COLOR VARIATIONS ON EROS FROM NEAR SHOEMAKER MULTISPECTRAL IMAGING.

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Abstract – Multispectral images of Eros’s surface reveal large albedo variations due to exposure of bright materials on steep slopes. The associated color variations are weak, but consistent with a lesser degree of space weathering. A difference in the relationship of albedo and color between Eros and the moon shows that space weathering’s effects are quantitatively different on Eros.

Introduction: NEAR Shoemaker’s Multispectral Imager (MSI) has obtained measurements at seven wavelengths (450-1050 nm) to characterize albedo and color properties of Eros. The highest-resolution whole-disk data, 180 m/pixel, were obtained for northern and equatorial regions during the last pre-orbit insertion sequence on 12 February 2000 [1]. The same and other areas were imaged again in color at 10-20 m/pixel from high orbit in March-April and October-November 2000, and selected targets have been studied in color at resolutions as high as 2 m/pixel [2,3]. These measurements reveal little variation in visible-wavelength color, but they do reveal several percent differences in the 950-nm/760-nm reflectance ratio. Due to MSI’s limited wavelength coverage, that ratio is used here as a proxy for depth of the 1-µm mafic mineral band.

Data Reduction: In addition to phase angle-dependent variations in color [4], Eros exhibits a strong dependence of 950-nm/760-nm ratio on incidence angle, comparable in magnitude to color variations associated with surface features. To measure surface color variations and their relationship with albedo, and to provide estimates of uncertainties in both, data were corrected photometrically to $i=30^\circ, e=0^\circ$ using two different methods. Uncertainties were derived from comparison of results of the two methods, and from comparison of results obtained for the same regions imaged at different illumination geometries. One method was the Hapke correction also applied to data from the Near-Infrared Spectrometer (NIS) [4]. The other method followed the form of McEwen’s empirical lunar phase function [5,6], with width and amplitude of the opposition surge taken from Eros measurements [4]. McEwen’s Lunar lambertian correction for incidence and emission angles, which is wavelength-independent, was also replaced with a wavelength-dependent Minnaert correction. Reflectances at $i=30^\circ, e=0^\circ$ from the two methods agree to ±0.005. The typical precision of reflectance and color determinations is 0.02.

Albedo and Color Variations: The northern hemisphere exhibits average reflectances at $i=30^\circ, e=0^\circ$ of 0.136±0.007 at 760 nm and 0.115±0.006 at 950 nm, equivalent to geometric albedos of 0.30±0.02 and 0.26±0.02 respectively. On different surfaces, 760-nm reflectances vary over the range ~0.10-0.22 (Fig. 1). The highest reflectances occur on the interior walls of two large craters, Psyche and Himeros, and on the walls of smaller craters that exceed several hundred meters in size. However, Eros is conspicuously deficient in the bright annuli found exterior to the rims of small craters on the other two S asteroids imaged by spacecraft at close range, Gaspra and Ida [7,8].

The spatial distribution of reflectance variations is closely related to surface slopes (Fig. 2). Little variation occurs on slopes <20º, but steeper slopes become progressively more dominated by sharp-edged, lobate-shaped brightness patches oriented downslope (Fig. 3). On average, the brightness of these patches is ~1.7 times that of the surrounding darker regolith.

Despite Eros’s large albedo variations, there is only ~10% variation in the 950-nm/760-nm reflectance ratio. Reflectance and color are highly correlated (Fig. 4), with higher reflectances corresponding to lower 950-nm/760-nm ratios (or equivalently, to deeper 1-µm bands). The relationship between reflectance and color, as well as the occurrence of reflectance heterogeneities as downslope-oriented patches on steep slopes, are consistent with spatial differences in the extent of regolith aging by space weathering [9].

Eros’s Strange Reflectance-Color Systematics: On the lunar surface, which is dominantly a mixture of pyroxene and plagioclase, with increasing exposure age 760-nm reflectance and 950-nm/760-nm reflectance ratio approach those of a theoretical end-product of space weathering (Fig. 4). To a first order, the rate at which color ratio changes as albedo decreases is a function of Fe content [10,11]. Results from the Xray Spectrometer [12] show that Eros’s Fe content is comparable to that in the lunar maria, but Eros’s variation of color with decreasing albedo is ten times smaller. In addition, with increasing exposure age, Eros’s albedo and color are being driven to a different end state than on the moon. The differing effects of space weathering may result from Eros’s different (olivine-dominated) mineralogy [cf. 13], or alternatively from different microphysical processes involved in space weathering in Eros’s lower-gravity environment at greater heliocentric distance.

Fig. 1. Simple cylindrical projection of 760-nm reflectance corrected to $i=30^\circ$, $e=0^\circ$, from the Multispectral Rotation Sequence of 12 February 2000.

Fig. 2. Relationship of 760-nm reflectance, corrected to $i=30^\circ$, $e=0^\circ$, with surface slope relative to the local gravity vector.

Fig. 3 (left). Lobate bright patches on the interior wall of Psyche.

Fig. 4 (right). Relationship between 760-nm reflectance and 950-nm/760-nm color ratio, both corrected to $i=30^\circ$, $e=0^\circ$, for Eros and the Moon. As lunar materials are space-weathered, 760-nm reflectances and 950-nm/760-nm ratios converge toward a theoretical end state (arrows). The slope of the trend for a single material is highly correlated with FeO content. The trend formed by Eros's 760-nm reflectances and 950-nm/760-nm ratios does not converge toward the same theoretical end product as on the Moon.