Detection of Sm and Gd with the Lunar Prospector Neutron Spectrometer. S. Maurice[1], W.C. Feldman[2], R. Little[2], R.C. Elphic[2], D.J. Lawrence[2], O. Gasnault[2], A. Binder[3], [1]Observatoire Midi Pyrénées, 14 avenue Edouard Belin, 31400 Toulouse, France, [2]Los Alamos National Laboratory, MS-D466, Los Alamos NM 87545, USA, [3]Lunar Research Institute, 9040 South Rita Road, Tucson, AZ 85747, USA.

Rare Earth Elements (REE) are typical incompatible trace elements: they remain in the liquid phase when minerals begin to crystallize. Thus they have been studied intensively from lunar samples, as they indicate the sequence of igneous processes that formed the lunar rocks [1, for a review on REE]. Except for Eu (Europium), REE form a coherent geochemical group, which can be represented by Sm (Samarium). As an example, concentrations of Sm and Gd (Gadolinium) correlate very well with each other; Gd/Sm = 1.16. REE are also strongly correlated with other incompatible trace elements in highland materials, but the correlation degrades in mare basalts. This last fact is particularly true for Th (thorium). Although concentration mechanisms have enriched REE in some lunar materials to levels three orders of magnitude above their abundance in meteorites or in the bulk Moon, they remain trace elements: < 0.1 wt%. Nevertheless the Lunar Prospector Neutron Spectrometer (LP-NS) has the capability to map Sm+Gd over the entire Moon with a 2°x2° resolution.

The neutrons that escape the Moon as an equilibrium energy flux distribution are sorted into 3 energy bands recorded by the LP-NS: the thermal range below 0.3 eV, the epithermal range from 0.3 eV to 500 keV (considering the detector efficiency, the upper cutoff is at ~10-100 eV), and the fast range from 0.5 to 8 MeV [2]. Recent publications have reported relations between measured neutron fluxes and regolith composition [3-5]. Here we report a new correlation between epithermal neutrons and REE. Sm and Gd are strong neutron absorbers in the thermal range. This has permitted Elphic et al. [3] to map the abundance of Sm+Gd using thermal neutron fluxes. The exercise is difficult since Fe and Ti are also strong absorbers in the thermal range. To remove that signal, the authors had to introduce known Fe and Ti maps from Clementine spectral reflectance [6] data and include interelement correlations (Ca, Si, and Fe) tabulated in [1]. The amount of determined REE was therefore dependent on established models of Fe, Ti, Ca and Si. Sm and Gd have also large cross-section resonances in the epithermal range. Besides, it is known that the epithermal range is almost independent of composition, except for H implantation at the poles [7]. This insensitivity to major element composition thereby allows identification of trace constituents such as H, Gd, and Sm. We also note that the spatial resolution of epithermal neutrons is better than that of thermal neutrons.

We have used neutron data from the entire LP mission, merging low and high altitude datasets. Normalization to the cosmic ray rate has been applied, and observation biases have been removed to the best of our knowledge: latitude and height dependencies, spacecraft motion and shadowing, etc. Each pixel corresponds to an average within 60km. The final map has a min-to-max 17% dynamic range. Figure 1 shows a cylindrical projection for the lower half of the dynamical range. Absorbers at the poles are H-deposits [7]. For the central mare and SPA, the nearly uniform signal corresponds to Ti and Fe, a signal similar to that of the thermal neutron fluxes. Red dips around Imbrium basin are identified here as Gd and Sm. To support this identification, we first note a good match with earlier maps by Elphic [3]. Differences should enable us to test the accuracy of the Ti and Fe models used in the thermal neutron techniques. Furthermore we observe an excellent correlation with the high thorium abundance regions identified by Lawrence et al. [8-9], using a different instrument and technique (Figure 2). As described by [1], Gd and Sm are well correlated with Th in returned sample measurements.

Finally, numerical simulations have been performed to determine the epithermal flux integrated between 0.3 and 10 eV as a function of Gd+Sm impurities added to a ferroan anorthosite composition. These simulations show that the escaping epithermal flux intensities decrease as the Gd+Sm abundance increases, amounting to a 7.5% epithermal flux reduction for [Gd] = [Sm] = 75 ppm.

In summary, we have identified Sm+Gd on the Moon using LP-NS data. Three facts support this identification: a positive comparison with a previous study where Gd+Sm was identified using thermal neutrons, a comparison with the thorium abundance map obtained by gamma-ray spectroscopy, and numerical simulations which reproduce the intensity of the signal. Our goal is now to quantify the amounts of REE detected, and see the implications for the formation of the Moon.

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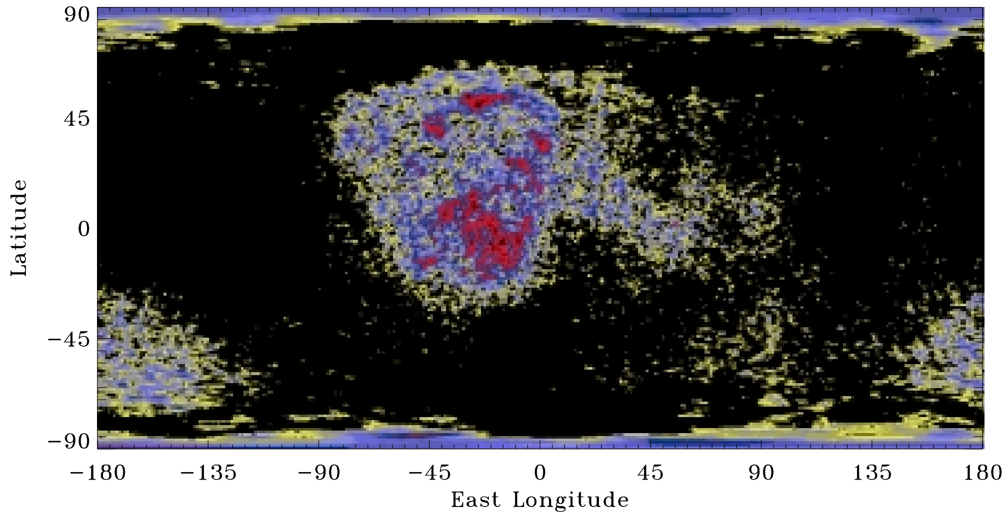

Figure 1: Map of Epithermal Neutrons

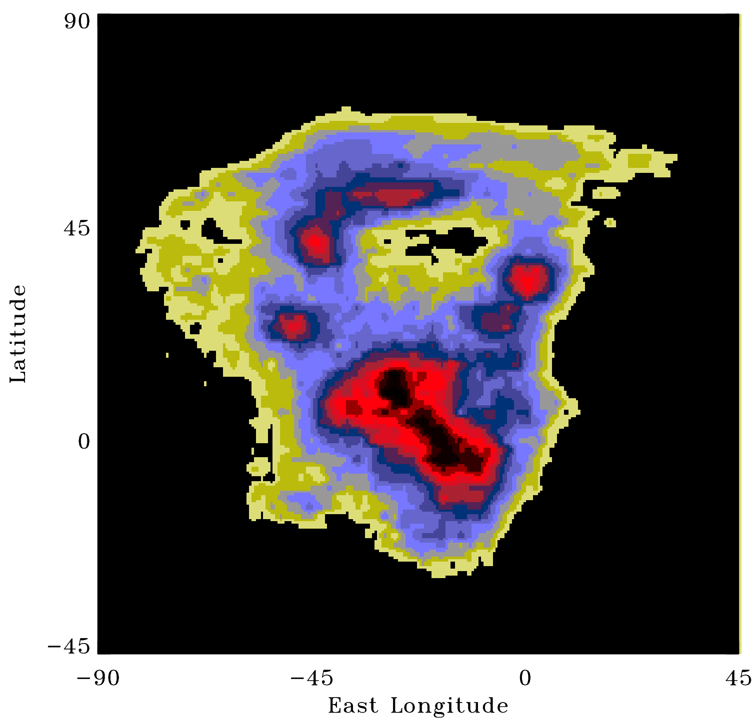

Figure 2: Map of thorium for the central mare region