Experimental constraints on Fe-isotope fractionation at the core-mantle boundary

CHARLES E. LESHER[1*], JAMES BRENAN[2], GRY H. BARFOD[1], AND JUSTIN GLESSNER[1]

[1]Dept Geology, University of California, Davis, USA,
celesher@ucdavis.edu (* presenting author),
ghbarfod@ucdavid.edu, jjglessner@ucdavid.edu
[2]Dept Geology, University of Toronto, Canada,
j.brenan@utoronto.ca

Background

The core-mantle boundary (CMB) is the largest thermal boundary layer within the Earth with temperature differences estimated between 1000-1500 K over length scales of 10-100's km. This complex boundary layer, including reaction products between the outer core (molten Fe ± light elements) and the lowermost mantle (silicates), may be partially molten and bounded below by a stagnant layer (10-100's km thick) of buoyant molten iron alloy. The conductive geothermal across the CMB and uppermost portion of the outer core thus creates a setting wherein diffusive transport of components along a temperature gradient can occur. This process of thermal (Soret) diffusion can be an agent of isotopic fractionation. The sense, magnitude and rates of isotopic fractionation by Soret diffusion of core-forming melts are largely unknown.

Results and Conclusion

We report experimental results of Soret diffusion of pure Fe and Fe (Ni-S-C) alloy melts conducted at 2 GPa within a temperature gradient from 1750 and 2000°C. We show that the sense of fractionation is consistent with Chapman-Enskog theory based on classical mechanics predicting that lighter isotopes are preferentially enriched at the hot end, while heavy isotopes are enriched at the cold end of the temperature gradient [1]. At steady-state, $\Delta\delta^{56}Fe/^{54}Fe$ between the hot and cold ends of the temperature gradient are 6-8 ‰ - similar in magnitude to those reported for silicate melts [2-4]. Steady-state profiles are also linear in temperature at high temperatures – as also observed for silicate melts. Time studies show that the approach to the steady state occurs rapidly and governed by Fe self diffusion. Simple scaling suggests that significant fractionation of Fe isotopes can occur across a stagnant boundary layer at the top of the outer core transporting heavy Fe into the overlying mantle. Soret effects should not be dismissed as an agent of iron isotope fractionation in the vicinity of the CMB.

[1] Lacks (2012) *PRL,* **108**, 065901. [2] Kyser (1998) *CMP*, **133**, 373-381. [3] Richter (2008) *GCA* **72**, 206-220. [4] Huang (2010) *Nature* **464**, 396-400.

Clay minerals and geochemical indicators of past environments on Earth and Mars

RICHARD J. LÉVEILLÉ[1*], JENNIFER BENTZ[1,2]

[1] Canadian Space Agency, St-Hubert, QC, Canada, richard.leveille@asc-csa.gc.ca (* presenting author)
[2] University of Saskatchewan, Saskatoon, SK, Canada, S7N 5A8

Introduction and Background

Identifying and characterizing specific minerals present on Mars is critical to reconstructing past environmental conditions and geological processes, and is essential for accurately assessing past habitability. Various clay minerals have been identified in ancient rocks on Mars, including rocks at Gale Crater, and their presence suggests an early, active hydrologic system. The formation of these minerals would have required the presence of persistent liquid water over extended periods of time. However, the timing, duration, and extent of hydrologic activity and nature of mineral formation processes are poorly constrained. While Al- and Fe-Mg-phyllosilicates seem to be most common on Mars, Mg-rich phyllosilicates (e.g., serpentine, talc, saponite, Mg-smectite) have also been identified. Due to the greater solubility and mobility of Mg, compared to Fe and Al, Mg-clay minerals generally indicate sustained aqueous conditions (either long-term presence of liquid water or high water-to-rock ratios). On Earth, Mg-clay minerals form most commonly in circumneutral to alkaline conditions, either by direct precipitation (neoformation) or via transformation of precursor phases. In fact, pH is a major control on clay mineral precipitation and Mg-phyllosilicates will form mostly at a pH >8.0, with specific minerals often being indicative of narrow pH ranges. Hence, the presence of Mg-phyllosilicates on Mars may indicate areas of increased or extended liquid water activity, and/ (or) aqueous environments where circumneutral pH may have favored habitable conditions or the preservation of organics. However, Mg-clay minerals can also form at high temperatures in hydrothermal systems, such as deep-sea hydrothermal vents, or during low-grade metamorphism. Therefore, developing criteria to distinguish between low and high temperature Mg-clay formation is needed to assess past environmental conditions and habitability of Mars.

Results and Conclusion

We present the results of our characterization of analog natural and synthetic clay minerals using a Terra XRD instrument, a laboratory laser-induced breakdown spectroscopy (LIBS) instrument, a prototype multi-spectral microscope, and regular laboratory analytical facilities. We critically assess the likelihood of distinguishing clay minerals formed at low and high temperatures on Mars by combining mineralogical, elemental and isotopic information. In particular, we target elemental indicators of hydrothermal activity, such as Ti, Mn, and Ba within clay minerals, that can be readily detected by LIBS. This information will be invaluable for the Mars Science Laboratory mission, where an integrated mineralogical and geochemical approach using a suite of instruments will enable accurate mineral identification, geochemical analyses, and paleoenvironmental reconstructions on Mars.