

CO₂-olivine interaction in porous media - an experimental study

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Increased anthropogenic CO₂ emissions have caused an imbalance in the CO₂ cycle and resulted in climate change. One potential way to reduce CO₂ is to convert it to carbonate minerals. Mafic and ultramafic rocks provide good candidates for such carbonate sequestration due to high availability of divalent cations like Mg²⁺, Ca²⁺ and Fe²⁺. Such permanent CO₂ storage in basalts has recently received considerable attention.

In order to study the mineralization reactions upon continuous injection of aqueous CO₂ solutions into porous media containing Mg-Fe rich rocks, reaction transport experiments and simulations were conducted. The system studied involved reacting olivine (93 % forsterite) with aqueous solutions containing CO₂ and NaCl at acid to alkaline pH values. The experiments were conducted using a 1-D flow-through reactor at 70°C. Using the solution chemistry, the reaction progress, carbonate mineralization rate and porosity changes were studied as a function of time. The experimental results were supported by 1-D reactive transport simulations conducted with the aid of the PHREEQC program. According to the experimental results and the reactive transport simulations olivine progressively dissolves forming secondary minerals and solutes that are partially transported out of the column (system). The exact reaction path was found to depend on solution composition and pH and reaction progress (time). The mass movement of the system at a particular steady state as well as porosity changes may be divided into three stages. Stage I is characterized by initial olivine leaching, stage II is characterized by mineralization formation and decrease in porosity and stage III is characterized by remobilization of the previously formed secondary minerals and eventual increase in porosity. The results of this study have important implications on the continuous CO₂ injection and potential carbonate sequestration into porous rocks.

Redox state during core formation on planetesimals

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Formation of the terrestrial planets likely involved accretion of planetesimals large enough to have previously differentiated metallic cores. However, the physicochemical conditions prevailing during planetesimal differentiation remain poorly understood. The asteroid 4-Vesta is the smallest extant planetary body known to have differentiated a metallic core. HED (Howardite, Eucrite, Diogenite) meteorites, which are thought to sample 4-Vesta, provide us with an opportunity to study core formation in planetary embryos.

Partitioning of elements between the core and mantle of a planet fractionates their isotopes according to formation conditions. One such element, silicon, shows large isotopic fractionation between metal and silicate, and its partitioning into a metallic core is only possible under very distinctive conditions of pressure, oxygen fugacity and temperature. Therefore, the silicon isotope system is a powerful tracer with which to study core formation in planetary bodies.

Here we show through high-precision measurement of Si stable isotopes that HED meteorites are significantly enriched in the heavier isotopes compared to chondrites ($\Delta^{30}\text{Si} = 0.1 \pm 0.06 \text{‰}$). This is consistent with the core of 4-Vesta containing at least 1 wt.% of Si, which in turn suggests that 4-Vesta's differentiation occurred under more reducing conditions ($\Delta\text{IW} \sim -4$) than those previously suggested from analysis of the distribution of moderately siderophile elements in HEDs.