ORBITAL MULTISPECTRAL MAPPING OF MERCURY BY MESSENGER: EVIDENCE FOR THE ORIGINS OF PLAINS UNITS AND LOW-REFLECTANCE MATERIAL. Scott L. Murchie1, Rachel L. Klima1, Brett W. Denevi1, Carolyn M. Ernst1, Mary R. Keller1, Deborah L. Domingue2, David T. Blewett1, Nancy L. Chabot1, Christopher D. Hash3, Erick Malaret3, Noam R. Izenberg1, Faith Vilas2, Larry R. Nittler4, Jeffrey J. Gillis-Davis5, and James W. Head6. 1Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA (scott.murchie@jhuapl.edu); 2Planetary Science Institute, Tucson, AZ 85719, USA; 3Applied Coherent Technology Corp., Herndon, VA 20170, USA; 4Carnegie Institution of Washington, Washington, DC 20015, USA; 5University of Hawaii, Honolulu, HI 96822, USA; 6Brown University, Providence, RI 02912, USA.

Introduction: A principal data product from MESSENGER’s primary orbital mission at Mercury is a global, multispectral map in eight visible to near-infrared wavelengths, acquired at low solar incidence angles and an average pixel scale of 1 km by the Mercury Dual Imaging System (MDIS). This map addresses three major science objectives [1,2]: (a) constraining formation of geologic units using differences in color as stratigraphic markers; (b) constraining crustal mineralogical composition and compositional heterogeneity on the basis of reflectance, spectral slope, and any absorption features; and (c) understanding surface processes, including space weathering, from reflectance and color trends. Lower-resolution MESSENGER and Mariner 10 flyby imaging [3,4,5] reveal key spectral properties. Plains units are divided into high-reflectance red plains (HRP) with a relatively steep spectral slope, and low-reflectance blue plains (LRM) [6] with a shallower spectral slope. Low-reflectance material (LRM) is exposed by impact basins and craters [4]. There are no unambiguous absorptions due to Fe²⁺ in silicates as on the Moon, Mars, and many asteroids; a lower reflectance of optically fresh material than on the Moon suggests a pervasive opaque component [7]. Here we describe the MDIS eight-color map and the geological properties of the crust that it reveals.

Analysis of the Map: MESSENGER’s orbit at Mercury is polar and non-Sun-synchronous. Combined with Mercury’s 3:2 spin:orbit resonance, this geometry yields large variations in solar incidence angle (i; 0°–90°) at the low emergence angle (e) at which most data were taken. Observed reflectance was corrected to a standard geometry of i=30°, e=0° with a photometric model [8]. Corrected data were plotted against photometric angles to test for residuals at extreme geometries [8]. From those results, areas with i>70° and e>20° were excluded from further analyses. The masked map is shown in Fig. 1.

Scattered-light artifacts in some images complicate assessment of weak color variations. To minimize effects when comparing widely separated areas, principal component analysis was used to isolate major sources of spectral variability; principal component 1 (PC 1) correlates with overall reflectance, and PC2 with the difference in spectral slope between LRM and HRP [4]. Optical maturity [5] and scattered light are mixed in higher-order components. Optical maturity is therefore represented instead by the ratio of reflectance at 430 nm to that at 900 nm. Fig. 1 shows variations in these parameters.

Color Variations of Plains: Morphologic mapping from MDIS images collected at moderate to high incidence angles shows that smooth and intercrater plains are the dominant morphologic units on Mercury [9,10]. Morphology, elevation, crater density, and geologic setting all suggest that intercrater plains are a more heavily cratered equivalent of smooth plains [10,11]. To evaluate a reported distinction in color properties of smooth and intercrater plains [e.g., 12], we used the photometric masks described above, and compared the frequency distribution of values of PC2 in smooth plains (as mapped by Denevi et al. [9]) with those in other units. Smooth plains were further divided into the northern volcanic plains (NVP), HRP interior to Caloris, the annulus of LBP [9] surrounding Caloris, and all other smooth plains, and the sub-units were also compared. Older units were grouped, undivided; they are dominated by intercrater plains but also include LRM.

Results are shown in Fig. 2. NVP have distinct color and high PC2, but there is a low-PC2 tail indicating that the NVP are not uniform in color; some are closer to IP. PC2 values in Caloris interior plains are typically lower than in NVP but higher than in other smooth plains, on the boundary between HRP and IP. PC2 distributions in other smooth plains deposits are similar to those in intercrater plains plus LRM. The two major differences are that intercrater plains plus LRM contain a low-PC2 tail corresponding to LRM, whereas remaining smooth plains have a high-PC2 tail that represents HRP, mostly within Rembrandt and Faulkner basins. Thus, excepting the two largest smooth plains occurrences (NVP and Caloris interior plains), smooth and intercrater plains are not spectrally distinct, consistent with morphologic interpretations that the two units differ mainly in age.

Search for Absorption Features: To constrain absorptions from potential Fe²⁺-bearing silicates, sulfides, and candidate darkening phases, three-point band depths were calculated using the methods of Clark and Roush [13] and mapped. Absorptions due to sulfides centered at 650–700 nm, low-Ca pyroxene centered near 900 nm, high-Ca pyroxene or olivine centered near 1000 nm, and the broad 600 nm absorption reported for LRM from MESSENGER flyby data [4] were all evaluated. At 10- to 20-km scale, there is no unambiguous absorption due to sulfides or Fe²⁺ in silicates ≥2% in depth. This result agrees with the non-detection of those...
absorptions by the MESSENGER Atmospheric and Surface Compostion Spectrometer, and with limits those results place on sulfide abundance and Fe\(^{2+}\) content in surface silicates [14]. The broad 600-nm feature is detected in some, but not all, LRM. Fig. 3 shows large LRM deposits away from scattered-light artifacts. The broad 600-nm feature is present at Basho and especially Rachmaninoff, but not at Tolstoy or Titian, demonstrating that LRM is spectrally heterogeneous.

**Characteristics and Composition of LRM:** LRM has been proposed to be an intrinsic component of Mercury’s crust excavated from depth [4,5,15], or the product of space weathering [16] or incorporation of meteoritic material [17]. The examples in Fig. 3 are all ejecta; they range from pre-Tolstojan through Kuiperian in age of excavation, yet all are comparable in reflectance, consistent with their being an intrinsic component. To test the ability of darkening agents proposed in the literature to produce LRM’s low reflectance and 600-nm feature, we modeled mixtures of laboratory mineral spectra, including sulfides, graphite, Fe\(^{0}\), and ilmenite, with NVP spectra by converting corrected reflectance to single-scattering albedo (SSA), combining SSA values using weight-percent abundance weighted by particle size, and converting to reflectance. Particle sizes for NVP of 20–80 \(\mu\)m and 2–20 \(\mu\)m for the darkening phase were considered. Of proposed darkening agents, either graphite [5,18] or a mix of nanophase and microphase Fe [16,19] appears capable of reproducing observed spectral reflectances within measured limits on elemental abundances [20,21]. These two working hypotheses are testable with low-altitude MESSENGER Neutron Spectrometer measurements now being collected.