Water as a driver of martian magmatism

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Martian igneous rocks provide our best window into the compositional evolution of the martian mantle. The best-known martian igneous rocks are the martian meteorites; including the shergottites which represent tholeiitic magmas in various states of crystallization and several cumulate rocks. The shergotittes represent some of the youngest magmas on Mars; however, it has been difficult to place these rocks into a proper martian geologic context. Rovers on the martian surface have located mostly alkaline igneous rocks that do not match the shergottites in composition, and spacecraft-based measurements suggest that the youngest volcanoes do not match the shergottites in bulk-rock composition or mineralogy. Notably, the volcanoes are SiO_2-poor and Th (and incompatible-element)-enriched relative to the shergottites.

Previous models for martian magmatic evolution suggested highly-oxidized sources or gradually thickening crust with time; however, these models fail to simultaneously explain the chemistry and geologic context of both the shergottites and rocks on the martian surface. We propose instead that volatile elements drive martian magma composition changes through time, supplemented by interactions with enriched reservoirs.

If significant quantities of water were retained in the martian mantle after accretion, it would lead to widespread magmatism early in the planet's history, possibly associated with post-magma-ocean overturn events. This magmatism would build much of the martian crust out of hydrous magmas and is consistent with 4.1 ga meteorite ALH84001 and the observation of hydrous differentiation trends in igneous rocks from Gusev and Gale crater. As the martian mantle dehydrated, melting would localize to hotspots where temperatures were sufficient to continue magmatism. Younger magmas, such as the Tharsis and Elysium volcanoes, would become gradually depleted in SiO_2 and also more likely to be contaminated by Mars's crust, as has been proposed for the parent magma of the nakhlite and chassignite meteorites. Rocks such as the recent shergottites would be generated by melting of primordial, hydrated mantle material similar to the source of ALH84001, as suggested by isotopic links between ALH84001 and the enriched shergottites.