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High-frequency palaeoenvironmental fluctuations recorded in Jurassic coral- and sponge-microbialite bioconstructions

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Abstract

During the Jurassic, coral and sponge reefs were particularly widespread along the northwestern Tethys. These bioconstructions occurred from shallow- to deep-shelf settings, in pure carbonate, carbonate-dominated or clay-rich mixed carbonate-siliciclastic sedimentary contexts. According to the depositional environment, the amount of microbialites strongly fluctuates, to form up to 70% of the reef volume. This study focuses on bioconstructions where microbialites constitute at least 15% of the reef volume. Analysis of the close relationships between the reef structures and the stacking pattern of laterally-deposited sediments reveals analogous architectures and growth modes between coral- and sponge-microbialite bioconstructions. Firstly, corals or sponges erected a primary framework more or less projected above the sea floor (constratal or superstratal growth fabrics). Contemporaneously, a thin microbialite layer encrusted the local dead parts of corals or sponges. In a second stage, microbialites largely developed and entirely covered the reef surface, becoming the main reef builders. The whole development of coral- and sponge-microbialite reefs corresponds to a 'low-frequency reef-growth phase'. These bioconstructions also display surfaces of reef growth interruption delimiting 'medium-frequency reef-growth phases'. They include several 'high-frequency reef-growth phases' (or elementary units) corresponding to coral or sponge frameworks plus microbialite crusts. At the scale of the elementary unit, microbialites are interpreted to reflect nutrient-richer conditions and developed to the detriment of phototrophic-, mixed- or heterotrophic-dominated assemblages of corals or sponges. The development of Jurassic coral and sponge bioconstructions was punctuated by high-frequency (millennial time-scale) ecological crises during which microbialites occurred at the reef surface. Such ecological shifts from skeletal reef metazoans (i.e. corals or sponges) to microbialite crusts were recorded whatever the palaeogeographical position (shallow-proximal platform or deep-distal shelf) along the northwestern Tethys margin. Three main orders of climatic oscillations, correlated to the 'high-, medium- and low-frequency reef-growth phases', could have directly regulated the amount of terrigenous materials and nutrients delivered to the ocean, which in turn controlled platform carbonate production and accumulation, as well as reef development. ***To cite this article: N. Olivier et al., C. R. Palevol 6 (2007).***

Résumé

Fluctuations paléoenvironnementales à hautes fréquences enregistrées dans les récifs jurassiques à coraux ou à spongiaires riches en microbialites. Au Jurassique supérieur, la marge nord-téthysienne présentait une large extension des plates-formes carbonatées et mixtes, carbonatées-silicoclastiques. Des plates-formes proximales aux bassins épicontinentaux, les écosystèmes récifaux à coraux et à spongiaires étaient abondants. En fonction du milieu de dépôt, ces récifs peuvent être largement constitués de microbialites (jusqu'à 70% du volume récifal). Cette étude a été effectuée sur des bioconstructions composées au minimum de

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15% de microbialites. Les relations géométriques entre les structures bioconstruites et l'agencement des dépôts latéraux révèlent une architecture et un mode de développement analogues entre les récifs corallo- et spongio-microbialitiques. Les coraux ou les éponges édifient une structure primaire, plus ou moins élevée, au-dessus du fond marin (trame récifale constratale ou superstratale). Dans le même temps, une première couche microbialitique s'installe sur les parties nécrosées des madréporaires ou des spongiaires. Ensuite, les microbialites recouvrent largement l'intégralité de la structure bioconstruite. Les microbialites jouent alors un rôle édificateur majeur. La totalité de la bioconstruction est assimilée à une « phase de croissance récifale de basse fréquence ». Des surfaces majeures d'interruption de croissance délimitent des « phases de croissance récifale de moyenne fréquence ». Ces dernières sont composées de plusieurs « phases de croissance de haute fréquence » (ou unités élémentaires), correspondant à la succession entre une trame squelettique primaire (corallienne ou à éponges) et un encroûtement microbialitique. À l'échelle d'une unité élémentaire, le développement des microbialites, qui s'effectue au détriment des assemblages phototrophes, mixtes ou hétérotrophes de coraux ou d'éponges, est interprété comme reflétant une augmentation de la teneur en nutriments. Les récifs à coraux et à spongiaires riches en microbialites ont enregistré des crises écologiques à haute fréquence (à l'échelle de quelques milliers d'années), pendant lesquelles les microbialites se formaient à la surface de bioconstructions situées sur les plates-formes proximales, comme dans les bassins épicontinentaux. Trois principaux ordres d'oscillations climatiques, corrélés aux « phases de croissance récifale de basse, moyenne et haute fréquences », contrôlaient probablement la quantité de matériel terrigène et de nutriments déversés dans les océans, et du même coup le développement des récifs. ***Pour citer cet article : N. Olivier et al., C. R. Palevol 6 (2007).***

Keywords: Coral and sponge reefs; Microbialites; Nutrients; Accumulation rate; Palaeoenvironments; Jurassic

Mots clés : Récifs à coraux et à éponges ; Microbialites ; Nutriments ; Taux d'accumulation ; Paléoenvironnements ; Jurassique

1. Introduction

In the Recent, the presence of coral reefs reflects peculiar environmental conditions of marine waters (e.g., nutrient content, turbidity, light, water depth, temperature, and salinity; [22]). Modern coral reefs are very sensitive ecosystems with respect to environmental disturbances, notably pointing to a complex relationship between corals and algal–cyanobacterial benthic communities [40]. Since a decade or more, an increase of algae in coral ecosystems is evidenced, due to various natural and/or anthropogenic disturbances such as major storms, deforestation, or overfishing [21,24]. However, if carbonate precipitation of microbial mats frequently lead to the formation of microbialites in some Pleistocene and Holocene coral reefs [4,6], microbialites are only locally observed at the surface of modern coral bioconstructions [63]. Environmental changes and their frequency of occurrence, which could durably affect modern reef ecosystems and favour microbialite formation, are difficult to constrain at the scale of human observations. In this context, ancient reef systems are of first interest for understanding the behaviour of reef organisms in response to major environmental fluctuations.

In Late Jurassic oceans, coral and sponge bioconstructions were particularly abundant, forming a discontinuous reef belt over 7000 km along the northern Tethys and central Atlantic margins [39]. Late Jurassic times were also a period favourable to the formation of microbialites [58,67]. Coral reefs developed in relatively shallow and proximal settings, whereas sponge bioherms occurred in deeper environments [10,37]. Various proportions of microbialites commonly contributed to coral and sponge reefs, up to form pure microbial reefs [11,23,35,36]. The presence of surfaces of reef growth interruption shows that the development of Jurassic coral- and sponge-microbialite reefs was not continuous and probably recorded palaeoenvironmental fluctuations. Moreover, the two main reef components, skeletal metazoans (i.e. corals and sponges) and benthic microbial communities do not necessarily reflect the same palaeoenvironmental conditions. If the internal structure of sponge-microbialite bioherms has been intensively studied [16,17,48,51], detailed analysis of coral-microbialite reefs are only supported by rare studies [46,49,60] and comparative works on the architecture of these two types of bioconstructions is still lacking. Moreover, the understanding of the respective role of physical-chemical parameters that controlled Jurassic microbialite-rich reefs is still debated.

Based on a detailed analysis of Jurassic coral- and sponge-microbialite reefs from various depositional setting of France and Germany, this work (*i*) synthesizes and compares the growth modes of these two types of bioconstructions, and (*ii*) discusses the main palaeoenvironmental factors controlling reef development at the scale of the shelf.

2. Material

The analyzed bioconstructions correspond to Middle (Bajocian) and Upper (Oxfordian, Kimmeridgian) Juras-