstructions of large reefs which only have generic analogies with the small reef at Valzemola.

Conclusions.

The Valzemola area is characterized by the presence of a small algal and coral reef intercalated in a prevalently terrigenous succession. On the whole nine different facies have been distinguished, of which seven are directly linked to the reef and two to a quite nearshore environment and that give evidence of a regressive phase. We will summarize briefly the principle characteristics of the aforesaid facies:

Facies I. Fossiliferous conglomerate and sandstone, with corals and/or coralline algae: colonization stage in a dominantly terrigenous environment. It is a shallow facies (Infralittoral), strongly influenced by fluvial activity and a high rate of sedimentation, with mobile substrates in a low to moderate energy regime.

Facies II. Coral framestone with rare and thin fossiliferous packstone layers: diversification stage, inner reef front facies near to reef crest. It is an environment with a low rate of sedimentation, medium to strong energy regimen, and depths within the first 20 m.

Facies III. Coral bafflestone with *Actinacis rollei* (Fig. 6; Fig. 7) and wackestone matrix, and rare lenses of coarse sandstone: colonization stage and an inner reef slope facies. It is an environment of moderate depth, medium energy and a high rate of sedimentation with a depth of about 25 m.

Facies IV. Coral bindstone with tabular and encrusting corals in living position and packstone matrix: domination stage, reef crest facies. It is a high energy environment with a depth of not more than 10 m.

Facies V. Coral bindstone and floatstone with plate-like corals and packstone or wackestone matrix: colonization stage, it is the carbonate counterpart of Facies I. It is an environment of mobile substrates, low rates of sedimentation and moderate to low energy levels.

Facies VI. Coral and algal floatstone with rhodoliths and wackestone or packstone matrix: accumulation facies of reef material. It may be an environment with a depth analogous to that of Facies V or a back-reef facies very near to the core of the reef at a decidedly reduced depth.

Facies VII. Coral rudstone with massive coral fragments and wackestone matrix: we are dealing with an environment which we suppose to have steep slopes and accumulation sites of material from the reef crest; it may be comparable in part to a reef flat or a rubble & pavement zone of the back reef.

Facies VIII. Very poorly fossiliferous conglomerate and sandstone lacking corals and coralline algae: terrigenous sediments in a very shallow marine environment, whose deposition is strongly controlled by fluvial activity. They represent regressive conditions.

Facies IX. Massive limestone with undulated-zoned fabric, vertical structures, veins filled by clear calcite, and pisoids: it is a deposit linked to an upper intertidal or supratidal environment.

On the basis of the facies distinguished it is possible to put forward some hypothesis on the type of reef that was developed in the Valzemola area. In particular we may observe that we are dealing with a structure situated very near the coastline, but the state of preservation does not allow us to define precisely what the relationship to that coastline may have been. The absence of a facies which is clearly referable to a lagoon environment suggests a structure such as a fringing reef, but the presence of facies probably referable to a back reef (Sections E and F) with an architecture or a depth which tends to exclude a typical reef flat facies contrasts with this hypothesis and tends moreover to support a reconstruction on the model of the actual bank barrier reef (James & Macintyre, 1985); but neither is there clear or indisputable evidence in favour of this hypothesis. We may be dealing with an intermediate situation, in which a bank barrier reef tends to join itself with the shoreline and therefore, at least partially, assumes the characteristics of a fringing reef (in agreement with that described by James & Macintyre, 1985).

The settlement of the Valzemola reef may be placed in a general transgressive environment which characterizes the Oligocene sediments of these sectors of the T.P.B. The marine advance is characterized by terrigenous sediments (i.e.: sandstones and conglomerates, and breccias at the contact with the substrate) progressively stabilized by a coral fauna of prevalently laminar morphology and by a coralline algae flora. On these hardened substrates the reef could grow. Subsequently the biohermal deposit was suffocated by an arenaceous-conglomeratic deposition linked to an increase in the terrigenous influxes from the dry land. This was probably connected to a phase of increase of erosion rate determined by tectonic uplift of the relief in the proximity of the basin.

The progressive shallowing of some sectors, probably facilited by minor brittle deformation, documented by the presence of breccia horizons, allowed the establishment of conditions suitable for carbonate deposition in an upper intertidal or supratidal environment.

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PLATE 1

Fig. a - Undulated-zoned structures (polished slab, natural size). Section G, level 4b.

Fig. b - Microscopic view of "b" type structures characterized by radial aggregates of sparry calcite and by micritic rings. Section G, level 4b; 20x.

PLATE 2

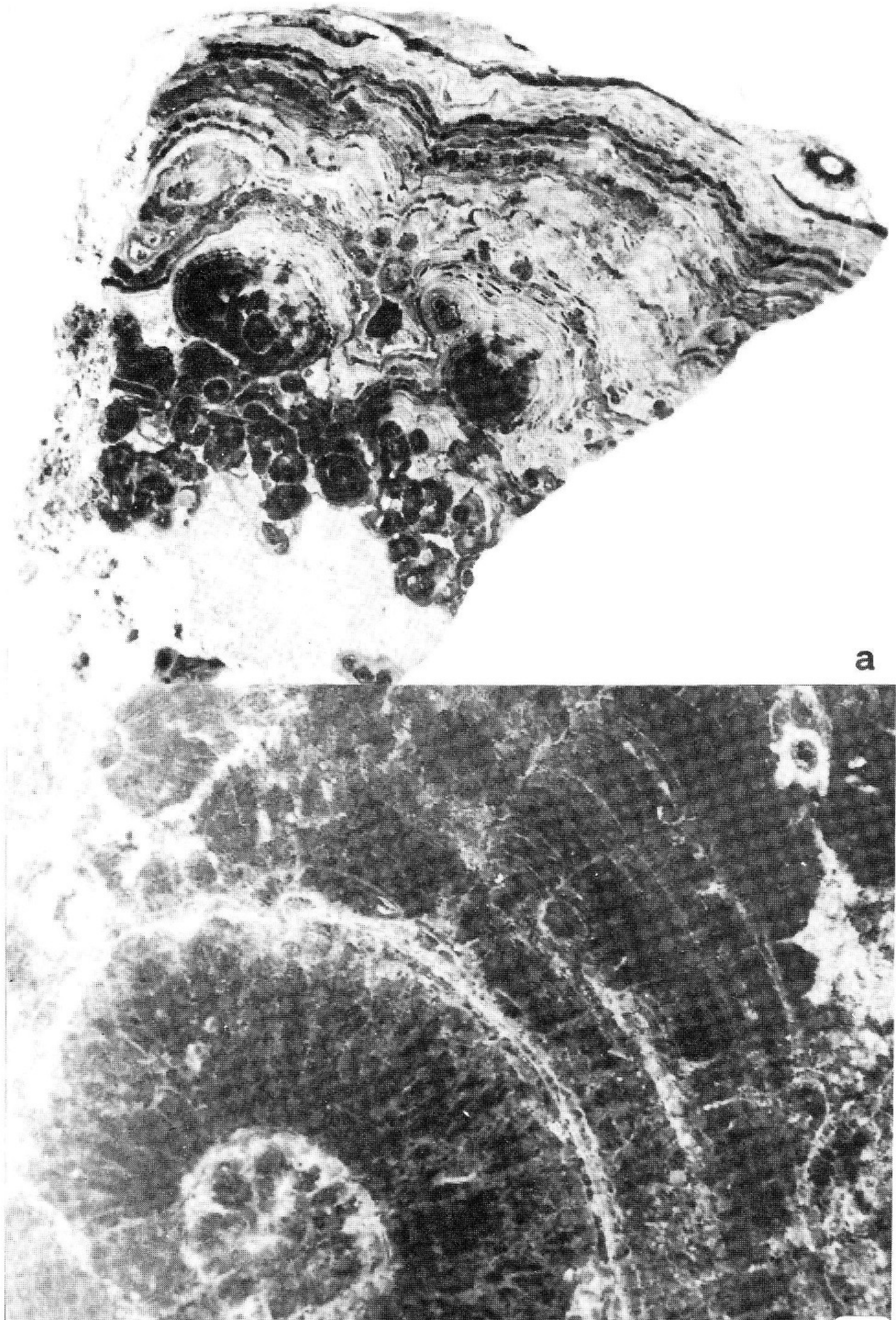
Fig. a - Crustose thalli of *Lithothamnion ishigakiense* Johnson. Section F; 20x.

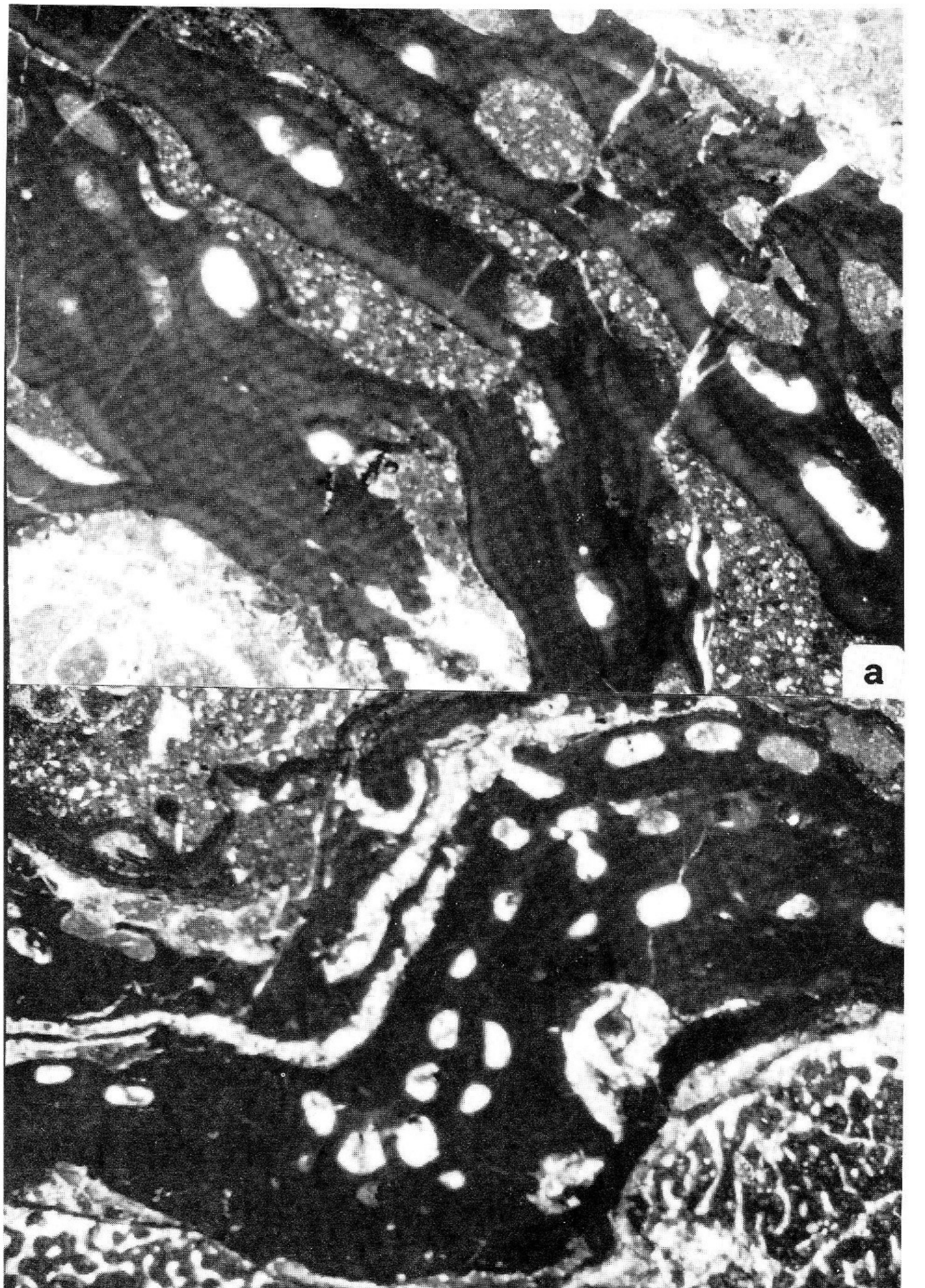
Fig. b - *Lithothamnion moretii* Lemoine on a coral fragment (bottom) and *Lithoporella melobesioides* (Foslie) Foslie (top). Section F; 20x.

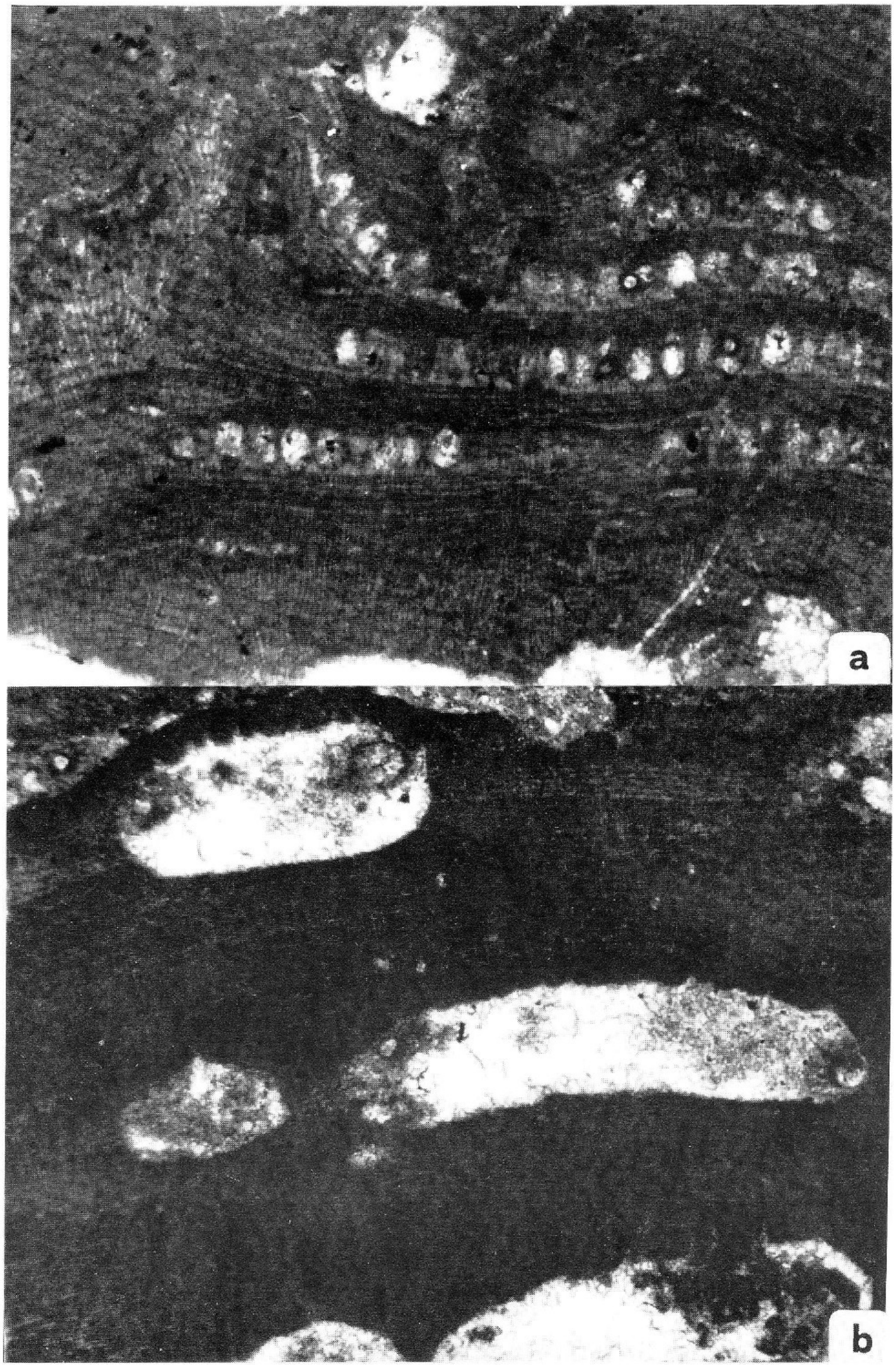
PLATE 3

Fig. a - "*Archaeolithothamnium*" *varium* Mastrorilli. Section C, level 5; 80x.

Fig. b - *Mesophyllum vaughanii* (Howe) Lemoine. Section C, level 6; 80x.




a
b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