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Martian Volcanism through the Ages: Geochemical Signature of Planetary Evolution

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The recent accumulation of mineralogical, chemical and morphological observations of the surface of Mars allows us to take a fresh look at the evolution of magmatism and volcanism of the red planet. The diversity of volcanic features offers an increasing body of evidence for changes in magma composition and eruptive dynamics. The most widely accepted case is the relation between age and relief of volcanic edifices, illustrated on one side with the low shield volcanoes south of the Martian hemispheric dichotomy, formed between 4.0 and 3.6 Gy (e.g., Syrtis Major, Hesperia Planum or the six vents defining the Circum-Hellas Volcanic Province) and on the other side with the shield volcanoes in the Tharsis and Elysium regions culminating at a height of more than 20 km with evidence for volcanic activity extending significantly into the Amazonian period. In this context, abundance maps of Silica, Iron and Thorium derived from the Gamma Ray Spectrometer (Boynton et al., 2007) are particularly relevant to understand the genesis of the volcanic rocks. Taking the average abundances of SiO2 and FeO at the Tharsis dome, El Maary et al, 2009 have shown that the chemical composition of the surface can be interpreted as the signature of a primary melt derived from the primitive mantle of Mars proposed by Dreibus and Wanke (1985). Additional thermodynamical modeling of partial melting and fractional crystallization processes, to explore possible magma composition as a function of plausible mantle compositions, depth, and degree of partial melting, and degree of fractional crystallization have been performed to complement this result. Extending the analysis to major volcanic provinces, we reveal that the compositions for old volcanic provinces are well explained by partial melting of the composition proposed by Dreibus and Wanke (1985), for 10 – 15% melting at pressures of 10 - 15 kbars. Younger volcanic compositions can be also interpreted as primary melts formed at about 15 – 20 kbars, but this interpretation requires depletion in Thorium of the mantle relative to the composition of Dreibus and Wänke (1985), consistent with melting of a depleted mantle source. Values of the pressure of melting and the degree of melting are combined to estimate lithospheric thickness and mantle potential temperature, values which reveal that deepening of the magma source is associated with a decrease of the potential mantle temperature, a situation consistent with the cooling of planet with a stagnant-lid. The interpretation of these geochemical signatures suggests that the martian heat flow has decreased by about 50 % during the time extending from the emplacement of the older southern shields to the last major resurfacing events at the Tharsis dome.