EGU22-955, updated on 12 Aug 2022
https://doi.org/10.5194/egusphere-egu22-955
EGU General Assembly 2022

Taphonomy of early life: Role of organic and mineral interactions

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Biogenicity and taphonomy of the early life fossil records are debated as most of the previous studies focussed mainly on isotopes geochemistry. The non-metamorphosed Paleoproterozoic (~2.1 Ga) sedimentary succession of the Francevillian Basin (Gabon) contains the oldest complex multicellular organisms embedded in black shale facies. Several studies have confirmed the biogenicity of these soft-bodied organisms. Here, we used multi-proxy techniques to show that the preservation of these macro-organisms happened in a close system that limits interaction with their host rocks, which leads to their good preservations. The macro-organisms are present in different shapes and sizes: lobate (L), elongate (E), tubular (T), segmented (S), and circular (C), and are often associated with bacterial mats. Except for the C form, most of the other specimens are pyritized. Sulfur isotopes data confirms that pyritization occurred by bacterial sulfato-reduction during early diagenesis. We compare the clay mineral assemblages between the pyritized specimens and the late-diagenetically formed pure pyritized concretions in the sediments because the early pyritization process could not explain the taphonomic preservation alone. Our clay mineralogical data show that the specimens are dominated mainly by randomly mixed layer Illite-smectite (IS MLMs), illite, and chlorite relative to the host rocks. The abundance of IS MLMs indicates incomplete illitization of smectite, potassium deficiency, and limited mineral reactions in a semi-close local chemical system within the fossils. In addition, the authigenic chlorites are more iron-rich and show vermicular habitus. By contrast, the pyritized concretions mainly consist of well-crystallized illite and less iron-rich chlorite, while the smectite phases are absent. These results confirmed that the diagenetic reaction is controlled by interaction with an open late diagenetic system. We concluded that taphonomic preservation of the ancient fossil record resulted from the early diagenetic growth of pyrite crystals during bacterial sulfato reduction in the fossils, which creates a semi-closed system that drastically reduced fluid-rock interactions with the host sediments.