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Numerical models of Martian mantle evolution induced by magmatism and solid-state convection

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To consider the thermo-chemical evolution of Martian mantle, various studies have been performed, but most of them are based on parameterized convection models. Hence, they needed strong assumptions about the process of the evolution. Here we present numerical models of mantle evolution including magmatism in 2-D convecting mantle. By including magmatism, our models can reproduce compositionally layered mantle structure and surface crust spontaneously, and can treat the whole evolution process consistently. The viscosity is strongly temperature-dependent, and the lithosphere is stagnant. Magmatism is modeled as a permeable flow of basaltic magma generated by decompression melting. The effect of partitioning of heat producing elements into the melt is also included. When the initial mantle temperature is sufficiently high, a reminiscence of magma ocean develops to generate a thick basaltic crust and make the mantle compositionally layered. The upper layer consists of compositionally buoyant residue of the basaltic crust, while the lower layer consists of compositionally denser materials not depleted in the basaltic component. Hot plumes grow from the lower layer and make it thinner with time by erosion. The plume magmatism also keeps the mantle temperature below the solidus by efficiently extracting heat as soon as the mantle temperature exceeds the solidus. When the mantle is initially not so hot as to develop a sizable magma ocean, the compositional layering becomes milder, and a broad lateral heterogeneity temporally develops in deep mantle depending on the viscosity of the lithosphere. Martian mantle is likely to have evolved as a relaxation from a compositionally layered state formed by magma ocean, and plume magmatism probably has played a crucial role in the relaxation process.

Keywords: Mars, mantle evolution, magmatism, basaltic crust