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Implications of a realistic crustal rheology and intrusive magmatism on Venusian tectonics: a geodynamic perspective

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From the observations on ~1000 recognizable impact craters on Venus' surface, the average surface age for Venus is comparable to the average surface age for Earth, and is significantly younger than the surface ages of other solar terrestrial planets. To explain Venus' young surface without plate tectonics, the global tectonics of Venus have often been proposed to be in an episodic-lid regime with catastrophic global overturns. Previous episodic-lid geodynamic models often assume an olivine-diffusion-creep rheology for Venus' crust, resulting in global overturns followed by stagnant-lid phases with near-zero surface mobilities. However, some tectonic units on Venus' surfaces show substantial tectonic deformation, such as tesserae and coronae. Recent analyses of satellite images on Venus' surface also suggest possible widespread lithospheric mobilities in the lowland basins. And these observations can hardly be explained by the stagnant-lid phases between overturns in the episodic-lid models.

In this study, we test the influence of (1) a composite, experiment-based crustal rheology (including diffusion creep, dislocation creep, and plasticity), and (2) intrusive magmatism, on Venus' surface tectonics, using the mantle convection code StagYY in a 2D spherical annulus geometry. Our results show that applying the experiment-based rheology and intrusive magmatism in the model results in (1) both global and regional overturns, (2) high and continuous surface mobilities that indicate substantial surface deformation between global overturns, and (3) a young and thinner crust that is consistent with current estimations. As for volcanic activities, contrary to olivine-diffusion-creep models, there is no persistent mantle plume in our models when the realistic crustal rheology is applied. The basalt cumulated between the upper and lower mantle affects convective flows in the mantle and mantle upwellings from the core-mantle boundary. Also, there are short-term, randomly located volcanisms within crust between global overturns, which are consistent with recent observations of active magmatism on Venus' surface and the short-term plumes suggested by coronae formation models. The surface tectonics in our models are dependent on the heat transfer efficiency in the upper mantle. And the tectonic regime is different from both episodic-lid regime and plutonic-squishy-lid regime that are proposed in previous literature, and can provide insights on the tectonic style for Venus and early Earth.