DISTRIBUTION AND EVOLUTION OF GLOBAL COLOR PROVINCES ON THE MOON. Laurence A. Soderblom and Joseph M. Boyce, Branch of Astrogeology, Flagstaff, Arizona 86001

A multispectral reflectivity map has been recently completed for most of the lunar frontside. These data were acquired in visible and near-infrared wavelengths (0.4, 0.56, 0.7 and 0.8 micrometres) using the 30-inch reflector at Lowell Observatory, Flagstaff, Arizona. Although these images have relatively low spatial resolution (approximately 35 kilometres) they provide synoptic coverage in which colorimetric units can be correlated over large distances across the moon. The low resolution also suppresses high frequency natural noise generated by impact mixing and exposure of fresh materials. Hence, regional provinces within the maria, expressed by extremely subtle variations in the spectral reflectance, can be mapped. These data provide the global context for high resolution multispectral maps of small areas as those obtained by other groups (1, 2).

The data was acquired by scanning the moon in four narrow-band-passes simultaneously. A spinning filter wheel, containing four filters, which spins at ~1000 rpm is used to chop the incoming radiation into four spectral bands. Signals from an ITT FW 130 photo-multiplier tube, used in a pulse-counting mode, are fed into four digital counters and recorded on magnetic tape. Counts are accumulated for intervals of about one second (the time required to scan one aperture) in which 15 revolutions of the filter wheel are sorted into the four channels. Because all four wavelengths are monitored with a single detector the data is extremely accurate, limited primarily by counting statistics (~0.1%). Further, temporal variations in detector sensitivity, registration errors between spectral bands, temporal variations in the overall transmission of the atmosphere, and spatial variations in index of refraction and transmission of the earth's atmosphere do not affect the data.

The data are presented in the format of both color ratio composites and color ratio-albedo hybrids. The first of these is acquired by simply dividing each spectral band by a particular band chosen for normalizing, in this case 0.56μ. Thus, color ratio composites are generated from individual ratios: 0.4μ/0.56μ, 0.7μ/0.56μ and 0.8μ/0.56. The color ratio-albedo hybrid is created by compositing two of these ratios with a single contrast enhanced band. Thereby albedo variations are included in the color composite. The hybrid composite is found to be most useful as it segregates the maria and uplands materials into two classes of colors. For instance, the green channel in the composite was used for the albedo component. Materials which are bright (high albedo), are therefore represented by mixtures of green with red and blue (turquoise greens, whites, yellows and oranges). Maria

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units, which are low in albedo, are represented by colors in which little green is present (violets, blue, purples, magentas, reds and scarlets). As has been pointed out previously (3), most variation in the uplands are correlated with craters differing in degree of maturity. Extremely fresh uplands materials are distinctly "blue" in coloration and high in albedo. Thus, in the hybrid composite very fresh upland craters appear "turquoise." With time, they evolve through green, yellow, finally to orange. This happens in very short period of lunar time (4). As has also been pointed out (5), the variation in color in the maria is strongly correlated with TiO_2 (ilmenite) content in this part of the spectrum. Apollo sample studies show that soils derived from basalts with extremely high ilmenite content are very blue. Thus, it is inferred that the colors in the hybrid composite, which represent the maria, range from dark blue for extremely high titanium through violet, purple, magenta, scarlet; and finally to red for extremely low titanium content.

These data can be compared with maps of relative age derived from measurements of crater erosion (6), to establish the distribution, type, and sequence of emplacement of mare units. In an earlier general model (7), the sequence of mare emplacement was suggested as follows: Stage I - early (~3.5 to 3.8 billion years ago) high titanium basalt flooding of the eastern maria; Stage II - intermediate age (~3.0 to 3.5 billion years ago) low titanium basalts flooding of the ring maria; and Stage III - late (after ~3.0 billion years ago) moderately high titanium basalt flooding in the western maria. The first and second stages were sampled by Apollo 11, 12, and 15, confirming the correlation between high ilmenite content and blue soils. The correlation between blue soil and high TiO_2 is only inferred for the third stage. Although in general correct, this early model was based on incomplete data and is found here to be an oversimplification. For example, the new data indicate, (a) that early intermediate titanium basalts flooded Mare Nectaris, contemporaneous with Stage I, (b) high titanium basalts were emplaced in Mare Fecunditatis during Stage II, and (c) Stage II basalts show a larger dispersion in TiO_2 (low-intermediate) than previously thought. The late high titanium stage suggested by the earlier model is supported.

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