LUNAR SPECTRAL UNITS: A NORTHERN HEMISPHERIC MOSAIC, T. V. Johnson, J. A. Mosher and D. L. Matson, Jet Propulsion Laboratory, Pasadena, CA, 91103.

Multispectral imaging using silicon vidicons has been developed in the last few years as an extremely useful tool for studying the distribution of spectral units on the lunar surface (4,8). Precise relative spectrophotometry within a single vidicon frame has been demonstrated (7,4). Extending this quantitative analysis to widely separated lunar regions, imaged in separate frames at different times requires the production of a geometrically and photometrically controlled mosaic. McCord et al. (8) have published spectral ratio mosaics of a large fraction of lunar mare regions. The individual ratio frames were uniformly processed and printed to ensure reasonable frame-to-frame consistency but still contain abrupt variations at frame boundaries. However, these variations are equivalent to only a few percent change in greatly enhanced ratios. The mosaics are not geometrically controlled. We present here a northern hemisphere multispectral mosaic which has been reduced through additional stages of image processing and computer mosaiced. New features of this mosaic include: 1) Geometry—the mosaic is a Mercator projection, 2) Photometric calibration-groundbased spectrophotometry has been used to provide control points for inter frame calibration.

Once the data have been processed and a mosaic for each spectral bandpass produced (we have used four filters in this study: $\lambda_0 \sim 0.38 \mu m$, $0.56 \mu m$, $0.85 \mu m$ and $1.05 \mu m$; $\Delta \lambda \sim 150 \AA$), there are several forms of display available. First, an enhanced color image can be made from any three of the individual mosaics. In this method, the computer takes the very small color variations in the scene and expands the dynamic range of hue and intensity to produce greatly enhanced shades and tones in the combined three color image. Second, ratios between pairs of images are produced and greatly contrast enhanced in the computer to create a set of black-and-white ratio images similar to those displayed in McCord et al. (8). These ratio frames can then be combined optically to produce a color ratio composite, where the information from four spectral channels (three ratios) is combined. The same data set can also be used with automatic or interactive classification programs, yielding computer-generated maps of units with similar spectral properties (see 4). Finally, for any designated area within the mosaic the digital ratio values relative to the Serenitatis standard can be obtained and compared with ground-based data.

Preliminary examination of the data products described above allows discussion of specific aspects of the distribution of spectral units in the northern hemisphere. The characterization of the various lunar spectral types is based on previous spectrophotometric studies of small (about 20 km square) areas, particularly those of McCord et al. (6) and Pieters and McCord (11). Since our mosaic can be quantitatively related to these spectral classes, we can for the first time study in detail the spatial distribution of these materials and to compare units in widely separated regions. Some of these results, briefly summarized, are: 1) Mare Basalt Types: Pieters and McCord (11) have produced a classification of spectral characteristics of mare types based primarily on $0.40$ to $0.57 \mu m$ ratio which is related to $TiO_2$ content in mature soils (see 3) and infrared ($0.8 - 1.1 \mu m$) spectral features which are related to agglutinate and iron content. The bandpasses used in our study are capable
of differentiating among many of these major types. Several of the apparently unsampled basalt types are abundant in northern and western Imbrium. Particularly abundant are the high and moderate titanium content type 2 varieties \( (H_2 \text{ and } h_2) \) and the low titanium, red, \( L \) types (see Pieters and McCord (11) for discussion of nomenclature). No exposure of these units is apparent in the near vicinity (i.e. about a hundred kilometers) of any Apollo site, confirming Pieters and McCord's suggestion that these types are probably unsampled even among the sampled impact ejecta. While unsampled \( H_2 \text{ and } h_2 \) high titanium mare units are abundant in the regions of Procellarum within our mosaic we do see an area of material apparently similar to the Apollo 11 type 1 high titanium unit \( (H_1) \) to the southwest of Aristarchus. The higher titanium content reported in the Aristarchus vicinity by Bielefeld et al. (1) may be related to this area since it lies primarily within the Apollo 15 ground track. This unit also correlates with a region of older \( D_p \) age identified by Boyce (2).

2) Serenitatis-Our earlier work on a single frame containing the Serenitatis standard area suggested some degree of local heterogeneity. Our mosaic data confirms this and suggests that there are at least two units of similar but still spectrally distinct material mixed in the central mare. Data from the Apollo 17 radio sounding experiment suggest relatively thin layering in the southern part of Serenitatis (5,9). A history of thin layering is also suggested by the interpretation of stratigraphy in the rim of the crater Bessel (12). Our data certainly are consistent with vertical mixing of those two units.

3) Dark Mantling Material-Our mosaic shows several regions of high infrared relative reflectance characteristic of high glass and/or agglutinate content, including previously studied 'lunar black spots' (see 10). Not all of these areas (particularly Sulpicius Gallus) share the high blue spectral signature of the Apollo 17 site and other areas studied by Pieters et al., suggesting variety in the chemistry or state of glassy deposits. Aristarchus plateau is not similar in spectral character to any of these units.

In this abstract we expand on some and modify other models and processes we have proposed to: (1) Account for trace element relationships among samples arising from the original melting and differentiation of the lunar crust; and, as a result, identification of the sites from which samples originated. (2) Account for the relative distribution of siderophile Ru and Os in basalts as being the result of partitioning in the early surface ocean and the distribution in breccias as the result of mixing of a primitive and a fractionated component.

I. Assignments of New Samples To Surface Ocean Convection Cells

Halogen, U, Te and P₂O₅ data for new samples are listed in Table 1. Sample 14053 was selected as an additional Fra Mauro related basalt, 14310 has been reported. Apollo 17 basalt 75035 is quartz normative, a class not previously measured, and 71055 is olivine normative and represents a station for which we only have data for a soil. Breccia 79215 was analyzed primarily because of the reported Cl-apatite content (1). However, this was the only sample so far measured in which residual Clᵣ was not detected. The Apollo 14 and 15 breccias were a part of the Imbrium Consortium study; a detailed report on this is available.

The assignment of samples to cells of differentiating early surface magmas is based on the residual Clᵣ/P₂O₅ ratio. Ratios of 0.021 (liquid I), 0.009 (liquid II), 0.004 (liquid III), 0.0011 (liquid IV) and 0.048 are observed (2). The samples all fall into one or another of these groups as have over 80 other samples. Apollo 17 basalt 75035 falls in liquid II along with previously reported basalt 70135 and basaltic soil 71501. We attribute these basalts to the secondaries, possibly ejected from the crater Plinius in Tranquilitatis, that created most of the craters in the valley floor.

Basalt 71055 falls in liquid III with 74275 basalt from Shorty crater; these could be Imbrium ejecta. Breccias 14064-inclusion and 15445 are intermediate members of the liquid II sequence. Our P₂O₅ data places basalt 14053 in liquid I and it becomes the only exotic sample in this sequence. Literature P₂O₅ places this sample with the Apollo 11 basalts (liquid II); the P₂O₅ is being rechecked. Breccia 15455-white falls in liquid III and along with 14082 is the most anorthositic member of this sequence which includes Apollo 12 and 15 basalts. The dark part of 15455 breccia falls in liquid IV.

The results on the Apollo 14 and 15-front samples permit the observation that most breccias are local and are not Imbrium ejecta. It is striking that a significant number of samples collected near secondary craters are exotic to the site-14305 and 14312 from near Triplet and Doublet craters, 15445 at Spur crater and a number of basalts, including 71055 and 75035, from near the Central cluster at Apollo 17, Table 2. They are probably fragments of the crater-producing projectiles and their region of origin can be identified.