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The coral fauna of Vitigliano: qualitative and quantitative analysis in a back reef environment (Castro Limestone, Late Oligocene, Salento Peninsula, Southern Italy)

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ABSTRACT — *The Castro Limestone, Middle Chattian in age, consists of various reef facies and has been described as a fringing reef complex developed along the Cretaceous-Eocene rocky coast of the Salento Peninsula. The reef facies outcropping near Vitigliano and the associated coral fauna, which have been previously interpreted to be part of a back reef subenvironment, are here defined both qualitatively and quantitatively. Together with palaeontological and sedimentological observations, three main quantitative methods have been used for the characterization of the back reef facies: 1) count of coral colonies on a subvertical measured surface, 2) line-transect, 3) quadrat. The composition of the coral fauna was identified in the field mainly at the generic level and abundance of the different genera has been analyzed. The results obtained from the various quantitative methods are compared and discussed. Moreover, the coral density has been quantified from both linear and areal measurements and has been evaluated to be around 20%. However, corals occur as scattered colonies and do not form a true framework.*

RIASSUNTO — [La fauna a coralli di Vitigliano: analisi qualitativa e quantitativa in un ambiente di retroscogliera (Calcare di Castro, Oligocene superiore, Penisola Salentina, Italia meridionale)] – *Il Calcare di Castro, una formazione di età tardo oligocenica già descritta ed interpretata come una classica scogliera a frangia che orlava la costa rocciosa cretaceo-eocenica della Penisola Salentina, è rappresentato nei pressi dell'abitato di Vitigliano da una tipica facies di scogliera interna e retroscogliera. La corallofauna associata a tale facies viene qui caratterizzata sia qualitativamente che quantitativamente utilizzando in particolare tre diversi metodi: 1) conteggio di tutte le colonie coralline visibili all'interno di una superficie verticale nota, 2) tracciati paralleli alla stratificazione, 3) quadrati. Vengono quindi paragonati e discussi i risultati ottenuti dall'utilizzo dei diversi metodi quantitativi, soprattutto per quanto riguarda i componenti della fauna a coralli (classificati sull'affioramento, per la maggior parte a livello di genere) e le relative proporzioni all'interno di essa. Inoltre il calcolo della densità della corallofauna, sia in una che in due dimensioni, ha fornito un valore del 20%. Tuttavia le colonie coralline risultano prevalentemente isolate e non formano una vera e propria impalcatura corallina («framework» s.s.).*

INTRODUCTION

Development of quantitative methods in ecological studies of present-day coral reefs (Loya & Slobodkin, 1971; Loya, 1978; Dodge *et al.*, 1982; Chiappone & Sullivan, 1991), recently led geologists and palaeontologists to adopt similar quantitative approaches for more objective descriptions and comparison of reef biofacies (Weidlich *et al.*, 1993; Perrin *et al.*, 1994). However, most palaeoecological interpretations of ancient reefs are still based on descriptions and qualitative data.

The primary aim of this study was to obtain objective and quantitative data across a composite

fossil reef profile, in order to improve definition of reef-building assemblages and to reconstruct the associated palaeoenvironments. In particular, the various biofacies outcropping discontinuously along a still preserved reef palaeotopography allowed four main reef subenvironments to be defined and these have been selected to apply and test a qualitative and quantitative approach. As an example, preliminary results are presented here for a small back reef tract. The easy access to the outcrop and, most of all, the very well preserved, *in situ* coral colonies provided a good opportunity to apply the methods and to give a detailed characterization of the coral fauna.

GEOLOGICAL AND STRATIGRAPHICAL SETTING

The Castro Limestone outcrops discontinuously along the eastern coastline of the Salento Peninsula (Apulia region, Southern Italy) (Text-fig. 1) and has been recently interpreted as a fringing reef complex developed on a Cretaceous-Eocene rocky escarpment during Late Oligocene time (Bosellini & Russo, 1992).

The age of the Castro Limestone has been determined mainly on the basis of larger foraminiferal associations (Bosellini & Russo, 1992; Parente, 1993). In particular, the occurrence of *Lepidocyclina* (*Eulepidina*) *dilatata*, the highly evolved form of *Lepidocyclina* (*Nephrolepidina*) *praemarginata*, and the absence of Miogypsinidae assign the Castro Limestone to the Middle Chattian, according to the European-Mediterranean Oligocene correlation scheme of Drooger & Laagland (1986).

Moreover, physical stratigraphic relationships observable directly in the field led Bosellini & Russo (1992) to consider the Castro Limestone as a classic unconformity bounded depositional sequence (Vail *et al.*, 1977; Van Wagoner *et al.*, 1988), with a thickness varying from 10 to 80 m. In particular, the Castro Limestone disconformably overlies a mildly deformed Cretaceous platform and its associated discontinuous Eocene deposits (Late Middle Eocene-Priabonian according to Parente, 1993). Its upper boundary is characterized by an erosional surface, overlain by a distinctive rhodolith horizon, which constitutes the base of the overlying

Porto Badisco Calcarene (Late Chattian in age according to Parente, 1993).

A reef model showing the zonation of reef sub-environments and associated facies has been already proposed by Bosellini & Russo (1992, 1993), and detailed quantitative and qualitative studies, still in progress (Bosellini & Perrin, 1993; Perrin & Bosellini, 1993), have been recently carried out in four main subenvironments across the reconstructed reef profile (Text-fig. 2).

THE VITIGLIANO BACK REEF SECTION

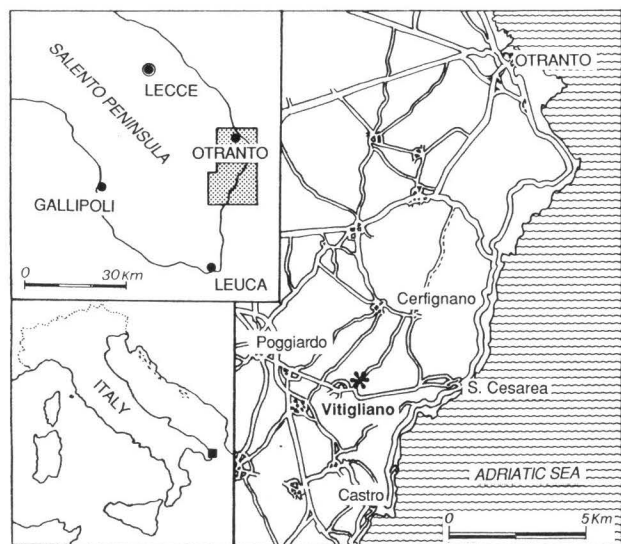
This section outcrops along both sides of the road from Vitigliano to Cerfignano, in the vicinity of the former village, and represents the most shoreward part of the exposed reef area, about 2 km from the present shoreline (Text-fig. 1).

The Castro Limestone has been assumed to be subhorizontally stratified with a maximum outcropping thickness of about 5 metres. This has been interpreted as partly due to the limited accommodation space available on the platform during deposition (Bosellini & Russo, 1992).

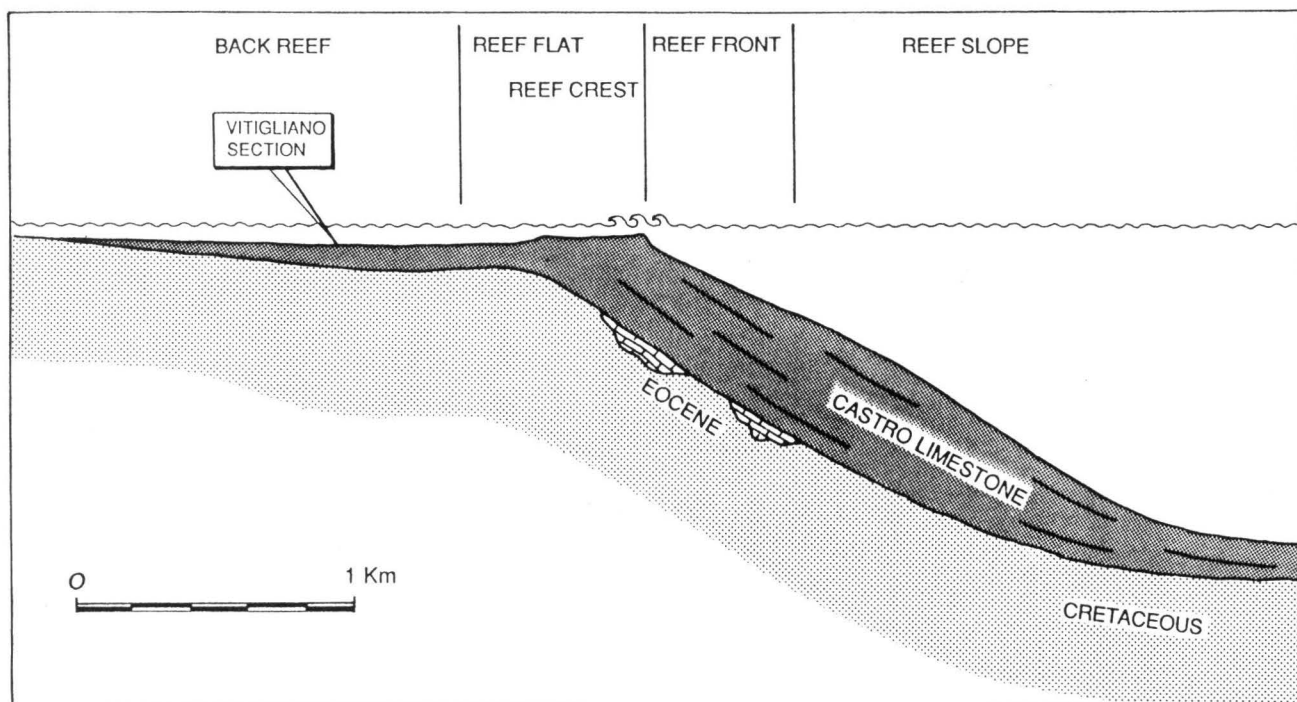
The structural setting of the Castro Limestone and its restricted inland extension, together with the observed sedimentological and palaeontological characteristics, suggest that the Vitigliano section was part of a narrow, sandy nearshore back reef or reef flat subenvironment, rather than a true protected reef lagoon (Text-fig. 2).

Scattered and well preserved coral colonies, most of them in growth position, are embedded in a coarse bioclastic sediment. Coral colonies are commonly encrusted by coralline algae (mm to cm-thick crusts) and perforated by boring organisms, especially the bivalve *Lithophaga* which appears to be particularly common in the corals *Stylocoenia*, *Tarbellastraea* and *Favites*.

Microfacies examination reveals a packstone-grainstone texture which, associated with a lack of muddy matrix, further indicates a relatively poorly protected area. In some voids, a thin microsparite cement has been observed. Grains consist of coral and coralline algae fragments, echinoid plates, gastropods, bivalves and larger foraminifera. Reef-dwelling larger foraminifera are represented mainly by *Lepidocyclina* (*Nephrolepidina*) *praemarginata* and *Neorotalia viennoti*, together with *Heterostegina* sp., *Operculina complanata* and rare tests of *Lepidocyclina* (*Eulepidina*) *dilatata* (Parente, 1993).



Text-fig. 1 - Study area showing location of the studied section, close to the village of Vitigliano.



Text-fig. 2 - Schematic reconstructed reef profile of the Castro Limestone fringing reef complex.

QUALITATIVE DESCRIPTION OF THE CORAL FAUNA

The coral fauna recognized with the quantitative methods has been identified mainly in the field and consists of the following taxa:

Stylocoenia
Astreopora
Pavona
 Agariciids
Siderastrea
Actinacis
Goniopora
Porites
Alveopora
 Poritids
Favites
Hydnophora
Colpophyllia?
Montastraea
Tarbellastraea
 Faviids
 Mussids
 meandroid corals

About 13 genera were differentiated and poorly preserved or unidentified corals were grouped

into families (Agariciidae, Poritidae, Faviidae, Mussidae) or even in more general groups («meandroid corals»). As regards corals not identified at generic level, poritids may include recrystallized colonies of *Actinacis*, *Goniopora* or *Porites*; poorly preserved colonies of *Hydnophora* and *Colpophyllia* were grouped as «meandroid corals», while faviids, as used here, included colonies of *Favites* and *Montastraea*. Consequently, problems related to identification of corals in the field must be considered when evaluating quantitative data on abundance of the different genera.

Observations of coral colonies in growth position indicate different types of growth habits and a quite variable range of coral dimensions (Pls. 1, 2, 3). In particular, the following types of colonial growth forms have been observed: 1) massive-subglobose, 2) «mushroom» shaped, 3) platy, and 4) branching.

Poritids in general, *Actinacis* and some faviid genera (*Tarbellastraea*, *Hydnophora*) mostly exhibit an irregular massive growth form, usually wider than they are high (Pl. 1, figs. 1-2). This is a general trend in developing wide colonies further emphasized by the occurrence of «mushroom»-like and platy growth forms. Quite large colonies of faviid corals (*Hydnophora*, *Favites*, etc.) showing a typical «mushroom»-like habit, can be observed

across the Vitigliano section (Pl. 2, figs. 1-2). A laminar-platy growth form is quite frequent in this back reef subenvironment and is represented mainly by relatively small colonies of the agariciid coral *Pavona* and by few *Favites* (Pl. 3, figs. 1-2). Branching colonies are only represented by few thick-branched small colonies of *Alveopora* in growth position.

Although zonations of coral form associations along reef profiles have been proposed in several studies (Graus & Macintyre, 1976; Chappell, 1980; James, 1983) and different growth forms within coral species have often been considered as environmentally induced phenotypes, we believe that considerable care is required in using growth forms to interpret ancient reef environments (Stearn, 1982; Fagerstrom, 1987).

QUANTITATIVE ANALYSIS

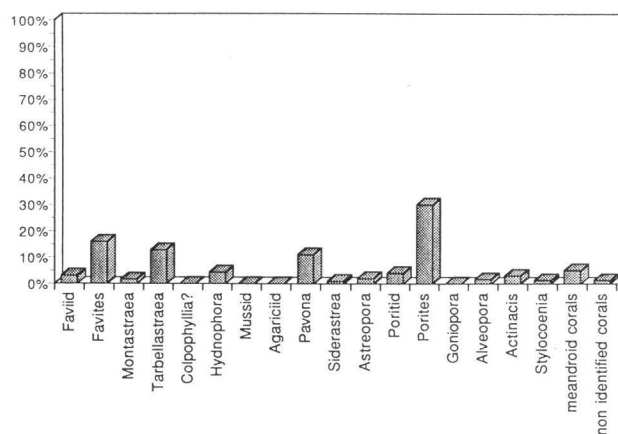
The following three types of quantitative methods have been used in the field to characterize the coral assemblages and to complement the previous qualitative observations with more objective information:

- count of coral colonies on a subvertical measured surface,
- linear intercept method (Loya & Slobodkin, 1971; Perrin *et al.*, 1994),
- quadrats placed on the subvertical outcrop surface.

Distinction was carefully made between corals in growth position, tilted or overturned colonies and fragments. Coral genera have been directly identified in the field and sampled for detailed taxonomic studies in the laboratory (still in progress).

Coral count

310 coral colonies were counted on a 375 m² surface. As regards this back reef environment, tilted or overturned colonies were considered to be *in situ* as no evidence of transport was observed. The percentage of individual colonies of each genus was derived from these quantitative data (Text-fig. 3).



Text-fig. 3 - Individual colony count on a 375 m² surface: percentages of individual colonies for different genera, families and more general groups of corals identified in the field.

Main results clearly show that the coral fauna is dominated by the following genera in decreasing order of abundance: *Porites*, *Favites*, *Tarbellastraera* and *Pavona*, associated with frequent *Hydnophora* and *Actinacis* (Text-fig. 3). It should be noted that the percentage of non identified meandroid corals (about 5%) undoubtedly includes some colonies of *Hydnophora*.

Line transect

A 99.5 m long tape oriented NE-SW was placed horizontally on the outcrop, assuming an horizontal stratigraphy at this site. Intercept length of corals and coralline algae in growth position and matrix were recorded along 2 m long horizontal sampling lines placed at 4 m intervals along the line, except for an interval of 13.5 m where rock was not exposed. Fifteen sampling lines, giving a total sample length of 30 m, were measured and provided data for the following parameters: 1) total length recorded for each genus (Text-fig. 4b), 2) relative abundance of each genus (Text-fig. 4a), 3) framework density (*sensu* Perrin *et al.*, 1994) (Text-fig. 6c).

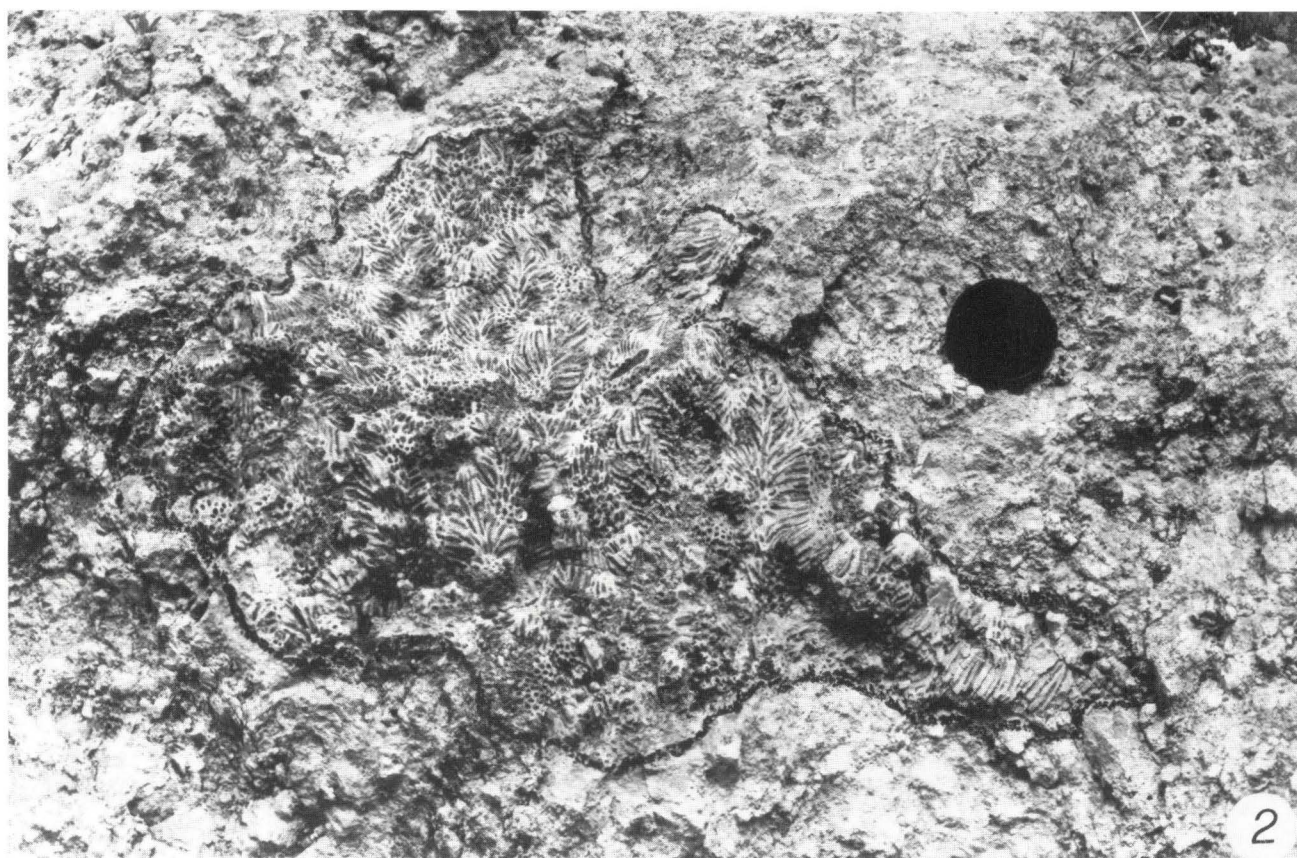
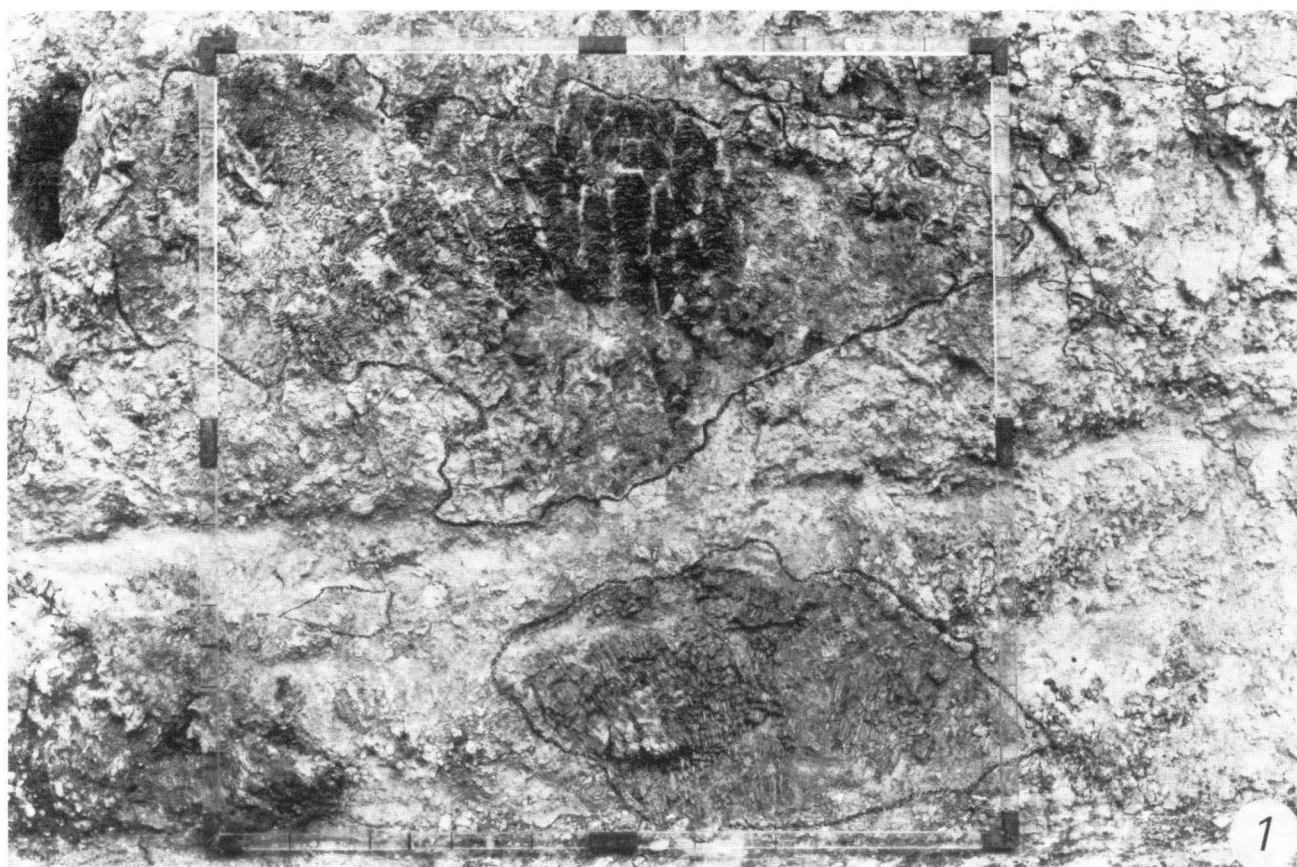
Results obtained from this technique show a

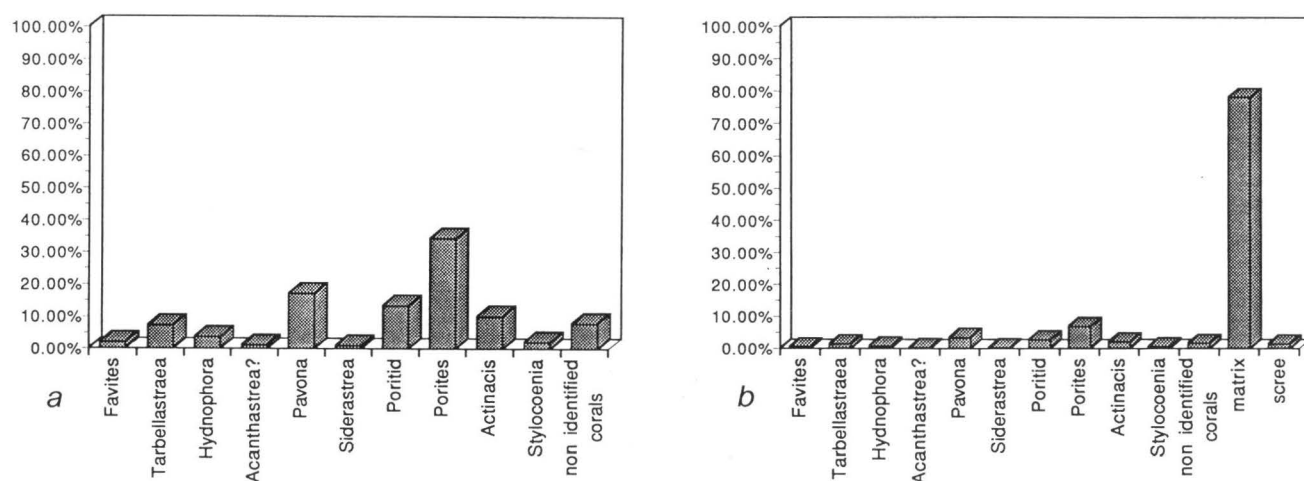
EXPLANATION OF PLATE 1

Coral colonies in growth position: irregular massive growth forms.

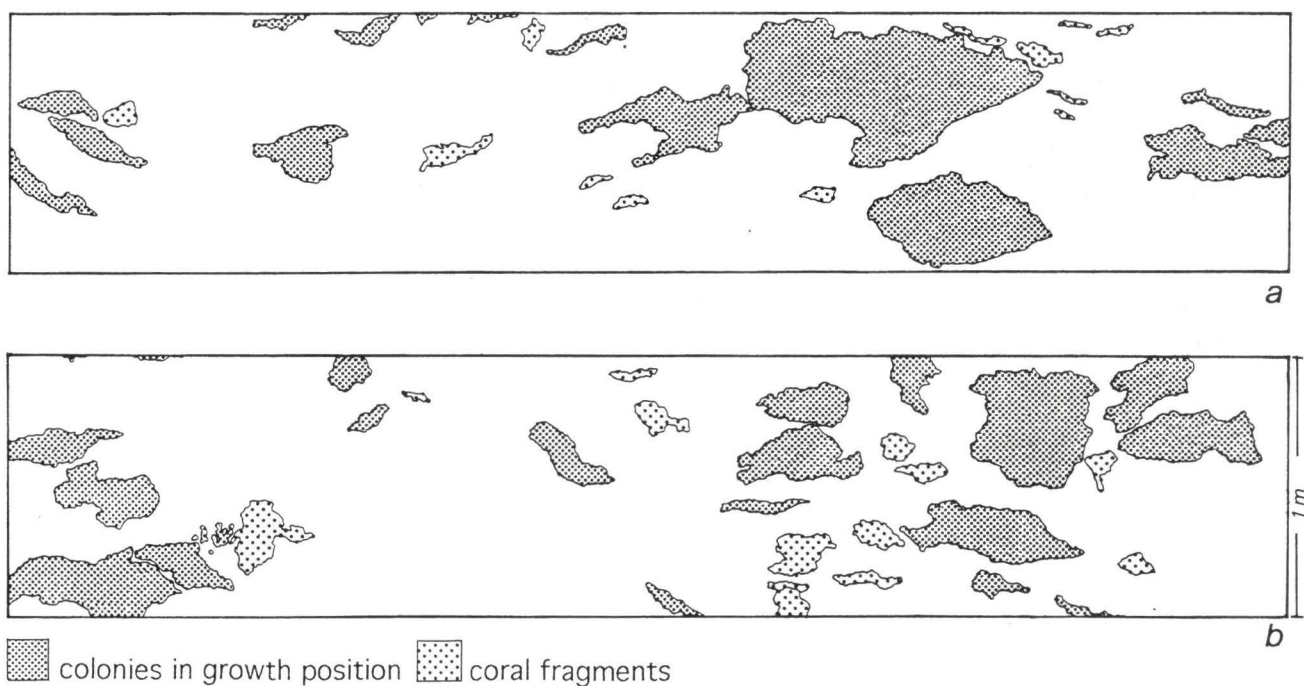
Fig. 1 - Colony of *Porites* (above): 118 x 56 cm; colony of *Hydnophora* (below): 71 x 36 cm. The quadrat used for quantitative measurements is visible on the subvertical outcropping surface.

Fig. 2 - Colony of *Tarbellastraera*: 53 x 31 cm.





Text-fig. 4 - Line transect (30 m). A- Relative abundance of each coral genus in growth position identified along the transect. B- Proportions of different components (coral colonies in growth position and matrix) compared to the total measured length.



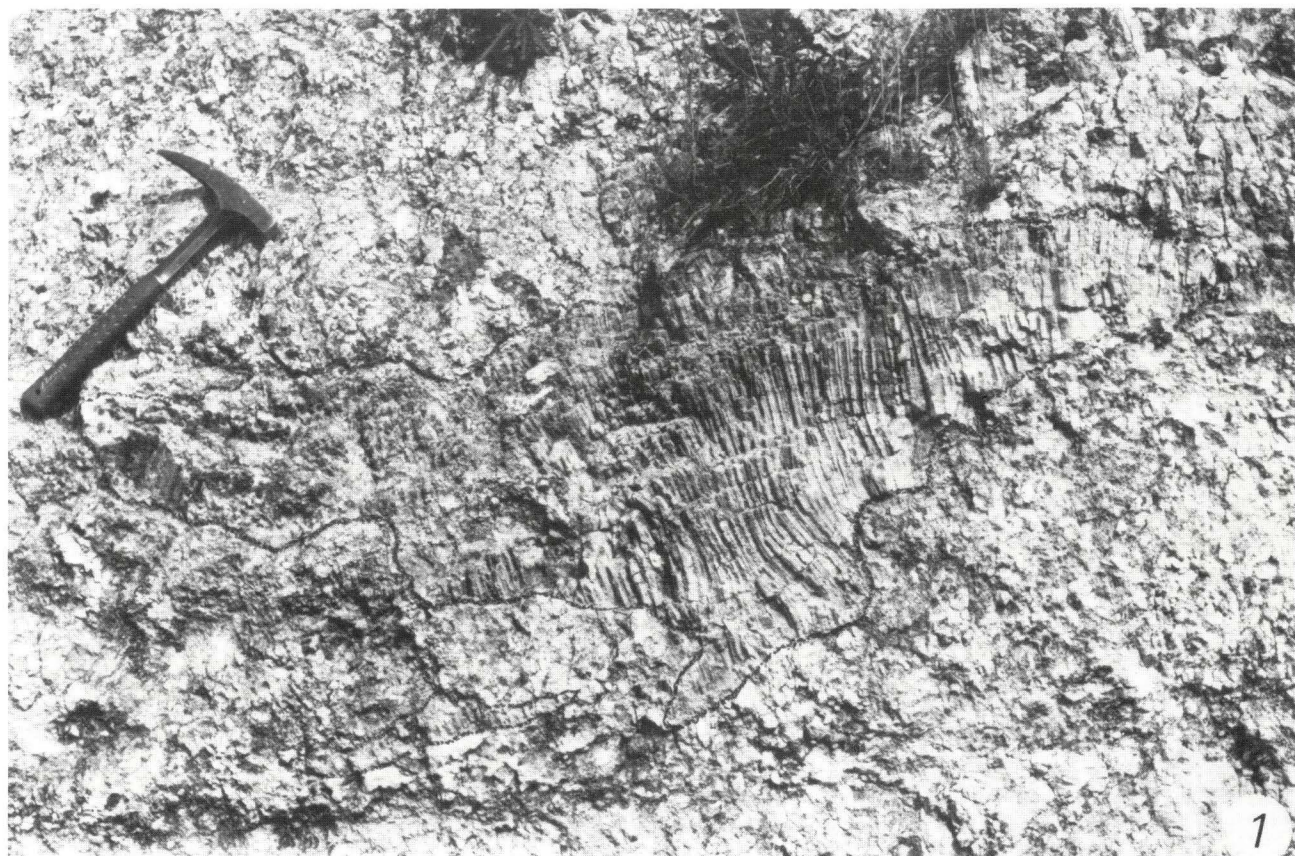
Text-fig. 5 - Sketches of the two 5 m² quadrats showing corals mapped directly in the field from photo-mosaics (corals in growth position and coral fragments are differentiated). A- quadrat 1. B- quadrat 2.

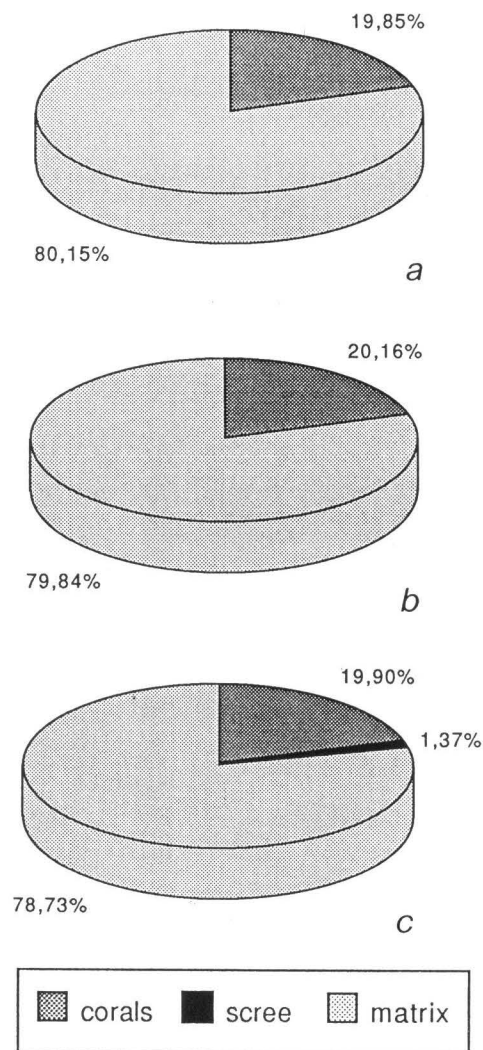
EXPLANATION OF PLATE 2

Coral colonies in growth position: «mushroom» shaped growth forms.

Fig. 1 - Large colony of *Favites*: 121 x 47 cm.

Fig. 2 - Large colony of *Hydnophora*: 134 x 50 cm.

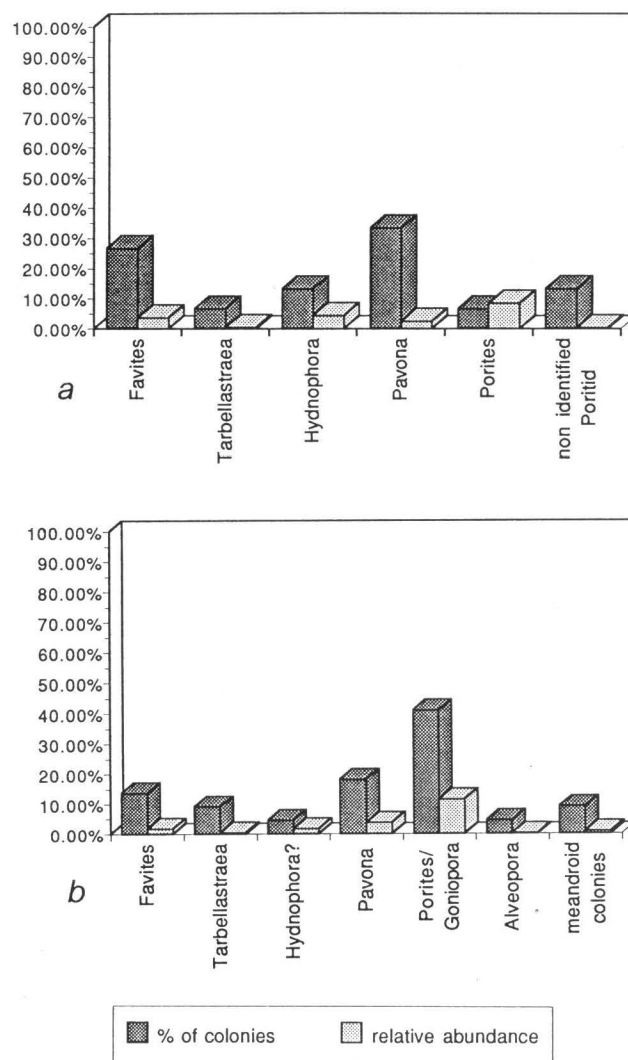




Text-fig. 6 - Representative diagrams of the density of the framework from areal and linear measurements. A- quadrat 1. B- quadrat 2. C- transect line.

dominance of *Porites*, *Pavona*, poritids and *Actinacis* with relatively frequent *Tarbellastraea* and *Hydnophora* associated with *Stylocoenia* and *Favites*. Rare corals (<2%) are represented by *Acanthastrea?* and *Siderastrea*. (Text-fig. 4a).

Framework density along the individual transects varies from 8% to 38%, with an average of 19,9% for the total measured length of 30 m (Text-fig. 6c).



Text-fig. 7 - Results from the two 5 m² quadrats: percentage of individual coral colonies in growth position and relative abundance of each genus. A- quadrat 1. B- quadrat 2.

Quadrats

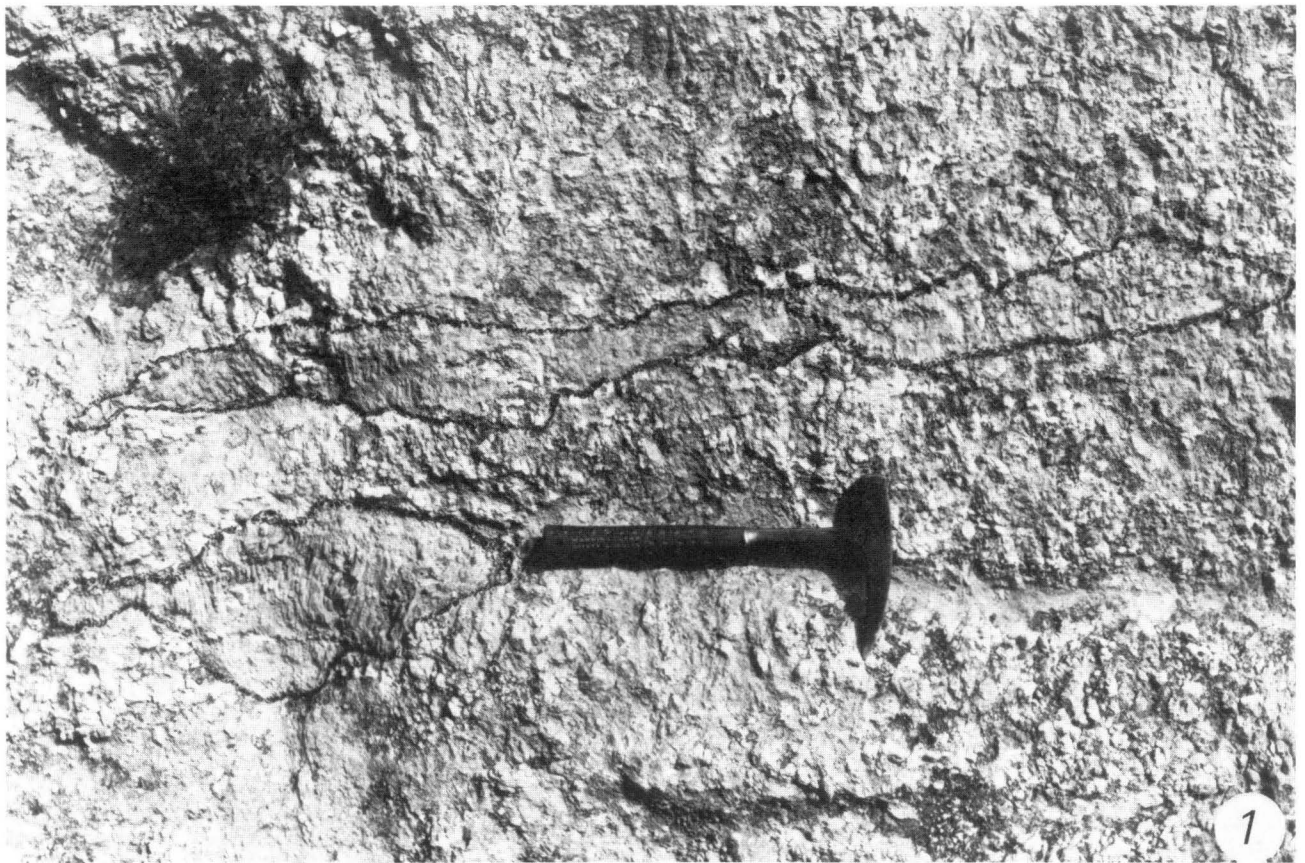
Two 5 m² quadrats were placed randomly on the subvertical outcropping surface and corals were mapped directly in the field from a photograph mosaic (Text-fig. 5; Pl. 1, fig. 1). The area occupied by individual colonies in growth position was computerized and calculated in order to estimate the following parameters: 1) percentage of individual

EXPLANATION OF PLATE 3

Coral colonies in growth position: platy growth forms.

Fig. 1 - Colony of *Favites* (above): 116 x 9 cm; colony of a non identified meandroid coral (below): 43 x 20 cm.

Fig. 2 - Colony of the agariciid coral *Pavona*: 63 x 13 cm.



colonies of each genus (Text-fig. 7a,b), 2) relative abundance of the different genera: i.e. surface occupied by one genus per square metre (Text-fig. 7a,b), 3) framework density: i.e. total surface occupied by coral colonies per square metre (Text-fig. 6a,b).

Fifteen and 20 colonies in growth position were recorded for quadrat 1 and quadrat 2 respectively, with related assemblage density values of 3 and 4 colonies per square metre. Values of framework density were 19.85% and 20.18% respectively (Text-fig. 6a,b) and the main framebuilders were: *Porites/Goniopora*, *Pavona*, *Favites*, poritids and *Hydnophora*, associated with frequent *Tarbellastraea* (Text-fig. 7a,b). Except for the rare genus *Alveopora*, the coral genera recorded from the two quadrats corresponded with the most dominant forms of the whole assemblage (Pls. 1,2,3).

Comparison of results

Colony count has shown the occurrence of at least 13 genera, associated with other more general groups. According to the line transect method, 9 genera, i.e. 69% of the assemblage obtained from the first technique, were present; while both quadrats recorded 6 genera representing only 46% of all observed genera. However, despite differences probably related to different scales and methods of measurement (linear and areal), results obtained from the three quantitative methods show remarkable consistency concerning the dominant and common genera and framework density, estimated to be around 20%.

CONCLUSIONS

Comparison between the quantitative methods used in this study shows the general value of this approach.

The back reef coral fauna of the Vitigliano section has been well characterized, the results showing that *Porites*, *Pavona*, *Favites* and *Tarbellastraea* are dominant and associated with less frequent *Hydnophora* and *Actinacis*. By comparison with quantitative data obtained from measurements in other subenvironments of the Castro Limestone reef complex, only the coral *Stylocoenia* can be considered as characteristic of the back reef, while *Pavona*, *Favites* and *Tarbellastraea*, less developed in other subenvironments, typify the coral assemblage of this back reef facies.

In addition to the coral fauna, also the density of the framework has been quantitatively estimated; results from linear and areal measurements both indicating a density of about 20%.

Finally, this study has demonstrated that a combination of both qualitative and quantitative methods can provide a valid and useful tool for a better palaeoenvironment interpretation and objective analysis of the coral fauna of fossil reefs.

Even if application of these methods is probably limited to well exposed and relatively undeformed reef complexes, this approach is a step towards an objective description of reef palaeoenvironments and associated faunas and the quantitative data here presented can be used for comparison in other reef settings.

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