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# Stromatolitic structures associated with sulfur-bearing limestones from the Miocene (Badenian) of the Carpathian Foredeep (S Poland)

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The Middle Badenian (Miocene) evaporitic unit is widespread in the Miocene of the Carpathian Foredeep (South Poland). The unit is predominated by sulfates (gypsum + anhydrite) and locally in the northern marginal part of the foredeep contains carbonate complexes up to 45 m thick. The carbonate series are lithologically heterogenous and change from clayey and marl interlayers through marly to pure limestones and may be either sulfur-bearing or barren limestones locally intercalated by sulfate beds and layers. The bulk of the limestones consist of more or less calcareous, either non-bedded or bedded, laminated or streaky mudstones. The series is locally intercalated by breccia, rudstone (nodular) and gypsum-ghost facies. A characteristic feature of the carbonate mudstones lithofacies is the presence of variously developed sparse, thin and finely laminated layers and small (up to few centimeters in height) domal forms clearly resembling stromatolitic structures. The laminated layers usually are up to about 20 cm, discontinuous (up to a few tens meters long) and occur in various stratigraphic positions. The structures reveal wavy or flat, thin and subtle lamination consisting of intercalation of discontinuous native sulfur and calcareous laminae. They are lacking of gypsum selenite relics. There are two kinds of laminae: 1) thicker ones composed of finer to coarser crystalline calcite, sometimes with various clay admixtures and 2) thinner, commonly more or less discontinuous composed of subtle, fine crystalline and pure native sulfur. The calcite laminae are commonly barren with microfossils. The native sulfur laminae are commonly re-crystallized but often contain honey-comb like structures and local pockets with variously preserved sulfur microbial remains. The microfossils are poorly preserved and include coccoid and filamentous remains. The microbial structures are locally associated with irregular patches of structureless amorphous material resembling mucilage associated with many recent microorganisms. The calcite laminae are characterized by variable [U+F064]18O values ranging in between -3.3 and -6.8%■ PDB and [U+F064]13C ones from -31.7 to -57.2%■ PDB. The native sulfur forming laminae has positive [U+F064]34S values changing from 4.6 to 17.2%■ CDT. Both the structural and isotopic data allow to interpret the stromatolitic structures as a result of microbial activity of syntropic sulfate-reducing and methanotrophic consortia + sulfide oxidizing bacteria. As it may be inferred from sedimentological and geochemical features of both the sulfur stromatolitic structures and associated sulfur-bearing limestones, the environment was generally shallow water, penesaline and euxinic, interrupted by meteoric influxes with precipitation of calcite and native sulfur, supply of both detrital and produced in situ organic matter. Such laminated structures have commonly been believed as a lithological equivalent of stromatolitic gypsum beds preserved due to massive replacement of solid gypsum by limestones and limestones + native sulfur. However, a more detailed comparison of geometry and distribution, sedimentological and petrologic features, as well as geochemical signatures accordingly exclude the native sulfur stromatolites as an analogue of the stromatolitic gypsum selenites. It argues against epigenetic replacement of solid sulfates and for syndepositional origin sulfur-bearing limestones.