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Mantle evolution in terrestrial planets controlled by the dynamic behavior of the lithosphere

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The mantle evolution of terrestrial planets strongly depends on the dynamic behavior of the lithosphere. In a planet like Mars and the moon, where the lithosphere behaves as a stagnant lid, the recycling of crustal materials into the mantle is inhibited, and the internal heating rate in the mantle rapidly declines owing to the efficient extraction of heat producing elements by plume magmatism. A series of numerical models suggest that the activity of plume magmatism itself rapidly declines, and that the mantle monotonically tends toward a final compositionaly homogeneous state in such planets. In contrast, the tectonic plates of Earth allow basaltic crusts to efficiently recycle back into the mantle. This crustal recycling is likely to let the mantle evolve in two stages: The strong internal heating by the recycled basaltic crusts induces frequent burst of hot materials from deep mantle to induce vigorous magmatism and chaotic plate tectonics on the first stage. The mantle bursts subside, accumulations of subducted basaltic crusts develop on the core mantle boundary, and well-ordered plate tectonics takes place on the second stage. The resurfacing and continuing plume magmatism observed on Venus is difficult to understand under this context, because the lithosphere of Venus currently behaves as a stagnant lid. A preliminary numerical model suggests that plume magmatism rapidly declines and a mantle overturn vigorous enough to cause resurfacing occurs only in the earliest stage of the mantle evolution in spite of the size of Venus, if the lithosphere has behaved as a stagnant lid; significant amount of crustal recycling at the time of resurfacing, for example, may be necessary to induce repeated resurfacing of Venus.

Keywords: mantle evolution, crustal recycling, dynamics of the lithosphere, terrestrial planets