Microbially-accelerated carbon sequestration

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This investigation modelled microbially-accelerated carbon sequestration through the precipitation of carbonate minerals. A microbial consortium, collected from a natural hydromagnesite playa near Atlin, British Columbia, Canada, was used to inoculate a 10 m long flow-through bioreactor. The consortium contained cyanobacteria, which are able to mediate magnesium carbonate precipitation by changing the water chemistry, particularly by increasing pH. A bicarbonate-rich nutrient solution containing 1 g/L Mg was added to the bioreactor at a rate of 5 L/day for 7 weeks. Major ion concentrations, pH, dissolved oxygen, and conductivity were monitored weekly along the length of the bioreactor. The concentration of Mg^{2+} and other major cations was determined using inductively coupled plasma atomic emission spectroscopy, while ion chromatography was used for major anions. An alkalinity titration was used to quantify the bicarbonate concentration. The precipitation of carbonate minerals was inferred by the measured decrease in $[Mg^{2+}]$ and alkalinity along the length of the bioreactor. Carbonate precipitation occurred, primarily as dypingite, which was confirmed using light microscopy, scanning electron microscopy, and x-ray diffraction. The first 3 m of the bioreactor, dubbed the active zone, was responsible for removing over 37% of the Mg added to the bioreactor from solution, versus 61% Mg removed from the entire system. A mass of 0.362 kg of Mg carbonate precipitated in the active zone via microbially-mediated mineralization. This amount of mineral precipitation over the course of the experiment translates to a carbon sequestration rate of 5.88 kg of CO_2/m^2 of microbial mat/year.

This investigation demonstrated the process of microbe-induced carbonate precipitation on a larger scale than previous studies [1,2]. This biogeochemical process may have industrial applications if it can be implemented on the scale of mine tailing storage facilities such as those at the Mount Keith Nickel Mine in Western Australia. Magnesium weathered from ultramafic waste rock would react with CO_2 in the presence of the microbes and aqueous chemistry conditions studied in this investigation. The Mount Keith Mine produces tailings at a rate of 11 Mt/year, with tailings covering an area of ~19 km^2 [2,3]. Application of the biogeochemical process studied in this investigation to the Mount Keith Mine could result in a CO_2 sequestration rate of over 111 700 t/year. Globally, there are many mine sites with microbially-accelerated carbon sequestration potential, making the results of this study relevant to the current efforts to reduce net greenhouse gas emissions.

[1] Power *et al.* (2007) *Geochem. Trans.* **8**:13 [2] Power *et al.* (2011) *Env. Sci. and Technol.* **45**, 9061-9068. [3] Grguric (2003) *Aust. J. Mineral.* **9**, 55-71.

Compositional models of the Earth and early planetary evolution

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New chemical data along with a broad range of other chemical, isotopic and physica data that have come to light over the last decade will be integrated into a coherent planetary model. Present day compositional models for the planet are non-unique and strongly influenced by the method used in its construct: cosmochemical, geochemical/petrological, and geophysical. Cosmochemical models examine candidate accretion materials (i.e., chondrites) from which the Earth was built and compares these compositional input against physical data that describes the planet to minimize the misfit. Geochemical models deconvolve compositional data from samples of the mantle and crust to estimate the concentration of elements in the primitive mantle and then compares these input against chondrite data to describe the core composition with a minimum misfit. Geophysical models use the present day boundary condition for the Earth to find consistent solutions to the thermal evolution of the planet and the mineralogy of the mantle.

Recently reported geoneutrino data are consistent with most existing Earth models, and now exclude, at the 67% confidence level, models that invoke a homogeneous, fully radiogenic Earth model. Stable (O, Ca, Ti, Cr, Ni, Mo) and radiogenic (142Nd, Sr, Hf) isotope data for chondrites provide a perspective and perhaps a constraint on which group of chondrites best fit the bulk Earth composition. Increasingly, these data find the greatest misfit between the composition of the Earth and that of carbonaeous chondrites, whereas better fits are observed for the Earth and enstatite and ordinary chondrites. Models that describe the planetary proportion of Fe, O, Si, Mg (>90% of the Earth's mass) define the mass of core and mineralogy of the mantle, with the latter potential describing a compositionally layered state. No chondritic material, present in our collections, are consistent with data for the Earth and demonstrate that adhoc adjustments are needed to describe the nature of the building blocks of the Earth. Matching compositional models of the primitive mantle with that for the continental crust constrains the family of permissible compositional and mineralogical models for the present day mantle and any potential stratification. Data and uncertainties will be presented for quantitative models that describe the concentration and distribution of elements, particularly the heat producing elements, in the present day mantle. Models invoking deep mantle reservoirs (BMOL, 142Nd-layer, primitive mantle regions, upper/lower boundaries) will be assessed quantitatively. All model predictions from the three approaches described above are presently permissible given uncertainties, however ever accumulating geoneutrino data sets will provide tighter bounds by which one can critically assess the viability of Earth model compositions.