TECTONICS ON TRITON; Steven K. Croft, Lunar & Planetary Laboratory, University of Arizona, tucson, AZ, 85721.

Summary. Tectonic features on Triton have been mapped as part of a larger study of the geology of Triton. Few purely tectonic structures are found on Triton: some grabens and possibly some compressive ridges. However, most of the other structures seen (primarily cryovolcanic in origin) exhibit tectonic control. A regional tectonic network has dominant orientations of: N-S, E-W, NE-SW, and NW-SE. Most of the orientations are consistent with tidal deformations related to Triton's decreasing orbital radius. Localized quasi-concentric patterns may be due to interior processes such as mantle plumes.

Tectonic Features. A sketch map of tectonic features seen on the USGS 1:5 M shaded relief map of the Slidr Linea quadrangle is shown in figure 1. Of the features mapped, few are apparently unmodified tectonic structures. The most readily identifiable tectonic features are the fossae, which appear to be simple grabens. The fossae occur in two width classes: 1) narrow fossae 2-3 km wide, including Jumna Fossae, a parallel pair of valleys ≈300 km long, and Yenisey Fossa, a single valley ≈800 km long, and 2) the wide fossae ≈15 km wide, occurring in a single group, Raz Fossae, which is an en echelon pair of valleys about 350 km long. Another type of possibly unmodified tectonic features are the sinuous ridges and scarps which occur in three groups: the Awib dorsa (center near 7S,77E), an unnamed group just southwest of Raz Fossae (3N,14E), and another unnamed group near Bheki cavus (15N,310E). The Raz group of ridges are 15 to 50 km long, highly sinuous in plan, axisymmetric in section with sharp to rounded crests and steeply sloping sides. Structures in the Awib Dorsa and the Bheki group are morphologically somewhat different: the structures are longer, 30 to 150 km, broadly curvilinear in plan, and their crests are more rounded. The crests of these structures are axially asymmetric, steep slopes on one side and much shallower slopes on the other, morphologically reminiscent of the lobate scarps on Mercury and might be more appropriately referred to as scarps rather than ridges. While few purely tectonic features are seen on Triton, the locations and orientations of many features exhibit strong tectonic control, including the grid-like network of the linear ridge materials, the network of rugged ridges in the cantaloupe terrain, and pit chains, notably Set Catena. These features are cryovolcanic or tectono-volcanic in origin, though interpretations differ: e.g., the linear ridges were interpreted as flooded grabens by (1) but as dike-related deformations and cracks by (2).

The Tectonic Network. Directional trends of these different geologic features are similar, both locally and globally. Taken together, these features define a network with four major trends: N-S, E-W, NW-SE, and NE-SW. Most individual structures follow one or another of these trends, while several of the long linear ridges switch from one trend to another: e.g., Tano Sulci (NE-SW to N-S) and Vimur Sulci (E-W to NW-SE and back). Mapping of the dense network of rugged ridges and linear ridges in the cantaloupe terrain suggest minor tectonic trends concentric and radial to two centers (one near 10°N,310°E and the other near 15°N,355°E in figure 1), confirming the observations of (3). While best seen in the cantaloupe terrain, the dominant tectonic trends also affect structures in the plains areas of Monad and Bubembe Regiones. The long axes of the sinuous ridges south of Raz fossae run mostly E-W. The long axis of Tuonela Planitia is N-S. Indeed, a major NW-SE "cryovolcanic" axis is defined by the locations of all four of the walled plains, most of the ring paterae, the long axes of many of the pit paterae (e.g., Kibu Patera), and the crests of the Awib Dorsa and Bheki group of scarps.

There is some localization of tectonic tends. Features trending N-S and E-W are mostly within ≈20° of the equator (Tuonela Planitia is an exception). NW-SW and NW-SE trending features tend to occur at higher latitudes. The single bright linear ridge near the south pole runs nearly parallel to a constant longitude line: 120°E over the pole to 300°E.

Discussion. Most of the observed tectonic trends are consistent with models of despinning (4) and tidal distortion (5). However, the nature of the surface failure on Triton is opposite to that usually considered, because instead of despinning and decreasing distortion due to tidal recession from a primary, Triton has undergone spin-up and increasing distortion due to its tidally-driven approach to Neptune, regardless of origin. For this case, the predicted tectonics due to increasing distortion along an axis through Neptune include N-S trending normal faults in a circular zone centered on the sub-Neptune point, NW-SE and NE-SW trending strike-slip faults over the rest of the equatorial and mid-latitude bands, and compressional faults parallel to the 0°long meridian over the poles. This predicted pattern corresponds well to most of the trends and even the extensional nature of the fossae seen on the map, noting that the map is centered on the sub-Neptune point. The somewhat broader than expected distribution in longitude of N-S trending features may be accounted for by adding a globe-girding equatorial bulge due to spin-up. However, the E-W trend and the 120° trend of the single polar ridge are unaccounted for by either model. The two concentric trends followed by the rugged ridges and linear ridges in the cantaloupe terrain are apparently due local stress fields or tectonic imprints due possibly to ancient large impacts or endogenic processes (3). An endogenic model is favored here, specifically mantle plumes are proposed. Radial and concentric patterns are formed by a rising, then cooling plume head. Concentrations of the possibly cryovolcanic cavi are found in the interiors of both concentric patterns and clusters of likely cryovolcanic features such as dark lobate and bulbous smooth deposits dominate the center of the eastward pattern, consistent with the location of cryovolcanic activity that would likely be associated with a plume. Additional evidence of interior activity interacting with surface tectonic patterns is provided by the "cryovolcanic" axis: virtually all of the smooth materials and paterae interpreted as cryovolcanic in origin lie along this axis. It is a global-scale feature. Although the areal density of cryovolcanic structures and the predominance of stratigraphically younger features tends to increase to the NW along the axis, stratigraphic ages along the axis do not change uniformly, suggesting a mantle "hot line" rather than a moving "hot spot". Using stratigraphy, a few events can be established about Triton's tectonic history. The formation of the tectonic grid, and presumably most of the strain and failure, occurred before the formation of the current surface formations: the piercement locations of upwelling cryovolcanics were apparently governed by weaknesses in the grid. The oldest surface is the cantaloupe terrain, which is superposed by smooth plains units. Raz Fossae lie partly under a patch of smooth high plains, while Yenisey Fossa cuts a different patch of smooth high plains and a linear ridge. This indicates that either the fossae or the patches of smooth plains were formed at different times. The smooth material in the walled plains superpose both the Jumna Fossae the smooth high plains, making them the youngest deposits on Triton. The average global extensional strain represented by the fossae is very small: only about 10^{-4}, orders of magnitude smaller than the $\approx 1\%$ strain seen on other icy satellites (6). The sinuous ridges and lobate scarps also superpose smooth materials, but no general time relation between the fossae and ridges can be established. If the ridges and scarps are compressional tectonic features, the strain represented is also small.

The stress fields directly responsible for forming the fossae, ridges, and lobate scarps are ambiguous. They may have been formed by local stress systems associated with movements of mantle material or magmas at depth: their total strains are very small, they are areally restricted in location, and their times of formation appear interleaved with cryovolcanic events. On the other hand, they formed towards the end of significant melting, and presumably heating, which, if related to capture, came after circularization of Triton's orbit. However, the orbit would continue to decay, tidally stretching the globe near the sub-Neptune point, which is where most of the fossae are found. The suggestion was made in (1) that (mis)alignments of some linear features indicate large-scale strike-slip movement to the NW of Raz fossae. However, topographic features in this area are numerous and tend to follow the NW-SE, NE-SW grid directions, so the perceived alignments may be fortuitous. There is no corroborating evidence of large horizontal movements elsewhere.

References. 1) Smith, B.A. et al (1989) Science 246,1422. 2) Croft, S.K. (1990) LPS XXI, p. 246. 3) Boyce J.M. & P.G. Rogers (1992) LPS XXIII, p. 145. 4) Melosh, H.J. (1977) Icarus 31,221. 5) Melosh, H.J. (1980) Icarus 43,334. 6) Croft, S.K. (1992) LPS XXIII, p. 267.