ORIGIN OF ITHACA CHASMA, TETHYS, II: THE IMPORTANCE OF THE LITHOSPHERE; William B. McKinnon and L.A.M. Benner, Department of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, Saint Louis, MO 63130.

The nearly globe-girdling canyon system Ithaca Chasma on Tethys is apparently unique in the solar system. It forms a great circle nearly 90° from the large basin Odysseus, which initially suggested that the two were related [1,2]. One of us (WBM) subsequently hypothesized that viscous rebound of Odysseus caused the observed fracturing by inducing viscous drag at the base of the Tethyan lithosphere [3], essentially a slow, steady-state version of multiringed basin mechanics [4,5]. Another principal difference would be that the crater driving the flow is large compared to the satellite radius. Recently, Thomas and Squyres modeled the viscous flow induced in whole satellites by large craters [6]. They found that the flow can switch to a unidirectional "whole-satellite" mode for crater-diameter-to-body-radius ratios similar to that of Odysseus (the largest ratio known). They postulate that this is the reason Ithaca Chasma formed and that other similar structures have not. Tangential (colatitudinal) stresses, $\sigma_{\theta\theta}$, were shown to remain extensional out to ~90° only in the case of unidirectional flow. These were viscous flow stresses evaluated at the deforming free surface, however. Our purpose is to more carefully evaluate the influence of the elastic lithosphere. A more detailed morphological analysis has also been provided by P.M. Schenk.

Structure. In the highest resolution image (2 km/px), the canyon appears to be composed of numerous sub-parallel fractures. Topographically, this is expressed as a flat-floored graben, with several medial ridges or platforms. The best-fit pole for the Chasma (19°N, 104°W) is actually offset from the center of Odysseus (33°N, 131°W) by ~28°, falling just just outside the rim. The morphology of of the canyon system varies as a function of its distance from Odysseus. It is deeper, narrower, and begins to fragment into two parallel graben in the sectors where it deviates most from the Odysseus great circle (Fig. 1); the width varies over 65–140 km. The canyon is not prominent where it most closely approaches the crater.

Mechanics. The lithosphere is modeled as a thin shell subject to basal drag toward or away from the crater. The problem is entirely determined by the colatitudinal displacement u_θ [5,7]. The equilibrium equation expressed in terms of this quantity is integrated numerically. The colatitudinal membrane stress, $\sigma_{\theta\theta}$, is set to zero at the crater rim, reflecting the thinness or weakness of the lithosphere there or simply its role as a stress boundary during uplift (of the basin floor). Some results are shown in Figs. 2–4. In Fig. 2, the crater rim is at 15° ($\equiv \theta_o$), and the basal shear towards the crater falls off with a canonical $(\theta/\theta_o)^{-4}$ dependence [4,5]. Results are similar to the planar case, in that $\sigma_{\theta\theta}$ goes through a tensional maximum and the hoop stress $\sigma_{\phi\phi}$ is compressive near the crater, because the crater is relatively small compared to the satellite radius R. For larger craters ($\theta_o = 30°$ in Fig. 3), the tensional maximum is suppressed. It is interesting to note that the θ_o range where the tensional maximum disappears, 20–25°, is similar to that where unidirectional flow first appears [6]. Nevertheless, in both of these examples significant tension is generated in the hemisphere opposite the crater; it is given in units of SR/H, where H is lithosphere thickness and S is the magnitude of the basal shear at the rim (~$\rho g d/10$, where ρ is surface density, g is gravity, and d is crater depth). The lithosphere acts as a stress guide, and such antipodal extension may have contributed to the significant plains volcanism opposite Odysseus.

Figure 4 shows a case (for $\theta_o = 30°$) in which the basal shear is given by $S\{(\theta/\theta_o)^{-4} - 0.25(\theta/\theta_o)^{-2}\}$. This shear falls to zero at one crater radius outside the rim and becomes outward directed beyond. This gives a better representation of basal drag when the crater rim load is included [5,6]. The effect is to reduce the distant extension and restore the tensional maximum. So-called bidirectional flow [6] is not necessarily incompatible with extension at $\theta = 90°$.

Further work needs to be done. The position of initial faulting is sensitive to the form of the basal drag function. Odysseus's uniqueness may still be the result of unidirectional flow. What needs to be more carefully studied is the self-consistent response of thick lithospheres to viscous rebound flows.

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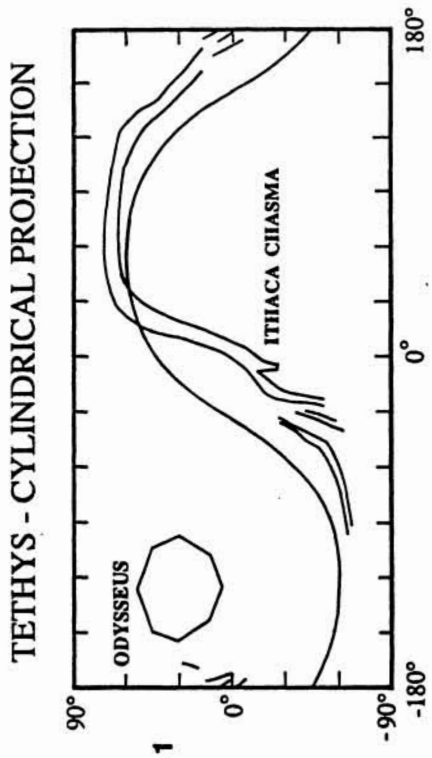

Fig. 1