Modeling Rollback Subduction Dynamics on Venus.

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Abstract: The tectonic and convective histories of Venus are highly enigmatic. On Earth, plate tectonics continuously recycles the surface to cool the interior; however no such unifying conceptual framework for Venus exists. To explain Venus's observed uniform surface age, it has been suggested that the planet has undergone an episodic style of resurfacing with intermittent stable periods of lithospheric thickening via conductive cooling [1,2]. The current paradigm favors this catastrophic-overturn hypothesis, in which episodes of lithospheric recycling occur on a global scale and are followed by a period of rapid resurfacing [3,4]. A competing theory, referred to as regional equilibrium resurfacing, suggests that smaller and more frequent volcanic resurfacing events may also explain Venus' uniform surface age and crater distribution [5,6]. A relatively recent study, *King* (2018), has suggested that the observed value for the center of mass and center of figure (CM-CF) offset for Venus is incompatible with models of a global catastrophic overturn event [7]. It is therefore important to study the dynamics of regional-scale subduction on Venus to better understand the viability of subduction as a regional resurfacing mechanism.

To this end, we have created a series of numerical experiments using the finite volume code, StagYY [8]. The code solves equations of mass, momentum, and energy for highly viscous flow in a 2D spherical annulus geometry. The rheology of the model is strongly temperature-dependent, and we have incorporated Earth-like phase transitions throughout the mantle with depths adjusted for Venus's lower gravity. A pseudo-free surface "sticky-air" upper boundary condition is used to allow the development of topography. The initial condition is designed to study density-driven instabilities in regions of non-uniform lithosphere thickness representing a rift zone or former mantle upwelling. We systematically varied the strength and buoyancy of the lithosphere primarily through variations in 3 parameters: maximum lithosphere thickness [200, 250, 300 km], maximum lithosphere viscosity [1e23, 1e24, 1e25 Pa*s], and relative crustal buoyancy [$\Delta\rho_{crust}$ = -175, -265, -350, -400 kg/m^3]. The evolution of bending radius through time was calculated in order to compare timescales of the onset of subduction and identify periods of steady-state subduction. The resulting topography was also analyzed through time, including forebulge height, trench depth, and rate of trench retreat during rollback subduction. We discovered that subduction generally occurs on faster timescales when the lithosphere is thick and the strength (maximum viscosity) of the plate is weak (Fig. 1). A stagnant-lid regime is favored when the crust is more positively buoyant and the lithosphere is thin. We found that the length scale of resurfacing varies between 2500 km and 3100 km, with more resurfacing occurring with increasing positive buoyancy of the crust. Our models resulting in limited subduction may be compatible with the observed CM-CF offset and regional resurfacing. Further work will be done to investigate smaller scales of resurfacing consistent with previous regional resurfacing predictions [9].

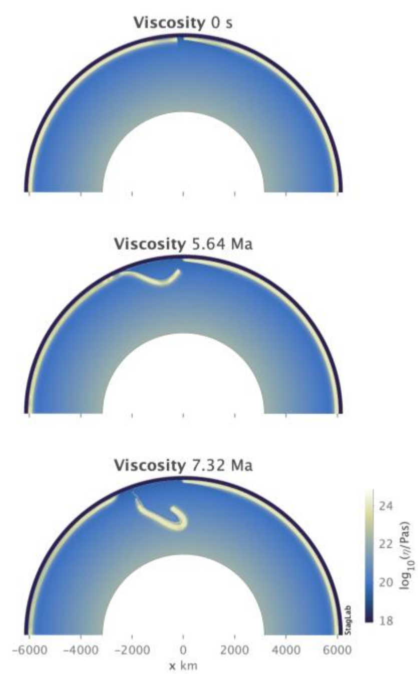

Fig. 1: Viscosity field evolution of a regional-scale lithosphere instability.

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