Hf-W equilibration in a magma ocean at very high P and T

S.B. JACOBSEN[1]*, J.L. REMO[1], M.I. PETAEV[1] AND D.D. SASSELOV[2]

[1]Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138 USA (*correspondence: jacobsen@neodymium.harvard.edu)
[2]Department of Astronomy, Harvard University, Cambridge, MA 02138 USA

The most recent simulations of the Moon-forming giant impact imply a collision between a proto Earth and a Mars-size body resulting in nearly complete disruption of the projectile and a significant destruction and re-accretion of the Earth. The peak shock pressures (P) and temperatures (T) in the Earth reached in ~10-20 minutes after this impact were ~ 300 GPa and ~20,000 K. This implies that the projectile's core and most of the Earth's mantle must be molten to form a deep, hot magma ocean extending from the Earth's surface down to the core-mantle boundary (P>100 GPa). Such high P and T are beyond the reach of most modern experimental techniques. We used high energy density laser-induced shock melting of powdered Fe metal-dunite targets at P's (200 – 500 GPa) and T's (15,000 – 35,000) comparable with those of the putative Moon-forming giant impact to shed light on the behaviour of metal-silicate system during and right after the giant impact. It was found that the homogenization of target materials was extremely rapid: it takes <10 ns to homogenize an approximately 1 mm target. If this was a diffusion-driven process, then it requires a diffusion coefficient of ~1000 higher than expected, suggesting enhanced mixing from RM and RT instabilities. Scaling our results to giant-impact conditions predicts a complete homogenization of the projectile material on a scale of ~ 10 km in just a day. Within this volume metal blobs of up to 60 m in diameter are capable of nearly complete extraction of Ni from FeO-rich impact melts. In addition, the post-giant impact terrestrial magma ocean could have been much more ferrous (~15-25 wt.% FeO) than the current mantle (7.6 wt.%). This implies that more than half of FeO from the primary magma ocean must have been reduced to Fe to be transported into the Earth's core as metal droplets. Our experimental results strongly support the Hf-W system as the best tool for dating core formation in terrestrial planets.

An experimental perspective on microbial weathering mechanisms and their role in the long-term carbon cycle

A.D. JACOBSON

Department of Earth and Planetary Sciences, Northwestern University, 1850 Campus Drive, Evanston, IL 60208-2150, USA (adj@earth.northwestern.edu)

Batch reactor experiments were conducted to examine if, how, and to what extent heterotrophic bacteria influence the chemical weathering of basalt, granite, and calcite. Reactors were inoculated with a common soil bacterium (*Burkholderia fungorum*) and were incubated at ambient T, pO_2, and pCO_2 conditions over time periods spanning 21 to 36 days. Bacteria were supplied with minimal growth media containing either glucose or lactate as a C source, NH_4^+ or NO_3^- as a N source, and either $H_2PO_4^-$ or, in the case of basalt and granite, trace apatite as a P source. Emphasis was placed on quantifying the rates and mechanisms of Ca^{2+} release, owing to the important role of Ca-silicate weathering in the long-term carbon cycle.

B. fungorum affected Ca^{2+} release by modifying solution pH and alkalinity, with the exact effect dependent upon the ionic forms of N and C and their rate and extent of utilization relative to the reactivity of the rocks and minerals involved. Relative to abiotic conditions, utilization of uncharged organic matter and NO_3^- raised pH and alkalinity, thereby minimally impacting Ca^{2+} release. A similar pattern resulted during utilization of organic anions and either NO_3^- or NH_4^+. In contrast, utilization of uncharged organic matter and NH_4^+ lowered pH and alkalinity, thereby accelerating Ca^{2+} release by a factor of ~5 for basalt and granite and ~2 for calcite. Trace apatite in basalt supplied ~15% of the Ca^{2+} while silicate minerals provided ~85%. Trace phases in granite, including apatite, calcite, and fluorite, provided ~95% of the Ca^{2+} while plagioclase supplied only ~5%.

The effects of heterotrophic microbial growth on solution pH and alkalinity, and thereby, weathering and long-term CO_2 drawdown, can be predicted a priori by combining redox half reactions for the oxidation and utilization of organic C in the presence of O_2 and various N sources. Noting that HCO_3^- is the principle anion that balances NH_4^+, the following Urey-type reaction mechanism is proposed: To maintain charge balance, bacteria release one mole of H^+ for every mole of NH_4^+ utilized. Two moles of H^+ react with $CaSiO_3$ to yield one mole of Ca^{2+}. The resulting 2:1 ratio of HCO_3^- to Ca^{2+} is identical to that obtained by reaction of H_2CO_3 with $CaSiO_3$. This implies that heterotrophic bacteria using NH_4^+ accelerate silicate weathering reactions that consume atmospheric CO_2 but that the effect is greater for basalt versus granite. The effect on calcite dissolution directly follows traditional carbonate equilibria models where calcite dissolves in water, which is in equilibrium with CO_2 gas and to which strong acids or bases have been added.