HIGH-ENERGY NEUTRONS FROM THE MOON

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Introduction. Galactic cosmic rays that impact the lunar soil produce neutrons with energies from fractions of eV's to ~100 MeV. The high-energy band from 0.6 to 8.0 MeV is referred as the "fast neutron" band, which is measured by Lunar Prospector (LP) Gamma-Ray Spectrometer [1].

Fast neutrons play an important role in neutron spectroscopy [2] that may be summarized as follows: fast neutrons define the total neutron input to the moderating process toward low energy populations, so that epithermal and thermal neutron leakage currents must be normalized to the leakage of fast neutrons; they allow the determination of the burial depth of hydrogen, a measure necessary to understand characteristics of water deposits; they provide information on the surface content in heavy elements, such as Ti and Fe; they provide a direct insight into the evaporation process. As discussed hereafter, fast neutron may yield information on other oxides, such as SiO_2.

Data sets and data processing. This study uses fast neutron data from December 20th, 1998 to May 22nd, 1999, when the spacecraft altitude was between 10 km and 50 km. The data reduction includes normalization to the cosmic ray rate, to the spacecraft height and latitude, and finally to the gain drift.

From all-Moon maps at a 2^ox2^o-equal-area resolution, we learn that *i/* all mare identified, from the largest ones, Imbrium, Frigoris, Fecunditatis, to the smallest ones, Undarum, and Spumans, are high neutron emitters; *ii/* there are extended regions, such as South Aitken Basin, or the area around Schickard, which are medium-to-high neutron emitters; *iii/* highlands are definitively low fast neutron emitters, which form the blue-background of the map; *iv/* the largest craters are resolved in fast neutrons.

Figure 1 is a map of the central mare region. White data represent missing data. Mare have numerous features, which are resolved in fast neutrons. For instance, the region extending North-West of Aristarchus (23.7°N, 47.4°W) is clearly separated from Montes Harbinger (27.0°N, 41.0°W) by a high emission channel, and Mare Vaporum (13.3°N, 3.6°E) is separated from Sinus Aestuun (10.9°N, 8.8°W) by a low emission area.

Moon Composition. We present a new technique to extract information on soil composition from the fast neutron measurements. The analysis is applied to the central mare region. There are two steps for the development of the technique.

(1) For the first step, which has been fully completed [3], we assume that variations of fast neutron counting rates are due solely to TiO_2 and FeO. Upon this assumption, we correlate Clementine Spectral Reflectance iron and titanium oxide maps [4] with fast measurements. Correlation with FeO is displayed on Figure 2. Above 16.5% of iron oxide, effects of TiO_2 variations show in LP data. Below 6.5% of FeO, iron cannot be discriminated; this is the region of most highland terrains.

Under assumption of only two oxides to modulate the signal, we show that fast counts are 3.2 times more sensitive to FeO than to TiO_2. The resolution in FeO weight percent is 1.2%, and in TiO_2 is 3.8%. These results are very satisfying, specially for the distribution of iron oxide. However, they do not permit reproduction of Clementine TiO_2 map from the residual of the fast counting rates and Clemetine FeO correlation. Particularly, the discrimination between hi-Ti and low-Ti mare is not striking.

(2) The second step is still under development. We assume that variations of fast neutron counting rates are primarily due to FeO, but also to TiO_2, SiO_2, CaO, Al_2O_3, MgO, and Na_2O. Gasnault et al. [5] have calculated the number of fast neutrons in our energy band of interest to be :

Na	1.28	Mg	1.68
Al	2.09	Si	2.26
Ca	1.75	Ti	3.02
Fe	2.81	O	0.165

per weight fraction of each element, for an average cosmic ray flux. This simulation is for a FAN soil. It will have to be refined and iteratively adapted to the soil composition.

With information on TiO_2 and FeO distributions from Clementine, and the coefficient above, we know the global soil content in the other oxides (weighted by Gasnault et al. coefficients). On the other hand we have from return samples estimates of correlation between oxide concentrations. We demonstrate that such processing allows estimations of SiO_2 variations in the lunar regolith.

References: [1] Feldman et al., *NIM*, 422, 562-566, 1999; [2] Feldman et al., *Science*, 281, 1489; [3] Maurice et al., JGR-planets, submitted, 1999; [4] Lucey et al., *JGR*, 103, 3679, 1998; [5] Gasnault et al., JGR-planets, submitted, 1999.

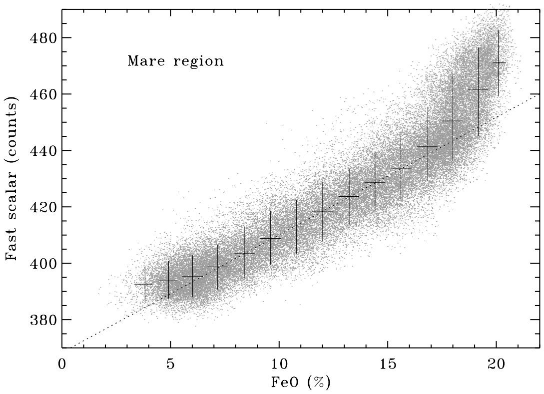

Figure 1

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Figure 2