THE TECTONIC AND IGNEOUS EVOLUTION OF ENCELADUS

S. Pozio[1] and J.S. Kargel[2]; [1] Reparto di Planetologia, Viale dell' Università 11, 00185 Roma, Italy; [2] Lunar and Planetary Lab, University of Arizona, Tucson, AZ 85721.

Voyager 2 provided high-resolution images of the small, icy Saturnian satellite, Enceladus. These images show evidence of a complex history, during which the satellite was subjected to widespread tectonic activity and several episodes of partial re-surfacing. Squyres *et al*. described extensional tectonic features; they recognized only one ridge, and as it is bounded on either side by troughs, they ascribed to it an extensional origin as well (1). Smith *et al*., on the other hand, observed both extensional and compressional tectonic features (2).

This work supports that of Smith *et al*., as we also observe a highly complex tectonic style. Figure 1 is a tectonic map of Enceladus. This map is non-interpretive, as features are mapped only according to their topographic expression. Included are features of likely compressional origin (ridges), others of probable extensional nature (troughs, scarps, and crater chains), and features of uncertain character.

Near the sub-Saturn point is a system of troughs oriented perpendicular to and truncated by a west-dipping fault scarp which previously was interpreted as a strike-slip fault by Kargel (3). South of these troughs are several other sub-parallel lineaments, at least two of which also are troughs. This whole area is a lightly cratered plains unit exhibiting only extensional and possibly trans-tensional tectonic styles. North of this area, extending to the North Pole, the crater density is substantially higher, although again, compressional tectonics are absent. At high latitudes and near the terminator in the highest resolution images, many craters appear to be highly relaxed, as if this region at some time experienced a regionally elevated thermal gradient (4).

Centered on the trailing hemisphere is an area of 'ridged plains' bounded by a 750-km-long system of curvilinear ridges. We observed only two small craters on this entire area (109,000 km^2); several more could be present under high solar incidence, but we are confident the crater density actually is extremely low, since many craters are visible in other areas under similar illumination and lower resolution; of course, this requires that the ridged plains are the youngest region observed on Enceladus. The marginal ridges characteristically are bounded by troughs. These ridges have either a compressional or an igneous constructional origin. Photometric profiles have indicated local relief of about 1.5 km (4); however, local relief as great as 4 km can be observed in limb profile (e.g. PICNO 1320S2). The whole system looks remarkably like the Himalayan Orogen or the complex series of island arcs in the western Pacific Ocean. We have considered two models for the possible origin of the curvilinear ridges: 1) folding; and, 2) plate flexure under volcanic line loads. Either case requires a mechanically layered lithosphere, with layer thicknesses on the order of 10-100 cm in case 1, or 100-1000 m in case 2. The inferred layering, in either case, suggests a volcanic origin for the lithosphere; therefore, the mechanical lithosphere of Enceladus also appears to be a chemically differentiated crust.

In the middle of the ridged plains, nearly symmetrically disposed relative to the marginal ridges, is a system of lineaments which truncate each other in a rectilinear pattern. Since this system is situated near the sub-solar point in the best images it is not possible, taking into account the lack of shadows, to say if many of them are ridges or troughs. However, at least one ridge in this region was observed in limb profile (PICNO 1505S2); and, it appears that at least one other feature here also is probably a ridge. The tectonic relationship of this rectilinear grid to the marginal curvilinear ridges, and to the ridged plains in general, is uncertain, but is likely to be significant.

North of the ridged plains, between 210 and 320^o longitude, is a photometrically banded terrain, where diffuse-appearing bands may be the fronts of either *en echelon* overthrusts, or of thick (100's of m) volcanic flows. This area has about the same crater density as the younger areas of cratered plains.

Other extensional features include two morphologically similar rifts. The most prominent one is located between 30-80° N. lat., 310-335° long. Crater densities indicate that the floor of this rift was resurfaced, but not very recently. Following or concurrent with resurfacing the floor of this rift was again extensionally disrupted. The other rift is centered near 25° N. lat, 180° long. and is bounded by two scarps. It is poorly resolved, but may also have been resurfaced.

The global tectonic pattern is quite interesting. Extensional tectonics dominate the North Polar region, the Saturn-facing region, and the anti-Saturn region; apparently compressional tectonics dominate the region near the trailing point. It appears that the internal convective patterns in Enceladus either are governed by or control the orientation of the tidal/rotational axes of Enceladus.

We have constructed models of the thermal steady-state evolution of Enceladus and find that for reasonable circumstances radiogenic heating alone was sufficient to permit melting near the ammonia-water peritectic early in Enceladus' history; with the enhanced tidal deformation of a differentiated body, tidal heating then may have allowed Enceladus to remain magmatically and tectonically active until the present day.

REFERENCES
1. Squyres, S., et al., 1983, Icarus, 53, 319-331.
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4. Passey, Q.R., 1983, Icarus, 53, 105-120.

Figure 1.

Tectonic map of Enceladus.