

The influence of magmatism and magmatic fluids on the geochemical evolution of the Martian crust

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Experimental investigations of phase equilibria of martian lithologies have delineated the thermal stability of martian magmas and the minerals that crystallize from them under a variety of pressures and water contents. These experiments explain the basaltic character of the planet and predict variations in magma chemistry over time as the secondary crust thickened. Of particular importance to understanding the past surface environment is assessment of the role of magmatic processes in contributing halogens, water, and S to the surface and near-surface environments. This is accomplished through first and second boiling of volatile-bearing magmas. However, the nature of the fluids exsolved, as well as the pressure at which exsolution occurs is strongly dependent upon melt composition as well as relative volatile abundance. Unlike the case for water-rich magmas, little is understood about the controls on fluid stability, the nature of such fluids, and their evolution during second boiling for water-poor, Cl-, S-, and F- enriched magmas with high Fe contents (as likely characterizes late martian magmas produced from a dehydrated mantle.) Such magmas may retain volatiles until close to the surface and thus become major contributors to the surface environment.

Experiments have been launched to evaluate the effect of Cl, S, F on mineral and melt stability in martian magmas and the effect of pressure on volatile retention. First experiments have been conducted on an evolved Cl-, S-, F- enriched water-poor (~0.4 wt% water) liquid from a Backstay parent and indicate a pronounced effect on mineral stability, most notably, on olivine, feldspar, and Ti- amphibole. Volatiles other than S are retained in the liquid. Additional experiments indicate, however, that at higher water contents, fluid can exsolve during first boiling at mid-crustal levels and produce amphibolite through reaction with a Humphrey composition wallrock. This amphibolite sequesters water and halogens, impeding their access to the surface. Additional experiments on water-poor compositions are assessing low-pressure exsolution, the nature of fluids given off, and their effect on wallrock alteration.

Characterization of natural hydrogen sources in ophiolitic context

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In an investigation of natural hydrogen sources and fluxes, gases with high concentrations of hydrogen were sampled in the Samail (Oman), Zambales (Philippines) and Antalya (Turkey) ophiolites. Chemistry and analyses of carbon, hydrogen and noble gases isotopes were associated to measurements of pH, Eh and temperature of the associated water where the gas is bubbling.

Two types of gas composition exist in Oman: the first with about 75% hydrogen, 15% nitrogen and 10% methane, associated to ultrabasic pH waters and reducing conditions (pH about 11 and Eh < -250mV) whereas the second type is pure nitrogen associated with neutral pH water. The $\delta^{13}\text{C}$ of methane are extremely heavy ($\delta^{13}\text{C} = -10$ to $+5\text{‰}$) and demonstrate an inorganic origin, while the noble gas analyses indicate a purely crustal source.

The gases only seep from the ophiolitic rocks (gabbros and peridotites). The reaction yielding hydrogen is most likely to be a reaction of serpentinization:

Olivine + Water \rightarrow Serpentine + Hydrogen + Magnetite with:
 $2\text{Fe}^{2+} + 2\text{H}_2\text{O} \leftrightarrow 2\text{Fe}^{3+} + \text{H}_2 + 2\text{OH}^-$

and the evolution of gas compositions corresponds to a secondary reaction generating methane through the reduction of CO_2 :



This second reaction is variable from different geological areas: the Zambales ophiolite produces up to 50% methane, the one in Antalya (Turkey) produces more than 80% of methane. This exotic generation of hydrogen and methane may be present in much more common locations, extending the gas exploration out of the sedimentary basins.