Modeling the evolving interiors of planets

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There is a clear correlation between the size of a terrestrial planet and the style of tectonic activities that are caused by mantle convection in that planet: There is no clear indication of tectonic activities on the present Moon where the Rayleigh number of the mantle is below the critical Rayleigh number; plume magmatism has occurred almost throughout its 4.5 Gyr history on Mars where the Rayleigh number marginally exceeds the critical value; plume magmatism and tectonic activities are pervasive on the present Earth and Venus where the Rayleigh number is well above the critical value. To develop a comprehensive model of tectonic activities and evolution of these planets, it is necessary to systematically explore the elementary processes that exert control over mantle dynamics. Through my two-dimensional models of magmatism in convecting mantle, I have listed several crucial elementary processes: (1) the magmatism-mantle upwelling feedback that operates in Mars, Venus, and the Earth; (2) mantle bursts that occurs in the Earth and Venus owing to an interaction between magmatism and a high pressure induced solid-solid phase transition of mantle materials; (3) plate tectonics that occurs on the Earth probably because of the ocean that the planet hosts. Here, I argue that a three-dimensional modeling of these processes is necessary for ultimate understanding of mantle evolution in terrestrial planets.

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