**EFFECTS OF CRUSTAL-SCALE MECHANICAL LAYERING ON MAGMATIC RESERVOIR FAILURE AND MAGMA PROPAGATION WITHIN THE VENUSIAN LITHOSPHERE.**

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**Introduction:** Radiating dike systems are a common feature on Venus [1]. Their occurrence has been explained using different models, ranging from lateral injection directly from a magma body at a level of neutral buoyancy [2] to the interplay between a magma reservoir and large-scale tectonic stresses [3]. Magma reservoirs on planetary bodies have been studied using homogeneous lithosphere mainly composed of crustal material [4, 5]. However, planetary lithospheres may include substantial fractions of mantle material. The mechanics of a heterogeneous lithosphere may influence the failure of a magmatic reservoir and the propagation of magma via intrusions.

**Methods:** Following previous methodology [3, 4] we created axisymmetric finite element models using COMSOL Multiphysics [6]. A spherical magma chamber was modeled within an elastic, mechanically layered lithosphere at the crust/mantle boundary, reflecting a magma trap at the level of neutral buoyancy [2]. The model was subjected to three different tectonic loads: 1) lithostatic; 2) upward flexure due to a rising mantle plume; and, 3) downward flexure due to the weight of a basaltic shield volcano. In each scenario the crustal thickness, and thus the depth of the magma chamber, varied from 5-35 km with a total lithosphere thickness equal to 20, 30 or 40 km. We studied in each case: 1) the overpressure needed to reach failure; 2) the location of failure; 3) the type of stress controlling the failure of the magma chamber (tangential or hoop stress); and, 4) the orientation of the local stress field within the lithosphere.

**Results:** We observe that the normal horizontal ($\sigma_r$) and vertical ($\sigma_z$) stresses increase linearly within both lithospheric layers, with different slopes reflecting the difference in densities. In the upward and downward flexure cases, $\sigma_r$ shows a singularity at the crust/mantle boundary controlled by the stiffness difference [7].

In all model scenarios examined, magma chambers can be either stable (i.e., chambers need overpressure to fail) or unstable (i.e., chambers fail without overpressure, which inhibits their formation) (Figures 1 and 2). Stable magma chambers can fail at their middle (i.e., at the crust/mantle boundary) or at their base. In the latter case, magma chambers are considered to be unviable. The failure of the magma chambers can be controlled by either the tangential or hoop stress promoting lateral sills (for angles <30°) or radial dikes, respectively. Figures 1a and 2a show that in lithostatic conditions the amount of overpressure required to cause failure of the magma chamber is proportional to the thickness of the overlying crust, and the failure is controlled only by the tangential stress at the middle of the chamber, promoting lateral sill injection. In upward and downward flexural environments the overpressure needed to rupture the magma chamber is linear but not continuous (Figure 1, B and C). The discontinuity occurs at the transition between the regions where hoop or tangential stress controls failure. We observe that in the upward flexure environment (Figures 1B and 2B) magma chambers fail closer to the surface with the hoop stress dictating that formation of radial dikes should occur. As reservoir depth increases, failure is controlled by the tangential stress. In the downward flexure environment (Figures 1C and 2C), we observe the opposite, with failure of magma chambers close to the surface controlled by the tangential stress while hoop stress controls the rupture of deep chambers. These results correlate with the state of horizontal stress in both environments: horizontal compression in the upper part of the lithosphere and horizontal extension in the lower part of the lithosphere during downward flexure [4], and the opposite for upward flexure [3].

**Conclusions:** Akin to recent models looking at shallow reservoir systems [8]; our finite element models show that mechanical contrast at the crust-mantle boundary in the lithosphere can allow the formation of radial dike systems. Such mechanical contrast does not require coupling tectonic mechanisms (i.e., uplift and subsidence) [3], but only particular crust/lithosphere ratios allow the formation of radial dike systems (Figures 1 and 2). These systems have more chance to form in environments subjected to upward flexure. When downward flexure occurs instead, magma may flow directly into radial dikes without forming magma chambers since the magma chambers are unviable.

**Future work:** The purely elastic behavior of the crust and mantle layer is a first approximation. Future models will take in account the visco-plastic deformation of the different lithosphere components. In addition, future models should take into account how thermal properties of the magma chamber and lithosphere affect failure.

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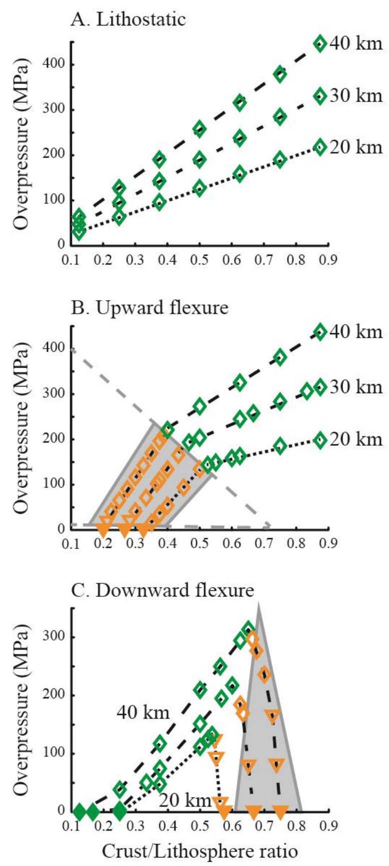


Figure 1: Amount of overpressure at failure and type of failure affecting the magma chamber for different tectonic environments.

For each graph, the dotted, dash and dots, and dashed lines represent finite element models with a lithosphere thickness of 20, 30 and 40 km, respectively. The grey areas represent the appropriate conditions for the formation of radial dikes >200km.

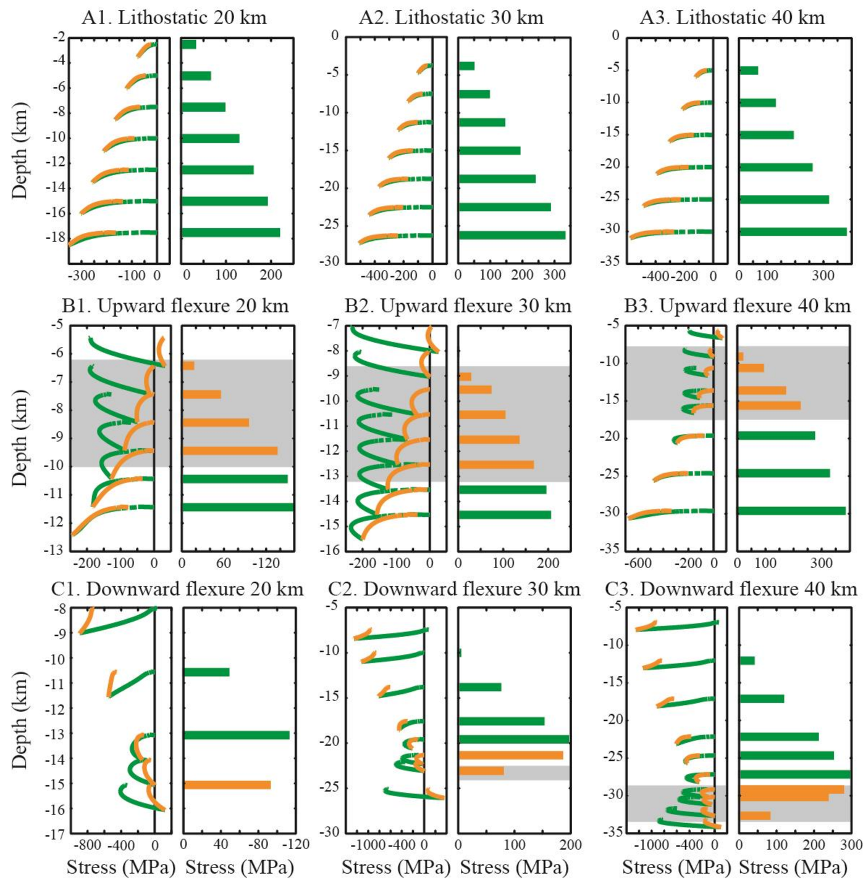


Figure 2: Overpressure and stresses controlling the failure of magma chambers for different crustal thickness for three lithosphere thicknesses (20, 30 and 40 km). For each figure, the left side represents the stresses along the lower half of the magma chamber; the right side represents the amount of overpressure needed to reach failure. In some cases, no overpressure is needed to reach failure as the magma chamber is unstable. The grey areas represent the appropriate conditions for the formation of radial dikes > 200 km.

Green = Failure controlled by Tangential Stress

Orange = Failure controlled by Hoop Stress

◇ = Failure at the middle of the magma chamber

▽ = Failure at the base of the magma chamber

Opened symbol = stable reservoir

Filled symbol = unstable reservoir