PETROLOGIC MAPPING OF THE MOON FROM CLEMENTINE AND LUNAR PROSPECTOR DATA: INCORPORATION OF NEW THORIUM DATA Paul D. Spudis, Lunar and Planetary Institute, Houston TX 77058, (spudis@lpi.usra.edu) D. Ben J. Bussey, ESTEC, ESA, Noordwijk NL, Jeff Gillis, Washington Univ., St. Louis MO 63130

Introduction. An initial attempt at producing petrologic province maps of the lunar highlands combined orbital and sample geochemical data in variation diagrams [1]. Later work [2] applied a ternary diagram approach to looking at global lunar petrologic variations; this method concentrated on the Fe - Th/Ti relation as this had the most spatial coverage with the available data and also appeared to be adequate at distinguishing between different rock types. In the ternary diagram, the apexes were assigned the average Fe and Th/Ti values of ferroan anorthosite, mare basalt and KREEP. Each apex was assigned a primary color (blue, green, or red) while the center of the triangle was represented by gray. Each point on the lunar surface covered by the Apollo geochemical instruments were then assigned a color depending on where in the triangle their composition placed them. The resultant classification map shows how the petrologic units vary spatially.

New Global Coverage. Previous work utilized the Apollo gamma and X-ray orbital datasets [1]. These provided limited coverage (gamma-ray ~ 19%; X-ray ~ 9%) of the lunar surface, mostly confined to the equatorial latitudes. With the Clementine and Lunar Prospector datasets we now have global maps of iron, titanium, and thorium [3, 4, 5]. In addition to global coverage, another advantage of the new data sets is spatial resolution. The resolution of the Apollo instruments was ~30 km for the X-ray and ~200 km for the gamma ray data [1]. The iron and titanium maps are derived from the full resolution Clementine UVVIS data is much higher, ~ 250 m/pix. The resolution of the thorium data obtained by Lunar Prospector's gamma ray spectrometer was initially about 150 km [5] but recent data from the extended mission, during which the altitude of the spacecraft was lowered, has been made available with an improved spatial resolution of about 75 km [6]. The other improvement provided by the recent lunar missions is increased precision of the data; the errors in Fe, Ti and Th values obtained by Apollo were 10-25 wt.%, while the error of the Clementine derived Fe and Ti values is ~ 1% [3], whereas the new thorium data have an error of approximately 1 ppm [5, 6].

We have investigated the petrologic variations on the Moon at a global scale using the new Clementine and Lunar Prospector elemental maps for iron, titanium, and thorium. Our methodology is based on the technique described in Davis and Spudis [1, 2]. Our new results use the extended mission, high resolution Th data [6]. We plot values of individual areas of the Moon, defined by Th resolution elements (2° square, or about 60 km on a side), in terms of Fe content (derived from Clementine spectral data [4]) versus Th/Ti ratio (Ti derived from Clementine images [4] and Th from the new LP data [6]). These points are plotted in a scattergram (Figure 1), showing the relative abundance of chemcially defined petrological provinces. The ternary space defined by these points are arbitrarily divided into 15 classes (Fig. 1) for convienence; end member classes (1, 11, and 15) are assigned the primary colors red (Mg-suite), blue (anorthosite) and green (mare basalt), respectively. Finally, these classes are shown spatially on the global petrological map (Fig. 1).

Results The new petrological map confirms an earlier conclusion [1, 2] that anorthositic rocks dominate the upper crust of the Moon, as evident by the predominance of blue and lavender colors in the highland areas of the map (Fig. 1). Indeed, some areas prevsiouly known to be rich in anorthosite (e.g., the inner rings of the Orientale basin [7]) also show up as anorthosite-rich (unit 11) on the new petrological map (Fig. 1). In addition, the large province of nearly pure anorthosite previously noted in the central northern far side [8] is portrayed in this map; anorthosite appears to be even more extensive than previously thought.

Although anorthosite and related rocks predominate, other rock types appear to be important in many regions. The most obvious petrological provinces are associated with the Procellarum “oval” and the floor of the South Pole-Aitken basin. Much discussion has attended to the origin of the petrologic anomalies

NEW PETROLOGIC MAPS OF THE MOON Spudis P.D. *et al*.

of these two regions [see New Views II Workshop, 1999]; Procellarum has higher concentrations of incompatible elements than SPA, but both terrains show large expanses of units 6 and 10, which fall on mixing lines between the KREEP/norite field and the mare basalt field. This suggests some affinity of composition. Among other things, both of these areas have anomaloulsy thin crust; one (SPA) is clearly the site of an ancient impact basin, while the other occupies a basin/depresssion of uncertain origin. The implication is that these areas represent crust quite different from the average upper crust seen at virtually all other highland locations (units 7, 11, 12, all related to anorthosite).

Large regions of unit 13, which falls midway between anorthosite and mare basalt, are found in the Schiller region, northeast of Smythii, in the Mendel-Rydberg basin, and Australe basin. These areas correspond to ancient, buried maria, as evidenced by the presence of dark halo craters that have excavated basalt from beneath highland light plains [9].

Examination of this map confirms earlier conclusions [2] that the Mg-suite (units 1-3) is not a major contributor to at least the upper lunar crust, but because of their presence on the floor of SPA basin and abundance in the ejecta from Imbrium basin (Fig. 1), we infer Mg-suite rocks may be a significant contributor to the lower crust [10]. Study continues on the problem of the crustal fraction of the Mg-suite, needed to determine the Mg# of the bulk crust, an important constraint on lunar origin [11].

References: [1] P. A. Davis and P. D. Spudis (1985) *PLPSC* **16**, D61 [2] P. A. Davis and P. D. Spudis (1987) *PLPSC* **17**, E387 [3] P. G. Lucey et al. (1998) *JGR* **103**, 3679. [4] D. T. Blewett et al. (1997) *JGR* **102**, 16319. [5] D. J. Lawrence et al. (1998) *Science* **281**, 1405. [6] Lawrence D.J. et al. (1999) *GRL* **26**, 2681 [7] Spudis P.D., et al., 1984, *JGR* C95 [8] Peterson C. et al., 1999, New Views II Conf., Flagstaff. 46 [9] Schultz P. and Spudis P. (1979) *PLSC* **10**, 2899 [10] Spudis P.D. (1999) New Views II, 61 [11] Drake M.J. (1986) Origin of the Moon, LPI Press, 105.

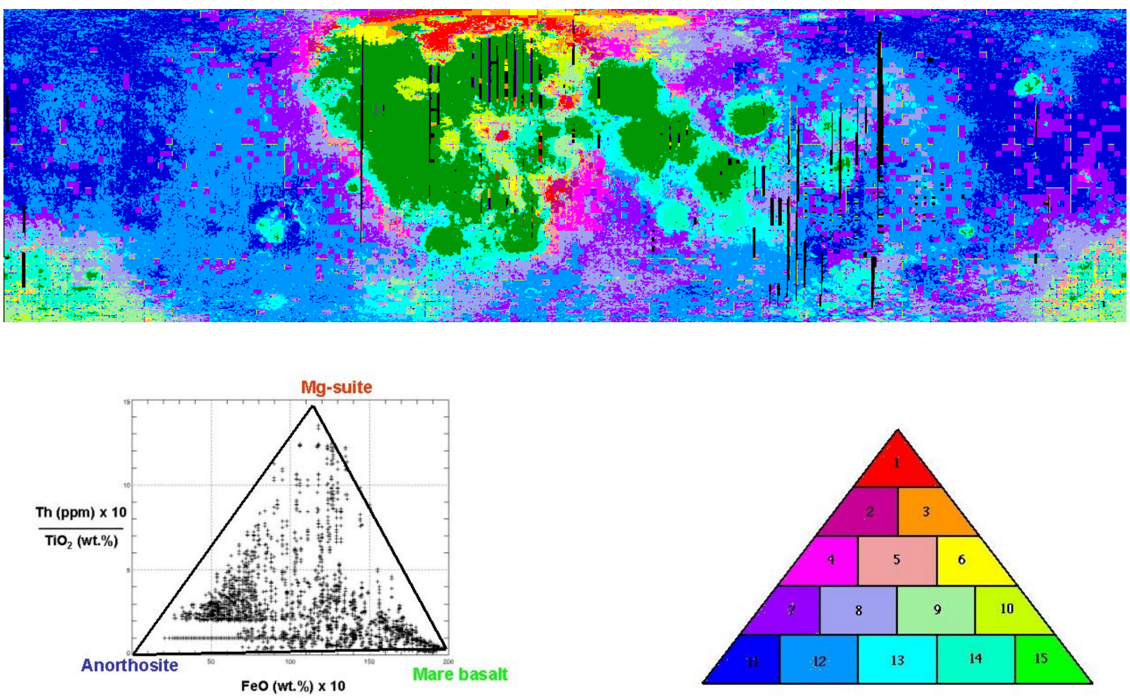

Figure 1. Petrological map of the Moon based on Clementine and LP chemcial maps. Scattergram (bottom left) shows data for 2° squares in Fe – Th/Ti compositional space. The color triangle shows the colors associated with these compositions. The map (top) shows the distribution of compositions on the Moon.