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Magnesium Isotopic Systematics of Carbonate

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Carbonate is the most important C sink in the surface Earth and has been playing the key role in maintaining the habitability. Understanding the carbonate formation would shed light on the global C cycle in the Earth's history. Magnesium (Mg) is a key constituent in carbonate minerals (e.g., aragonite, calcite, and dolomite), and Mg isotopes could serve as a potent tool for tracking the carbonate deposition and diagenesis. The high precision determination of Mg isotope ratios in the past two decades have generated abundant isotope data for both limestone (^{26}) and dolostone (^{26}). It is noticed that ^{26} data are systematically higher than ^{26} data, yet neither could be resolved by the isotopic fractionations in carbonate mineral precipitation as determined by laboratory synthesis experiments. In this study, we develop numerical models to simulate Mg isotope fractionation in Ca-carbonate mineral precipitation, diagenetic dissolution-reprecipitation reactions, and dolomitization, so as to interpret the ^{26} and ^{26} data. The Mg isotopic composition of primary Ca-carbonate precipitation is determined by the isotopic compositions of seawater and fractionation in precipitation, while the dissolution-reprecipitation reactions modify the primary mineral composition, explaining the lower ^{26} values. In contrast, ^{26} of penecontemporaneous dolomite is significantly affected by Mg diffusion from seawater to porewater, leading to a smaller isotopic difference between dolomite and seawater Mg as compared with isotope fractionation in dolomite formation. As for dolomite derived from advective flow dolomitization, ^{26} is controlled by the flow rate and dolomite precipitation rate, showing a clear reservoir effect in dolomite formation. This could explain the higher ^{26} data. Finally, we proposed that all the reported ^{26} and ^{26} data reflect the difference between seawater Mg isotopic composition and 'apparent fractionation' in carbonate precipitation, recording both the seawater composition and the processes of carbonate formation. It is recommended to combine the detailed petrographic analyses and numerical simulation to interpret the carbonate Mg isotope data.