PETROLOGIC MAPPING OF THE MOON: A NEW APPROACH. Paul D. Spudis[1], Nicolle Zellner[2], John Delano[3], D.C.B. Whittet[2] , and Brian Fessler[1] 1. Lunar and Planetary Institute, Houston TX 77058 spudis@lpi.usra.edu 2. New York Center for Studies on the Origin of Life, Rensselaer Polytechnic Institute, Troy, NY 12180 3. Department of Earth and Atmospheric Sciences, University at Albany, Albany, NY 12222

For many years, lunar scientists have struggled to understand remote sensing data sets in terms that relate to both the lunar sample collection and general geological principles. We have pursued the idea that various remotely sensed chemical data can be connected to lunar sample information to show the compositional affinities of regions on the Moon to known rock types. Specifically, we have used both Apollo gamma-ray data [1,2] and Clementine and Lunar Prospector (LP) data [3] to make maps showing the petrologic make-up of the surface and the regional distribution of provinces that have the composition of known pristine rock types and various mixtures of same [3,4]. Recently, we have reported on a new method that links Clementine maps of chemical composition to known impact-produced glasses in the regolith from the Apollo 14 site [5, 6]. In this contribution, we apply this new technique to the global Clementine data to 1) examine the regional geological settings of the Apollo and Luna landing sites to determine compositional relations; 2) see if the local relations inferred for the Apollo sites apply regionally and globally; and 3) make inferences about the composition, structure, and origin of the lunar crust on the basis of the new global petrologic map.

Method. The use of the Fe-Ti-Al ternary plot to describe the composition of impact glasses in the lunar regolith has a long pedigree in sample studies [5]. This plot allows us to distinguish between Ti-rich mare compositions, high-Fe, mafic silicate components (both mare and highlands), and the Al-rich highlands material found in all lunar soils [5,6]. The Clementine mission collected color image data that permit the derivation of maps of the concentration of Fe and Ti, at the full resolution of the image data (~200 m/pixel; [7,8]). Although we cannot directly detect Al concentrations, lunar soils and rocks show a strong inverse correlation between Fe and Al (e.g., [9, 10]). For this study, we used a newly derived relation [5] as follows:

$$\text{wt.\% ``Al''} = -0.82\ (\text{wt.\% Fe}) + 17.1$$
$$R^2 = 0.93$$

Although this linear fit is only approximate, it adequately describes the Al-Fe relation within the precision of the Fe mapping method (1-2%; [8]). For each pixel on the Moon, the quantities Ti, (Fe-Ti), and “Al” are calculated in atomic proportions and plotted in ternary space. We then assign a primary color red, green, and blue to each principal component – blue for “Al”, red for Ti, and green for (Fe-Ti) and scale these numbers for ease in reading the plot (Figure 1). Intermediate colors represent mixtures of these three components in ternary space; they are sliced into equal bins and numbered arbitrarily for ease of reference. The classified “units’ are then rendered into a color map image that shows the distribution of petrologic “units” that make up the lunar surface (Figure 1).

Results. The new petrologic map shows the distribution of units defined in Ti-(Fe-Ti)-“Al” ternary space on the Moon (Figure 1). In brief, on this image, feldspathic, anorthositic highlands appear in blue colors, high-Ti mare basalts are red, low and intermediate-Ti units are yellow and orange, and mafic, Fe-rich units are green. The distribution of these units confirm many early suppositions on the composition and structure of the lunar crust (e.g., [11, 12]). For example, the prevalence of units 10, 14, and 15 (blue) support the idea that anorthosite and anorthositic rocks are widespread in the highlands and make up the bulk of the far side highlands, especially in the northern hemisphere. Note that widespread occurrences of unit 15 (nearly pure anorthosite) are associated with basin rings, in particular, with the Inner and Outer Rook mountain rings of the Orientale basin, as previously noted [12, 17]. This distribution suggests that the uplifted basin inner rings expose a nearly intact “layer” of pure anorthosite, probably the remnants of the original, magma ocean-generated crust. Unit 1 (high-Ti mare basalt) occurs in Mare Tranquillitatis and Oceanus Procellarum; other, lower-Ti maria (units 2, 4, and 7) occupy the bulk of the rest of the maria on a global basis. The low-Ti, high-Fe units (units 7, 11, 12 and 13) have an interesting distribution. They occur as very low-Ti maria (e.g., Mare Frigoris), extensive deposits of ancient, buried maria (e.g., unit 13 in Schiller-Schickard basin, Lomonosov-Fleming basin; [13, 14]), and the floor of the South Pole-Aitken basin [14, 15]. Petrologically, these units comprise diverse geological settings and types of inferred rocks, but all represent a mafic component in the highlands. In most of these cases, units 11 and 12 are mixtures of mare basalt and highland materials, but much of the Fra Mauro Fm. (Imbrium basin ejecta; [16]) occurs as unit 8, a “highlands” basaltic unit (see composition of Apollo 14 in Figure 1 and in [6]).

Conclusions. We have developed a new method to show the distributions of petrologic units on the Moon. This method is based on the compositional relations shown by soils and impact glasses found in the regolith of the Apollo and Luna sites. We find that these glasses accurately represent lunar compositions of regional significance and that the new petrologic maps can help us decipher regional geological relations [6]. The new mapping technique nicely complements our earlier version [1-3], which portrays lunar compositional units in terms of their affinities to the groups of pristine rocks and mixtures thereof. The use of both mapping techniques provide a useful tool by which to study regional geology on the Moon [5, 6], unravel the complex structure of the lunar crust [11], or study the effects of localized processes in the evolution of selected regions of the Moon [13]. The new maps will allow us to understand lunar stratigraphy, composition, and evolution to an unprecedented level of detail.

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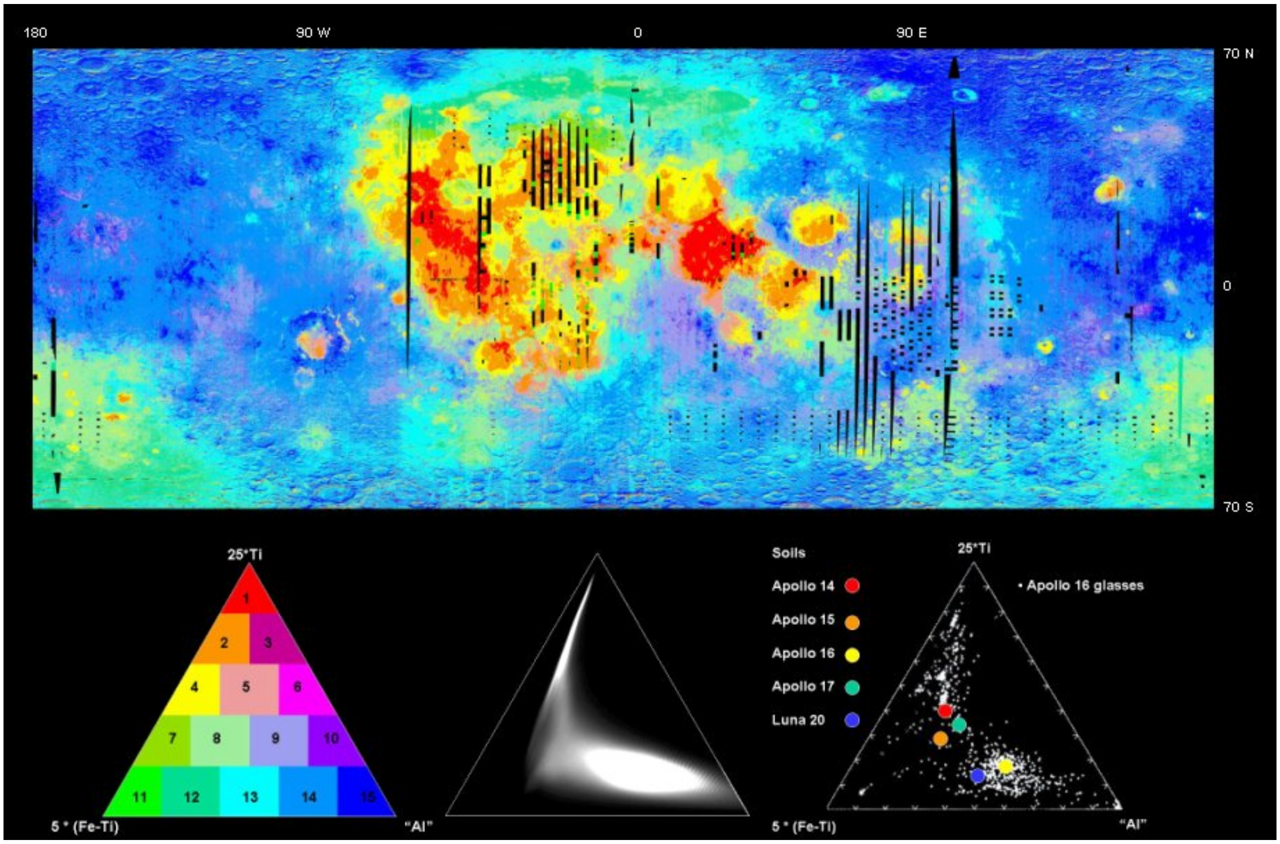

Figure 1. Petrologic map of the Moon based on the compostional systematics of the Ti – (Fe-Ti) – "Al" ternary system (see text for details). Plots at bottom are in atomic proportion. At left is the (arbitrary) breakdown of units in ternary space. The scattergram in the middle shows the distribution of compositional pixels in the global image. At right is a ternary plot of Apollo 16 impact glasses (white dots) and the average soil compositions from highland Apollo and Luna landing sites (color dots).