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Exploring biotic vs. abiotic controls on syngenetic carbonate and clay mineral precipitation

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A possible syngenetic relationship between carbonate and clay mineral precipitation has been reported for sedimentary rocks deposited in both lacustrine and marine sedimentary environments throughout the geological record. In particular, the mineral dolomite is often found associated with Mg-rich clays, such as stevensite. It is notable that this carbonate/clay association has been recorded in numerous samples taken from modern dolomite precipitating environments; for example, the Coorong lakes, South Australia, coastal sabkhas, Abu Dhabi, UAE and coastal hypersaline lagoons (Lagoa Vermelha and Brejo do Espinho) east of Rio de Janeiro, Brazil. An HRTEM study of samples from these three locations indicates a possible physical/chemical association between the Ca-dolomite and Mg-rich clays, demonstrating a probable co-precipitation. To test this hypothesis, we have conducted a series of biotic and abiotic laboratory experiments. If this syngenesis actually occurs in nature, what, if any, are the biogeochemical processes controlling these precipitation reactions?

Our experiments were designed to determine the extent of the biotic versus abiotic component influencing the mineral precipitation and, in the case of a biotic influence, to understand the mechanism through which microorganisms might mediate the formation of clay minerals. The experiments were carried out in the Geomicrobiology Laboratory of ETH Zürich using cultures of living microbes and artificial organic compounds that simulate functional groups present in natural biofilms formed under both aerobic and anaerobic conditions. In addition, pure inorganic experiments were designed to understand possible physico-chemical conditions for diagenetic processes that could induce dissolution of Mg-carbonates and precipitation of Mg-rich clays.

Our results show a remarkable biotic influence during the formation of clay minerals. Specifically, extracellular polymeric substances (EPS), released by microbes in their surrounding environments, appear to play a key role in the mineralization process, by binding and concentrating silica and by stabilizing cations in specific co-ordination positions. This step may be essential for the initial nucleation of the clay mineral. Also, the conditions of the biotic experiments probably helped to lower kinetic barriers and promote the reactions, which apparently remained kinetically constrained in the abiotic experiments. These initial experimental results provide information to understand the syngenetic relationship between dolomite and Mg-rich clay precipitation and furnish additional information to help reconstruct paleoenviromental conditions for similar deposits found in the geological record.