Loading-induced Stresses Near the Martian Hemispheric Dichotomy Boundary. P. J. McGovern[1] and T. R. Watters[2], [1]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058, (mcgovern@lpi.usra.edu), [2]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington D.C. 20560 (twatters@nasm.si.edu).

Introduction: The dichotomy between the northern and southern hemispheres of Mars is one of the fundamental physiographic features of the planet. The dichotomy is manifested in the topography, geology, tectonics, cratering record, magnetic field, and crustal structure. The origin of the crustal dichotomy between northern (relatively thin, constant thickness) and southern (relatively thick and thickening southward) crustal provinces [1] appears to date to the earliest Noachian [2], a period with scant remaining traces in the geologic record. However, subsequent geologic and tectonic events may contain clues as to the nature of the hemispheric dichotomy.

The Eastern Hemisphere Dichotomy Boundary (or "EHDB") of Mars between 40°E (western Arabia Terra) and 160°E (Terra Cimmeria) is characterized by a prominent topographic scarp (several km in height), compressional features on the highlands side and extensional features on the boundary ramp [3, 4]. Loading of the lithosphere due to emplacement of volcanic or sedimentary material on the lowlands side may be responsible for the observed highlands tectonics. A broken-plate flexural model with elastic lithosphere thickness T_e = 31-36 km provided a good fit to Mars Orbiter Laser Altimeter (MOLA) topography data across the EHDB [3].

Method: We use the finite element code Tekton [5] to model the response of the Martian crust and mantle to surface loads emplaced near the hemispheric dichotomy boundary. The model grid accounts for crustal and mantle structure in the vicinity of EHDB, as constrained by studies of gravity and topography [e.g., 1, 6, 7]. The grid exhibits plane strain geometry and extends 1760 km horizontally, 203 km vertically. In the left-hand section of the model, a crust of 40 km thickness (representing the northern lowlands of Mars) lies at the surface. In the right-hand section (representing the southern uplands), the crust is ~55 km thick, yielding isostatic compensation for a 3 km difference in topography between "North" and "South" sections [e.g., 3] corresponding to densities ρ_{crust} = 2900 kg/m^3 and ρ_{mantle} = 3500 kg/m^3. A section of elements 160 km wide accommodates the corresponding transition in crustal thickness. These dimensions simulate the change in elevation and width of the dichotomy boundary in the Eastern Hemisphere of Mars. The dimensions of various grid elements can be varied to reflect possible differences in initial conditions.

A portion of the grid isolating the transition section is shown in Figure 1. The grid starts in an isostatic configuration to reflect likely conditions at the time the crustal thickness variations were established. Stress differences in the mantle asthenosphere and crust were allowed to relax viscously. Then, the crustal elements were assigned "lithospheric" stiffness and viscosity properties, and excess mass was applied to a line of elements "northward" (to the left) of the boundary ramp to represent the emplacement of sediments or volcanic material. The asthenosphere (entire mantle in this model) was allowed to relax under the load. For simplicity, our baseline model assigns lithospheric stiffness values to the whole crust, yielding an effective T_e somewhere between 40 and 55 km in the dichotomy boundary region. Emplacement of material is modeled by increasing the density of the elements. Erosion can also be modeled by decreasing element densities.

Results: The stress state and displacements at the surface of the baseline model, resulting from loading of the lowlands, are shown in Figure 1. Extensional faulting is predicted at the surface of the boundary region, and further "southward" on the thick-crust region. Such faulting is consistent with the observed presence of normal faulting at the dichotomy boundary [e.g., 3]. Compressional faulting is predicted in the region of the load, consistent with the presence of numerous ridges in the northern plains [8, 9]. A modest flexural arch occurs just "south" of the crustal ramp, resembling the topography observed at the EHDB [3]. One more region of note is "south" of the normal faulting on the thick-crust section: differential stresses are slightly elevated, and stress orientations indicate horizontal principal compression. The stress state is consistent with the presence of compressional faults observed in the highlands [3, 4], although the magnitude of stresses is insufficient to cause faulting. Other sources of stress, such as global contraction, sub-lithospheric or intrusional loading, or thermal stresses, may be required in concert with the plains loading stress in order to generate faulting [3, 4]. Erosional unloading of the highlands "south" of the boundary (not shown) tends to reinforce the stress state of Figure 1, such that extensional faulting is enhanced near the boundary and compression is enhanced further "south".

Models with very low T_e (8-12 km) at the time of loading cannot produce appreciable flexural arch topography at the dichotomy boundary. In general, the magnitude of flexural arching increases with decreasing T_e. However, models with thin elastic lithosphere cannot maintain significant boundary arching, due to the tendency of the weak lower crust to flow. Such flow (from highlands to lowlands) tends to remove crustal thickness variations [10], and when superposed with the flexural arching, the signature of the latter is removed from the resulting topography. Models with low T_e also experience very high magnitudes of horizontal extensional stresses, yielding a prediction of pervasive normal faulting, oriented parallel to the dichotomy boundary, in the highlands. Such a stress state may have characterized the very early history of the highlands, but if so most of the evidence for it has been obscured by subsequent geologic activity. The failure of low T_e models to match the observed topography and tectonic signatures of the EHDB indicates that the processes responsible for those signatures occurred well after the epoch in which low T_e values characterized the southern highlands [6, 7].

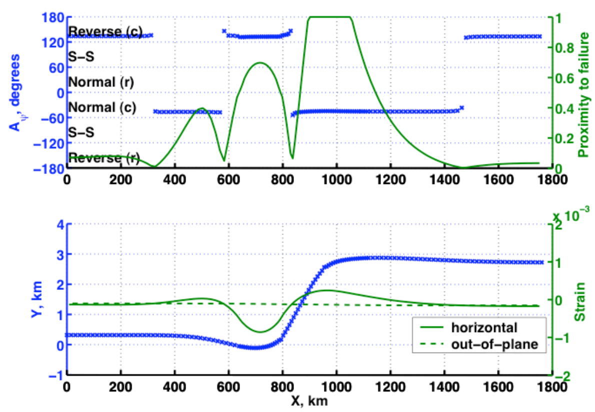

Figure 1. Stress state and deformation of the topmost layer of model elements, as functions of horizontal distance (X). Top, left axis: Failure parameter indicating type of failure (black labels) predicted by principal stresses (blue x symbols). Top, right axis: Proximity to failure, based on Mohr-Coulomb failure criterion (green line, value of 1 indicates stresses sufficient to cause failure). Bottom, left axis: surface topography of model (blue x symbols). Bottom, right axis: horizontal and out of plane strain (green solid and dashed lines, respectively).

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