CLASSIFICATION OF LUNAR TERRANES USING NEUTRON AND THORIUM GAMMA-RAY DATA.

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Introduction: A major scientific goal of the Lunar Prospector (LP) gamma-ray and neutron spectrometers is to classify all lunar terranes according to composition. A preliminary analysis of early data indicates this goal will be met for the major rock-forming elements on a spatial scale of about 200 km. The low-altitude phase of LP now in progress should allow reduction of this scale by about a factor of 10 for those elements that have sufficiently high measurable fluxes relative to their backgrounds. Most promising are the flux intensities of thermal, epithermal, and fast neutrons (which each average about 300 counts per 50 km of ground track) and 2.6 MeV gamma rays from thorium (which averages about 50 counts per 50 km of ground track). We therefore explore the information content of these measurables to classify the various lunar terrane types.

Theoretical Expectations: Computer simulations show that the ratio of lunar epithermal to thermal neutron flux is directly proportional to the macroscopic absorption cross section [1]. Estimates of these cross sections for the various Apollo and Luna samples [2] show that abundances of Fe, Ti, Gd, and Sm dominate [3,4]. Because the thermal neutron absorption cross section for Ti is about twice that for Fe, the ratio of epithermal to thermal neutron flux should primarily reflect the content of Fe+2Ti, with significant contributions from Gd+Sm in KREEP-rich terranes.

Simulations of lunar fast neutron fluxes (Gasnault et al., in preparation, 1999) show that their variation reflects only variations in Fe and Ti, in equal proportions. A combined analysis of all three neutron energy ranges should then be sufficient to separate abundance variations in Fe from those of Ti and Gd+Sm. Separation of these last two components can be implemented by adding an analysis of thorium gamma rays because of the measured strong correlation amongst all incompatible elements [2].

Results: Equal area 2°x2° maps of thorium abundances and of fast-neutron fluxes have been published previously [5,6]. The map for the ratio of epithermal to thermal neutrons is similar to these maps but is not shown here. All three maps show relatively high intensities within the front-side Mare, smaller, but somewhat enhanced intensities within the South Pole Aitken basin, and very low intensities in the highlands.

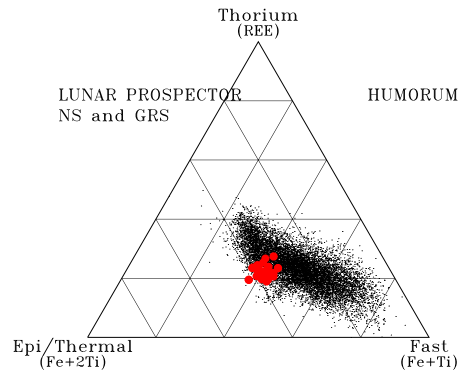

Figure 1: *Ternery diagram for a classification of 2° by 2° equal area spatial pixels on the Moon according to measured epithermal/thermal and fast neutrons fluxes and to the LP GRS thorium abundances. Large red circles give measurements within Mare Humorum.*

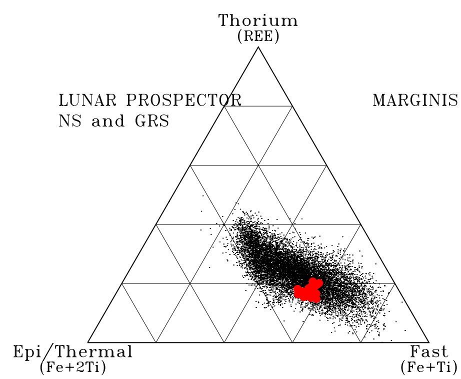

Figure 2: *Ternery diagram for a classification of 2° by 2° equal area spatial pixels on the Moon according to measured epithermal/thermal and fast neutrons fluxes and to the LP GRS thorium abundances. Large red circles give measurements within Mare Marginis.*

These three data sets were combined into a ternary diagram by first normalizing each measurable to the range spanning from 0 to 1 for each 2°x2° spatial pixel on the Moon. Resultant triplets of normalized counts were then renormalized so that they add in quadrature to unity.

One ternery diagram for a region relatively high in Ti (Humorum) is shown in Fig. 1, and one for a region relatively low In Ti (Marginis) is shown in Fig. 2. Plotted in red are spatial locations within the selected region while those in black are for the rest of the Moon. A close inspection reveals the following: 1) Locations within LP ternary diagrams for a given region, cluster about well-defined centroids that vary from region to region. 2) Comparison of the horizontal positions of these centroids with Ti abundances as determined using Clementine Spectral Reflectance (CSR) data [7] shows that regions of higher Ti content locate closer to the Epithermal/Thermal neutron vertex, and those having lower Ti content locate closer to the Fast neutron vertex.

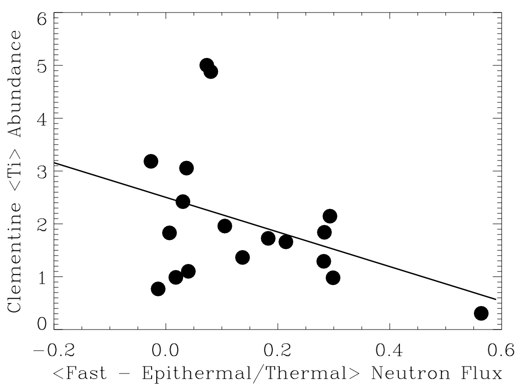

Figure 3: *Correlation between titanium abundances determined using Clementine Spectral Reflectance data and the difference between normalized fast and epithermal/thermal neutron fluxes. The correlation line has significance given by R=-0.4*

This trend is quantified in Fig. 3 by the correlation between Ti abundances as determined using the CSR data and the horizontal centroid positions in LP ternary diagrams. Inspection shows a weak, although significant correlation. Reasons for the substantial scatter that is very evident at low values of the <Fast - Epithermal/Thermal> neutron flux are not known but need to be investigated.

References: [1] Feldman, W.C. et al., (1991) GRL, 18, 2157. [2] Haskin, L., and Warren, P., (1991) in 'Lunar Sourcebook' Heiken, G., Vaniman, D., and French, B.M. eds., pp 357-474. [3] Elphic, R.C. et al., (1998) Science, 281,1493. [4] Lingenfelter, R. et al., (1972) Earth Planet. Sci. Lett. 16, 355. [5] Lawrence, D.J. et al., (1998) Science, 281, 1484. [6] Feldman et al., (1998) Science, 281, 1489. [7] Lucey, P.G., (1998) JGR 103, 3679.