Fractionation of magnesium isotopes during bacterially mediated carbonate precipitation; A new tool for understanding the origins of Mg-rich carbonates

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Project description: Bacterial carbonate precipitation is known to have occurred in modern and ancient Earth surface environments and provides an important link between the evolution of life and surface processes. While bacteria and carbonates are intimately linked in many modern environments, it is still unclear what role bacteria play in the precipitation and diagenesis of carbonates; do they provide a substrate on which carbonates can form or do bacteria directly mediate the precipitation of the carbonates themselves? For example, the origin of sedimentary dolomite has been a long-standing geological problem because dolomite can only be produced inorganically at temperatures of >50˚C. Therefore, it has suggested that bacteria may play a role in their origin [1] and there is growing field and experimental evidence to support a bacterial origin [2], although the exact mechanisms are still unclear.

Magnesium isotopes potentially provide a means to understand the role of bacteria during the precipitation of magnesium-bearing carbonates. Magnesium is an abundant element in the Earth and as such it is an essential component of life, with pivotal roles in the generation of cellular energy as well as in plant chlorophyll. The biogeochemical cycling of Mg is associated with mass dependent fractionation (MDF) of Mg isotopes. However, recent experimental evidence has shown that cellular enzymes utilise ^{25}Mg in preference to other Mg isotopes during the generation of ATP energy. This mass independent fractionation (MIF) of Mg isotopes offers a potential smoking gun for detecting bacterial life in ancient carbonate rocks.

In order to determine whether this MIF occurs during the formation of carbonates the student will undertake a series of bacterially-mediated carbonate precipitation experiments. In previous experiments we have successfully precipitated low-Mg calcites with a seawater tolerant bacterial strain. The specific objectives of this study are to understand MIF during experiments that precipitate high-Mg calcite and dolomite using mixed bacterial assemblages from seawater to hyper-saline environments commonly associated with modern dolomite. Detailed microbiological studies of the run products will be used to evaluate role of bacteria during precipitation, including the indirect role of formation of microbial exopolymeric substances in absorbing Mg ions. Additionally, the student will undertake a comprehensive study of modern dolomites, pore fluids and bacterial communities from modern and recent cyanobacterial mats in the Middle East. Magnesium isotope measurements will be undertaken using a newly developed double-spike technique for accurate determination of MDF of magnesium isotopes coupled with high-precision analyses of any MIF.

[1] McKenzie, J.A. & Vasconcelos, C., 2009. Dolomite Mountains and the origin of the dolomite rock of which they mainly consist: historical developments and new perspectives. Sedimentology, 56, 205– 219.
[2] Bontognali, T.R.R., et al, 2012. Dolomite-mediating bacterium isolated from the sabkha of Abu Dhabi (UAE). Terra Nova, doi: 10.1111/j.1365-3121.2012.01065.x