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Coralligenous "atolls": Discovery of a new morphotype in the Western Mediterranean Sea

Atolls de coralligène : découverte d'un nouveau morphotype en Méditerranée occidentale

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ABSTRACT

Coralligenous habitat and rhodoliths beds are very important in terms of biodiversity in the Mediterranean Sea. During an oceanographic campaign, carried out in northern Cap Corse, new coralligenous structures have been discovered. These structures, never previously identified in the Mediterranean Sea, are named "coralligenous atolls" because of their circular shape. The origin and growth dynamics of these atolls are still unknown but their form does not appear to result from hydrodynamic action and an anthropogenic origin also seems unlikely. However, this kind of shape seems rather closer to that of other circular structures (e.g. pockmarks) the origin of which is related to gaseous emissions. Further studies are needed to confirm this hypothesis through chemical analysis.
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RÉSUMÉ

Le coralligène et les associations à rhodolithes jouent un rôle important en termes de biodiversité en Méditerranée. Au cours d'une campagne océanographique, menée au nord du Cap Corse, de nouvelles structures coralligènes ont été découvertes. Ces structures, jamais identifiées en Méditerranée, sont appelées « atolls de coralligène » en raison de leur forme circulaire. L'origine et la dynamique de ces atolls sont encore inconnues mais leur forme ne semble pas résulter de l'action de l'hydrodynamisme et, une origine anthropique semble également peu probable. Néanmoins, ce type de forme semble proche de structures circulaires (e.g. *pockmarks*) dont l'origine est liée à des émissions de gaz. De nouvelles études sont nécessaires pour confirmer ces hypothèses et ce, notamment à travers l'analyse chimique de composés spécifiques.
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1. Introduction

Coralligenous habitat is considered as a typical underwater seascape and a high spot of biodiversity in the Mediterranean Sea. It consists of biogenic concretions mainly produced by accumulation of calcareous encrusting algae, growing in dim light [1].

The morphology and inner structure of coralligenous depends greatly on the depth, turbidity, topography, and nature of prevailing algal builders [2] and [1]. Two main morphologies have been described [3,4]:

- banks (flat frameworks with a variable thickness [0.5 to 4 m] and built on horizontal substrate);

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- rims (structures developed along vertical cliff with a thickness range of between 0.2 and 2 m).

The main species of the coralligenous assemblage belong to Corallinaceae and Peyssonneliaceae [1]. Coralligenous bottoms may occur on the sea-floor between –20 and –120 m [1,2,5,6]. They are common all around the Mediterranean coasts, with the possible exception of those of Lebanon and Israel [4].

Mediterranean rhodolith beds should be defined as sedimentary bottoms covered by a carpet of free-living calcareous algae (Corallinales or Peyssonneliaceae). They develop under dim light conditions and a high level of current [7,8]. In the Eastern Mediterranean, they occur down to depths of 180 m while in the Western Mediterranean they rarely occur below 90–100 m [8,9].

Although calcareous bio-concretions (coralligenous and rhodolith beds) seem to be well represented in the Mediterranean Sea, their true range of distribution is not well known [10] and is a major issue in the context of biodiversity conservation in the Mediterranean, as highlighted in the "action plan for the conservation of the Coralligenous and other calcareous bio-concretions in the Mediterranean Sea" [7]. In this context, two oceanographic cruises ("Capcoral" 1 and 2) were undertaken around Cap Corse (Northwestern Mediterranean) for the purpose of identifying and locating these calcareous bio-concretions, between 30 and 100 m of depth [11].

During these cruises, further investigations took place in an area characterized by the presence of seamounts.

2. Material and methods

The studied site is located between 25 and 30 km to the north of Cap Corse and covers an area of approximately 700 ha. The depth varies between –70 and –150 m (Fig. 1).

Acoustic data was collected during the "Capcoral 2" campaign conducted during summer 2011, aboard the Ifremer vessel, N/O L'Europe. Two complementary types of equipment were used:

- a multibeam echosounder (EM 1000™), providing continuous three-dimensional bathymetric data;
- a side-scan sonar (Klein 3000™), allowing identification of bottom types (texture, color).

The data obtained by means of these sensors was processed with the Caraibes 3.6® software program. The bathymetric data collected by the multibeam echosounder enabled us to develop a Digital Terrain Model (DTM). The data obtained by the side-scan sonar takes the form of sonograms assembled to make up a mosaic with a resolution of 0.5 m.

The identification of the sea bottom was validated by observation by using a "Remote Operated Vehicle" (ROV), and samples taken by means of a Van-Veen grab and a dredge. The use of a corer Kullenberg also provided

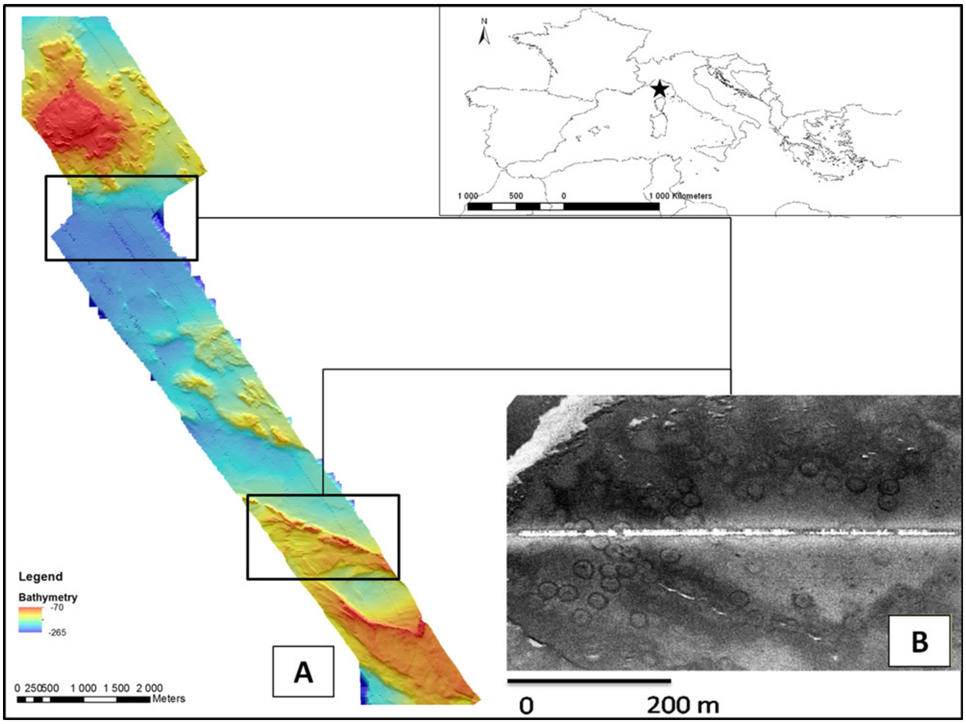

Fig. 1. Cap Corse seamounts (A), "coralligenous atoll", identified on sonographs (B).

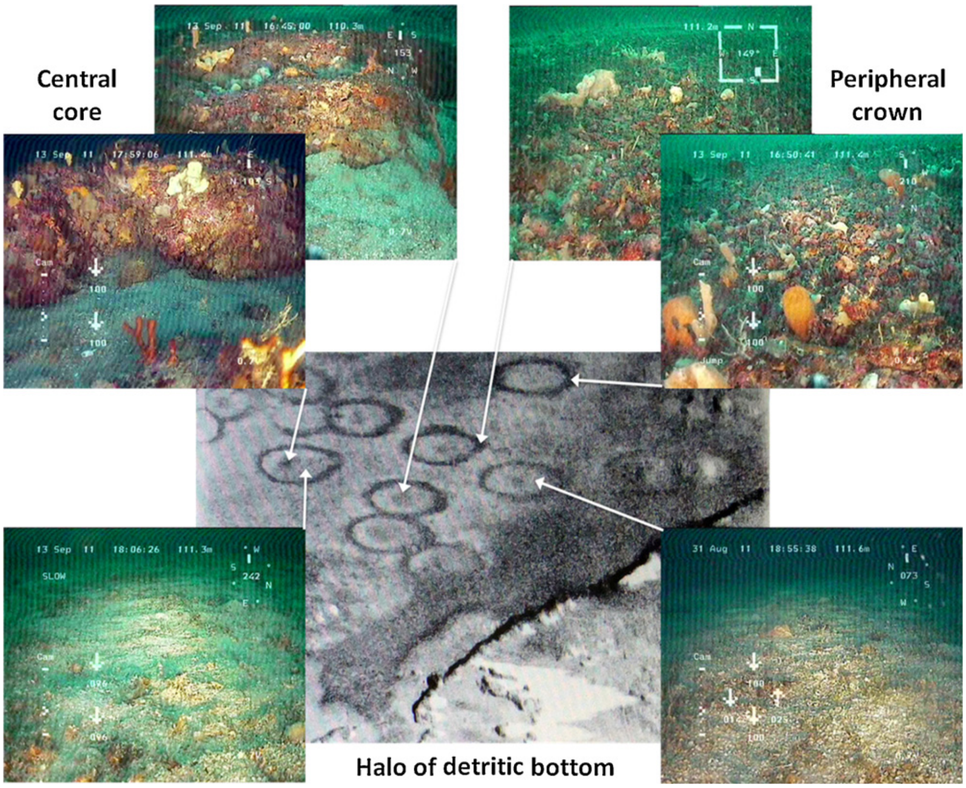

Fig. 2. Structure of ''coralligenous atolls'' in northern Cap Corse.

information on the composition of the underlying sediment layer (1.0 to 1.5 m thick).

The collected samples were studied in the laboratory: identification of the main species encountered, granulometric and calcimetric analyses.

All of the data was integrated in a Geographic Information System (GIS) ArcGis 9.3®, the framework used is the Mercator projection (based on WGS84).

3. Results

Several seamounts were highlighted in the study area (Fig. 1A); between 100 and 150 m depth, rising to 75 m below the surface. They are mainly colonized by coralligenous communities while their bases are surrounded by detritic bottom (coarse sediment with an average size of between 0.5 and 1 mm).

Among the soft bottoms, at depths ranging between 106 and 112 m, 200 to 300 structures, in the shape of ''atolls'', were identified on sonographs (Fig. 1B).

These ''atolls'' are visible in the form of dark circular structures, drawn on a soft bottom that may be of lighter color and, in the center, a dark core (Fig. 2). All these structures are of similar size (20 to 30 m).

Observations and samples in situ show:

- a massive central core constituted by a coralligenous structure (one to two meters in diameter and 0.2 to 0.5 m high);
- a halo of detritic bottom, about ten meters wide, with a high level of calcium carbonate (85 to 92 %), with a few sparse rhodoliths and a large amount of organic debris;
- a peripheral crown from one to three meters wide, consisting of a coralligenous structure, combined with free rhodoliths (pralines) and many invertebrates (including sponges, bryozoans and echinoderms; Fig. 2).

4. Discussion

The structures in the shape of ''atolls'' identified in this study have never been previously observed at the base of these formations nor apparently in any other sector of the Mediterranean Sea.

While these ''atoll'' structures can be described fairly accurately (Fig. 2), their origin and dynamics are more difficult to understand. However, their position and size are very similar, which suggests a common origin. Their bathymetric range also seems to be very similar (between 106 m and 112 m depth) and they are only observed at the foot of seamounts.

Around the Balearic Islands (Spain), Aguilar et al. [12] mention large bio-concretions forming round circles of around two meters in diameter and 10 to 20 cm high on the top of a seamount at depths of between 80 and 120 m. These structures appear to be similar to the ''central core of the atolls''; these authors offer no hypothesis concerning their origin, but stress that their existence probably dates back a long time. On the basis of the growth rate of the coralligenous (between 0.11 to 0.26 mm/yr; [6,13]), the age of these "cores" could be estimated at several thousand years. Their appearance would correspond to a time when the sea-level was a great deal lower [14,15].

The "middle halo" consists of detritic bottom which corresponds to a biocenosis well represented in this sector [11]. Its size and its calcium carbonate content (very high) are quite comparable to what is generally observed in this area [11,16].

The "peripheral crown" is a unique structure with a relatively constant diameter (between 20 and 30 m). While it consists of free-living rhodoliths, its form does not appear to result from hydrodynamic action (e.g. preferential accumulation in the ripple mark in [17,18], and an anthropogenic origin also seems unlikely). Circular structures may be observed in several regions of the world (New Scotland – Canada, Gulf of Mexico, Gulf of Guinea, Congo and Niger, North Sea; [19–22] as well as in the Mediterranean [23–25]). Some of these structures, located between –45 m and several hundred meters deep, are also identified as Marine Habitat Type in the EUNIS classification under the name of "pockmarks". They result from the interstitial biogenic exhaust gas or thermogenic gas deeper down [26] and they give rise, in sandy sediments, to circular or elliptical structures, which can reach a width of 10 m and a depth of one meter [27]. They have been reported in Spain [28], Malta [29] and Sicily [30] between 500 and 700 m depth. These methane-rich emissions seem to play an important role in the development of complex chemosynthetic biological communities (e.g. tubeworms, bivalves [31]). Thus, the chemical conditions near the vents (high concentrations of methane) appear to favor the growth of calcifying macrobiota [32], such as the calcareous algae *Mesophyllum alternans* species characteristic of coralligenous assemblages [33] and [1]. This gives rise to the provision of habitat by both calcite deposits and bioconstructional organisms, which would in turn increase species richness, creating secondary substratum for the settlement of encrusting organisms and numerous interstices and microcavities for the cryptic species [32].

Thus, questions regarding their origin remain to be solved. If the "pockmarks" hypothesis must be raised, certain differences should be noted. The coralligenous atolls are observed at shallower depths (106 to 112 m) and on a substrate coarser than those where the pockmarks are usually located (sandy-muddy) [34]. In addition, "pockmarks" form depressions related to the release of gas bubbles [35], and appear to differ in this respect from our atolls, where the core seems to be conic and built by concretions. Finally, the distribution of the coralligenous atolls appears to be regular while "pockmarks" are distributed randomly, and with a larger diameter.

It would be of interest to:

- check whether these coralligenous "atolls" are associated with the emission, current or past, of hydrothermal gas through chemical analysis of specific compounds (trace metals);
- collect fragments of coralligenous blocks in the central core of the atolls in order to:
  - make thin sections and characterize their internal structure (bio-concretion or other),
  - perform mineralogical analyses (presence of inorganic compounds such as pyrite or barite associated with carbonate precipitation in the case of gaseous emissions),
  - achieve isotopic dating of these structures;
- try to understand the structure of the under-underlying substrate (seismic analysis).

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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