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MARINE BIOGENIC CONSTRUCTIONS IN THE MEDITERRANEAN
A REVIEW

by Jacques LABOREL *

Résumé : Le but de cet article est de présenter les phénomènes de bioconstruction marine en Méditerranée. Ce phénomène complexe dont l'aspect le plus connu est représenté par les récifs coralliens des mers tropicales, est assez largement représenté en Méditerranée, à diverses profondeurs et sous diverses formes. On trouvera une description systématique des formes bioconstruites de Méditerranée, avec des détails sur leur structure, leur écologie et leur répartition géographique. L'accent est mis sur la valeur esthétique de ces formations, souvent menacées par l'homme, dans l'espoir que les décideurs sauront préserver ce patrimoine des périls auxquels il est soumis du fait des activités humaines, et d'autre part prendront des mesures pour l'exploiter intelligemment, en particulier sur le plan touristique.

Abstract : This paper is aimed at a general presentation of Marine bioconstruction in the mediterranean area. This wide and complex phenomenon, best represented by tropical coral reefs is present in the Mediterranean under different forms, linked to various biota. This paper gives a description of the various types of bioconstructions, along with their structure, ecology and geographical repartition. The aim of the study is to raise a greater interest for mediterranean bioconstructions, in an effort to preserve and manage many interesting and sometimes beautiful sites which, in many cases, are strongly menaced by man's activities and require urgent protection.

FOREWORD

It is a widely overlooked fact that the Mediterranean sea is rich in biogenic buildings of various types. Although the latter may be less conspicuous than those of tropical seas, they are neverthless important and urgently need a general survey in order to :

1) present the different types of construction in a single, easily available document

2) allow to protect them against man's abuse, pollution and decay of all kinds

3) encourage littoral nations to make good use of their esthaetic properties as attractive features for developing original surface and underwater touristic activities.

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WHAT IS A BIOGENIC STRUCTURE ?

Many marine plants and animals have a solid (generally calcareous) skeleton by which they stick to the substrate and which perdures at the same place after the death of the organisms. In some cases, provided the growth of the organisms is sufficiently rapid and the skeletons are sufficiently dense and crowded, the accumulation of limy remains may lead to a permanent rocky structure of chara' :eristic pattern and variable size the upper surface only of which is living over an accumulation of more or less fused and cemented dead parts. These structures may grow for centuries and reach important size, and, in some cases may still be seen as fossil remains many centuries or even millenia after the death of the building organisms.

Such features, the most representative of which are the tropical **coral reefs,** *are known under the general denomination of* **biogenic buildings.**

Some biogenic buildings are too small or too inconspicuous to be of more than scientific interest, but, in many parts of the Mediterranean, *examples of such buildings are known which, by their size, form and colors, may be extremely attractive and conspicuous to the surface or underwater observer.*

In the Mediterranean region, current biological and geological research during the last thirty years has described more than a score of diverse types of biogenic buildings, growing at various depths and in different types of places or biota. Many papers have been devoted to their description but synthetic accounts are rare (PERES & PICARD, 1952) and are not aimed at conservational purposes.

I shall present these diverse types of bioconstructions briefly, taking into account their vertical and horizontal location, the degree to which they have been surveyed in the various parts of the Mediterranean, their potential attractiveness as natural momuments and the various dangers that are threatening them.

DESCRIPTION OF TYPES

Two important factors must be taken into account when dealing about biogenic structures : these are the *depth at which the structure is growing* and *the nature of its biological components.* In the Mediterranean area, seven different types at least of biogenic buildings may be found which are, according to the depth at which they develop :

a) **surface and subsurface buildings** (littoral zone)

1) The *Lithophyllum lichenoides* rim
2) The algal-vermetid rim and its variants
3) The *Corallina* rim
4) The *Lithophyllum incrustans* rim

b) **underwater buildings**

5) Serpulid rims and reefs
6) *Cladocora* banks
7) « coralligene » algal banks.

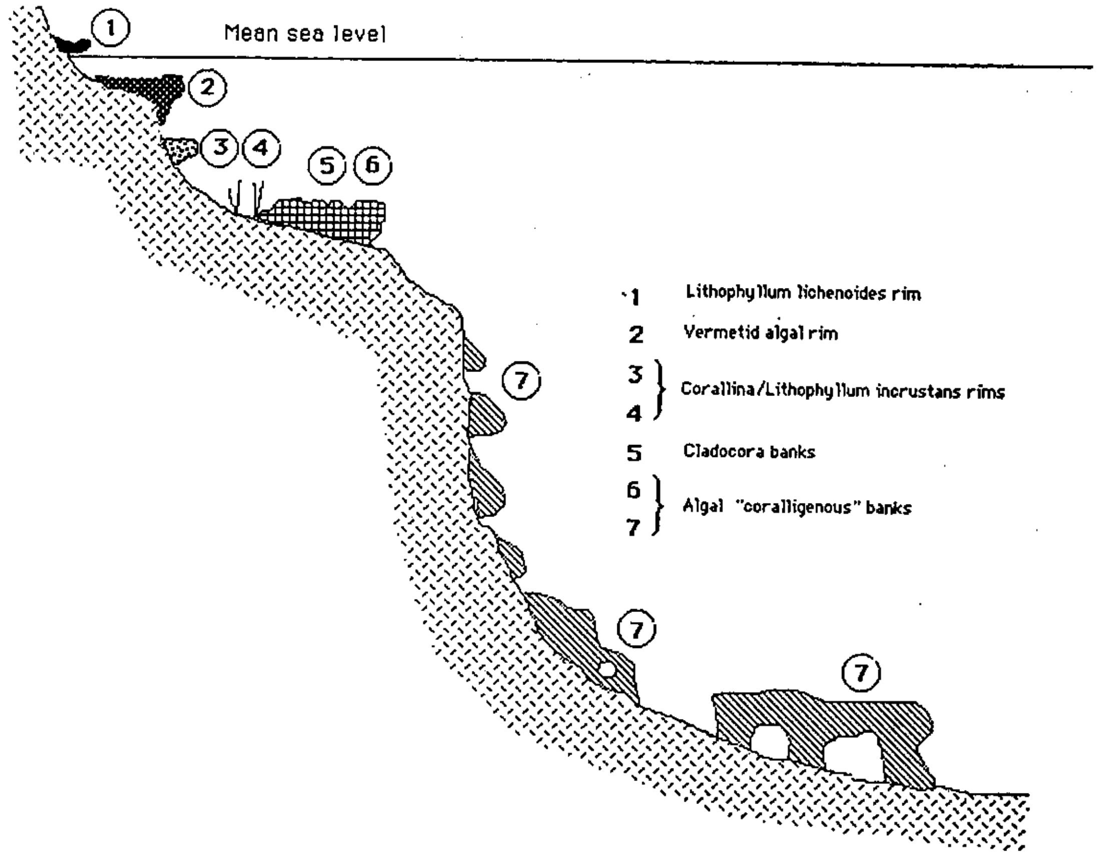

Fig. 1 : Zonation of some forms of mediterranean biogenic constructions.

Depth in itself is not a significant factor : more important is the **place in the benthic zonation** as defined by marine biologists and notably by PERES & PICARD whose latest zonation scheme (PERES & PICARD, 1964) is now considered as a standard in the Mediterranean for the bulk of marine scientists working in that area. Following these authors we shall consider biogenic buildings growing from the surface to the edge of the littoral shelf :

midlittoral zone buildings represented only by (1)
upper infralittoral zone buildings : (2), (3), (4), (5)
lower infralittoral zone buildings : (6), (7)
circalittoral zone buildings : (7).

The following figure (Fig. 1) gives an idea of the vertical range of these biologic buildings in the Mediterranean.

THE *LITHOPHYLLUM LICHENOIDES* RIM

This is a well known feature in the western Mediterranean basin, its structure has been extensively studied in the last thirty years (PICARD, 1954 ; BLANC & MOLINIER, 1955 and others) and it has been successively referred to as « trottoir à *Tenarea* », « trottoir à *Lithothamnion* », or « trottoir à *Lithophyllum tortuosum* ».

Zonation

This is the highest biogenic building in the Mediterranean, it is always found a little over the main sea level, in the so called *midlittoral zone* (or surf zone). This means that when the sea is calm in the more or less tideless western Mediterranean basin, it stands almost completely out of water.

The rim is limited to places where the exposure to surf is strong, but not exceedingly so. It is best developped on coasts exposed to prevailing winds, in coves, fends or crannies open to the surf. Since the dominant factor is the mean wave energy on a year-round scale, the actual height of the rim above sea level is variable : in places of strong exposure it is generally higher and thicker than in calmer localities.

Biological agent

From a structural point of wiew, the rim is monospecific and entirely made of the calcified thalli of a red alga *Lithophyllum lichenoides (Rhodophyta, Corallinaceae)*.

Structure

The morphology of the rim varies from a simple coating to a wide steplike rim. In the latter case it may consist of a wide overhanging cornice with a flat or slightly depressed upper surface, up to two metres wide, ending in a salient rim with a vertical face.

In some cases two facing cornices may coalesce and bridge over a fend in the rock or even over a small embayment.

The inner structure is complex (Fig. 2) and shows at least three different layers :

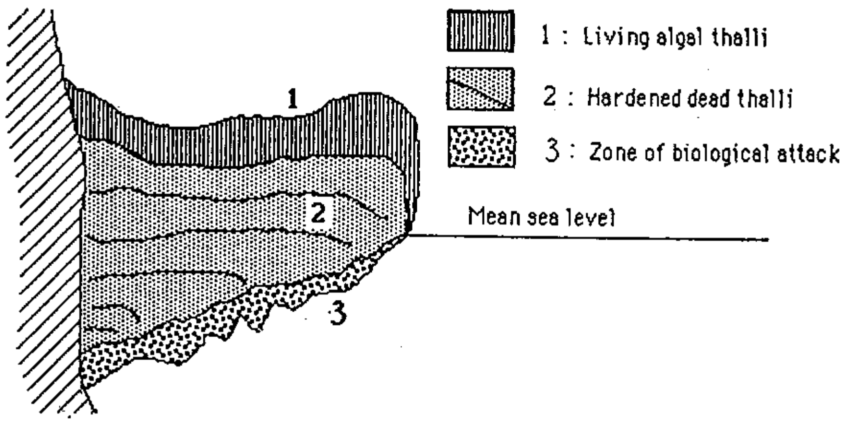

Fig. 2 : Structure of the *Lithophyllum lichenoides* rim (LABOREL *et al.*, 1983)

— a porous outer layer (1), made of the living thalli of the coralline alga, this layer is only some inches deep and limited to the upper surface and outer face of the rim. — Under the living layer a hardened zone (2) of variable thickness is to be found, which is the result of complex biological (vertical growth) and geological (diagenesis, cementation) phenomena. This hard zone is often multi-layered, a structure which probably originates from periodic dessication and death of algal thalli, due to long periods of exposure to air in conditions of stable high atmospheric pressure (anticyclonic conditions) (LABOREL *et al.*, 1983).

— The lower surface of the rim is dead and more or less covered by shade loving (sciaphilous) assemblages of algae and invertebrates, including various rock boring species such as Clionid sponges and boring mussels *(Lithophaga)* the action of which results in a more or less intense biological erosion (3).

The relative thickness of the latter three zones is variable according to the place of growth, local wave energy and geological history of the littoral where it develops.

Geographical range

The *Lithophyllum lichenoides* rim is a common feature along the coasts of the western mediterranean basin (although isolated thalli of the alga may also be found out of that area, notably the coasts of Portugal and Gulf of Biscay) but it seems to be absent from the eastern mediterranean basin where many previous descriptions of « trottoir à *Lithophyllum* » are due to confusing with vermetid-algal rims or erosional benches.

Well developed rims are known from the coasts of Spain, littoral France (Marseilles, coast of Var and Alpes maritimes including the islands of Port Cros, Porquerolles, Le Levant and Corsica), Sardinia, western Italy and Sicily, and North Africa. A detailed survey is yet to be made but few very important « trottoirs » (exceeding a width of one metre) are presently known, except in the island of Porquerolles at « Le Grand Langoustier » (PICARD, 1954), and now dead (Fig. 13) and on the western coast of Corsica, south of Calvi, at Punta Palazzu.

THE ALGAL-VERMETID PLATFORMS AND REEFS

First described in Sicily in 1854 by the French biologist Henry DE QUATREFAGES, these formations were later reviewed by PERES & PICARD (1952), BLANC & MOLINIER (1955), and later compared with tropical reef formations by KEMPF & LABOREL (1968) and SAFRIEL (1974).

Biological agents

The platform is partly built by the close association of two species : a Vermetid Gastropod, *Dendropoma (Novastoa) petraeum* (Monterosato) often referred to in biological papers as *Vermetus cristatus* and a coralline Alga : *Neogoniolithon notarisi* (Dufour) Setchell & Mason. These two species are completed by a number of epiphytic and endolithic species among which the sessile Foraminifer *Miniacina miniacea* plays an important part as a cavity filler. The relative ratio of the two main components is highly variable, following the degree of exposure to surf. In conditions of high energy, Vermetids are abundant whereas they tend to disappear in low energy stituations. In the latter case pure *Neogoniolithon* formations are to be found, as it is the case in the sheltered hypersaline waters of Bahiret el Bibane, Tunisia (THORNTON *et al.*, 1978, DENIZOT *et al.*, 1981).

Zonation

The upper surface of vermetid-algal formations is more or less dry at low tide or in very calm weather, but always at a lower level than the *Lithophyllum lichenoides* rim. This difference may be seen clealy whenever the two types of formations coexist (in Corsica for example), the thalli of *Lithophyllum* growing at the summit of the Vermetid rim or slightly higher. From a biological point of wiew, the surface of the Vermetid-algal rim marks the upper limit of the infralittoral zone and may be considered as a *remarkable biological marker of mean sea level* (FEVRET & SANLAVILLE, 1966) the interest of which for tracing ancient shorelines will be emphasised in a later paragraph.

Structure

The morphology is highly variable and three types at least are currently met with.

a) the *bench or platform type,* which is is a more or less wide platform, extending at sea level and covered by shallow pools, a few centimetres deep. Observation of the platform shows that the latter is not built-up by marine organisms but that it is generally an **erosion form** cut into the rock itself (sandstone, soft limestone or shales). At the edge of the platform lies the biogenic structure iself, under the form of a more or less thick rim. The latter may be a complex structure, suported by short pillars and enclosing small cavities. The upper surface and sides are often covered by brown algae, mostly *Cystoseira.* This is the commonest form in Corsica, Spain, Sicily and North Africa (MOLINIER & PICARD, 1594 *a, b*) (Fig. 3, 14).

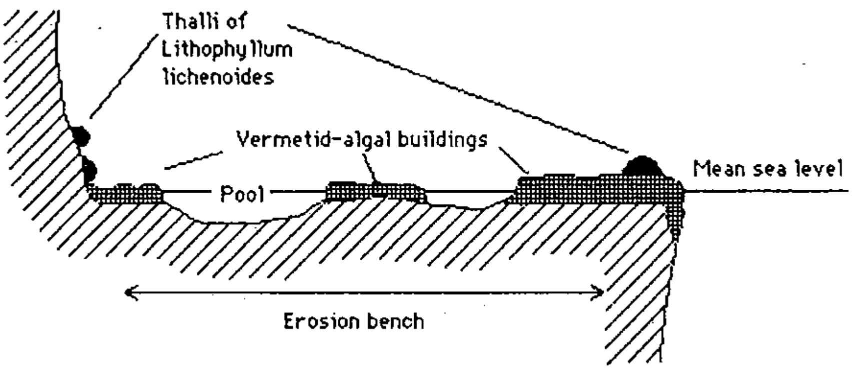

Fig. 3 : Vermetid-algal rim (from BLANC, MOLINIER, 1955)

b) *the « atoll » type,* is a common form in the eastern mediterranean basin, notably in Crete (KELLETAT, 1979) and Israel (SAFRIEL, 1974).

Fig. 4 : Vermetid-algal « atoll » on the coasts of Israël and northern Crete. From SAFRIEL (1974) and KELLETAT (1979).

In the latter type, a complex combination of constructive and erosive forces lead to the formation of an annular structure with a built-up rim and hollowed « lagoon », which is very near the famous « boilers » of Bermuda islands (KEMPF & LABOREL, 1968; SAFRIEL, 1974) (Fig. 4). It is known from the warmer parts of the Mediterranean basin only.

c) *the « cornice » type,* was described from Corsica by Roger MOLINIER (1955 *a* and *b,* 1960). It is the simplest form of all, a mere horizontal bourrelet running along a vertical cliff and looking very much like a low lying *Lithophyllum lichenoides* cornice. In the latter case the basement is a hard volcanic or crystalline rock and erosive forces are not at work.

Inner structure

It is dominated by the brown coiled tubes of the Vermetid gastropod and the chalky white compact thalli of *Neogoniolithon,* with occasional pink « flakes » of *Miniacina* : it is generally impossible to make any mistake with other types of biological buildings. In very rare occasions mixed structures were observed with superposed layers of *Lithophyllum* and *Dendropoma* : these all were fossil forms corresponding to a sudden change in sea level (THOMMERET *et al.*, 1981).

Geographical range

The Vermetid-algal formation is a typical warm water component of the mediterranean landscape. Its associated fauna and flora show a high proportion of tropical genera and the biogenic formation itself is very near the « algal ridge » of tropical coral reefs. According to these tropical features, vermetid algal formations are found in the warmest parts of the Mediterranean, excluding the continental coasts of the Gulf of Lion (Northern coast of Spain, french continental coasts, northern coasts of Italy at least down to the latitude of Roma). On the corsican coasts, its distribution is patchy and the cornices are always small owing to a mixture of cold and warm influences. Best developed formations are known from Sicily, Tunisia (MOLINIER & PICARD, 1953, 1954), and the whole eastern basin (notably Crete, Lebanon and Israel) (KELLETAT, 1979 ; FEVRET & SANLAVILLE, 1966 ; SAFRIEL, 1974).

OYSTER-VERMETID FORMATIONS FROM SOUTHEASTERN TURKEY

An interesting formation, here described for the first time is that of mixed Vermetid *cum.* Oysters biostromes recently found by the author off the southeastern coast of Turkey between Cevlik and Samandaj, two small sities situated near the mouth of river Orontes.

These biologic structures are very limited in range but show distinctive characters which make them unique among the mediterranean biconstructions. They were unfortunately dead at the place where we described them and no sign exists that they could still be alive in other parts of that region.

Description

The bedrock was a succession of beds of soft Miocene limestones including rhodolites and rolled corals and outcrops of hard green ophiolites.

The region is tectonically active and was struck by important earthquakes in early byzantine time (THOMMERET *et al.*, 1981), resulting in noticeable elevation of the shoreline. A set of three different lines of biogenic buildings are thus to be seen at 0, + 0,60 and + 2,6 m. The lower line corresponds to present times and the two upper to tectonic episodes now subject to isotopic datation. Unifortunately, the line corresponding to present sea level seems to be dead everywhere along the 10-15 kilomètres of coast. I could survey during my visit. The cause of that demise may probably be correlated with the building of a littoral road, resulting in heavy siltation along the coast.

Morphology and structure

Since our survey was done during the windy season we had no opportunity of studying in detail the dead lower line; but we had sufficient access to the two elevated lines in order to sample them thoroughly and study their outer and inner structure which appear markedly different from all other formations known in the mediterranean.

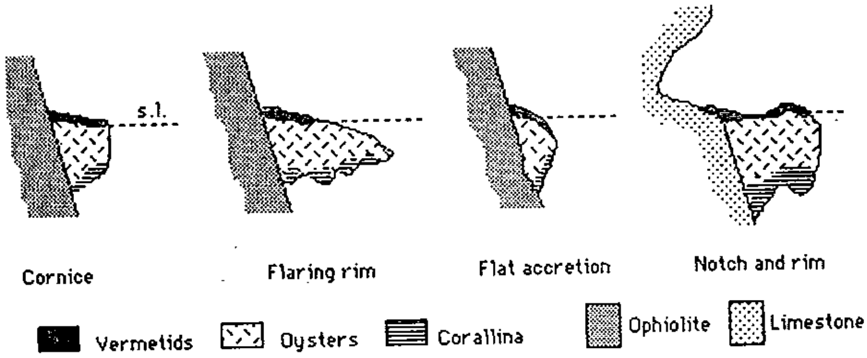

Fig. 5 : Variation of profile and structure of vermetid-oyster formations (original).

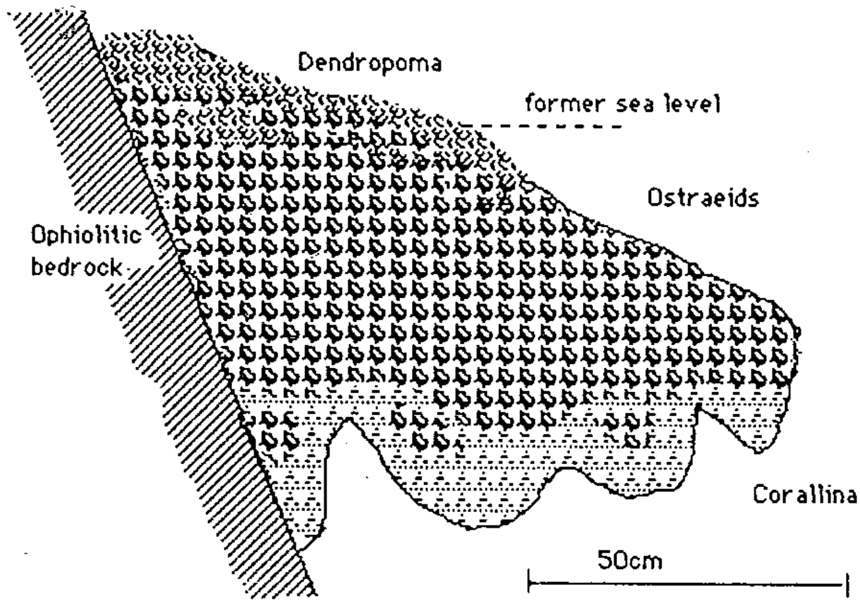

Fig. 6 : Section through a Vermetid-oyester rim (original).

The lines are thick (0,5 to 1 + metre) and visor shaped with an outwardly flaring upper surface. In some places they may also clad the rock with a thick crust one metre high and 0,3 m wide (Fig. 5, 16).

Breaking the rock reveals the composite nature of the formation : The upper part is formed by a dense monospecific gowth of vermetids *(Dendropoma petraeum)* which are remarkably free of calcareous algae (Fig. 6). Under the Vermetids and intermingling with them occurs a dense layer of small oysters the growth of which is responsible for the flaring profile of the rim. For the time beeing, these oysters have not been determined, but they present some characteristics of *Hyotissa* *hyotis* (L), a species presently unknown in the mediterranean region (P. ARNAUD, pers. comm.). The lower part of the rim is hard and shaped like short stalactites made of *Corallina*.

Biology-Ecology

Although the biological study is hampered by the apparent lack of living formations, a fair account of the structural development may be given by studying the lower elevated rim which is in a very good state of preservation.

First to install themselves on the rocky surface were the oysters, rapidly forming a thick veneer on the rock. Oyster shells are small (2-3 cm) and harly pressed against one another, voids between shells are filled up by an uncalcified sandy matrix.

After the development of the oyster rim, its upper part was covered by a thin crust of *Dendropoma* whereas the lower surface suported a dense growth of shade loving *Corallina*.

The importance of the inner, unconsolidated, sandy matrix inside the oyster rock, the very small development of calcareous algae associated with Vermetids, as well as the localization in a restricted zone around the mouth of the river Orontes show to evidence that mixed vemetid/oyster formations are not open-sea biological constructions but need the presence of a fresh water component.

The most interesting fact is that the oysters have developed at a lower level than the Vermetids, in the infralittoral zone. Such a fact is unknown among all oyster reefs known, in the Mediterranean as well as in tropical waters, the latter developing generally at a level higher than Vermetids, i.e. in the midlittoral zone.

THE *CORALLINA* RIM

Discovered in Corsica by MOLINIER (1955), this interesting and often spectacular building has never yet been surveyed in the Mediterranean and may have been overlooked in many places despite its interest.

Biological agent

As implied by its name the *Corallina* im is built by the basal layers of an otherwise erect and articulate coralline Alga : *Corallina elongata* Other algal and animal components may also be met with such as *Lithothamnium lenormandi* and *Miniacina miniacea*.

Zonation

The *Corallina* rim is not so strictly linked to the surface as the two preceding types of biogenic buildings and it may be found from just under sea level down to several metres deep. It is a shade loving formation, occuring on vertical or overhanging cliffs, in shaded places, mostly crevices and narrow embayments.

Structure

The morphology is simple : in many cases the *Corallina* formations are set as a series of horizontal ridges of variable length often parallel to an overlaying cornice of *Lithophyllum lichenoides* (Fig. 5). But the rims may be so short as to be more or less spheroidal fist-sized formations.

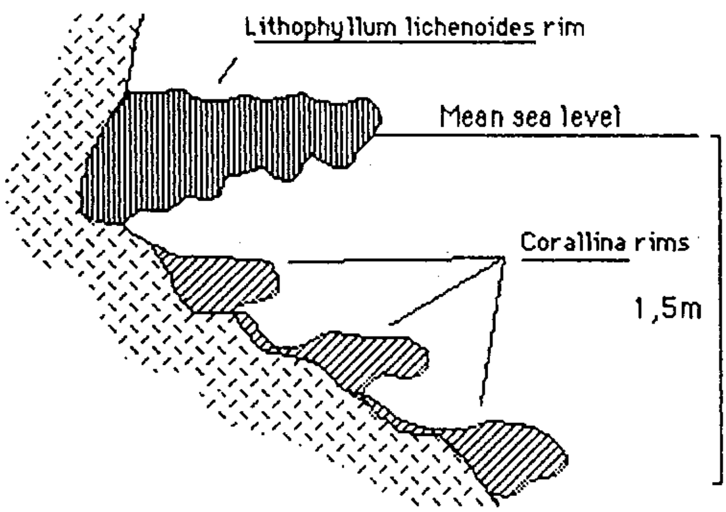

Fig. 7 : *Corallina* rims, Porticciolo, Corsica. From BLANC and MOLINIER (1955)

Inner structure

It is simple and compact : a hard laminated algal structure with numerous pink skeletons of *Miniacina*, some barnacles, Bryozoa and so on. But its main interest is that a living *Corallina* rim may often conceal (and protect from erosion) *a fossil core of Lithophyllum lichenoides*, marking an ancient sea level (LABOREL *et al.*, 1983) hence the great archeological interest of that litle known and often overlooked formation.

Geographical range

In the absence of a general survey at the mediterranean scale the range of *Corallina* rims is presently limited to Corsica and continental coasts of France. But there is a strong probability that it might be found in the whole western mediterranean basin and maybe in parts of the eastern Mediterranean as well.

THE *LITHOPHYLLUM INCRUSTANS* RIM

A little known and poorly developed formation of minor importance, it must be quoted altogether since, as the latter type it may conceal a core of fossil *Lithophyllum lichenoides* rim.

Biological agent

Lithophyllum incrustans is a pale purplish brown coralline alga which may develop in pools or on rocky surfaces. The thalli are often coalescent and build small size constructions in many place including outside the mediterranean area.

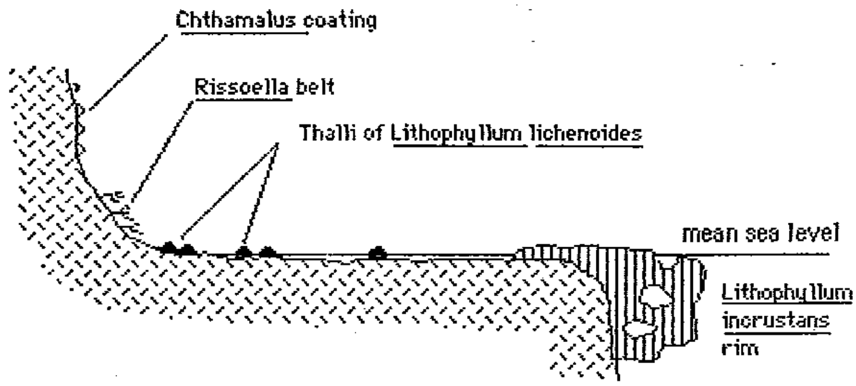

Fig. 8 : Rim of *Lithophyllum incrustans*, Farinole, northern Corsica, from BLANC and MOLINIER (1955).

Zonation

At the upper part of the infralittoral zone and down to several metres deep, mostly under shady overhangs.

Structure

There is no typical growth form for that small sized type of building : thick corniced formations have been described by MOLINIER (Fig. 8), but in many cases small fist-sized growth forms have been observed in well-lit conditions. The algal thalli make the bulk of the calcareous mass but other species such as the vermetid *Vermetus triqueter* and barnacles are also present.

Geographical range

The typical place of description (MOLINIER, 1955) is the North of Corsica, but smaller, still undescribed forms of that type have been observed in Port-Cros National Park and other places in the western mediterranean basin.

INFRALITTORAL SERPULID REEFS

These are very poorly known, with only fragmentary descriptions in the biological litterature. Some of them may even have been confused with vermetid formations. At least two different types have been described : euryhaline serpulid rims from open sea conditions and polyhaline « reefs » of hypersaline lagoons.

Biological agent

Several serpulid species are said to take part in the building of the « balcons de Serpulidés divers » (PERES & PICARD, 1952). As for the hypersaline reefs, those of the Tunis lagoon are made by the serpulid *Mercierella enigmatica* (HELDT, 1944).

Zonation

All serpulid formations are comprised between the surface and 15 metres deep.

Structure

The structure and morphology are very diverse : open water types seem to build unstable and poorly cemented cornices in very calm and sheltered situations, the *Mercierella* reefs, on the contrary are able to build large atoll-like structures several tens of metres wide, but easily destroyed by waves or by biological erosion.

Geographical range

Open water forms were described from western Corsica (Ile Rousse) and Marseilles by PERES and PICARD but no survey or recent work on these apparently rare and unstable formations was made following their initial description ; lagoon forms are known from the lake of Tunis and other mediterranean lagoons.

BANKS OF *CLADOCORA CESPITOSA*

These are extremely interesting formations since they are unique in the Mediterranean to be built by a true reef-coral (hermatypic Scleractinian coral) and to be related to true coral banks of tropical seas.

Biological agent

The Scleractinian *Cladocora caespitosa* Linneus is a bushy coral, made of many parallel branches, each with one calice at the tip (dendroid form). The tissues of the polyps are brown and loaded with numerous symbiotic Zooxanthellae. Since *Cladocora* possesses both principal characters of hermatypic corals : zooxanthellae and the possibility of building reefs, it may be classified as such without hesitation.

Cladocora caespitosa is an endemic mediterranean species tolerating relatively low winter temperatures, but its near-relative *Cladocora arbuscula* (Lesüeur) is a caribbean endemic which grows in similar conditions and may also take part in reef building processes.

Zonation

It is comparable with that of true reef corals : *Cladocora* may grow from just under the surface to some 25 metres deep. Corals may grow fixed on rocky substrates as well as free on soft substates, often associated with beds of *Posidonia oceanica*. Thus *Cladocora* banks clearly belong to the infralittoral zone of marine biologists.

Structure

Coral branches build big irregular masses (Fig. 17) which may fuse into banks several hundred metres wide. The surface of the bank is covered by the living polyps of the coral, green algae *Halimeda tuna*, *Udotea petiolata* and numerous species of Sponges.

Geographical range

Cladocora banks are only known presently from the gulf of Atalanti and the straits between Eubea and continental mainland (LABOREL, 1961). Isolated banks may be present in many places in the Egean but no survey other than a quick one has ever been made of these very original formations. In Tunisia, important dead banks of *Cladocora* are known which are now covered by siltation. In Corsica, dead coral masses of several metres diameter have been recently observed by us, covered and preserved from erosion by a thick incrustation of calcareous algae. A ^{14}C dating of these formations gave results ranging from 600 to 2400 years BP. As a matter of fact it appears that the present range of *Cladocora* in the Mediterranean may have shrunk recently compared with is fossil distribution. Ancient wrecks have been found resting on a pavement of silted coral colonies in places where the species is presently represented by scarce small-sized coloneis (TAILLIEZ, 1967). Reasons for this improverishment are not known but might be linked with climatic or ecologic changes. It would be all the more interesting to make a complete survey of these exclusive mediterranean « reefs » since *Cladocora* is now a menaced species, both sensitive to pollution and extensively collected by divers.

« CORALLIGENE » ALGAL BANKS

First described and named by the french biologist MARION in the last years of the XIXth century, these biogenic formations, which have been mostly studied by french and italian biologists, are often overlooked or underestimated by english-speaking authors.

The world « coralligene » (sometimes traduced as « coralligenous ») although widely used (and notably by PERES *in* KINNE, 1982) is certainly misleading since it gives the false impression to refer to coral reefs and reef-building Scleractinian corals. This name was eventually given by MARION to calcareous algal formations in the cavities of which the Precious red coral *Corallium rubrum* is commonly found growing. The term of « coralligene » algal banks or coralgal banks might give a better account of these perticular mediterranean formations.

Biological agents

« Coralligene » algal banks are built by a relatively great number of species, among which the following few are important (HONG, 1980) :

Mesophyllum lichenoides (Ellis) Lemoine
Pseudolithophyllum expansum (Philippi) Lemoine
Pseudolithophyllum cabiochae Boudouresque & Verlaque
Neogoniolithon mamillosum (Hauck) Setchell & Mason
Peyssonellia rosa-marina Boudouresque & Denizot
Several other calcareous algae occur, belonging to the families *Corallinaceae* and *Peyssonelliaceae*.

The banks themselves, which may be several metres thick, are built by the algal thalli loosely overgrowing one another. Fixed animals also play their part in the building of the « coralligene » banks : most important beeing the Foraminifer *Miniacina miniaceae* along with many species of Bryozoa, some scleractinian corals, the precious red coral *Corallium rubrum*, and Serpulids. All these animal components live in the shade of the overthangs and crevices which are so characteristic of the banks. Many non-building algal and animal species (notably Sponges, Gorgonian corals. Annelids, Crustacea and so on) also occur in that remarkably rich biotope.

Zonation

« Coralligene » banks have been at first described (PICARD, 1954 ; LABOREL, 1961 ; PERES & PICARD, 1964) as exclusively belonging to the so-called circallitoral zone. In the Mediterranean sea, such a place in zonation means that « coralligene » banks should always occur clearly below the lower limit of *Posidonia* meadows.

Recent investigations (SARA, 1967-1969 ; HONG, 1980) have shown however that such formations may also occur in significantly shallower waters, and especially that rhizomes of *Posidonia* can be sometimes completely covered and smothered by the development of *Mesophyllum lichenoides,* which is the more light-loving (photophilous) species among the bank-building coralline algae.

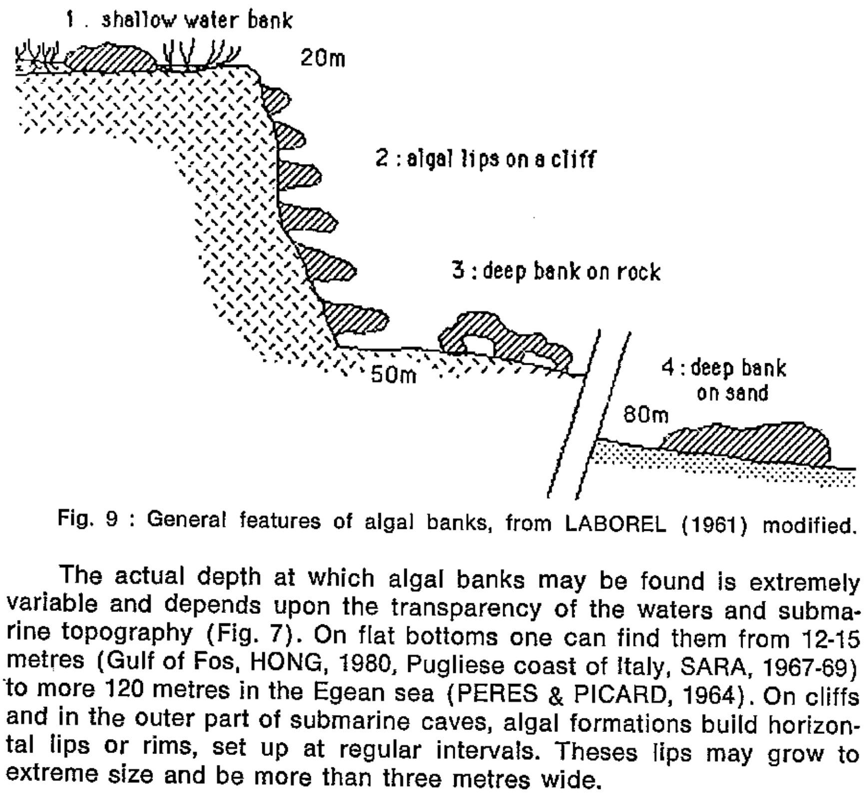

Fig. 9 : General features of algal banks, from LABOREL (1961) modified.

The actual depth at which algal banks may be found is extremely variable and depends upon the transparency of the waters and submarine topography (Fig. 7). On flat bottoms one can find them from 12-15 metres (Gulf of Fos, HONG, 1980, Pugliese coast of Italy, SARA, 1967-69) to more 120 metres in the Egean sea (PERES & PICARD, 1964). On cliffs and in the outer part of submarine caves, algal formations build horizontal lips or rims, set up at regular intervals. Theses lips may grow to extreme size and be more than three metres wide.

Structure

Morphology as well as inner structure are highly variable depending upon depth, topography and the nature of the prevailing building species (LABOREL, 1961).

banks : Shallow water *Mesophyllum lichenoides* built banks are generally flat or slightly rounded, with a light, foliaceous structure.

As the water deepens, the relative proportion of *Mesophyllum lichenoides* decreases and other algae develop. Banks are mostly flat structures with a thickness ranging from half a metre to 3 or even four metres when well developed. They are generally very cavernous, beeing excavated by boring organisms in all shaded places which are not coated by calcareous algae. These excavated parts generally bear shade-loving faunistical assemblages of which sponges and the precious coral *Corallium rubrum* are common components. The great development of cavities often leads to a very curious morphology of « undermined » banks, born by residual pillars.

Shallow water banks are generally covered with green algae *Halimeda tuna* and *Udotea petiolata*, which hide more or less completely the calcareous algae but, as the water deepens, the former species disappear and the surface-covering corallines appear. Figure 8 shows a typical bank in the relatively muddy waters of the south western shores of continental France in Banyuls (Pyrénées orientales), near the spanish border.

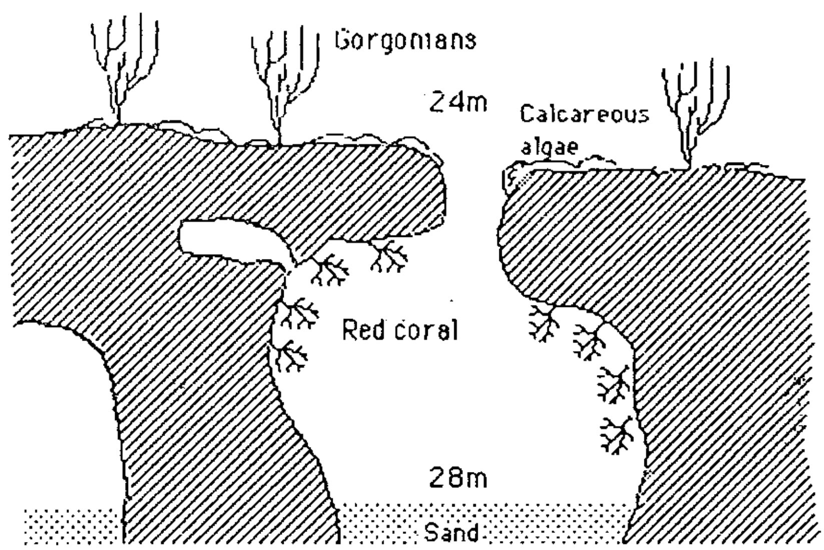

Fig. 10 : Section through an algal bank near Banyuls (France) (original).

In the eastern mediterranean, the lush growth of calcareous algae often presents the diver with spectacular landscapes, in which the algal thalli look like beautiful rosettes of pink china. In clear waters similar banks are commonly found from 40 to 70 metres down.

The structure of the deepest banks (lower than 70 metres) is poorly known. Since they are often surrounded by sandy bottoms, they were said (PERES & PICARD, 1954) to develop from the coalescence of free rolling algal thalli or rhodolithes (« coralligène de plateau » of french authors) at the difference of shallower formations which normally grow on top of rock surfaces. Further studies are neverthless necessary since it appears highly probable that many such deep banks have developed upon rock outcroppings.

Lips and rims are found in the outer part of marine caves and on vertical cliff faces and show a striking parallelism one to another. It seems that the regular periodic pattern of subequal horizontal rims of increasing width is produced by the growth of algal thalli in form of bracket-like horizontal colonies, bringing shade to the underlying surfaces, hence inhibiting algal deevlopment on the latter (Fig. 18).

The widening of the lips as depth increases was measured by me in Corsica : rim width on a vertical cliff was of 20-25 cm at 25 metres and grew to more than 2 metres at 45 metres, where rims were separated by intervalls of about one metre (Fig. 9, 11, 19). On deeper grounds (55-65 metres) rim width diminishes and lips tends to thicken and to fuse together (Fig. 20).

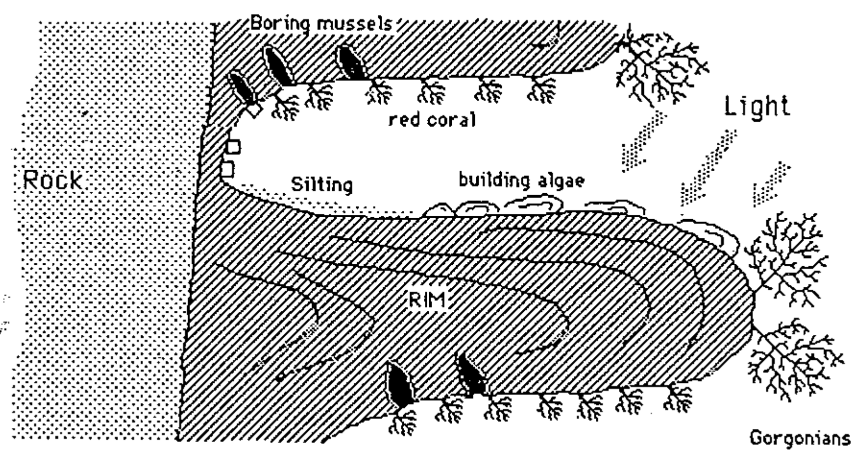

Fig. 11 : Profile of an algal rim on a submarine cliff.

Inner structure

The general complexity of « coralligene » algal formations is such that inner structure varies with such factors as depth, nature of the dominant species of bank building algae, abundance of sedimentation and the more or less important activity of rock-boring organisms (HONG, 1980). In the Egean sea the great development of sponges may sometimes lead to the development of mixed banks of low mechanical resistance which crumble easily (LABOREL, 1961) and may be compared with deep-reef formations off Jamaisa (LAND & GOREAU, 1970).

Coring inside « coralligene » banks has never been attempted at present time, but it may be an interesting subject of research in years to come. The presence of important inner voids and cavities makes algal banks an extremely rich and complex biotope, the fauna of which has been extensively studied (LAUBIER, 1965 ; HONG, 1980).

Geographical range

« Coralligene » banks are common all around the coasts of the Mediterranean, at the possible exception of those of Lebanon and Israel. Best developed formations are those of the Egean sea (LABOREL, 1961). Best studied are the banks of France, Corsica and eastern Italy.

BIOGENIC RIMS AND PAST SEA LEVEL

The fluctuating nature of sea level, although it was understood only recently, is now an important background for archaeological studies in the Mediterranean. Variations of sea level have been active for millenia, a slow but powerful surf, driving whole civilizations in its wake. If wide-scale fluctuations are now more or less documented, small-scale displacements of the shoreline are not always easy to trace and need combined studies by several kinds of specialists.

In that respect, the presence of eroded remains of biogenic rims above or under the present water line is a great asset : they may be conspicuous or not, but they are generally easy to date by means of radiochronometry, giving an accurate determination of corresponding past levels and, last but not least, they are often found on rocky coasts where other types of markers (sedimentological, archaeological and so on) are difficult to find.

Several types of biogenic buildings were used for that purpose : mostly Vermetid rims (FEVRET & SANLAVILLE, 1966, for Lebanon, THOMMERET *et al.*, 1983, for Crete) and *Lithophyllum lichenoides* rim (LABOREL *et al.*, 1983) for french continental and corsican coasts. Deeper living *Cladocora* and « coralligene » banks have been little used, since they canot give a good accuracy for the estimation of sea levels, but they may be used someday for paleoclimatical studies, with the help of isotopic methods.

The results of all these studies may give important hints about general elevation of the sea level in the past millenia as well as about tectonic or volcanic movements, sometimes associated with earthquakes (as in Crete : THOMMERET *et al.*, 1983). This may be of important concern regarding coast stability and future risks upon littoral cities.

Unfortunately there has been no general survey for biological sea level remains in the Mediterranean except regional studies for a limited number of coasts.

BIOGENIC CONSTRUCTIONS AS NATURAL MONUMENTS

The concept of natural monument is not a recent one, but it is presently developing and taking a wider extension. A natural monument must be something spectacular, of course, but, as our understanding of our planet grows, this concept tends to get more subtle and I think that many remarkable littoral or underwater sceneries may be called a natural monument.

As our knowledge of mediterranean shores extends, many remarkable phenomena may be observed, which were completely unknown some years before and which now are worth protecting and visiting : among these are some of the more developed among the biogenic constructions in that region.

Unfortunately no general survey has ever been made of places which merit to be classified as « natural monuments », and if some of the more beautiful sites are already protected because they are situated inside Parks or Natural Reserves, many others are unsuspected and may be destroyed or spoiled without anybody taking notice as was the

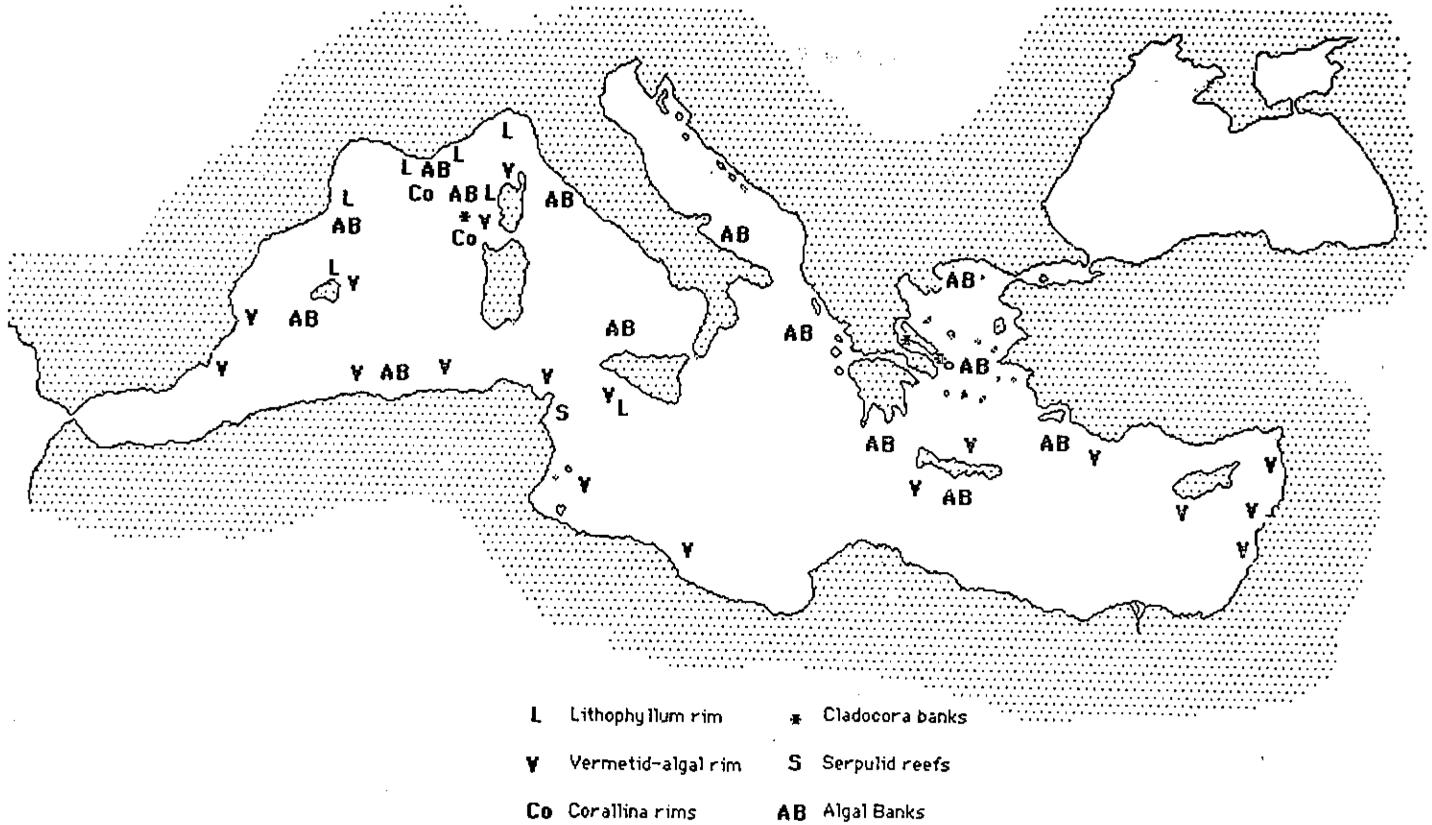

Fig. 12 : General repartition of biogenic buildings in the Mediterranean.

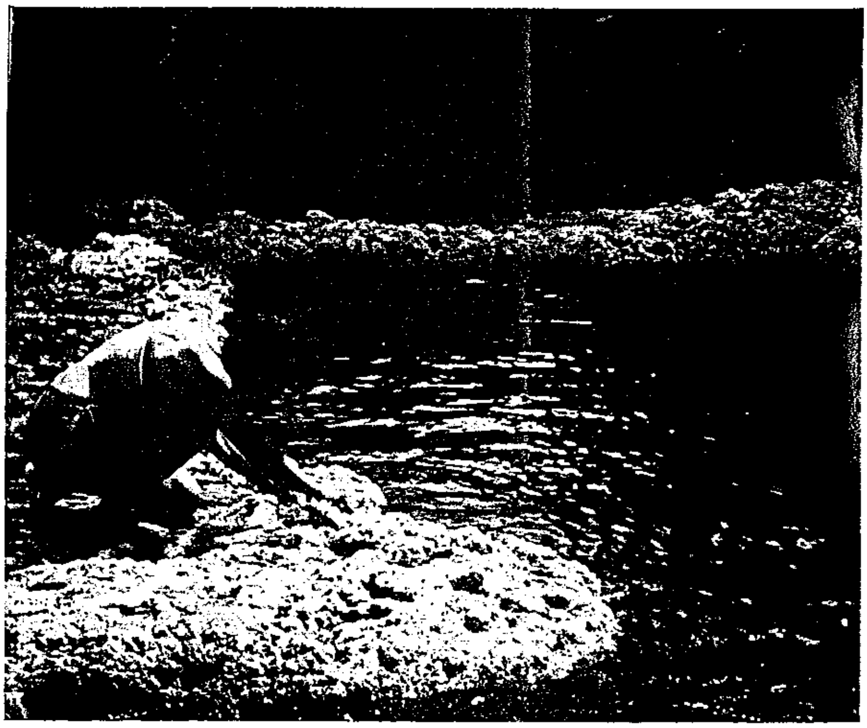

Fig. 13 : Image of a lost splendor : this beautiful rim was alive on the island of Porquerolles (Var, France) when this photograph was taken in June 1955. It has been killed since by polluted surface waters coming from the sewers of the city of Toulon, a few miles to the west

Image d'un passé récent : ce splendide trottoir se développait sur l'île de Porquerolles (Var, France) lors de la prise de cette photo, en juin 1955. Les eaux polluées en provenance des émissaires de Toulon, situés quelques milles à l'ouest, l'ont tué depuis.

Photo J. LABOREL.

case recently for the beautiful *Lithophyllum lichenoides* rims on the french island of Porquerolles which were killed by surface water pollution (Fig. 13), and for vermetid ridges in northern Corsica which were smothered by detrital sands from a neighboring asbestos mine (Fig. 14).

It is thus necessary to begin an international enquiry at the scale of the mediterranean basin, in order to complete our knowledge of these exceptional places and to try to put them under proper protection.

Some « biogenic natural monuments » in the mediterranean

I shall not try here to present an exhaustive list, which is of course prematurate, but to give some examples of sites that have already been described and may be worth protecting. Generally speaking these formations are scarce and extent on a limited area.

Obviously enough, vast extents of coasts in many mediterranean countries have not been covered yet but I do hope that the few examples I quote here will help to realize that the survey is worth doing.

Fig. 14 : A fine example of Vermetid reef at Albo, northern Corsica in 1956. This reef was smothered and killed by sediments from an asbestos mine.

Un bel exemple de trottoir construit à Vermets dans le Cap Corse ; Marine d'Albo, Corse du Nord. Cette formation, photographiée en 1956 a été tuée et recouverte par des sables en provenance d'une exploitation d'amiante.

Photo J. LABOREL.

The *Lithophyllum* rim at Punta Palazzu, Regional Park of Corsica

This is a remarkably beautiful place and natural formation, albeit completely unknown from the visitors of the Park. The site is a narrow canyon-like indentation, 100 m long and 5 to 30 metres wide, cut into reddish volcanic cliffs.

On the vertical walls of the crevice, a lush growth of calcareous algae has created a continuous pavement-like rim which attains a maximum width of more than two metres, slightly over sea level. The rims on both sides are so developed that they bridge the chasm over at its narrowest part. The surface of the rim is covered by palm-sized cushions of light purplish algal thalli hard and brittle as chinaware, which contrast strongly with the red walls and the deep of the water. No description of the place has yet been published, but the study of underwater, vestigial rims allowed us to find and date traces of several past sea levels, going back to the Antiquity and the Bronze Age.

The site is located inside the Marine Reserve of Scandola, and is of difficult access, since surf may prevent entering the crevice for weeks and the sole access possible is by small boat. It is thus well protected from anthropic interactions, but is strongly exposed to the accumulation of wind-drifting refuse and spills which may accumulate for weeks in the crevice.

Fig. 15 : A fine of fossil Vermetid reefs in Western Crete. These reefs were uplifted following a violent earthquake 1550 years ago.

Ligne de récifs à Vermets surélevée de la côte occidentale de Crète. Ces formations ont été soulevées à la suite d'un tremblement de terre, il y a 1550 ans.
Photo P. PIRAZZOLI.

Algal-Vermetid platforms at Torre del Isola (Sicily)

These platforms were discovered by the french naturalist A. de QUATREFAGES in 1854 who interpreted them erroneously as massive vermetid buildings. They have been described by MOLINIER & PICARD (1953) and it seems that no further study was made in recent years. From the brief description and photographs given by the latter authors it appears that the length and width of these platforms is somewhat remarkable.

Since the place is relatively far from Palermo, in a rocky environment of difficult access (J. PICARD pers. comm.), there is a reasonable possibility that these very remarkable vermetid platforms have not disappeared recently under the influence of pollution or human activities. It should then be interesting to make a new survey with the help of italian scientists and to ask for a protection of the site.

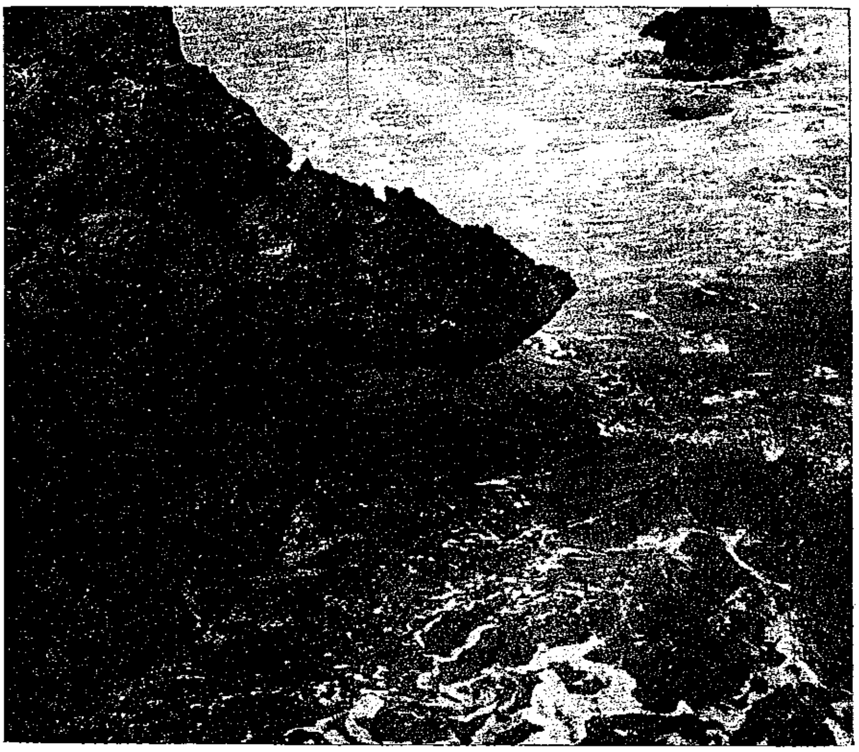

Fig. 16 : First photograph of a mixed Vermetid and Oysters reef in eastern Turkey (Cevlik). The flaringrim is dead and tectonically uplifted at + 0,60 m, it was carbon dated 2040 years BP. The lower rim corresponding with the present sea-level has been killed by road-building operations.

Première photo d'une formation mixte à Vermets et Huîtres des côtes Sud Est de Turquie (Cevlik). Le large surplomb supérieur est mort et soulevé, il a été daté de 2040 BP. Le bourrelet inférieur correspond au niveau marin actuel, il a été tué récemment par les travaux de construction d'une route côtière.

Photo J. LABOREL.

Vermetid platforms at Tipasa (Algeria)

These were also described by MOLINIER & PICARD (1953) but no recent study is available. They are built on the same model as those of Palermo with only small differences in the thickness of the algal vermetid layer. No photograph is known from these formations which are said (Dr J. PICARD pers. comm.) to be extensive and beautiful.

Vermetid platforms at Mikhmoret and Shikmona (Israel)

These were described by SAFRIEL, and are extensive vermetid rimmed eroded eolian platforms of some dozens metrés diameter (Mikhmoret) or rounded « microatolls » (Shikmona). They are certainly sufficiently developed to receive some kind of protection.

Vermetid platforms on the coast of Lebanon

They have been described recently by DALONGEVILLE (1977), and occur on a long stretch of the lebanese coast from Tyr north to Tripoli.

Associated with living platforms, many traces of ancient platforms corresponding to past sea levels elevated by recent tectonic activity have been described. Since the geographical range of these formations is wide (several hundred kilometres) and in the absence of more detailed descriptions it is presently not possible to select the more developed and interesting sites.

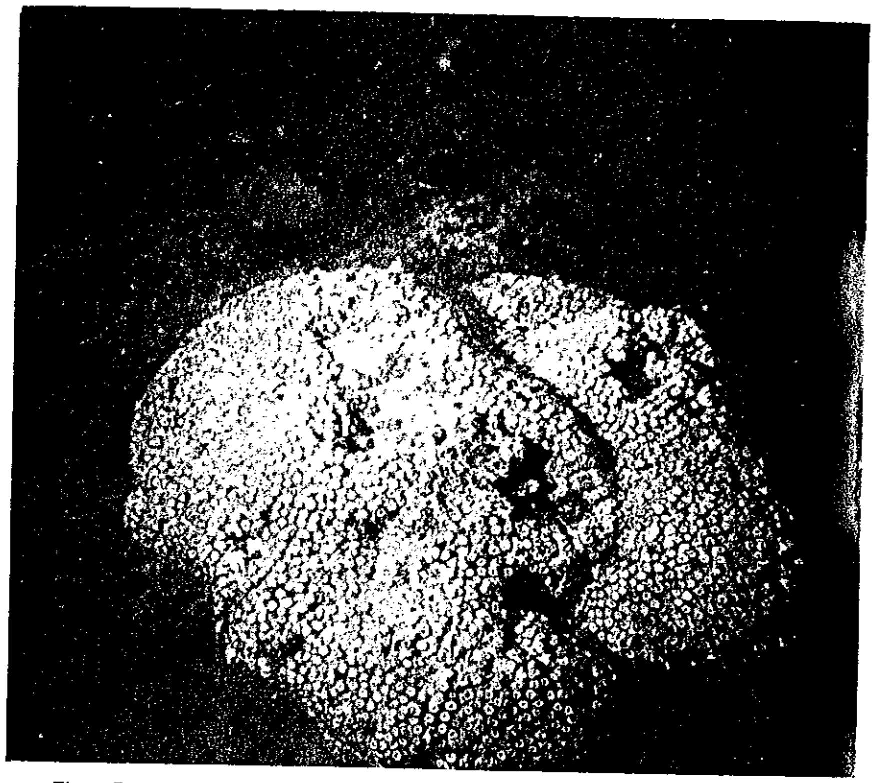

Fig. 17 : Large confluent heads of the scleractinian coral *Cladocora cespitosa* in Adriatic waters, 12m depth, Bari.

Une série de têtes confluentes du Madréporaire Cladocora cespitosa en Adriatique, Bari, 12 m.

Photo J. VACELET.

Algal rim at Bahiret el Bibane (Tunisia)

This closed bay lies on the south eastern tunisian shores, near the libyan border. Recent papers by THORNTON *et al.* (1978) and by DENIZOT *et al.* (1981) have described this very beautiful formation, which extends for about 30 kilometres on the inner side of a sandstone spit separating an hypersaline lagoon from the open sea.

The remarkable morphology of the algal formations include « atoll »-like algal patches, fusing into straight algal ridges. The biological component is mainly *Neogoniolithon notarisii,* a normal component of the algal-vermetid rims, but vermetids appear to lack completely.

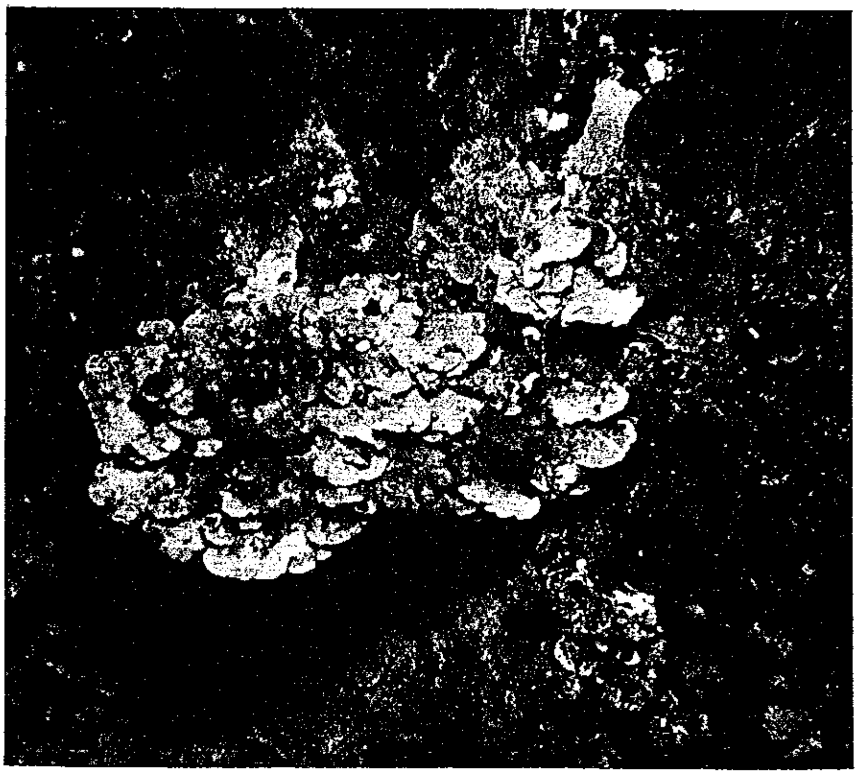

Fig. 18 : Incipient growth of flattened coralline algae developping on a vertical surface, Centuri, northern Corsica, 45 m.

Début de développement de thalles aplatis de Corallinacées coralligènes sur une falaise verticale. Centuri, Corse du Nord, 45 m.

Photo J. LABOREL.

The Bahiret el Bibane reefs may be interpreted as an impoverished vermetid-algal formation, in a very calm and hypersaline environment, it is at present a unique case with no other similar formation in the whole mediterranean basin and must certainly be protected and gain the status of natural monument.

Ancient shorelines and recent formations of western Crete (Greece)

The western shores of Crete appear to be remarkably interesting since the island of Crete has undergone a strong and sudden tectonic tilting some 1500 years ago, which left extensive parts of its shoreline dry, preserving event the slightest details of coastal morphology and marine life (THOMMERET *et al.*, 1981) (Fig. 15). Since very beautiful living vermetid platforms and « atolls » are also foud there (KELLETAT, 1979) it could be interesting for this island select a zone on its western coast for what could be a future Park.

The region of Falasarna should be ideal for that purpose since it contains three major elements of interest : i.e. : an elevated ancient city and harbour, very fine traces of complex elevated shorelines and beautiful vermetid « atolls ».

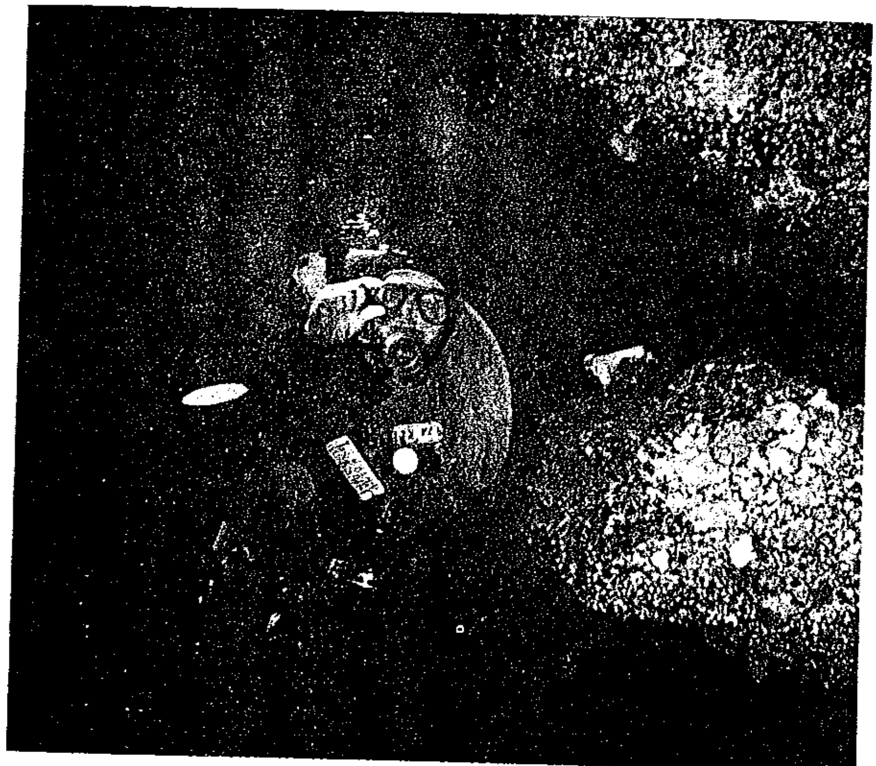

Fig. 19 : Large « coralligene » algal cornices, several metres wide, developping on a vertical cliff, Elbu bay, Scandola marine Reserve, Northern Corsica, 40 m.

Grandes corniches coralligènes, larges de plusieurs mètres, se développant sur paroi verticale, Baie d'Elbu, Réserve naturelle marine Scandola, Parc régional de Corse, Corse du Nord, 40 m.

Photo J. LABOREL.

Cladocora reefs in the Gulf of Atalanti (Greece)

Although not visible from the surface, these formations are unique in the Mediterranean and represent the only known case of what could be called a mediterranean coral reef. It seems interesting to promote a new survey with the help of greek scientists in order to select and protect at least a part of the gulf of Atalanti shores.

The « coralligenous » banks

Coralligenous formations are such a common feature in the Mediterranean that it is somewhat difficult to select interesting sites for protection. This is neverthless quite necessary since « coralligene » banks and rims build beautiful submarine landscapes, an important factor if one considers the forthcoming development of underwater touristic industry.

Many marine parks and reserves already include beautiful banks which are thus protected : this is notably the case of the french parks : Parc National de Port-Cros, Marine Reserve of Banyuls, and Marine Reserve of Scandola (Which is part of the Regional Park of Corsica).

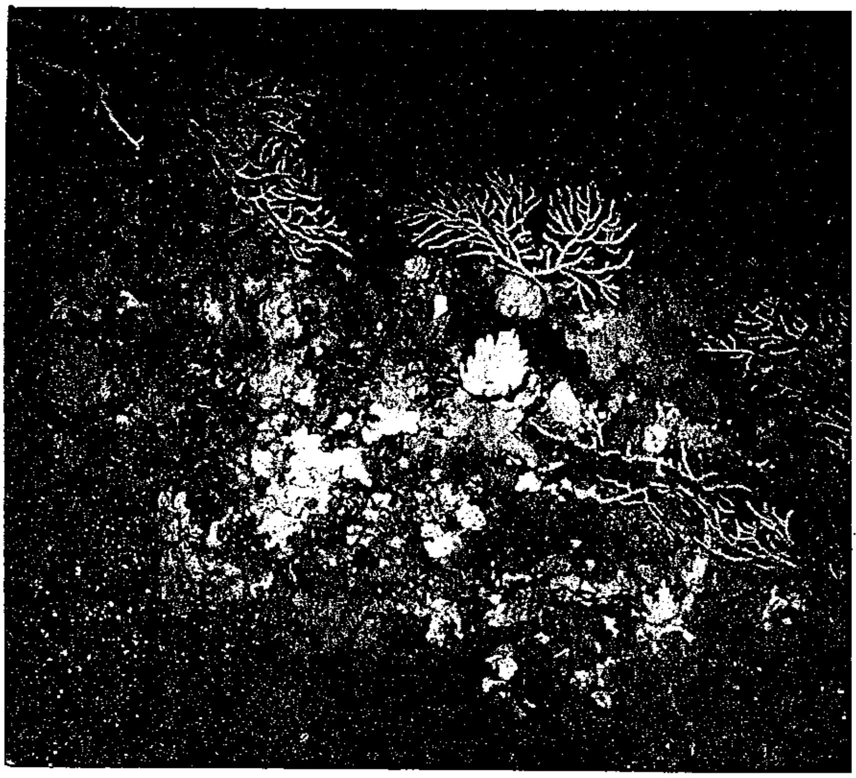

Fig. 20 : Lower surface of a deep algal bank, covered with sponges, sea whips and red coral, 60 m. Parc national de Port-Cros (Var, France).

Partie inférieure d'un banc coralligène profond, couverte de spongiaires, gorgones et corail rouge. 60 m. Parc national de Port-Cros, Var, France.

Photo J. LABOREL.

Many other fine sites exist on the mediterranean shores of continental France, notably in the region of Marseilles.

The absence of a general survey in the mediterranean area is a serious drawback and it will be necessary to launch an international inquiry. We already known that extensive and interesting banks have been studied on the italian side of the Adriatic (SARA, 1967-1969), but we known very few about spanish and north african shores. The most interesting region is of course the Egean sea (LABOREL, 1960, 1961) where remarkable zones could be easily picked out if a research program was established with Greek and Turkish scientists.

THE INFLUENCE OF MAN

It is sad to say that many sites, all around the Mediterranean, which were enthusiatically described in scientific papers 30 hears ago are now dead, dying or suffering excessive strain from pollution or from various impacts of man's activites. Particularly vulnerable to polluted surface waters are all types of littoral formations (notably *Lithophyllum* and Vermetids). Organic pollution, low salinity rainwaters, oil slicks, etc. are a constant menace for surface bioconstructions.

As an example the demise of a very wide and spectacular rim, more than 2m wide, on the island of Porquerolles (Var, France), has occured, unnoticed, during the last 20 years under the influence of untreated sewer waters drifting from the city of Toulon (Fig. 14).

Sediment laden waters, under the influence of developmental programs, such as building of littoral « touristic » roads may kill marine formations over large stretches of coast. : such seems to have been the fate of the original and interesting Vermetid-oyster rims of southeastern Turkey which could not be observed living. In norhtwester Corsica, fine vermetid formations have been killed and completely covered in recent years by sediments coming from the exploitation of asbestos (Fig. 16).

Even at depth pollution takes its toll : some beautiful algal bioconstructions have been found to disappear in polluted areas, under the influence of limestone eating clionid sponges, the development of which is enhanced by dissolved organic matter.

The aim of that paper is to help saving many beautiful formaitons which, if not preserved will disappear in a few years, sometimes before they have been scientifically described.

MANAGEMENT OF BIOGENIC CONSTRUCTIONS

It is too early to give a detailed account of what should be made to protect and to manage properly the more interesting biogenic consructions in the mediterranean region. It seems neverthless that the best protection and management possible is to include these sites into any kind of protected zone (National or Regional Park, Marine Reserve and so on). The extension and beauty of biogenic formations may be such that the latter might be considered as the main component (or core) of the Park : this is the case for extensive vermetid formations and possibly also for the *Cladocora* banks. In some other cases, extensive but otherwise common formations may be included into Parks of more general scope as is already the case for the french parks quoted here. This applies mainly for coralligenous banks.

Keeping pace with preservation measures it will be necessary to present the general public with some kind of written or diagrammatic explanations about the nature, the biological components and the morphology of biogenic buildings, and care should be taken to obtain a proper supervision of visitors since many types of biogenic formations are easily degraded by simply walking on them or taking « souvenir » samples. *If such precautions are not taken, protection will not only be unadequate but sites will be degraded which were naturally protected when they were unknown from the layman and far from beaten tracks.*

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