EARLY RESURFACING OF UMBRIEL: EVIDENCE FROM VOYAGER II PHOTOMETRY.
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Umbriel's dark, heavily cratered surface is remarkable for its apparent blandness in Voyager II images (1). In the present study, however, we present new visual albedo maps of Umbriel's surface which reveal a more diverse range of terrains than previously recognized. Our specific objectives are (a) to describe the average photometric properties of Umbriel's surface at visual wavelengths in terms of Hapke's (2) recent bidirectional reflectance equation, (b) to map the spatial distribution of normal albedoes over Umbriel's surface using Hapke's equation, and (c) to interpret our results in the context of Umbriel's geological evolution.

The five parameter version of Hapke's equation used in other studies (3,4, 5,6) was adopted here. The parameters are w, the average particle single-scattering albedo, h, a "compaction parameter" describing the angular width of the opposition effect, S(0), a parameter describing the amplitude of the opposition surge, g, the asymmetry factor in the well-known Henyey-Greenstein particle phase function, and $\bar{\theta}$, the average topographic slope angle of subres-oluton-scale macroscopic roughness. Helfenstein et al. (5) have derived values of these parameters for Umbriel (Table I) from the Voyager, clear-filter (0.497 micron) disk-integrated observations of Veverka et al. (4) and suggested that better-constrained values of w and $\bar{\theta}$ be obtained from disk-resolved observations. We have collected disk-resolved measurements of Umbriel's brightness from five Voyager clear-filter images (FDS 26788.15, 26797.22, 26825.51, 26840.04, 26904.04) covering phase angles 10.4-142.9 and averaged in 5 degree bins of photometric latitude and longitude over the each visible disk (excluding the few visible bright craters). The parameters of Hapke's equation were fit to the data using an improved version of the method described by Helfenstein and Veverka (7). Since the angular width of the opposition surge is poorly constrained by images having acceptable reso-lution for disk-resolved analysis, we fixed our value of the h parameter at that reported by Helfenstein et. al. (5) from disk-integrated observations covering a more complete range of phase angle. Our results (Table I), are in excellent agreement with those obtained from disk-integrated observations.

Using our Table I results, we renormalized our highest resolution images (FDS 26797.22, 26797.51, 26840.04) to represent normal albedo (r_n) and mapped them into standard polar stereograpic projections. Contrast stretches of the normal albedo maps revealed the presence of polygonal discontinuities between coherent regions of lower and higher albedo. Some of the discontinuities define closed polygons around uniformly darker areas (hereafter referred to as umbral polygons) and brighter areas (hereafter referred to as penumbral polygons) ranging from less than 50 km to greater than 600 km in size. In many cases, albedo contrasts between adjacent polygonal areas were variable along their boundaries and only partial polygons could be traced. Figure 1 is a preliminary photometric terrain map showing the observed distribution of these terrains. On scales less than about 100 km, polygons appear to have random orientations. However, subglobal scale polygons at [30°N, 300°W], [73°N, 270°W], and [60°N, 100°W] are elongated with subparallel NE-SW trending lengthwise boundaries.

At highest Voyager resolution (11 km/lp) there are no apparent struc-tural boundaries separating polygons -- they are visible only by virtue of their albedo contrasts. Table II lists normal albedoes of selected features on Umbriel from our data. For comparison, the mean normal albedo of Umbriel is 0.095 ± 0.02. From Table II, the photometric contrast between the most prominent umbral polygons and typical penumbral regions is only about 2.4%. Although there is no obvious stratigraphic relationship between umbral and penumbral polygons, their existence as well as systematic patterns of global orientation argue for their being relics of tectonic breakup and resurfacing of Umbriel. Strom (8) has suggested on the basis of cratering statistics that Umbriel was indeed resurfaced early in its geological history. If the albedo of polygons is correllated with age, and if the surface has darkened with time due to accumulation of meteoritic debris, surface lag deposits, and/or radiation darkening, then the low photometric contrast between polygons, as well as the apparent absence of structural boundaries (presumably eradicated by cratering) supports this hypothesis.

Table I: HAPKE PARAMETERS FOR UMBRIEL FROM VOYAGER CLEAR FILTER PHOTOMETRY

OBSERVATIONS	w	h	S(0)	g	$\bar{\theta}$	Source
DISK-INTEGRATED	0.30	0.06	1.13	-0.20	21°	Helfenstein et al. (5)
DISK-RESOLVED	0.34	(0.06)	1.28	-0.18	28°	This work

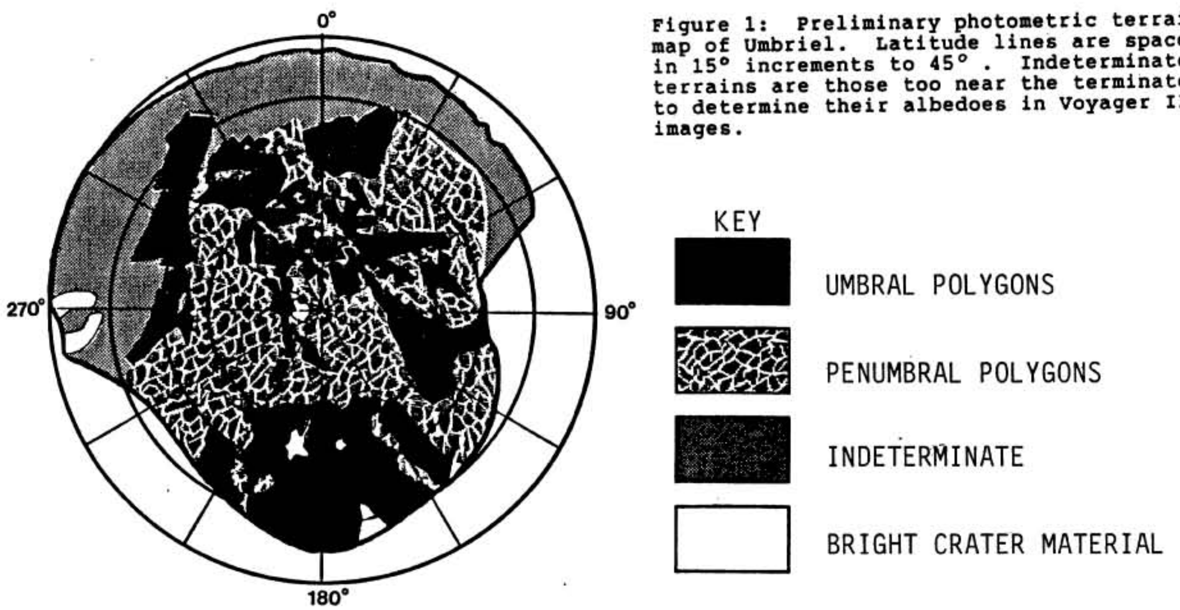

Figure 1: Preliminary photometric terrain map of Umbriel. Latitude lines are spaced in 15° increments to 45°. Indeterminate terrains are those too near the terminator to determine their albedoes in Voyager II images.

TABLE II: VISUAL NORMAL ALBEDOES OF SELECTED FEATURES ON UMBRIEL

FEATURE	LOCATION	NORMAL ALBEDO
Umbral Polygon	23°N, 293°W	0.091±0.005
	68°N, 5°W	0.086±0.002
Penumbral Polygon	83°N, 135°W	0.092±0.001
	83°N, 98°W	0.094±0.001
	56°N, 257°W	0.091±0.001
Bright Annulus	5°N, 269°W	0.221±0.023
Bright Crater	80°N, 256°W	0.104±0.003
	38°N, 180°W	0.102±0.002

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