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Frutexites from microbial/metazoan bioconstructions of recent and Pleistocene marine caves (Sicily, Italy)

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ABSTRACT

Frutexites-like structures were recorded in small bioconstructions from Recent and Pleistocene marine caves. The skeletal/microbialite frameworks hosting Frutexites form in cryptic environments characterized by poor light availability and reduced water circulation leading to confinement, oligotrophic conditions and the development of typical cave communities. Biostalactites and biotic crusts develop in the more confined parts of the both Recent and Pleistocene caves. They are composed of skeletal organisms engulfed in fine micrite sediments deposited in situ via microbial metabolic activity. The Frutexites, composed of Iron and Manganese oxides, are confined to microcavities or microfractures of the bioconstructions. They grow from an original discontinuity surface into the surrounding consolidated micritic sediments. A model based on the increase of the microporosity of micritic sediments due to the dissolution of the original material and precipitation of ferromanganesiferous compounds was proposed. This process occurs during the syndepositional diagenetic stage due to the intrusion in the bioconstruction framework of acidic continental water rich in Iron and Manganese. Mesophilic Fe–Mn autotrophic and chemoheterotrophic bacteria flourish on the microcavities and induce the precipitation of Fe and Mn oxides.

1. Introduction

Metazoan–microbialite bioconstructions can be regarded as a particular confined facies of the dark cave biocoenosis. Metazoan–microbial associations are still relatively poorly known in present-day environments, but ongoing studies have revealed that they are more common in caves and in other extreme environments than previously thought (Rosso et al., 2013; Sanfilippo et al., 2015). Biostalactites formed by cryptic and sciaphilic dwellers and microbialite have been discussed from submarine caves in the Plemmirio Peninsula (Guido et al., 2013a, 2014; Sanfilippo et al., 2015). These rigid structures were synsedimentary lithified by clotted-peloidal microbial carbonate that has a high bacterial lipid biomarker content characterized by abundant compounds derived from sulfate-reducing bacteria (Guido et al., 2013a). Heterotrophic bacterial communities flourish in confined sectors of cave environments and can develop symbiotic relationships with skeletal organisms. A commensal association between polychaete worms, especially terebellids, and sulfate reducing bacteria has been reported in Recent marine caves (Guido et al., 2014).

A central problem for the study of microbial biomineralization concerns recognition of both the organisms and the processes involved. Carbonatogenesis represents the main biosignature to identify microbial activity in the carbonate fossil record. Fine grained lamination, clotted peloidal texture and aphanitic micrite are the leading fabric induced by microbial processes (Riding, 2000; Guido et al., 2012b, 2013b). Many other non-carbonate microstructures do not, or at least do not readily, preserve clear evidence of the organisms responsible for their formation. Most of these structures, and particularly Frutexites, have been linked to microbial processes but their origin and distribution in sedimentary environment are not yet clarified.

The term Frutexites was coined by Maslov (1960) in order to describe arborescent, finely laminated to opaque structures consisting of Iron and/or Manganese oxides and calcite. The term has been also referred to as ferruginous or manganiferous microstromatolites (e.g., Szulczewski, 1963; Hofmann, 1969; Horodyski, 1975). The actual mechanism of Frutexites formation is not well understood yet, and therefore abiotic, biotic, as well as coupled abiotic–biotic processes, have been proposed.

These structures remain a matter of controversy, as they have no obvious modern marine analogs (Jakubowicz et al., 2014). They have been described in marine environments like shallow and deep water stromatolites, microbial limestones, hardgrounds, condensed pelagic limestones as well as in cavities, sheet cracks, veins, and Neptunian dikes (Rodríguez-Martínez et al., 2011a). Furthermore they have been

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reported from alkaline lakes (Kazmierczak and Kempe, 2006; Kazmierczak et al., 2011), deserts (Krumbein and Jens, 1981), terrestrial caves and tunnels (Rodríguez-Martínez et al., 2011a) and hot springs (Chafetz et al., 1998). Further structures resembling Frutexites but lacking Fe- and Mn-enrichment have been described by Chafetz and Folk (1984) and Chafetz and Guidry (1999). The stratigraphic distribution of Frutexites from Proterozoic to Cretaceous marine carbonates (Hofmann, 1969; Mišík and Aubrecht, 2004; Reolid and Molina, 2010), and the various non-marine settings in which Frutexites-like structures have been reported so far, make the apparent lack of modern marine analogs difficult to explain.

The record of Frutexites is consistent with scarce light availability (Reolid and Nieto, 2010). Böhm and Brachert (1993) described Frutexites associated with stromatolite-like structures in aphotic environment and suggested a non-phototrophic behavior for Jurassic examples from Germany. Kazmierczak and Kempe (2006) registered Frutexites-like structures in modern shallow-water stromatolites growing in alkaline environments. A cryptobiontic lifestyle of the organisms originating Frutexites has been proposed by Myrow and Coniglio (1991), Böhm and Brachert (1993) and Cavalazzi et al. (2007).

Here we recognize small arborescent finely laminated to opaque Frutexites-like structures consisting of Iron and Manganese oxides as a

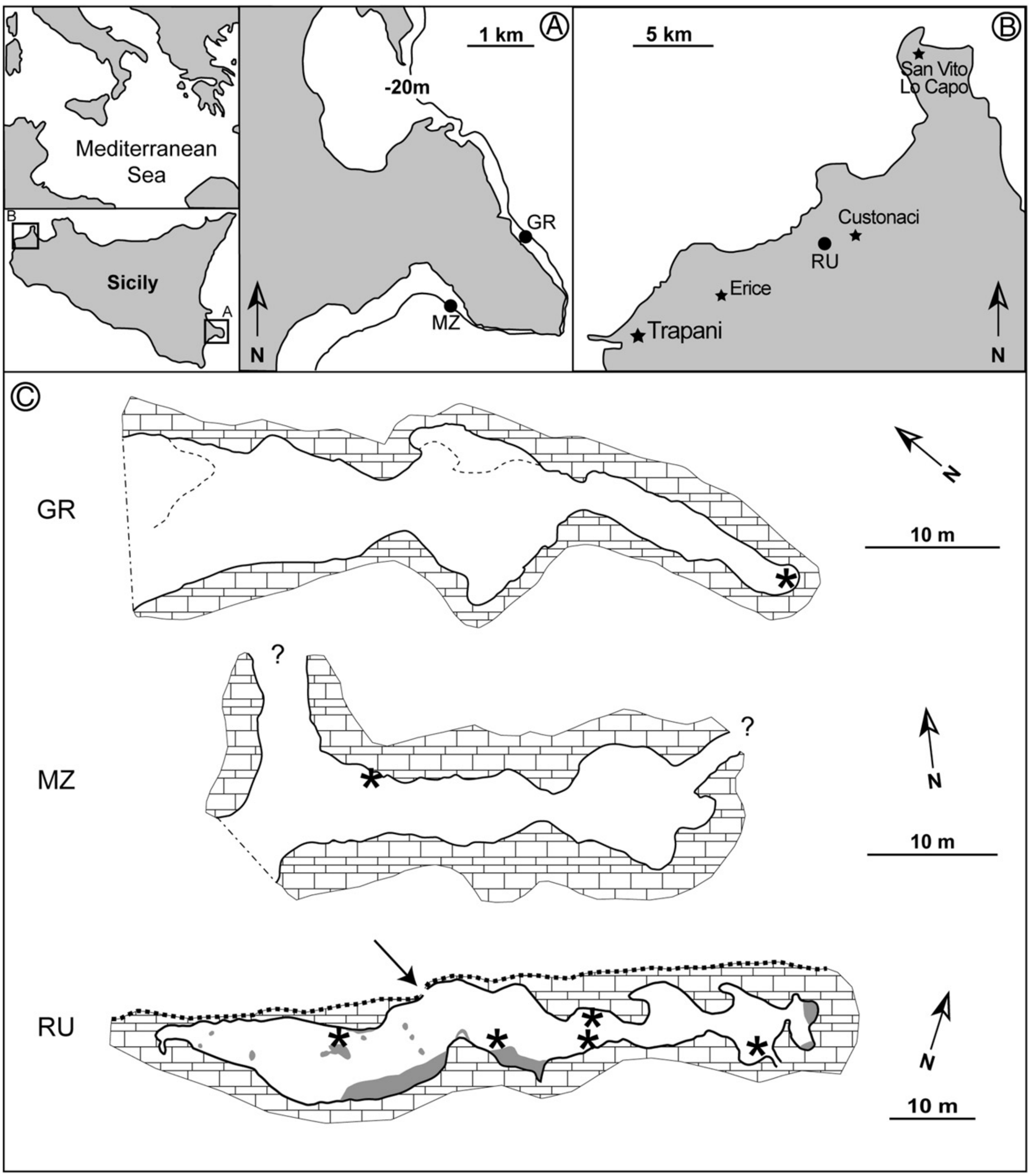

Fig. 1. Geographical location of the study areas. A) Plemmirio Marine Protected Area. B) Custonaci Area. C) Maps of the caves: (GR) Granchi cave and (MZ) Mazzere cave maps, from Rosso et al. (2012); (RU) Rumena cave map, in gray the main areas coated by karstic calcite, dotted line indicates the present-day cliff (from Ruggieri and Messina Panfalone, 2011). Asterisks: locations of the studied samples; question marks: unexplored areas. Present day openings are indicated by long dashed lines for GR and MZ caves ad by a short arrow for the RU cave.