Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.27444

Stability of Amorphous Magnesium Carbonate at Low T and Variable pH Conditions

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Numerous studies indicate that calcium and magnesium carbonates can develop in natural settings such as caves, lakes, and rivers through non-classical crystallization from amorphous precursors. Research has primarily focused on amorphous calcium carbonate (ACC) and amorphous calcium-magnesium carbonate (ACMC) due to their relevance in biomineralization processes. In contrast, the formation processes of amorphous magnesium carbonate (AMC) remain less understood. These processes, particularly at low T (0-25 °C), can play a vital role in capturing atmospheric CO_2 and forming deposits that may later integrate into the global carbon cycle.

Our recent study in Nerja Cave, Spain [1] suggests that AMC is a key precursor in the formation of crystalline Ca-Mg carbonates in "moonmilk" deposits, found in low-T environments (18.1 ± 0.1 °C) and near-neutral pH (8.0 ± 0.2). AMC and ACMC have been identified in these deposits alongside crystalline phases such as huntite ($CaMg_3(CO_3)_4$) and dolomite ($CaMg(CO_3)_2$). These findings prompted this research on how pH and temperature influence AMC stability. Our results indicate that pH along with T are key for AMC stability, decreasing its stability as pH and T drop. Below pH 10.5 and T of 18 °C, AMC instantly transforms into nesquehonite. Thus, the observation of AMC formation and long-term stability under the natural, low T and circumneutral pH conditions of cave environments suggest that the formation of huntite and dolomite after AMC does not occur abiotically in moonmilk. Our results suggest that other factors, such as dissolving silica and organic activity, play a crucial role in the precipitation and stabilization of AMC and the subsequent formation of crystalline Ca-Mg carbonates in natural (cave) environments. This research opens new perspectives on the role of organic material in stabilizing amorphous Mg phases and its influence on the subsequent crystallization process of mixed calcium and magnesium carbonate systems.

[1]Bonilla-Correa, S., Ruiz-Agudo, E., Asta Andrés, M. P., Huber, L., Jiménez de Cisneros, C., and Liñán-Baena, C. (2024): Non-Classical Crystallization in Moon-Milk Deposits in the Nerja Cave, Spain. EGU24, p.18784.