Evaluating the Loading History of Pavonis Mons, Mars using Lithospheric Flexure

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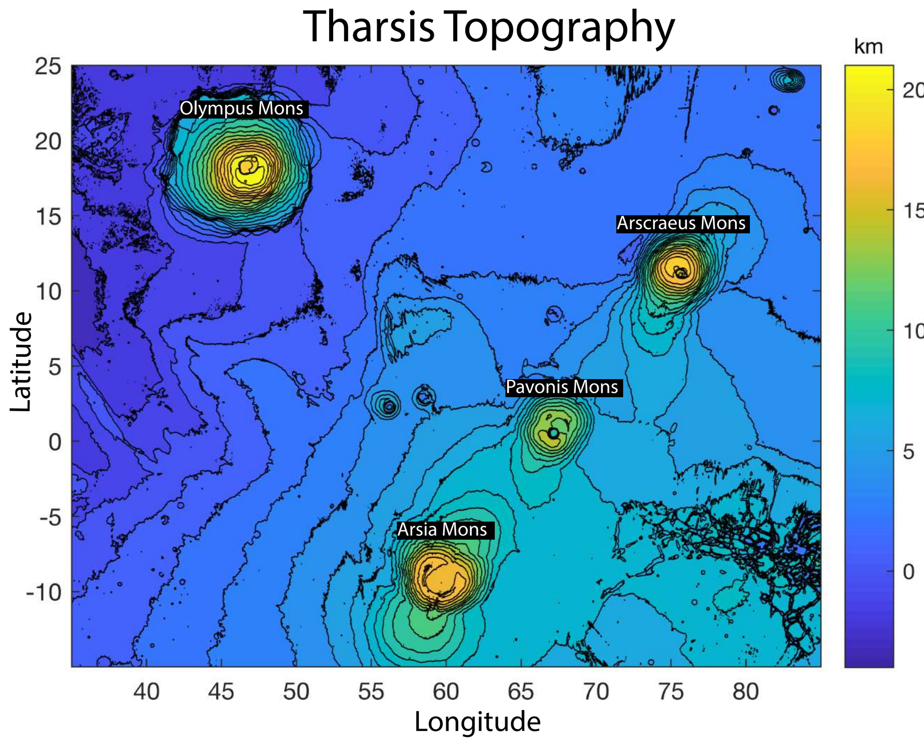
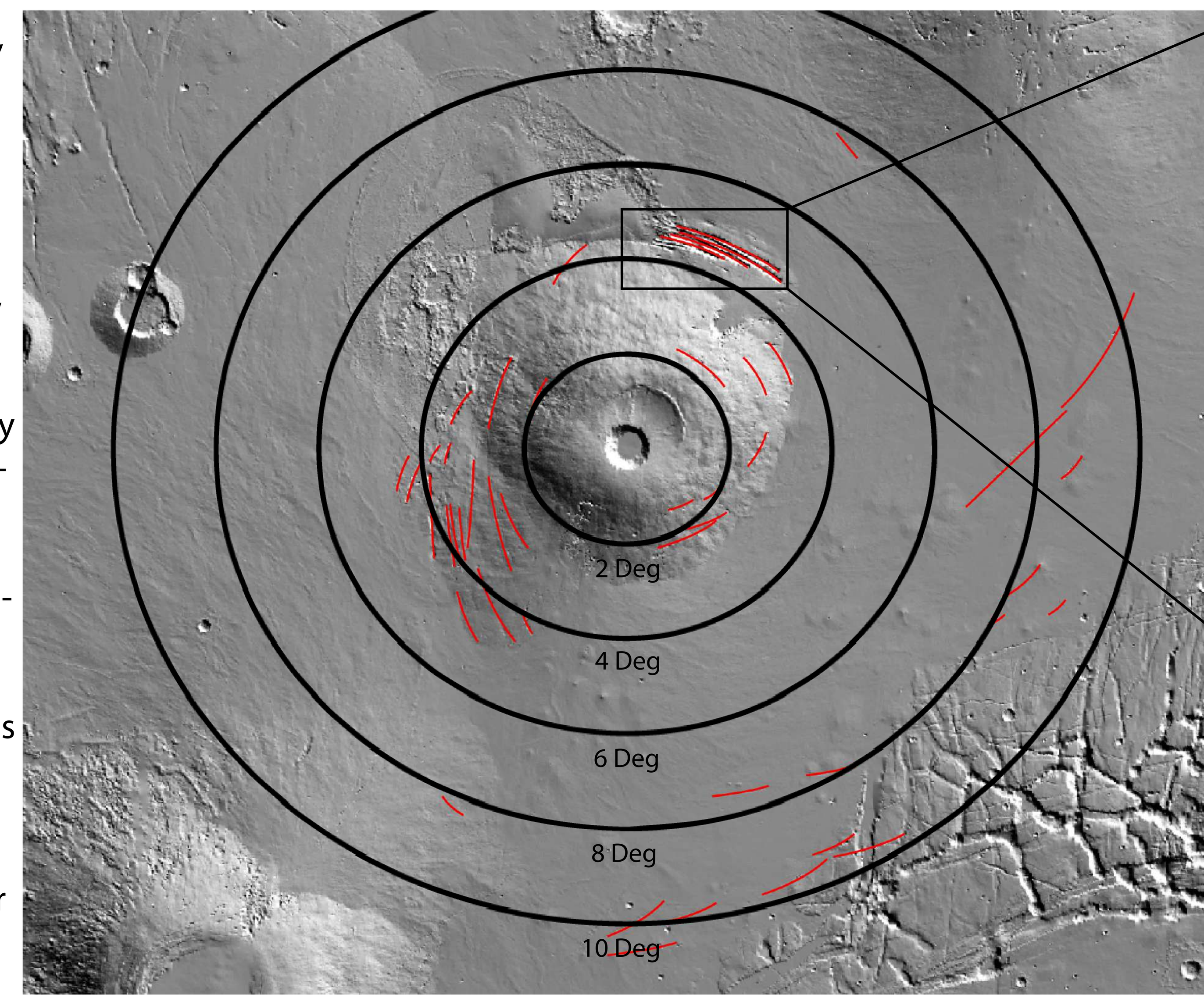
Pavonis Mons

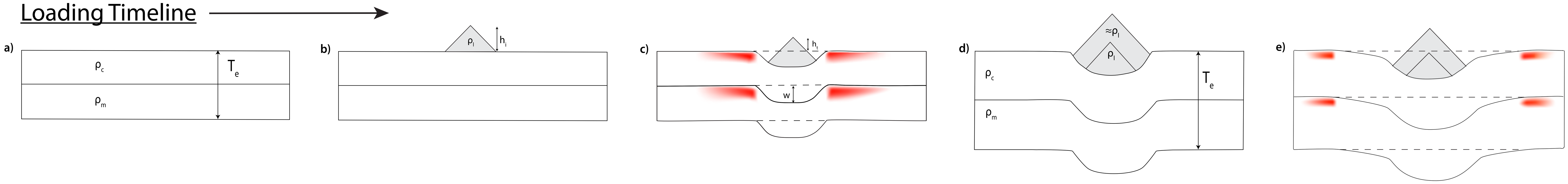


• Pavonis Mons is one of four large, shield-type, volcanos on Mars and has a height of roughly 14km.
• Pavonis, as well as the other volcanoes, has numerous concentric features surrounding the volcano that are interpreted to be grabens, troughs, chain collapse pits, and coalescing collapse pits (Montesi 2001). These features are caused by the outgassing of volatiles from intruded dikes.
• Pavonis Fossae is the largest of these features and is a series of collapse chain pits that have coalesced together to form a graben-like structure.
• The spatial distribution of features like Pavonis fossae are controlled by the regional stress of the region, as dikes will form in the areas with the least radial compressive stress.
• The lithospheric flexure caused by volcanic loading might be a significant control on the stress field in Tharsis.
• Thus, our goal is to model the radial tensional stress imparted on the lithsophere in order to constrain the elastic thickess of the lithosphere by comparing our expected stress with where we observe these extensional features.



• Above is a high resolution image of Pavonis Fossae from THEMIS. Its distance away from the center of Pavonis Mons is likely controlled by the concentration of radial tensile stresses caused from lithospheric flexure. Two recent papers have used spatio-spectral localization to constrain the elastic thickness beneath multiple Martian volcanoes but were unable to reach a satisfactory model fit with Pavonis unless the admittance was split into an upper and lower range (Broquet & Wieczorek 2019, Ding et. al. 2019). They have interpreted this discrepency as evidence for a two-stage growth model as suggested by Beuthe et. al. 2012.

Loading Timeline



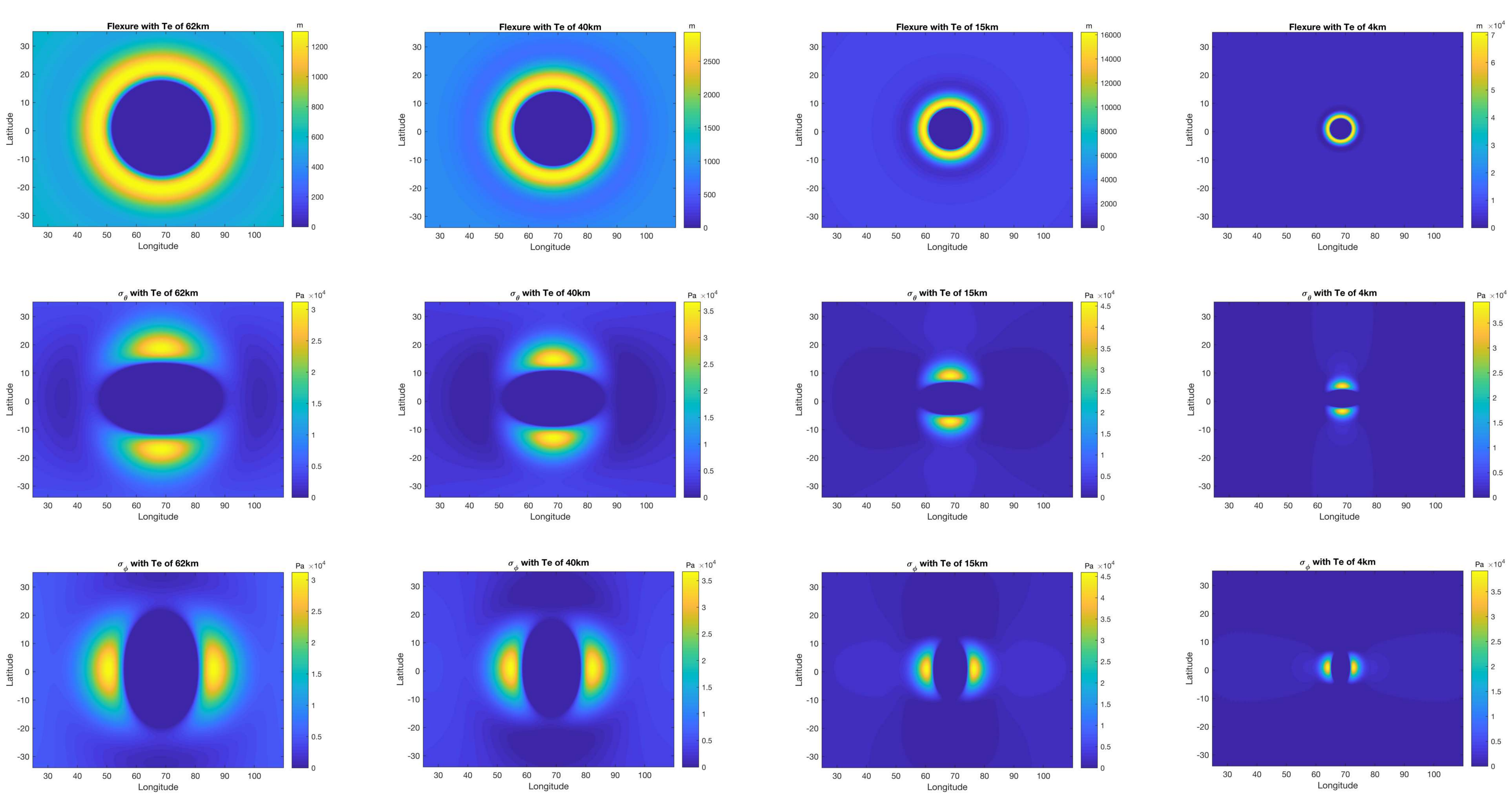
Modeling Methodology

• By varying the effective elastic thickness(T_e) from values resolved by a few different studies we can compare the stress field modeled from lithospheric flexure with the observed extensional features to help constrain the elastic thickness below Pavonis. We opt to model this in spherical harmonics due to the simplicity of the flexure and stress calculations.
• Lithospheric Flexure: $w = \frac{-\rho_l g}{\epsilon_l + \Delta\rho g} H$
• H is the initial topography caclulated from observed topography and the elastic term. ρ_l is the density of the load, $\Delta\rho$ is the difference in density between the mantle and the load. ϵ_l is the elastic term calculated from Banerdt 1986. The elastic term is dependent on the elastic thickness, Poisson's ratio, Young's Modulus, and the spherical harmonic degree. We used a poisson's ration of 0.25 and a Young's Modulus of 10^{11}. g is the gravitational acceleration of Mars, 3.71m/s^2 and w is the distance the lithsophere deflects. MOLA data was used for the observed topography.
• We now want to calculate the stresses associated with this modeled uplift. Only the poloidal term is calculated as topography loads don't have a toroidal component.
• These equations are found in Appendix A of Banerdt 1986.
• Only upward flexure is shown in the flexure plots and only tensile stress is shown in the stress plots. The restoring force of the upper mantle has not yet been implemented thus

Literature Values

Pavonis Fossae Value

Broquet & Wieczorek 2019 | Beuthe et. al. 2012 | Ding et. al. 2019 | This Study



Discussion and Interpretations

• For space reasons not every literature value was shown but are summarized here for completeness: Ding et. al. 2019 constrained the elastic thickness to be <15km for spherical harmonic degrees between 47-64, but could not constrain a reasonable fit for degrees between 31-35. Broquet & Wieczorek 2019 found a value of 62km for degrees between 32-48 and a value of 2km between 48-82. Beuthe et. al. 2012 split the loading process into two growth stages, for the first stage they found a value of <40km and for the second stage found a value between 60-120km. For both stages they used all degrees less than 25.
• As the elastic thickness increases the further from the load upward flexure, and thus tensile stress, occur.
• If Pavonis underwent more than a single growth stage then its likely that there were multiple stages early on to create the features seen between 4 and 8 degrees of the edifice when the lithsophere was relatively thin. Features seen directly on the edifice (<4 degrees) are likely not from flexure (Montesi 2001).
• For elastic thickness' greater than about 20km, the expected uplift becomes coupled with the uplift from the surrounding volcanoes (Arsia and Arscraeus) or the area is convered with extensive young lava flows. Thus, lithospheric flexure is not a good method to constrain the elastic thickness for these larger values because we can't observe or definitively discern flexural features.