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General palaeontology, systematics and evolution (Palaeobiogeography)

The Late Miocene coldspot of z-coral diversity in the Mediterranean: Patterns and causes

Le « point froid » de diversité des coraux symbiotiques au cours du Miocène supérieur en Méditerranée : patrons et causes

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A R T I C L E   I N F O

A B S T R A C T

The Late Miocene distribution and diversity of zooxanthellate-like corals in the Mediterranean are analyzed in their paleobiogeographical framework, using our REEFCORAL database. The Late Miocene Mediterranean pool reached 20 z-coral genera. Although this fauna could build flourishing reef ecosystems during the Early Messinian, it was a relict fauna with severely limited speciation that lived on the edge of its ecological requirements in terms of solar energy and temperature range. Most z-coral genera, because they had long stratigraphic ranges and had survived previous extinctions, were able to adapt to the Messinian environments, which were unusual for such biotas. Hence, *Porites*, the most widespread genus in the region and also the most dominant in ecological assemblages, was the best equipped to cope with the drastic changes related to the Messinian Salinity Crisis.

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R É S U M É

La distribution et la diversité des coraux symbiotiques méditerranéens au cours du Miocène supérieur sont analysées dans leur contexte paléobiogéographique, grâce à notre base de données REEFCORAL. Cette faune comprend 20 genres. Il est montré que la faune de coraux symbiotiques du Miocène supérieur méditerranéen, bien que capable d'édifier des écosystèmes récifaux florissants au cours du Messinien inférieur, correspond à une faune relique à spéciation fortement réduite et vivant à la limite de leurs exigences écologiques en termes d'éclairement et de température. La plupart des genres de coraux symbiotiques, grâce à leur large répartition stratigraphique dans la région, ont acquis une capacité d'adaptation à des conditions environnementales telles que celles du Messinien. Ainsi, *Porites*, le genre le plus répandu dans cette région et aussi le plus abondant dans les assemblages écologiques, était le mieux pourvu pour faire face aux importants changements environnementaux liés à la Crise de Salinité Messinienne.

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1. Introduction

Deciphering how regional diversity is linked to patterns of past taxonomic richness and its distribution in the area, and to ongoing adaptation of taxa to new and evolving environmental conditions, can be regarded as a major step towards an integrated understanding of the spatiotemporal framework in which the relationship between species richness and environment is embedded (Ricklefs, 2006, 2007). As a window on deep time, paleontology can explore such relationships on a variety of scales.

The low diversity of Late Miocene coral reefs and reef-coral assemblages in the Mediterranean region is well known and has been emphasized by many authors, becoming a typical feature of Late Miocene Mediterranean reefs (see Buchbinder, 1996; Chevalier, 1962a; Esteban, 1996; Esteban et al., 1996; Pedley, 1996a, 1996b; for reviews). Causes explaining this diversity have been implicitly linked to the increasing influence of abiotic conditions leading to the Mediterranean Messinian Salinity Crisis, favoring the influence of contemporary environment rather than the heritage of previous regional taxonomical richness.

In past decades, detailed descriptions and analyses of Messinian coral reef outcrops in the region have produced many data. These were accompanied by substantial improvements of our knowledge of Mediterranean paleogeography (Piller et al., 2007; Popov et al., 2004; Rögl, 1999; Sissingh, 2001) and the geodynamical context of the Messinian Salinity Crisis (Braga et al., 2006; Hüsing et al., 2010; Iaccarino and Bossio, 1999; Martín et al., 1989; van Assen et al., 2006). Synthetic works on the evolution of Cenozoic reefs on a global scale (Kiessling, 2006; Perrin, 2002; Perrin and Kiessling, 2010) have complemented those on Mediterranean z-corals during the Oligocene-Miocene (Bosellini and Perrin, 2008, 2010; Perrin and Bosellini, 2012).

The aim of this paper is to assess and discuss the diversity patterns of z-coral communities in the Mediterranean during the Late Miocene (Tortonian-Messinian) in the framework of the Mediterranean history including the Miocene geodynamical and climatic context, together with the Cenozoic evolution of scleractinian corals in the region.

2. Methodological approach and material

2.1. The REEFCORAL database

The REEFCORAL database (Bosellini and Perrin, 2008, 2010; Perrin and Bosellini, 2012) groups information relative to coral assemblages occurring in Oligocene and Miocene outcrops of the circum-Mediterranean area. This database comprises data extracted from three different sources: most of recent published literature, data provided by the study of coral collections in museums, in particular the collections of the MNHN in Paris, and our own coral collections. Stratigraphic data associated with each coral occurrences have been updated and homogenized and systematic revisions of some coral genera were done before entering information in the database. A symbiotic status was attributed to each genus following the uniformitarian approach discussed in Perrin and Bosellini (2012).

REEFCORAL currently provides information on more than 3200 coral occurrences from 332 localities in the circum-Mediterranean region. One hundred and fifty-eight genera are represented, 103 of them having a zooxanthellate or unknown symbiotic status (see details in Perrin and Bosellini (2012), Table 2, p. 6–7).

2.2. The Late Miocene dataset

The Late Miocene dataset comprises 20 coral genera, all of them with an unequivocal zooxanthellate-like symbotic status.

One hundred and fifty-three Upper Miocene localities are represented in REEFCORAL, including 83 in the Tortonian and 110 in the Messinian with 40 localities common to both stages. When the number of sites is weighted by the duration of each stage according to the 2012 Geological Time Scale (Gradstein et al., 2012), the number of z-coral localities per million years is three times more important in the Messinian than in the Tortonian, attesting to the prosperous expansion of z-coral communities during the Messinian, in particular during the lower part of this stage.

2.3. Biases and reliability

Three potential types of biases may affect the analysis of data extracted from the REEFCORAL database:

- biases related to spatial heterogeneity of data, with some areas potentially more investigated than others;
- temporal bias resulting from stratigraphic uncertainties and difficulties of dating with precision shallow-water carbonate rocks of this age;
- taxonomic bias, which in REEFCORAL has been minimized by homogenization of data and revision of some genera and also by considering coral genera rather than species, the latter being much more subjective than the first.

Biases have been already identified and discussed in previous papers (Bosellini and Perrin, 2008, 2010; Perrin and Bosellini, 2012). In addition, spatial and temporal heterogeneity of data has been analyzed in detail for the entire database (Oligocene-to-Miocene time interval) by Perrin and Bosellini (2012). In particular, the east-west disparity of data reported by these authors and due to a relative lack of data in the eastern regions, is also noticeable in the Late Miocene while the spatial disparity between the northern and southern margins of the Mediterranean Basin is less apparent for this interval than for the entire Oligocene-Miocene.

Finally, the two rarefaction curves established respectively for the Tortonian and Messinian z-coral genera (Fig. 1) show that the sampling size corresponding to data contained in REEFCORAL is significantly representative of the taxonomic richness in the Mediterranean region.