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The potential importance of phosphorus for martian magmatism

Michael Toplis
(michael.toplis@irap.omp.eu)

Magmatic rocks from Mars shows many important compositional differences compared to terrestrial counterparts. For example, one of the most striking features of volcanic rocks from Mars is that they are significantly richer in iron and poorer in silica than lavas produced by partial melting of the Earth's mantle. The iron-rich nature of Martian volcanics has been attributed to a higher FeO content of the Martian mantle [1], while the low silica content has no widely accepted explanation. It is also of note that the SNC meteorites generally show superchondritic Ca/Al, an observation which contrasts with most terrestrial basalts, and which places constraints on the composition of the mantle source which produced the SNC's. In addition to these differences in major-element chemistry, the available analyses of Martian rocks suggest that the sampled silicate portion of Mars is significantly richer in phosphorus than the Earth's crust/ upper mantle. On the other hand, no particular importance has been attached to this observation. It is the aim of this contribution to make the case that this difference may be potentially important.

One of the most significant influences of the addition of small amounts of phosphorus to a peridotite assemblage concerns the compositions of liquids produced by partial melting. The presence of phosphorus in a silicate melt is known to dramatically affect silica activity, as elegantly demonstrated by the experimental results of [2]. Using the MELTS thermodynamic calculator [3], it is shown that for a bulk Martian mantle containing $\sim$0.17wt% P2O5 [1], low degree partial melts on Mars will be particularly silica-poor, in contrast to the Earth where the relative absence of P and competing effect of alkalis leads to high silica contents. The difference in silica content between liquids produced from a mantle with 0 and 0.2 wt% P2O5 is predicted to be almost 10wt% SiO_2 when the degree of partial melting is 3%, a value more or less independent of pressure. In addition to the importance of phosphorus during partial melting, experimental studies have shown that P is a highly efficient flux, suppressing the crystallization of a variety of silicate and oxide minerals [4] such as magnetite and olivine. These effects may contribute to the very high FeO contents of martian magmas and be an important consideration when interpreting relative proportions of mafic minerals in the martian crust. Further to the chemical consequences, the difference in P-content between the Earth and Mars may also lead to very different transport mechanisms of magmatic liquids. For example, in the Martian mantle, low degree partial melts will have viscosities significantly lower than comparable terrestrial liquids, leading to more efficient transport (a difference of almost an order of magnitude is calculated for a 3% melt).

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