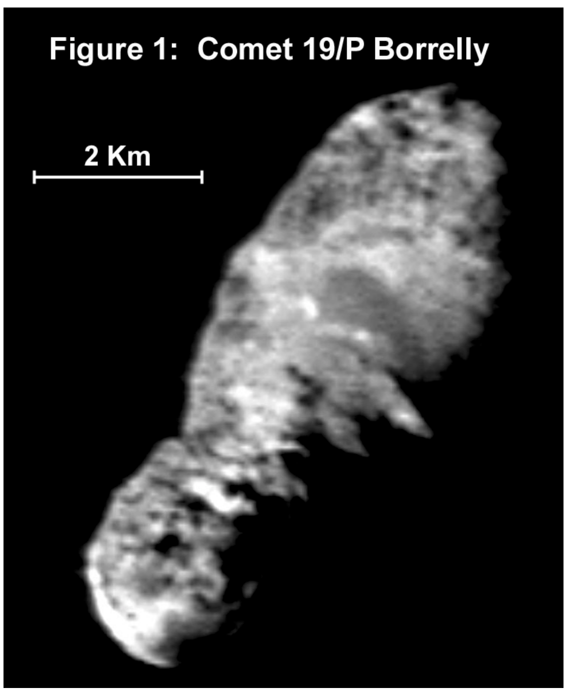
THE GEOLOGY OF COMET 19/P BORRELLY. D. T. Britt[1], D. C. Boice[2], B. J. Buratti[3], M. D. Hicks[3], R. M. Nelson[3], J. Oberst[4], B. R. Sandel[5], L. A. Soderblom[6], S. A. Stern[2], and N. Thomas[7], [1]University of Tennessee, Department of Geological Sciences, Knoxville, TN 37996, dbritt@utk.edu; AZ 86001, [2]Southwest Research Institute, [3]Jet Propulsion Laboratory of the California Institute of Technology, [4]DLR Institute of Space Sensor Technology and Planetary Exploration, [5]University of Arizona, [6]United States Geological Survey, Flagstaff, [7]Max Planck Institute für Aeronomie.

Introduction: The Deep Space One spacecraft flew by Comet 19P/Borrelly on September 22, 2001 and returned a rich array of data including imagery with resolutions of up to 48 m/pixel. These data converted the nucleus of Borrelly from an astronomical object, obscured by a coma of gas and dust, to a geological object with striking surface morphology and processes. These images provide the best window so far into the surface structure, processes, and geological history of a comet. Borrelly is a Jupiter-family, short-period comet with dust production rates an order of magnitude lower than the other comet imaged by spacecraft, 1/P Halley. Although showing much lower activity, DS1 imaged a number of active gas and dust jets [1]. Shown in Figure 1 is the highest resolution image of Borrelly.



Borrelly Morphological Units: Shown in Figure 2 is a map of the morphological units of Borrelly superimposed on the high-resolution image. Figure 3 is the unit map of the comet with the units shown in interpreted stratigraphic order. From the geological perspective, the youngest units are stratigraphically on top of the others. However, the "youngest" unit will probably have the longest surface exposure and thus be the most altered by exposure to the space environment. Borrelly is among the darkest objects ever imaged. The average geometric albedo is 0.022 ± 0.003, but surface reflectance varies by a factor of four between the dark spots with a reflectance as low as 0.007 to the brightest areas with a reflectance of 0.032 [2]. Some of this variation in reflectance may be due to particle size effects. In this analysis four units have been identified:

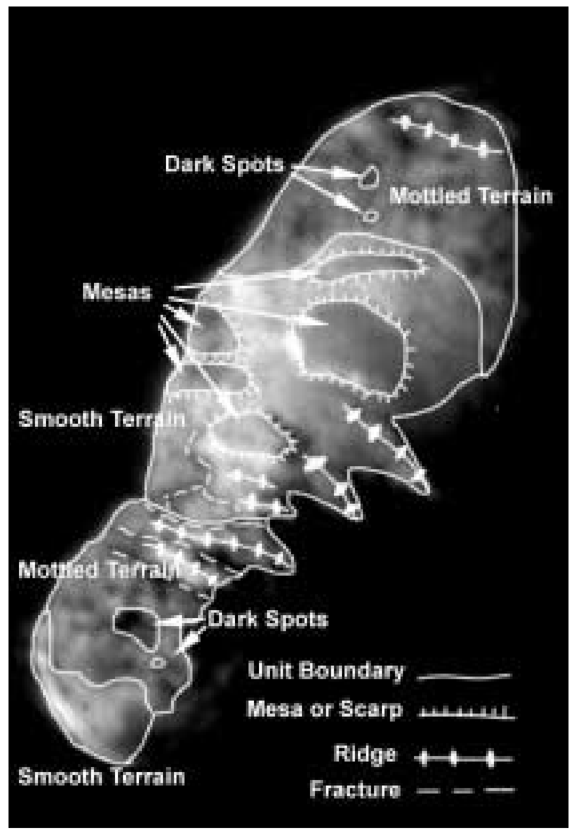


Figure 2: Map of Borrelly Morphological Units.

Dark Spots: These are the darkest areas on the comet with reflectance typically around 0.01 but as dark as 0.007 [2]. This unit is found on the ends of the comet associated with the Mottled Terrain. Photometric analysis shows properties similar to the Mottled Terrain [2]. Morphologically the Dark Spots appear to overlie the Mottled Terrain. These spots may be surface lags with the longest exposure to the space environment.

Mottled Terrain: The Mottled Terrain consisted of areas rough at pixel resolutions with irregular pits, troughs, and ridges. Textures suggest some degree of desiccation and terrain softening. This unit is generally darker than average, but shows strong albedo variations and it is not strongly associated with the active jet areas on the comet. The morphology and albedo suggest that the Mottled Terrain represents older surface lag deposits that have been subjected to reworking and terrain collapse.

Mesas: The Mesa Unit consists of several areas of bright slopes surrounding darker, flat-appearing tops. These features are primarily in the central portion of the comet and appear, along with the Smooth Terrain, to be associated with the active jets. The tops of the Mesas may be older, darker lag deposits that insulate the lower terrain against outgassing. The Mesa slopes may be some of the more freshly exposed areas that are subject to gas/dust loss.

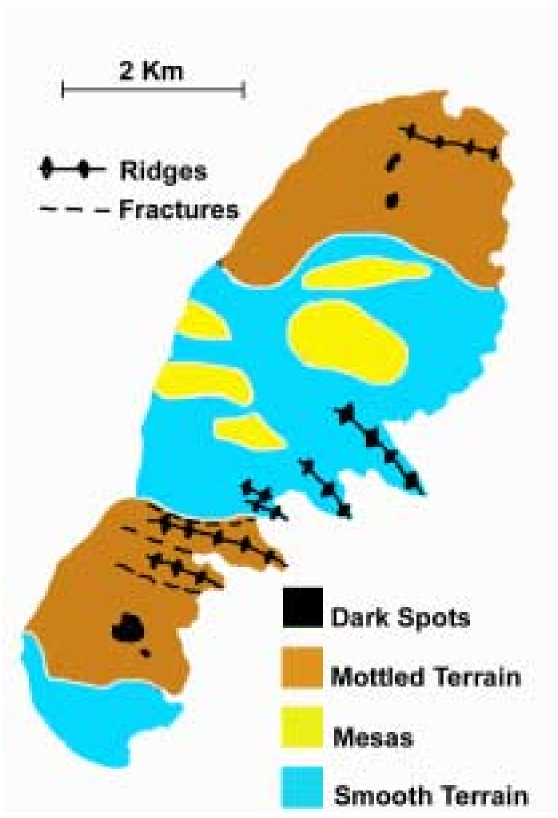


Figure 3: Borrelly Unit Map.

Smooth Terrain: The Smooth Terrain shows higher than average albedo, is smoother than average at pixel scale, and is associated with the surface locations of Borrelly's active jets [1]. Reflectances are as high as 0.032, but are typically 0.028 [2]. The surface of the Smooth Terrain shows a fine pattern of albedo variegations. Photometric analysis suggests that this unit is rougher than average at sub-pixel scales [2]. This unit may represent recent deposits of relatively large particle size material associated with the comet's active jets and is part of the active resurfacing processes from dust ejection. The albedo variegations may indicate areas of differential activity and/or surface age as part of the resurfacing processes.

Other Features: In addition to the units described above, Borrelly exhibits a number of other striking terrain features.

Ridges and Fractures: Near the narrowest portion of the comet there are a complex set of sub-parallel ridges and fractures that are oriented normal to the long axis of the comet. If the visible expression of Borrelly looks like a footprint, digital terrain models indicate that the area of the "heel" is canted about 15-20º relative to the "sole" [3, 4]. Most of the ridges and fractures are associated with the boundary of this canted area. This may indicate Borrelly is actually two pieces in loose contact and subject to complex compressional and/or extensional stresses that are produced during the comet's orbit by distant gravitational interactions with planets.

Craters: A number quasi-circular depressions are visible, but it is difficult to unambiguously identify any of impact origin. Quasi-circular depressions are most abundant in the Mottled Terrain, but these have roughly similar diameters indicating that they may be the product of surface desiccation. Several quasi-circular depressions are visible in the Smooth Terrain.

Conclusions: Analysis by Soderblum et al. [1] indicates that the comet's rotation pole is roughly aligned with the main jet and the north pole is near the central cluster of mesas. The subsolar point is at 60º N and rotation is likely around the short axis. During perihelion (the portion of the orbit closest to the sun) pole orientation and rotation keep the central portions of the comet shown in Figure 1 in constant sunlight. This energy input may be what drives not only the active jets, but also the albedo and morphology variation that are probably associated with the active areas.

References: [1] Soderblom, L. A. et al. (2002) *LPS XXXIII*, this volume. [2] Buratti, B. J. et al. (2001) BAAS 33, 1091. [3] Kirk R. et al. (2002) *LPS XXXIII*, this volume. [4] Oberst, J. et al. (2002) *LPS XXXIII*, this volume.