Mud mounds or not mud mounds? That is the question for the early Devonian red marbles of the Minervois (France)

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Carbonate mud mounds are currently the less understood bodies among the reefal structures, while they exist since the Precambrian and they still range from tropical to polar latitudes in the modern oceans. Carbonate mud mounds are dome-shaped biosedimentary buildups dominated by fine-grained carbonates supporting various types of fabrics, such as thrombolitic, fenestral, or stromatactoid structures. The geological record provides the key to understanding the diversity of ancient and today's carbonate mounds, their unconventional biosedimentary processes including the formation of their fabrics.

The Minervois red marble quarries are known to reflect the occurrence of at least seven carbonate mounds dated from the Emsian (Early Devonian). However, evidence for their presence is rather incomplete. Our study aims to consolidate their temporal and environmental frameworks and to investigate the processes of their origin and those behind their famous stromatactoid cavities.

Our study is based on geological mapping to identify the geometry of the carbonate mud mounds. We then analyzed sedimentary facies, constrained the various local tectonic phases, and carried out geochemical, isotopic and mineralogical analyses on 60 matrix, cavity, fault and vein-type objects from six main quarries.

Our study shows that only a few published mounds exhibit the typical mudstone to wackestone texture. On the contrary, they often show a low organic content associated with high bioclastic and detrital contents. The rare unfragmented macrofossils often show signs of reworking. In addition, the dome shape of some published mud mounds is induced by the secondary folds of the larger Minervois nappe fold. Therefore, only a few quarries may reflect the presence of Emsian mud mounds with a very flat, at best low-relief geometry (flanks between 5 and 10°) in the Minervois. It is important to highlight that stromatactoid cavities, supposedly characterizing a mud mound, occur in other facies and stratigraphic levels (up to the Famennian Griottes Formation).

Whenever the stromatactoid cavities occur within or outside a mud mound, their development correlates with sediment grain size and inversely with stratonomy. We show that their morphology and infill are not dependent on a particular sedimentary texture or the age of the rocks. We suggest that these cavities may be due to the decomposition/dissolution of transported organisms, to fluid escape phenomena within the sediment, and/or to the action of bottom currents opening breaches in the indurating micritic sediment. We show that the cavities have a polyphase filling of matrix micrite and radiaxial calcite precipitated in oxygenated seawater circulation.

We propose that calcitic sealing of cavities occurs within the oxic zone below the water/sediment interface during early diagenesis. Thus, cavities were mainly filled by different