AN INTRUSIVE DIKE ORIGIN FOR IAPETUS' ENIGMATIC RIDGE? H. J. Melosh[1] and F. Nimmo[2], [1]Lunar and Planetary Lab, University of Arizona, Tucson AZ 85721, jmelosh@lpl.arizona.edu, [2]Department of Earth and Planetary Sciences, UC Santa Cruz, Santa Cruz CA 95064.

Introduction: The striking equatorial ridge of Iapetus was discovered by the Cassini mission [1]. 18 km high, 100-200 km wide and 1600 km long, this ridge accurately encircles almost 1/3 of the satellite's equator. Iapetus is also unusual in that its shape is out of equilibrium with its current slow rotation rate: Best fits to its second order harmonic shape indicate that its equatorial bulge is consistent with a 16 hour rotational period, not its current 79.33 day rotation.

Several investigators have connected these two facts and suggested that the ridge is, in some way, connected with despinning [2,3]. However, the standard solution for the stresses in the lithosphere of a despun planet are consistent only with an equatorial band of strike-slip faults [4].

Compression: Compressional stresses do reach a maximum at the equator of a despun body, but their orientation is east-west, not north-south.

The morphology of the Iapetus equatorial ridge, moreover, is not consistent with other compressional features observed in the solar system, such as Mercurian lobate scarps or mare ridges: These features are typically lobate in plan, asymmetric in profile and display elevation offsets from one side to another. None of these characteristics apply to the ridge of Iapetus.

Extension: The features most similar to Iapetus' ridge in length, linearity and symmetry of profile are dikes. On Earth, dikes in the MacKenzie swarm stretch thousands of km across the Canadian Shield in nearly straight lines [5]. Ridges on Europa have also been described as the result of long linear intrusions and exhibit similar forms [6]. Indeed the Cassini September 10, 2008 close flyby of Iapetus revealed hints of bifurcation in its ridge suggestive of the well bifurcated ridges on Europa (Fig. 1). The somewhat discontinuous character of the ridge crest is also similar to terrestrial dike exposures.

The problem with a dike origin of the ridge is the stress field: Although the despinning stress pattern predicts north-south extension at the equator, the extensional stress in a shell of *uniform* thickness is actually a minimum at the equator and maximum in the polar regions, so it is difficult to see how an intrusion could have been guided so accurately to the equator. There is also the problem of how melts to fill a putative dike might have been generated.

We suggest that the solution to both these problems might be related. Tidal despinning itself generates heat that, near the surface, is concentrated toward the equator [3]. Similarly, convection might also lead to concentration of rising warm currents near the equator [7], although neither mechanism concentrates heat in a zone as narrow as the ridge itself.

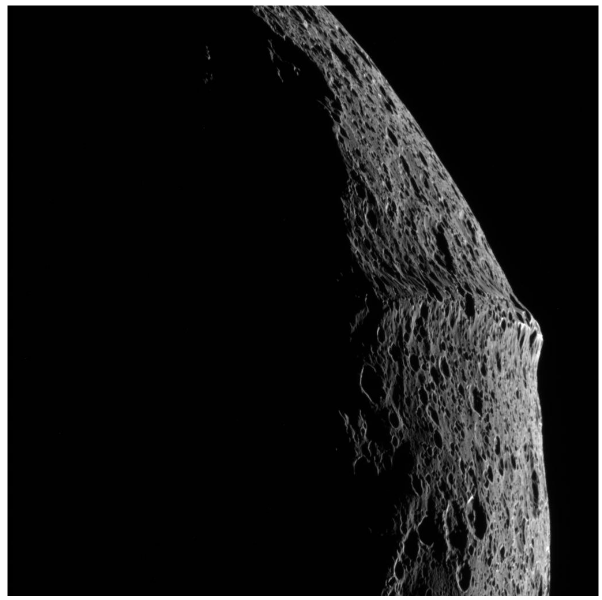

Fig. 1. High resolution imate of Iapetus' equatorial ridge: note indications of bifurcation near the limb, similar to ridges on Europa and theoretical computations of deformation near intrusive dikes [8]. Cassini Image 189028main_Iapetus-91828.jpg.

Stresses in a shell of non-uniform thickness: Non-uniform heating, however, may lead to a lithosphere of non-uniform thickness. In this case stresses may concentrate in the equatorial region. Straightforward solution of the stress equilibrium equations inicate that, if the thickness of the lithosphere is a function of colatitude θ, $h(\theta)$, then the product of $h(\theta)$ and the stress $\sigma_{\theta\theta}(\theta)$ satisfies the same equations as the stress itself does in a uniform shell. Thus, the latitudinal stress is given by:

$$\sigma_{\theta\theta} = \frac{\mu\,\Delta f}{3}\frac{\bar{h}}{h(\theta)}\left(\frac{1+\nu}{5+\nu}\right)\left(5+3\cos 2\theta\right)$$

where $\bar{h}$ is the mean lithosphere thickness μ is the shear modulus, ν the poisson ratio and Δf is the change in flattening.

Sufficient thinning of the equatorial lithosphre (by a factor of 4 or more) shifts the location of the maximum extensional stress from the pole to the equator. Moreover, any partial melting likely to occur near the surface of Iapetus will also occur where the lithosphere is hottest and thinnest: At the equator.

Integration of the elastic equations for a meridionally broken lithospheric shell of non-uniform thickness indicate that once failure of the shell begins near the equator, the shell displaces symmetrically northward and southward, opening a gap that, when completely relaxed (i.e., zero laititudinal stress at the equator) may reach several tens of km, similar in width to the central core of the ridge. Breaking the shell at higher or lower latitudes than the equator does not produce as much lateral displacement as a fracture at the equator itself.

Conclusion: Although one could complain that this combination of despinning stresses and equatorial heating is somewhat contrived, there seem to be few other scenarios that can fit the observations. Certainly, despinning and heating due to tidal flexing should be contemporaneous, so that an approximate time coincidence of the two is not unreasonable. The apparent great age of the ridge and the probable era of despinning are also in reasonable agreement. The narrow localization of the ridge must be attributed to the strain softening occuring upon plastic failure of the lithosphere.

We cannot attribute the full width of the ridge to the intruded material itself: The broad flanks of the ridge may have been tectonically uplifted by the intrusion beneath (or offshooting sills, or perhaps short extrusive flows, although evidence of flow fronts is lacking).

In spite of these difficulties, the only geologic features analogous to Iapetus' ridge are extensional dikes. The suggestion we offer here is still only tentative: questions such as the degree of heating by tidal despinning, nature of the intruding fluids and continued support of the equatorial bulge still need addressing. Nevertheless, we believe that further exploration of an intrusive, extensional origin of the bulge is likely to be fruitful.

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