GEOMORPHOLOGY OF TRITON'S POLAR MATERIALS; Steven K. Croft, Lunar & Planetary Laboratory, University of Arizona, Tucson, AZ 85721.

Summary. One of the Triton's most debated puzzles is the nature, distribution, and transport of its atmospheric volatiles. The full potential of constraints provided by detailed observations of the morphology and distribution of the polar deposits has not been realized. The objective of this study is characterization of the morphology, distribution, stratigraphy, and geologic setting of Triton's polar materials.

Description of Polar Materials. In the south polar mosaic of Triton (1), two primary types of polar materials are readily apparent: the slightly reddish south polar cap (SPC) itself and the bluish polar fringe with its north-trending rays. The bright fringe provides a continuous border to the SPC along its entire length with the exception of a small gap between 290°E and 320°E. Fringe Materials. The fringe is typically 100 to 200 km wide, broadening where it extends northward into the bright rays which are also 100 to 200 km wide where they seamlessly join the fringe, but typically broaden to the north. Fringe materials have the spectral characteristics of a frost (1). Fringe and ray materials range from translucent to opaque, and, except in the center of the equatorial "bar" near Yasu Sulci, show no topographic expression or visible "softening" of underlying features. The fringe overlaps the SPC along much of their common border, but a thin zone (nearly) free of bright material between the fringe and the cap edge begins near the center of the "bar" and continues eastward out of the high-resolution region. Color comparisons on the low resolution global mosaic suggest that the "detached" zone extends east to around longitude 150°E. Geologic Subdivisions of the SPC. These divisions represent a more detailed description of polar materials than given in the preliminary discussions (2,3). Bright Smooth Terrain (Bs) is a bright, flat plains unit with surface textures ranging from very smooth to slightly rough. The albedo of the surface is non-uniform, ranging from a predominate albedo estimated near $A \approx 0.85$ to relatively diffuse bright patches with $A \approx 0.9$. Albedo patterns of adjacent plains are discernable within the unit, indicating that unit Bs consists of a dark "bedrock" plains surface coated with bright material translucent in most places, but becoming opaque in the high albedo spots. Bright Rugged Terrain (Br) consists of a maze of rugged linear ridges and troughs with a few rugged, rimmed, quasi-circular depressions. The albedos of unit Br range from ≈ 0.85 to $A \approx 0.9$, the ridges being generally darker than the troughs. The size, distribution, and texture of the ridges and depressions are similar to like features in the cantaloupe terrain, indicating that unit Br consists of cantaloupe terrain coated with a bright material. The brightest opaque material occurs in topographic lows. Bright Featureless Terrain (Bf), a new division, consists of very bright ($A \approx 0.92$) featureless surfaces occurring in both isolated and connected patches. The bright patches are separated by a few narrow, slightly darker ($A \approx 0.88$) and higher ridges into large (few hundred km) quasi-circular to linear lobate planforms. Patches of unit Bf within unit Br are small, irregular, and conform to topographic lows. The largest connected patches of unit Bf seen in high resolution images occur near 45°S,300°E and 50°S,350°E. Large patches of similar-appearing material are seen in the lower resolution images between about 40°S and 60°S with only isolated patches occurring to the north or south. Maculae and Plumes are features with albedos between 0.65 and 0.75 are seen on the SPC. Most are "wind streaks" (2,4). A second type of dark feature comprises the plumes (2,5). A third class of dark features, apparently not previously described, comprises the diffuse dark patches. These patches have very complex albedo patterns: multiple fuzzy dark centers imbedded in a thick to diffuse matrix with feathered and diffuse edges. They are probably atmospheric phenomena: 1) the edges of the diffuse dark patches strongly resemble the diffuse edges of the plumes, 2) the relative darkness of the patches increases with the obliquity of the viewing angle as do the plumes, and 3) the areal extent of the edge of a patch near the Mahilani plume changed substantially between different images. The patches are suggested to be low hazes. The patches appear to exist at latitudes between about 35°S and 70°S all around the south pole. Bright Lineations (a new unit) are bright linear features seen to cross the SPC in medium resolution images, including a prominent one within 10° of the south pole. The bright lineations seen at high resolution are all linear ridges, suggesting that those seen at low resolutions are also linear ridges. Guttae and Aureoles (the "mushrooms" of 2 & #) are dark ($A \approx 0.7$) irregular spots with bright ($A \approx 0.9$), annular aureoles around them (3). The guttae have not previously been considered polar materials (2,3), but are reinterpreted as such here because: 1) they occur in a well-defined latitudinal band between 5°S and 45°S, on or near the edge of the SPC, 2) aureole materials are visually indistinguishable from the opaque bright material on the SPC, and 3) they rest unconformably underlying units like other polar materials.

Interpretation. The materials of the SPC appear to be a layer of bright material coating a darker bedrock of plains and cantaloupe materials. The thickness of the coating is non-uniform, changing from centimeters in the translucent sections that cover most of the polar region regardless of topography to tens of meters in the opaque sections that tend to cluster in topographic lows (3). The patches of unit Bf are interpreted as somewhat thicker deposits, perhaps as much as a few hundred meters, that nearly fill valleys between the barely visible ridge crests. Their lobate and elongated planforms may result from glacier-like flow in these thicker deposits. Thus the SPC materials within the high-resolution area do not form a thick, continuous, sheet-like deposit. Medium-resolution images covering the south pole and mid-latitude areas to the west of the high-resolution area show bright lineations that are probably linear ridges right down to the pole and albedos like the translucent areas of the Br and Bs units. The bright Bf units that may be thick materials occur in only local patches. A high-resolution (but high phase angle) image ,FDS 11401.38, shows another large swath of the SPC in the anti-Neptune facing hemisphere. Although the surface is partially obscured by hazes and clouds, circular features with sizes and cluster patterns like the cavi in the cantaloupe terrain can be seen as well as groupings of larger circular and elongate features with planforms and groupings like either paterae or patches of Bf material. The similarity of these features to those seen at high resolution suggest that the 1/3 of the SPC seen at high resolution is representative of the whole.

Models for seasonal transport of volatiles on Triton (e.g., 6,7) indicate that only centimeters of material can be moved in a tritonian year. Thus the thicker opaque materials must represent a permanent cap while the translucent materials apparently represent seasonal deposits. The transport models also predict significant sublimation near the current sub-solar latitude near 45°S and frost deposition in the equatorial regions and in the entire northern hemisphere. The plumes and diffuse dark patches may represent sublimated materials. The dark equatorial and northern plains raise the question: where is the freshly deposited frost? Suggestions have included dark frosts (6), deposition on N-facing slopes where it would be difficult to see in current images (8), and high internal heat flow in the north which prevents frost deposition (9). It is suggested here that frost deposition is going on, the frosts are bright, and the deposits are in plain sight: the polar fringe and the N-trending rays. These materials behave spectrally as frosts; they cover virtually the entire equatorial area and much of the northern plains. The rays darken (thin?) to the north, but then the amount being transported is very small. In addition, the light scattering properties of the rays may make then appear darker as they are seen at low phase angles near the terminator. Assuming that the fringe and rays are the sought-for frost deposits, the locations of the deposits are decidedly non-uniform. At least two possibilities exist: 1) to date, the transport models are 1-D; the frost deposition environment on Triton is 3-D: there are winds related to a Hadley cell circulation pattern (9), and presumably planetary waves propagating along the equator (suggested by the scallop pattern) that could create uneven frost distribution. Once started, a lightly frosted ares would tend to be cooler than its surroundings and collect more frost. The association of the fringe with the edge of the SPC rather than some arbitrary latitude is further evidence of circulation on deposition: the fringe could be due to condensation caused by air heating and rising sharply at the cap's edge like at the edge of the martian caps (10). 2) The frost could sinter quickly, becoming transparent (11). There is some evidence that the entire zone north of the fringe and between the rays is covered with transparent frost (12). The patches of dark, i.e., transparent, frost could be caused by different ground albedos; indeed the gap in the fringe is associated with a localized patch of dark mantling. Only a few degrees difference in surface temperature is needed to cause great differences in the sintering rate (10).

The conclusion that most of the SPC materials represent a permanent cap implies that it is residual. Similarly, I propose that the guttae are residual deposits of an even more extensive cap. The morphologies of the guttae are similar to outliers of the permanent martian caps which are shaped by ablation; the sharp SPC edge, with high topography exposed is also best explained by ablation. This may be viewed as morphological evidence that Triton's atmosphere was significantly thicker earlier in its history, as has been suggested on theoretical grounds (13). As the atmosphere thinned, it "dried" relative to the volatiles in the cap, causing net ablation. The guttae may be layered: the aureole extending under the guttae; candidates materials are N_2 with over CH_4, or CH_4 over CO_2 (14). Alternatively, the guttae may be the remnants of a less volatile material and the aureoles a later deposit; likely candidate materials are CH_4 guttae surrounded by N_2 aureoles. Is there a permanent northern cap? That it was not seen by Voyager is irrelevant: the martian permanent caps differ greatly in size. However, there has been no change in Triton's color since 1933 (15), when the sub-solar and sub-earth points were in the northern hemisphere, suggesting both a permanent northern cap and fringe. **References.** 1) McEwen, A.S. (1990) Geophys. Res. Let. **17**,1765. 2) Smith, B.A. et al (1989) Science **246**,1422. 3) Croft, S.K. (1990) LPS XXI,248. 4) Hansen, C.J. et al (1990) Science **250**,421. 5) Soderblom, L.A. et al (1990) Science **250**,410. 6) Spencer, J.R. & J.M. Moore (1992) Icarus **99**,261. 7) Hansen, C.J. & D.A. Paige (1992) Icarus **99**,273; Stansberry, J.A. et al (1992) Icarus **99**,242. 8) Yelle, R.V. (1992) Science **255**,1553. 9) Brown, R.H. & R.L. Kirk (1991) BAAS 23,1210. 9) Ingersol, A.P. (1990) Nature **344**,315. 10) Haberle, R.M. et al (1979) Icarus **39**,151. 11) Eluszkiewicz, J. (1991) J.G.R. **96**,19217. 12) Lee, P.E. et al (1992) Icarus **99**,82. 13) Lunine, J.I. & M.C. Nolan (1992) Icarus **100**,221. 14) Cruikshank, D. et al (1993) Science, submitted. 15) Buratti, B.J. et al (1993) Icarus, submitted.