MORPHOLOGY OF BOTTOM-DRIVEN RIFTS: IMPLICATIONS FOR VENUSIAN TECTONICS. L. G. J. Montési[1], [1]University of Maryland, Department of Geology, College Park MD20742, montesi@umd.edu

Introduction: Earth is unique in the solar system in that it displays clear evidence for plate tectonics. Other terrestrial planets like Venus and Mars are likely in a one-plate convection such as stagnant lid regime, in which convection does not generate enough stress to induce failure of the entire lithosphere [1]. Yet, rifting is possible on these one-plate planets. On Venus in particular, Devana Chasma displays a strong morphological similarity with terrestrial rifts, in particular the East African Rift [2,3]. Does this morphology indicate a plate-tectonic-like activity or can it be generated in the context of stagnant lid convection? I will discuss the conditions for which bottom-driven rifts are marked by surface faulting like edge-driven rifts to provide new constraints on the structure of the lithosphere on Venus.

Edge-driven vs. bottom-driven rifting: Many tectonic models have generated rifts by assuming that the lithosphere is stretching horizontally. By forcing extension, the model presupposes that there is enough stress in the lithosphere to exceed the yield envelope. Therefore, failure occurs throughout the lithosphere and generated faults near the surface. This assumption may be appropriate in the context of plate tectonics, in which stress from subducting plates is transmitted to the lithosphere [4]. In addition, finite plate motions make it possible to accommodate the imposed extension. These models are driven from their edges, often with a bottom free-slip boundary condition.

By contrast, model edges are not free to move in a one-plate planet and stress is properly imposed at the base of the lithosphere, not its edge. Because temperature increases with depth, the lithosphere is less strong at its base than near the surface. Therefore, it is difficult to transmit stress to the shallow portions of the lithosphere and induce near-surface faulting if stress is imposed at the base of the lithosphere. A weak lower crust may further isolate the surface from the lower lithosphere and prevent surface faulting.

The models presented here constitute an initial investigation of the characteristics of rifts that may or may not form when stress is imposed at the base of the lithosphere. I discuss at what depth convective stress must act on the lithosphere at the type of stratigraphy that allow surface faulting to develop.

Model description: Rift models were constructed using the Finite Element software LAYER5 [5]. Each element deforms according to the weakest of two rheologies: dislocation creep, which is implemented as a temperature-dependent power law relation between stress and strain rate; and pseudo-plastic yielding, for which yield strength increases with depth to represent brittle failure and decreases as strain increases, so that deformation localizes unto narrow faults [5].

For edge-driven rifting, one side of the model is moved at a constant velocity, with stress-free bottom boundary condition. For bottom-driven rifting, the model edge is fixed horizontally but a predefined velocity field is imposed at the bottom of the model. Specifically, the horizontal velocity varies as the sine of distance so that matching shortening and extension take place at either end of the model and there is no over extension of the model.

All models to date include a crust with rheology of dry diabase [6] and a mantle with rheology of dry olivine [7] and a geotherm of cold thermal gradient of 5K/km that maximizes the strength of the lower lithosphere. The maximum strain rate is $10^{-15}s^{-1}$. Deformation proceeds in 1% strain increments.

Preliminary Results: Figure 1 compares the morphology of edge-driven and bottom-driven rifts with a thin, entirely brittle crust. Total model thickness is 30km. A wide rift develops in the edge-driven case whereas extension is limited to the left side in the bottom driven case. The zone of compression that accompanies extension is not observed, either because it is wider than seen here or accommodated in a more diffuse manner. The morphology of rifts is remarkably similar in both cases. However, this similarity exists only for a limited range of lithospheric structures.

Figure 2 compares the deformation patterns obtained for different crustal thicknesses. In each case, the bottom velocities are imposed at 40 km depth. A well-defined rift develops when the crust is thin and entirely brittle. However, zones of diffuse deformation replace localized faults when a thick ductile lower crust is present. When the crust is 35 km thick, no rift is present at the surface.

Failure of the upper crust stops when the stress at the base of the crust is ¼ of the strength at the top of the mantle. Failure also stops when the bottom of the model is at depths greater than 40 km (not shown). In that case stress at the base of the model is less than ¼ of the yield strength of the upper mantle and deformation remains diffuse. Future models will determine whether this factor of 4 is a universal feature.

Implications for Venusian tectonics: If rifts like Devana Chasma developed on Venus in the absence of plate tectonics, convection-related stresses must have reached relatively shallow levels in the lithosphere and the crust must be thinner than a critical value. Based on preliminary models that use a cold 5K/km geothermal gradient, a crust thicker than 30 km is not able to transmit high stresses from the mantle into the strong upper crust. Stress at the base of the model must be 75MPa or higher, which is very high for convective stresses [8] . Additional stress sources such as buoyant uplift may be necessary to induce rifting. Uplift clearly played a role in the development of Beta Regio [9,10,11]. Future models will consider warmer geotherms and also consider the stresses due to uplift and how they modify the conclusions above.

Acknowledgment: This work is supported by NASA Grant NNX10AG41G.

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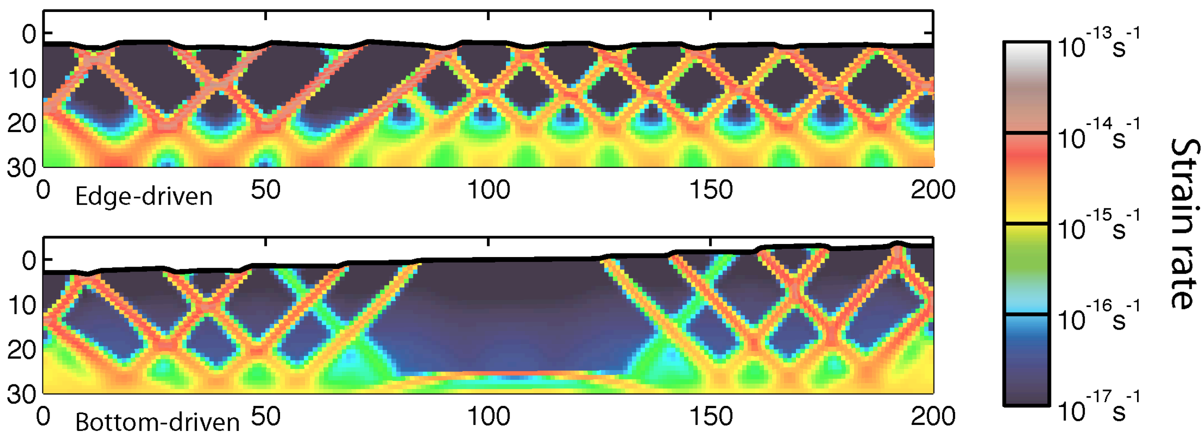

Figure 1: Comparison of the deformation field at 2% imposed strain for an edge-driven (top) and bottom driven (bottom) rifts with 10km crust over 20 km mantle. The entire crust is brittle.

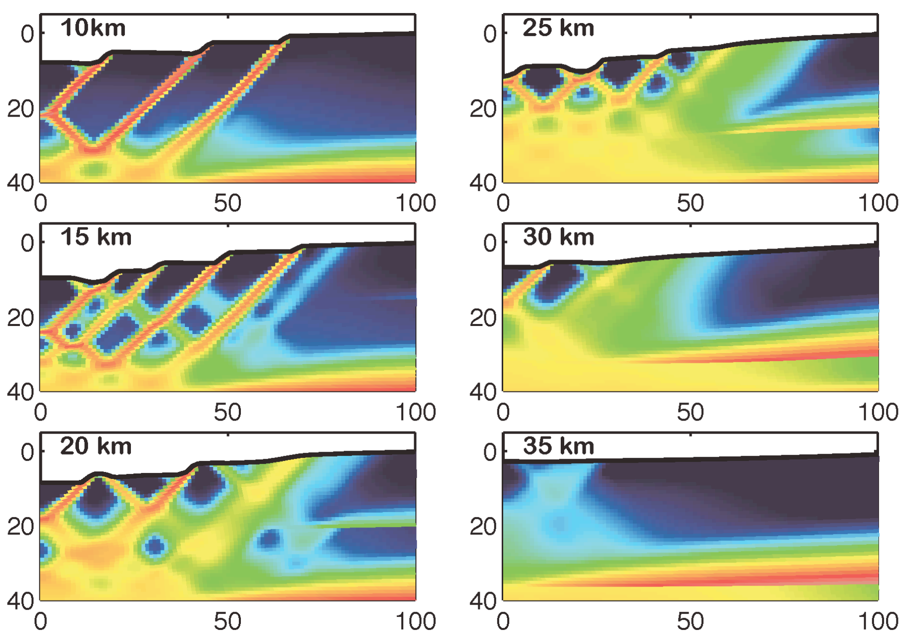

Figure 2: Deformation patterns obtain in the rifting portion of models with total thickness 40km and various crustal thicknesses. Other parameters and scale bar as in Figure 1.