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Evolution of Martian mantle

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One of the most prominent features of Mars is that magmatism occurs mostly in limited area, Tharsis and Elysium. Keeping this feature of Mars in mind, we develop a series of numerical models of mantle convection with magmatism. Martian mantle evolves in four phases: quench phase, stable phase, active phase, and cooling phase. In the quench phase during the first 50 Myrs, a shallow magma ocean develops and mantle temperature rapidly decreases. The crust generated by magma ocean subducts into the mantle and rapidly cools the core; the rapid cooling may explain the strong magnetic field suggested for the early Mars. The magma ocean also induces a chemical stratification in the mantle: (a) the crust enriched in radioactive elements and balaltic components, (b) the upper mantle depleted in these components, (c) the lower mantle with primitive chemical composition, and (d) the bottom mantle enriched in radioactive elements and basaltic components. The chemical stratification suppresses both magmatism and mantle convection in the subsequent stable phase. Mantle convection, however, reactivates in a depleted layer just below the lithosphere, and magmatism restarts in the uppermost mantle in the active phase that continues for billions of years after the stable phase. The strong internal heating in the primitive layer at depth often induces hot uprising plumes and the resulting hot spot magmatism. The planetary cooling mostly occurs through the heat transport by the plumes from the deep primitive layer. The hot plume activity, however, subsides in the subsequent cooling phase owing to the decaying internal heat source. Planetary cooling occurs mostly by heat transport due to mantle convection in this phase. The Tharsis and Elysium magmatism probably corresponds to the magmatism in the active phase, and suggests that Mars is still in that phase. In the numerical models, we found that the hot spot magmatism strongly concentrates to a limited area as observed for Mars only when the lithosphere belongs to the transitional regime where the lithosphere develops but sluggishly moves; the dynamics of the lithosphere is probably a major controlling agent of Martian magmatism.