

Environmental significance of microbialites in last deglacial reefs from Tahiti

Introduction

The last deglacial reefs from Tahiti (16 – 3 ka BP) are characterised by the abundant development of microbial fabrics, referred to as «microbialites» which were defined by Burne and Moore, 1987 as “organosedimentary deposits that have accreted as a result of a benthic microbial community trapping and binding detrital sediment and/or forming the locus of mineral precipitation”.

The occurrence of microbialites in last deglacial reef frameworks from Tahiti was firstly described by Montaggioni and Camoin (1993) followed by Camoin and Montaggioni (1994) and Camoin et al. (1999, 2006) in drill cores obtained by drilling the modern reef off Papeete and in samples dredged around Tahiti. Microbialites have been then reported in many Late Pleistocene to Holocene reef tracts from a number of areas (Zankl, 1993; Webb, 1996; Camoin et al., 1997, 2004; Cabioch et al., 1998, 1999, 2006; Webb et al., 1998). They have also been described from the walls of the deeper forereef slopes (Moore et al., 1976; James and Ginsburg, 1979; Land and Moore, 1980; Brachert and Dullo, 1991, 1994; Brachert, 1994; Dullo et al., 1998; Camoin et al., 2004, 2006) and in shallow-water caves (Macintyre, 1984; Zankl, 1993; Reitner, 1993; Reitner et al., 1995).

The understanding of microbialite development and their related sedimentological roles in the last deglacial reef frameworks from Tahiti is of prime importance both to constrain the controlling environmental factors and to unravel the evolution of reef framework architecture and growth patterns during the last deglacial sea-level rise.

The abundant material obtained through the drilling of the modern barrier reef off Papeete (Bard et al., 1996; Montaggioni et al., 1997; Camoin et al., 1999; Cabioch et al., 1999b) and of the successive terraces occurring on the modern reef slopes (IODP Expedition #310 “Tahiti Sea Level”; Expedition 310 Scientists, 2006; Camoin et al., 2007a,b) provides the opportunity to investigate the roles of microbialites in reef framework development, their growth patterns and habitats, and their environmental significance during the last deglacial sea-level rise. Furthermore, the Tahiti model might help in the understanding and the interpretation of the roles and environmental significance of microbialites that characterize reef buildups throughout the Phanerozoic (e.g. Jurassic - Leinfelder et al, 1993, 1996; Schmid, 1996; Olivier et al, 2003, 2008 – and Miocene - Riding et al, 1991; Braga et al, 1995).

The main objective of the proposed study is to better constrain the environmental conditions that controlled the widespread development of microbialites in those reef frameworks, and especially to analyse the trapping of volcanic material in microbial fabrics throughout the last deglacial reef sequence.

Methods

Radiometric dating: An accurate chronology of the microbialite development has been obtained through the radiometric dating of numerous triplets of contiguous corals, coralline algal crusts and microbialites from the Tiarei (18 corals, 10 coralline algae and 24 microbialites), Maraa (6 corals, 15 coralline algae and 22 microbialites) and Papeete (8 corals, 4 coralline algae and 8 microbialites) drill cores. Selected corals have been dated by radiocarbon AMS (Accelerated Mass Spectrometry) at ARTEMIS (Accélérateur pour la Recherche en sciences de la Terre, Environnement, Muséologie, Saclay, France). Coralline algae and microbialites (and 4 coral samples) have been dated by radiocarbon AMS at the MALT (Micro Analysis Laboratory, Tandem accelerator, The University of Tokyo, Japan). The graphitization method was employed to convert CO₂ extracted from samples into graphite, in the presence of H₂, using Fe powder as a catalyst (for more details on the method see Yokoyama et al., 2000, 2007 and Yokoyama and Esat, 2004).

ICP-analyses: An elemental analysis of the volcanic material trapped in microbialite crusts, especially concerning Si, Al, Fe, Ti and Mn, has been carried out on 43 samples (20 samples from Tiarei area and 23 samples from Maraa area) taken at various depths. This analysis was carried out on powdered sample of microbialite crusts (250 mg) which is fused with the Metaborate fusion method modified from Cantagrel and Pin (1994) and Germanique (1994). The samples are mixed with 500 mg of lithium metaborate (LiBO₂) in an open graphite crucible and fused for 30 mins in a muffle furnace at 1010°C. The hot melts are poured directly in 50 ml of HCl (2.4N). Solutions are stirred continuously until the dissolution of the shattered quenched melt droplets (about 30 min), before diluting to 100 ml with

deionised water. Solutions are then analysed with ICP-AES (Inductively coupled plasma – atomic emission spectrometry). Calibration is performed using geostandards: BE-N (basalt), AN-G (anorthosite), calcite (Euronorm-MRC n°701-1) and dolomite (Euronorm-MRC n°702-1).

Dissolutions: 20 microbialites samples were grinded and dissolved with diluted HCl solution. We weighted them before and after decalcification in order to quantify mass percentage of the residues (terrigenous grains). The residues are then analysed with XRD to determine their mineralogy. Before dissolution some microbialites were observed with SEM (scanning electron microscope).

Preliminary results

Radiocarbon dating of all reef components, including corals, coralline algae and microbialites provides the opportunity to reconstruct accurately the timing of microbialite development in reef frameworks. The offset between the growth of corallal assemblages and the development of microbialites ranges from 100 to 500 years (Searid et al, submitted). The offset values are relatively constant throughout the reef sequence implying a uniform microbialite development pattern in cryptic cavities of the corallal frameworks at some distance below the living reef surface. This offset implies that there was no direct space competition between those two communities. This could explain the apparent paradox of the coeval occurrence of oligotrophic zooxanthellate corals and microbialites which probably developed in nutrient-rich conditions (Camoin and Montaggioni, 1994; Camoin et al. 1999, 2006; Sprachta et al., 2001) in the Tahiti reef frameworks.

SEM observations of microbialite crusts show that detrital grains (carbonate and volcanic grains) are included in high-Mg calcite micritic matrix (Fig. 1). XRD measurements show that the trapped volcanoclastic grains are mainly pyroxenes (e.g. diopside) and in minor proportion feldspars (+iron oxides and pyrite). The mass percentage of volcanoclastic grains is higher in Tiarei (9 to 28%) than in Maraa area (0.7 to 3%). The trapping of small volcanic grains and clay minerals in microbialites indicates terrestrial sediment influx and river runoff, especially in the Tiarei area which is located in the vicinity of the Papenoo River, the main drainage of the island.

The concentrations of the elements: Si, Al, Fe, Ti and Mn are depending on the content of volcanoclastic grains trapped in microbial fabric. These concentrations are then dependent of the terrestrial sediment influx coming from the islands. The trace-element analyses results are shown in figure 1. Mn concentrations are very low for both sites (Tiarei: 190 to 820 ppm and Maraa: 0 to 140 ppm). The concentrations of all these elements are relatively higher in Tiarei (Si: 1.695 to 7.582 %; Al: 0.728 to 2.078%; Ti: 0.245 to 1.445% and Fe: 0 to 6.496%) than in Maraa area (Si: 0 to 0.537 %; Al: 0 to 0.441%; Ti: 0 to 0.226% and Fe: 0 to 0.860%). This is consistent with the sites characteristics as Tiarei drilled site is currently close to the main drainage of the island, the Papenoo River.

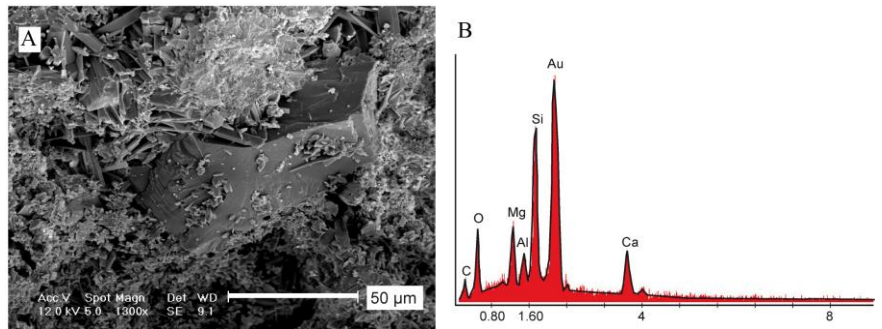


Figure 1: SEM photos of microbialites. (A) Microbial crusts with a trapped grain (~100 µm) whose elemental spectrum (B) shows that it is volcanic in origin. Before observations, samples were coated with thin layer of gold (Au).

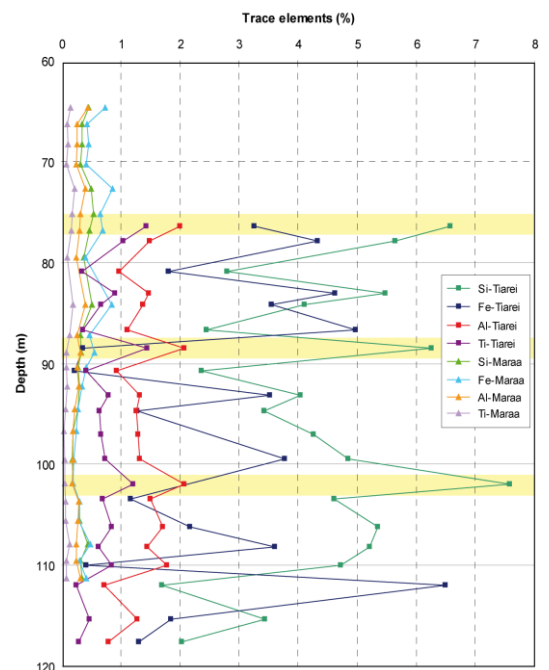


Figure 2: Evolution of trace element concentrations (Si, Fe, Al and Ti) through depth in Tiarei and Maraa areas.

The widespread development of microbialites in cryptic niches of reefs may be related to subtle fluctuations in ecological parameters, including in particular increased alkalinity and nutrient availability in interstitial waters (Camoin et al., 1999, 2006). Nutrient sources in interstitial waters may have different origins such as terrestrial ground water seepage and surface fluxes from adjacent rivers (Camoin et al., 1999). Our data, that indicate that an important amount of detrital material coming from the erosion of the island is trapped in microbial fabric, testify the influence of surface fluxes over the reef. These fluxes could have induced an increase in nutrient availability and alkalinity of interstitial reef waters, as the weathering of basalts and soils may lead to an increase of HCO_3^- and CO_3^{2-} concentrations. Periodic inputs of nutrient-rich and more alkaline waters in the vicinity of the reef may have therefore caused 'blooms' of microbial communities as it was reported in modern reef tracts (Sprachta et al., 2001), and enhanced CaCO_3 precipitation and calcification processes (Camoin et al., 1999). Because nutrients are rapidly taken up and incorporated by microbial organisms, the dissolved-nutrient levels may have remained low in surface waters and therefore did not significantly affect the overall reef growth (Camoin et al., 1999).

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