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The surface properties of carbonate rocks across scales: elucidating the role of biominerals

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The study of physical and chemical processes at mineral-water interfaces is essential to the development of more efficient strategies for geological carbon sequestration or enhanced oil recovery among others. Probing molecular interaction at the mineral-water interface will contribute to the understanding of physical and chemical processes at atomic scale while having an impact in a wide range of scales, from the nano- to the macro-scale.

Carbonate rocks are of special interest since they are abundant in the earth crust and form in a large variety of environments. They usually present a complex structure, heterogeneous composition – potentially including organic matter – and textures made of (bio)minerals, which results in a surface chemistry with an inherent heterogeneity down to the nanoscale. The scale of observation – from the mm to the nm – is therefore pertinent and potentially an important parameter when describing physical and chemical properties of carbonate rocks.

Here, we present a study of the surface properties of carbonate rocks probed at the nanoscale using Atomic Force Microscopy (AFM), but exploring multiple spatial scales up to the mm. We have measured the topographical features of carbonate rocks and identified various carbonate cements and 5 different bioclasts, namely bryozoans, mollusks, echinoderms, red algae and foraminifera. We have determined in detail the main microstructural features for each type of bioclast and compared them with that of the cements. In addition to multi-scale imaging of bioclasts, we also present their adhesion properties in air and in aqueous environments. From these observations we have further evaluated the spatial variability of surface chemistry properties across scales. The study of such nanoscale interfacial processes potentially enables us to relate the reactivity of biomineral with their characteristic microstructure and porosity resulted from diagenetic changes. Overall, this AFM study presents a detailed characterization of the carbonate biomineral nature in carbonate rocks and the role they play in the surface chemistry across scales.