ABSTRACT: Facies, fossils, morphology, laminar features, microstratigraphy, and composition of phosphate and iron-manganese nodules and crusts found in condensed limestones associated with stratigraphic discontinuity surfaces in Mesozoic successions of the Betic Cordillera of southern Spain, demonstrate that these structures are not diagenetic concretions, but bio- and sedimentary microbial accretions (stromatolites) that grew rhythmically at the sediment-water interface in pelagic environments. These structures accreted by bacterially mediated precipitation of authigenic minerals, by trapping and binding of fine-grained, pelagic, siliciclastic, and carbonate particles, and by encrustation of benthic foraminifera. SEM examination of stromatolite laminae reveals the presence of dense accumulation of spheroidal, ovoidal, and sausage-shaped strings of micrometer-sized bodies with a bacteria-like size and shape. XRD and microprobe (BSE and X-ray images) studies show the presence of authigenic minerals such as francolite, goethite, hematite, barite, pyrite, and glauconite, among others. Authigenic clays and complex poorly crystalline Fe-Mn-(Si) oxyhydroxides are always closely associated with these minerals. Marine authigenesis in stromatolites of the pelagic realm was achieved through microbially mediated synsedimentary precipitation of poorly crystalline or amorphous phases that preceded crystallization of the observed minerals. Deposition of fine-grained metals and silicate precipitates on bacterial surfaces favored preservation of microbial remains as external moulds. After degradation of bacterial organic matter, other components, such as francolite, nucleated within empty bacterial cells and other voids from bacterially precipitated amorphous precursors. Texture, mineralogy, and chemistry indicate the vertical and temporal evolution of the physicochemical conditions during the synsedimentary bacterial precipitation of amorphous precursors and the oscillations of the oxic-anoxic boundary (usually from oxic to anoxic conditions, although sometimes sulfidic conditions have been registered, allowing pyrite precipitation) during which the maturation of authigenic mineral phases took place. In conclusion, periods of very low sedimentation rate, now seen as sequence boundaries and/or transgressive surfaces in Mesozoic Alpine-Mediterranean palaeoenvironments, favored accretion of stromatolites in the pelagic realm and bacterially mediated precipitation of a wide spectrum of authigenic minerals that provide abundant information about paleoceanography, sedimentation, and early diagenesis in open marine mesozoic environments.

INTRODUCTION

The presence of phosphate-rich and iron-manganese-rich nodules and crusts is a common feature of condensed pelagic facies in the Mesozoic record of the Betic Cordillera (González-Donoso et al., 1983; García-Cervigón et al., 1986-1987; Martín-Algarra, 1987; Castro and Ruiz-Ortiz, 1991; Martín-Algarra and Vera, 1994; Vera and Martín-Algarra, 1994; Martín-Algarra and Sánchez-Navas, 1995; Nieto-Albert, 1997) and many other Alpine-mediterranean belts, such as the Alps (Bourbon, 1980; Föllmi, 1989; Delamette, 1990), Jura (Burkhalter, 1995), Apennines (Clari et al., 1995) and Sicily (Jenikyns, 1970, 1971), Carpathians (Krajewski, 1981, 1983, 1984), Dinarides (Wendt, 1973) and Hellenides (Pomoni-Papaioanou and Solakius, 1991; Pomoni-Papaioanou, 1994), as well as some condensed Mesozooic successions of Israel (Lewy, 1990; Soudry, 1994) and Oman (Blendinger, 1991), and many Paleozoic sites of the Variscan belt (Tucker, 1973, 1974; Wendt et al., 1984; Huckriede, 1996). These structures formed in moderately deep submarine plateaus and seamounts of tectonic and/or volcanic origin (pelagic swells) formed in distal regions of Paleozoic and especially Mesozoic tethysian palaeomargins (Jenikyns, 1978, 1986). They systematically concentrate in strongly condensed facies and stratigraphic discontinuity surfaces, which can be recognized in large areas.

These P-rich and Fe-Mn-rich structures sometimes have been considered ancient equivalents of phosphorite crusts and hardgrounds (Soudry, 1994; Föllmi, 1989, 1996, and references therein) and iron-manganese nodules of the modern deep ocean (Jenikyns, 1970, 1978). In spite of their systematic association with pelagic carbonate facies rich in planktonic-nektonic organisms (neritic, shallow water fossils always being absent), a detailed examination of the internal architecture of these crusts and nodules reveals that many are stromatolites because microbes actively participate in their accretion (see references above). These peculiar microbial accretions, formed in the pelagic realm, are mainly composed of typical marine authigenic minerals, such as francolite and Fe-Mn oxyhydroxides, with variable amounts of glauconite, pyrite, and other minerals. When they are studied in detail, it is possible to detect complex interactions between microbially controlled mechanical trapping and binding of pelagic, mainly fine-grained, bio- and siliciclastic particles, synsedimentary biominalization, and early to late diagenetic mineralization. Some common controls in the genesis of these structures can be recognized through study of P-rich and Fe-Mn-rich Jurassic-Cretaceous examples of different ages and sites in the Betic Cordillera. The aims of this paper are: (1) to illustrate, from selected examples, the main morphological, textural, and mineralogical features of such peculiar primary biosedimentary structures; (2) to discuss the role of microbes in the precipitation of authigenic mineral phases; (3) to present a general model for their accretion; and (4) to comment on some aspects of their paleoecographical significance.

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