Are Mars volcanic rocks dominated by primary melts and why?

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The 4 Ga-record of Martian volcanic activity has been well characterized over the last decade by various instruments, including remote sensing gamma ray spectroscopy, visible/near-infrared and thermal spectroscopy, and in-situ measurements. These instruments have revealed trends in surface chemistry and mineralogy such as variations in SiO_2 concentration and the relative abundance of high-calcium and low-calcium pyroxene end-members. These variations are found to show trends as a function of age, and petrogenetic modeling indicates that they can be explained in terms of variable degrees of partial melting of the Martian interior (Baratoux et al., 2011, 2013). In detail, the results of the modeling provide evidence for cooling of the mantle and associated thickening of the lithosphere. The scenario is constrained by data spanning the Noachian-Hesperian-Amazonian periods and indicates high production rates of crust on early Mars, implying that Noachian rocks exposed at the surface may be petrological expressions of this volcanism rather than being associated with mantle overturn following the crystallization of a magma ocean. This situation may be compared to the Earth highlighting the differences between the thermal evolution of a stagnant-lid planet and a planet with plate tectonics. This simple scenario, which relates the composition and mineralogy of surface rocks to conditions of melting in the mantle, relies on the assumption that the signature of surface igneous rocks is largely dominated by primary melts extracted from the mantle and emplaced at the surface without significant fractional crystallization or contamination by crustal rocks. Such a situation is necessarily intriguing for terrestrial petrologists, and contrasts with a widely used concept in planetary science suggesting the existence of a neutral buoyancy zone that is mainly controlled by surface gravity (Wilson and Head, 1994). A series of factors that may favor the rapid ascent of magma to the surface will be reviewed, including the large density contrasts between primary melts and crustal material, and the viscosity of iron-rich liquids produced by the partial melting of an iron-rich mantle. Estimated crustal densities range from 3200 to 3580 kg/m^3 (Grott and Wieczorek, 2012) suggesting that magma buoyancy may be a sufficient driving force for its ascent to the surface. In addition, experimental estimates of the viscosity of iron-rich liquids (Chevrel et al., 2013) indicate values at the liquidus as low as 1 Pa s. Magma ascent could be therefore faster than 10 m/s, limiting fractional crystallization as long as the magma remains buoyant.

Baratoux, D., et al. (2011). Nature, 472, 7343, 338-341. doi:10.1038/nature09903. Baratoux, D., et al. (2013) JGR-Planets, 118, doi:10.1029/2012JE004234. Chevrel, D. et al. submitted to Geochimica Cosmochimica Acta. Wilson, L., Head III, J. (1994) Rev. Geophys., 1994, 32, 221-263. Grott. M., Wieczorek, M.A. (2012) Icarus, 221, 43-52.

