MIMAS GROOVES, THE HERSCHEL IMPACT, AND TIDAL STRESSES. Paul M. Schenk, Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena, CA 91109

An interesting paradox in satellite geology is that the small icy Saturnian satellite Mimas is so blandly cratered while its nearby twin, Enceladus, is one of the most active of Saturn's satellites [1,2]. Mimas has a relatively large orbital eccentricity and hence has been subjected to tidal and rotational distortion. It has also experienced an unusually large impact event, the formation Herschel, with a depth of 10.5 km and a diameter of 140 km or ~70% of Mimas' radius. Indeed, the large impact Odysseus on Tethys was probably responsible for the circumferential Ithaca Chasma fracture, as well as several radial fractures there [e.g., 5]. The relatively large Herschel event should also have had profound effects on Mimas, and it has been suggested that Mimas may have been disrupted and reaccreted [2]. The only clear evidence of deformation or resurfacing on Mimas is the presence of 40 linear grooves distributed over the <50% of the surface that has been observed ([6], Fig. 1), indicating that stresses have disrupted the surface. Groove orientations are examined here to determine whether any of these forces were responsible for the deformation.

The most prominent of the grooves, Ossa Chasma, is 20-30 km wide, and 150 km long. It is up to 3-km deep and is roughly V-shaped (Fig. 2). Other grooves may have similar morphologies, although a few may be crater-chains. As such they superficially resemble the grooves on Phobos [7], but are not as densely spaced. The timing of fracturing, or at least the latest episode, may be qualitatively constrained by the continuation of several parallel grooves across the floor of Herschel (Fig. 1). Herschel may be one of the younger craters on Mimas, as evidenced by the lack of smaller craters on the floor and the presence of numerous craters outside the rim. These craters are also muted in appearance, indicating partial obscuration by ejecta from Herschel. Thus groove formation/activation may have been one of the last events to take place. This tends to rule out mechanisms, such as despinning, that occur very early in Mimas' history [8]. Global expansion due to freezing of a mantle or core is also unlikely for any likely thermal evolution [9,10], especially in the absence of obvious resurfacing or topographic relaxation. Nonsynchronous rotation is considered unlikely because of the probable presence of a permanent mass asymmetry (the tidal bulge) for most of Mimas' history [11]. Also, the Herschel impact was probably too small to have broken the synchronous lock and reoriented Mimas [12] because the satellite is so close to Saturn. Nor is the large mass deficit of the 10.5 km deep crater likely to have caused significant reorientation because of the large tidal bulge.

HERSCHEL. The two most probable mechanisms are shocks from the Herschel impact and tidal distortions due to orbital evolution or eccentricity. The crossing of Herschel by several parallel grooves (Fig. 1) indicates that the impact itself was not directly responsible for the activation of at least some grooves. Post-impact internal adjustments are unlikely to have produced fractures because Herschel has not viscously relaxed, as determined by crater depth/diameter statistics [13]. Such adjustments, as well as the impact itself, might be expected to result in axially symmetric stress patterns. A relationship with Herschel can be tested by determining centers of groove orientations. The best-fit centers of groove orientations are, assuming grooves formed concentrically, 66° S, 65° W, and assuming they formed radially, 27° N, 78° W (Fig. 1). The concentric center is consistent with the dominant E-W groove trend (with a peak at ~30° to E-W, Fig. 3), while the radial center is~35° from the center of Herschel. Groove orientations are only weakly radial with respect to Herschel itself (Fig. 4). The most prominent grooves form a nearly continuous chain of subparallel grooves between 0 and 30° S, the extension of which nearly bisects Herschel. This quasi-great circle oriented approx. radially to Herschel is perhaps the best evidence for impact related fracturing. Stresses occurring during impact may well have formed new fractures or reopened old ones, however, permitting the deformation we now see. Also, no antipodal effects are detectable in available images.

TIDAL DEFORMATION. Mimas' figure is dominated by a large tidal bulge, where the difference between the long and short axes, *a-c*, is ~17km [11]. The relatively high eccentricity results in changes in the equilibrium height of the bulge and can produce stresses at the surface of about 0.1 bar. Orbital recession could produce stresses on the order of a few bars, depending on orbital history. Groove orientations have been measured with respect to the resultant stress trajectories, which are parallel and perpendicular to the principle stresses. One set is approximately concentric about the long axis of the tidal bulge [e.g., 3,4,14,15]. Grooves are dominantly at high angles to these stress trajectories (Fig. 5a), with a moderate peak at 60-70° orientation. In this case, grooves would be interpreted as strike-slip faults, or as tensional fractures, consistent with their morphology. Although 30° and 60° peaks suggest strike-slip faulting, it has shown [16] that normal or reverse faults are to be expected in a likely Mimas lithosphere rather than strike-slip faulting of this type, although Mimas' lithosphere may be mechanically unusual [11]. (Interestingly, grooves are strongly radial to stress trajectories concentric about the axis pointing in the direction of orbital motion (0°, 90° W), with a weaker peak at 30° orientation (Fig. 5b). The problem is determining a mechanism for producing a stress field of this orientation.)

Grooves on Mimas may be due in part to the effects of the large impact Herschel, representing the incomplete early stages of the catastrophic break-up process. Groove orientations on Mimas also permit the possibility of tidal deformation, however. A further complication is that Herschel is on the equator very near Mimas' intermediate axis. Resulting stress patterns at low latitudes, where most current data is, may be very similar for both impact effects and tidal deformation. More importantly, the orbital evolution of the inner Saturnian satellites is poorly understood, and Mimas' orbital/tidal history may be more complicated than currently believed, including the passage through other resonances [11] with attendant deformation. Completion of Mimas mapping is needed to better constrain orientations, which offers the potential for placing constraints on orbital evolution, and is a potentially interesting task for Cassini.

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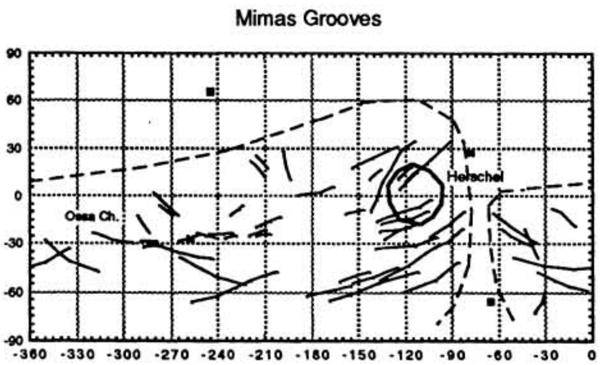
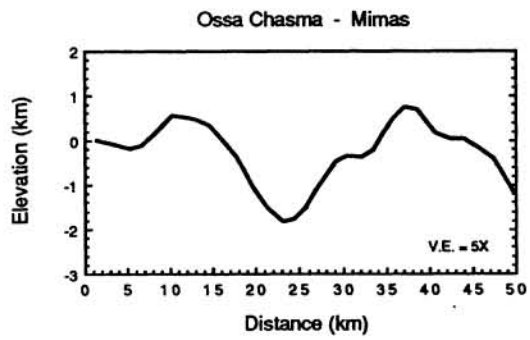


Figure 1.



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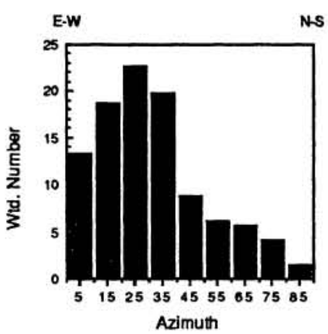

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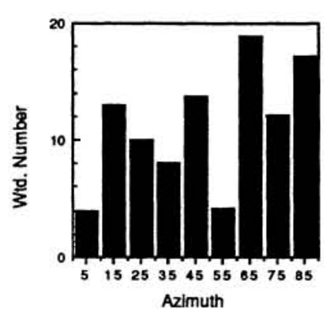

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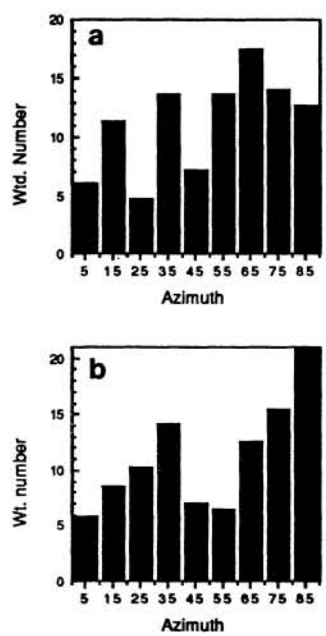

Figure 5.