PLANETARY SCIENCE RESEARCH DISCOVERIES
CosmoSparks

Quick Views of Big Advances



## *Making an Argument Against the Late Veneer Hypothesis for Mars*


It takes some cosmochemical knowhow to understand ***accretion*** and ***differentiation***, two fundamental processes in the building of planets and other solid bodies in our Solar System. Grappling with chemical details measured in rocks, meteorites, and materials created in lab experiments allows cosmochemists to construct plausible accounts of how planetary bodies form. One detail receiving a lot of attention is an overabundance of some iron-loving elements in Earth's silicate mantle that should have ended up in the iron-rich core. [See the highlighted box.] How is it possible to have high concentrations of highly siderophile elements (HSE) in the mantle? The question gets to the crux of a debate about core-mantle formation not only in the Earth, but also in the Moon and Mars.

> The iron-loving elements, better known as ***siderophiles***, are defined as those elements that preferentially partition into metal compared to silicate. During planetary differentiation, these and the highly siderophile elements *(HSE: Re, Au, Os, Ir, Ru, Pt, Rh, Pd)* would/should be removed from silicate mantle and concentrated in the core.

At issue are two plausible options: the abundances of ***siderophile*** elements, HSE, and volatile elements in planetary bodies were set by the time the core finished forming or were enriched later by addition of materials to the (bulk silicate) mantles. The work tests the idea known as the late veneer hypothesis, also known as the late accretion hypothesis. First presented in the 1970s (e.g. see reference by Chen-Lin Chou, University of Toronto), the hypothesis describes delivery of HSE by ***chondritic*** impactors to the mantle of early Earth after the formation of the core as a way to explain enhanced concentrations of HSE found in samples of the Earth's upper mantle. The hypothesis has since seen applications to the Moon and Mars to explain HSE abundances measured in lunar and Martian meteorites and Apollo lunar samples.

Laboratory experiments on metal-silicate ***partitioning*** can directly address mantle and core formation models by providing information on pressure, temperature, melting, ***fractional crystallization***, and sulfide saturation or undersaturation—issues known to affect HSE concentrations.

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~Image Details~

The team of Kevin Righter (NASA Johnson Space Center–Astromaterials Research and Exploration Science), Lisa Danielson and Kellye Pando (Jacobs ESCG, NASA-JSC), J. T. Williams and Munir Humayun (Florida State University), Richard Hervig and Thomas Sharp (Arizona State University) obtained new data on HSE partitioning between metal and silicate melt from three series of piston cylinder and multi-anvil press experiments run at a wide range of pressures and temperatures. The team experimented with rhenium (Re) partitioning at low to intermediate pressures, all eight HSEs at various conditions, and gold (Au) partitioning at variable pressure. Included in their paper are the first-ever results of high pressure and temperature effects on the partitioning of gold.

Combined with HSE data from previous experiments and analyses of Martian meteorites, the metal-silicate partitioning experiments by Righter and coauthors help to explain conditions during core-mantle formation on Mars. The data support the idea of a magma ocean on Mars that deepened with time during a continuous accretion process. Righter and team's experimental results suggest the range of HSE contents measured in Martian meteorites can be explained by metal-silicate equilibrium that reached approximately 14 ***GPa*** pressure and 2200 ***K*** temperature at mid-mantle depths as Mars grew to its final size. They conclude that core formation alone could have set the HSE contents of the Martian mantle, with the combined effects of pressure, temperature, and core composition (S- and C-bearing FeNi metallic liquid) contributing to lowering the metal-silicate partition coefficients to the values that can explain the mantle HSE contents. The high-pressure partitioning experiments contribute important information to help cosmochemists evaluate models of accretion and differentiation.

See references:
· Chou, C.-L. (1978) Fractionation of Siderophile Elements in the Earth's Upper Mantle, *Proc. Lunar Planet. Sci. Conf. 9,* p. 219-230. [ ***paper*** ].
· Righter, K., Danielson, L. R., Pando, K. M., Williams, J., Humayun, M., Hervig, R. L., and Sharp, T. G. (2015) Highly Siderophile Element (HSE) Abundances in the Mantle of Mars are Due to Core Formation at High Pressure and Temperature, *Meteoritics & Planetary Science,* v. 50, p. 604, doi:10.1111/maps.12393. [ ***abstract*** ].

See also:
· ***Multi-anvil/High-pressure petrology lab*** at NASA Johnson Space Center.
See related PSRD articles:
· Taylor, G. J. and Martel, L. M. V. (October 2012) Exploring the Mantle of Mars. *Planetary Science Research Discoveries.* ***http://www.psrd.hawaii.edu/Oct12/Mantle-of-Mars.html***.
· Taylor, G. J. (July 2005) Squeezing and Heating Rock to Scope Out How Metallic Iron Dribbled to the Center of the Earth. ***http://www.psrd.hawaii.edu/July05/cobalt_and_nickel.html***.

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