**LUNAR PROSPECTOR NEUTRON MEASUREMENTS AND LUNAR $TiO_2$.** R. C. Elphic[1], D. J. Lawrence[1], S. Maurice[2], W. C. Feldman[1], B. L. Barraclough[1], O. M. Gasnault[1], A. B. Binder[3], P. G. Lucey[4], and D. T. Blewett[4], [1]Space and Atmospheric Sciences, MS D466, Los Alamos National Laboratory, Los Alamos, NM 87545 USA (relphic@lanl.gov), [2]Observatoire Midi-Pyr n es, 31400 Toulouse, FRANCE, [3]Lunar Research Institute, Ste 2360, 9040 South Rita Rd., Tucson, AZ, 85747, [4]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i, Manoa, HI USA.

**Introduction:** Lunar Prospector neutron spectrometer measurements of the epithermal and thermal neutron leakage fluxes are used to provide constraints on $TiO_2$ abundances in lunar surface materials. We use FeO abundance estimates based on preliminary Lunar Prospector gamma ray spectrometer determinations to first establish a model thermal neutron absorption due to all major elements except titanium. Then we remove the additional absorbing effects due to the rare earth elements gadolinium and samarium by using Lunar Prospector gamma ray spectrometer thorium abundances as a rare earth element proxy. The result is an estimate of the macroscopic absorption cross section $\Sigma_a$ that lacks only the absorption contribution of $TiO_2$. This is then compared to the ratio of epithermal to thermal neutron fluxes, a parameter that relates directly to $\Sigma_a$. Observed departures from the ideal relationship between the measured neutron flux ratio and estimates of $\Sigma_a$ then point to the presence of the additional thermal neutron absorber, titanium. We can derive abundance estimates of $TiO_2$ and compare to other estimates derived spectroscopically. Our results show a significantly lower abundance of $TiO_2$ than has been derived using Clementine data.

**Approach:** In past work, we have used the epithermal and thermal neutron data from Lunar Prospector to infer the abundance of rare earth elements gadolinium and samarium [1,2]. This was achieved by using FeO and $TiO_2$ abundance estimates from Clementine spectral reflectance techniques [3—6]. The FeO and $TiO_2$ abundance estimates allow us to calculate how much thermal neutron absorption should be observed, and compare it how much is actually observed by the Lunar Prospector neutron spectrometers. The difference can be ascribed to Gd and Sm. However, it was also found that in some locations where thorium (hence REE) abundances are low, the $TiO_2$ estimates of [5] *Lucey et al.* [1998] and the observed neutron absorption could not be easily reconciled. In this paper we take a similar approach, but now use FeO abundance estimates provided by preliminary Lunar Prospector gamma ray spectrometer data [7]. We then compensate for the effects of the rare earth elements gadolinium and samarium through their good correlation with thorium. By estimating the absorption due to major elements (via FeO) and removing the additional the REE absorption effects, we can determine the residual neutron absorption due to titanium alone. This analysis thus results in a completely independent assessment of $TiO_2$ abundance in the maria and other sites containing mafic materials, such as South Pole-Aitken basin.

**Results:** Figure 1 shows a partial macroscopic thermal neutron absorption cross section $\Sigma_a$ plotted against the ratio of epithermal to thermal neutron fluxes. Ideally, these two quantities are linearly related via the composition of the lunar soils [2].

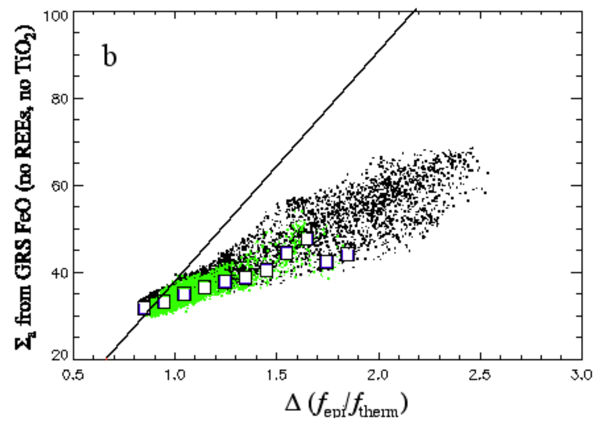


Fig. 1. Partial macroscopic absorption cross section vs. epithermal to thermal flux ratio.

Based on LP GRS FeO and a simple model of other major element thermal neutron absorption, we construct the partial $\Sigma_a$ without the effects of $TiO_2$ or the rare earth elements gadolinium and samarium. The points all lie below the ideal black line, indicated that we must account for other neutron absorbers, namely Gd and Sm as well as $TiO_2$. The green points are a subset of the data having less than 0.5wt% $TiO_2$ according to the Clementine spectral reflectance estimates [6]. Hence these points lie below the line only because we have not taken the REEs into account. We can remove the effects of Gd and Sm by using LP GRS thorium abundances as a proxy [8].

We are examining the departures of the observations from the ideal line of Figure 1, which we call $\Delta\Sigma_a$. Figure 2 shows the trend of the green (low $TiO_2$) $\Delta\Sigma_a$ points from Figure 1, versus the LP GRS thorium abundance estimates of [8]. A very clear trend in $\Delta\Sigma_a$ due to Sm and Gd emerges; we remove this effect using thorium as a proxy. Then any remaining unaccounted thermal neutron absorption, in the form of residual $\Delta\Sigma_a$ must be due to titanium.

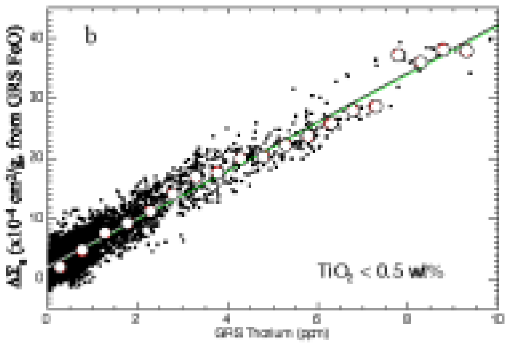


Fig. 2. $\Delta\Sigma_a$ for the low-Ti subset, versus LP GRS thorium abundance.

Figure 3 shows the residual $\Delta\Sigma_a$ expressed as equivalent $TiO_2$ wt% after the effects due to REEs have been removed, plotted against the Clementine estimates of $TiO_2$. The trend falls below the unity line, indicating that the neutron-derived values for titanium abundance are about a factor of 2 lower on average than the Clementine values. These low values for $TiO_2$ may reflect some heretofore unknown aspect of opaque minerals in mare basalt soils.

Figure 4 shows that the locations of the highest titanium concentrations are still in M. Tranquillitatis and O. Procellarum, as the Clementine data previously indicated. Though not shown here, the distribution of $TiO_2$ values is not bimodal as in the mare basalt sample suite, but continuous as spectral reflectance studies have shown [9].

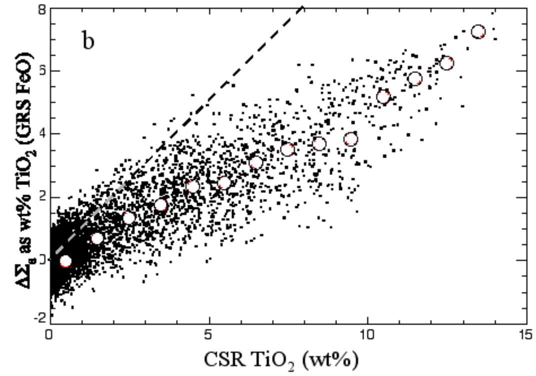


Fig. 3. Residual $\Delta\Sigma_a$ expressed as equivalent $TiO_2$ wt% vs. Clementine $TiO_2$ estimates. Dashed line is unity.

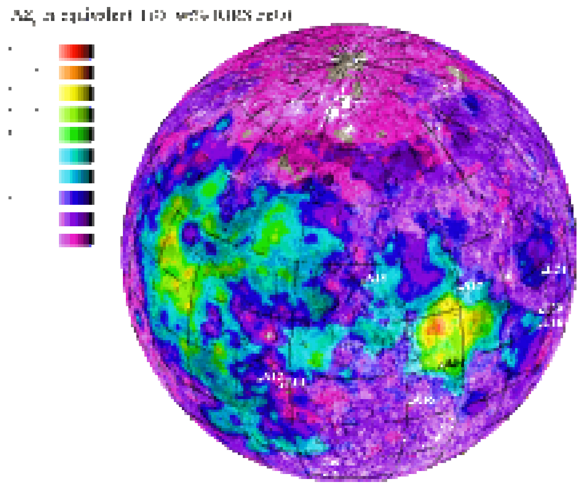

Fig. 4. Nearside map of $TiO_2$ abundance based on neutron analysis. The range of values is from 0 to 9 wt%.

**References:** [1] Elphic, R. C., et al. (1998), *Science*, *281*, 1493; [2] Elphic, R. C. et al. (2000), *JGR*, 105, [3] Lucey P. G., Taylor G. J., and Malaret E. (1995), *Science*, *268*, 1150. [4] Lucey, P. G., et al. (1996), *LPS XXVII*, 781. [5] Blewett D. T., et al. (1997), *JGR*, *102*, 16,319. [6] Lucey P. G., et al. (1998), *JGR*, *103*, 3679;. [7] Lawrence, D. J., et al. (2001), this conference; [8] Lawrence, D. J., et al. (2000), *JGR*, *105*,20,307; [9] Giguere, T. A., et al. (2000), *MeteoriticsPlanet. Sci.*, *35*, 193.