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Non-classical crystallization as a geochemical control on the formation of lacustrine calcium magnesium carbonates

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Calcium magnesium carbonate minerals can form via either: 1) classical nucleation and growth mechanisms or 2) non-classical nucleation and growth mechanisms. Most published laboratory syntheses of low-temperature abiotic very high magnesium calcite (VHMC; also known as protodolomite) precipitate VHMC via non-classical crystallization. Specifically, VHMC is formed from an amorphous calcium magnesium carbonate (ACMC) precursor phase. The crystal size and microstructure of natural VHMC from the Coorong Lakes, Australia preserves the morphological signature of non-classical growth. Coorong VHMC is also morphologically similar to laboratory synthesized VHMC produced via an amorphous precursor phase.

Numerous studies have noted the precipitation of VHMC (protodolomite) in both lacustrine and marine environments requires VHMC to be very supersaturated in the aqueous solution before crystallization occurs. However, if VHMC forms via an amorphous precursor, the aqueous phase must be supersaturated relative to ACMC before precipitation occurs. An ACMC phase with approx. 50:50 Mg:Ca ratio is 590 times more soluble than crystalline VHMC. Modern seawater and most modern alkaline carbonate lakes, including the Coorong Lakes, are undersaturated with respect to ACMC. Thus, determining the crystallization pathway of VHMC is key for determining the relative importance of kinetic limitations and equilibrium geochemistry in carbonate formation. Crystallization pathways may also affect equilibrium isotopic fractionation and trace metal incorporation into carbonates. Evaluating crystallization pathways can be applied to past and modern primary carbonate forming environments and to enhanced carbon capture, utilization and storage technologies.