AN ABSOLUTE NORMALIZATION FOR MODELED NEUTRON FLUX DISTRIBUTIONS; A.E. Metzger, Jet Propulsion Laboratory, Pasadena, CA 91109; D. M. Drake, Max-Planck-Institut fur Chemie, Mainz, FRG; E. L. Haines, Sunrise Research Inc., Eugene, OR 97404; J. Mazarik, and R. C. Reedy, Los Alamos National Laboratory, Los Alamos, NM 87545

Reactions produced by neutrons in planetary surfaces and meteorites have been found to be important as an indicator of exposure history as well as in computing resultant yields of characteristic gamma rays. Applied to remote planetary gamma-ray spectroscopy, knowledge of the neutron flux in combination with the observation of surface gamma rays is needed to calculate surface concentrations for most elements. Where direct measurements of the neutron flux cannot be obtained, the ability to model the depth and energy distributions reliably will allow proper interpretation of the data from remote observations as well as from core and meteorite samples. We report a comparison between modeling and observation which also provides a means of estimating absolute fluxes.

Neutron transport modeling is accomplished in two steps. First, calculation by the program LAHET produces the depth and energy distributions of the high energy neutron flux due to galactic cosmic rays incident on the planetary surface. A second program, either ONEDANT or MCNP, tracks the further scattering, absorption, and leakage of the fast (15 MeV) neutrons down to thermal energies.

We have been using the combination of LAHET and ONEDANT to evaluate the effect of variations in composition and density of planetary bodies on the neutron depth distribution. ONEDANT calculates moderated fluxes as a function of energy and depth for one initial high energy (LAHET) neutron. The subsequent multiplication by the yield of neutrons per incident proton obtained from LAHET will give a good absolute flux value if both transport programs, and in particular ONEDANT, correctly represent the processes of neutron scattering, absorption, and leakage.

A measurement is available from which to derive the normalization values (and in the process to check the modeling programs) in the form of the Apollo 17 Lunar Neutron Probe Experiment, in which the absolute magnitude and the depth profile of the lunar neutron density were determined by Woolum et al. (1). To do this the ONEDANT thermal and epithermal flux values were separately converted to neutron density and summed for 22 depths from 0-500 g/cm^2. Neutron density profiles were generated by spline fitting the 22 points and the resulting profiles were least-squares fitted to the measured neutron densities over their range of 50-380 g/cm^2. Two geometries of cosmic rays incident on the lunar surface were tested, isotropic and sphere-cosine, the latter a weighting of the 2π cosmic-ray flux by the cosine to the normal. The results are shown in the Figure. Both ONEDANT profile shapes match the measured values well but a chi-square test shows the cosine profile fits the data better. Sphere-cosine geometry has also been found to give a good fit to production vs depth for cosmogenic nuclides on the Moon (2). For the cosine case, the ratio of the

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measured value to that derived from ONEDANT is 9.51, which is equivalent to the flux of neutrons produced by the cosmic-ray flux during the Apollo 17 mission. This provides the value needed to derive absolute neutron fluxes from the output of ONEDANT.

References:

(1) Woolum, D.S., D. S. Burnett, M. Furst, and J. R. Weiss, (1974) The Moon, 12, pp. 231-50.
(2) Reedy, R.C., and J. Masarik, (1994) Lunar and Planetary Science XXV

Lunar neutron density, data of Woolum et al., compared with calculated profiles based on isotropic and "cosine" cosmic ray fluxes.