EFFECTS OF ROCKS ON NEUTRON AND GAMMA-RAY PRODUCTION IN MARTIAN SURFACE SOIL.

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Summary: We studied the effects of a dry rock sitting on a 3% water-containing martian-surface soil on neutron and gamma-ray fluxes. Rocks with radii of ~25 cm and bigger significantly affect these fluxes and the flux ratios of certain gamma rays.

Introduction: The rock surface abundances on Mars are inferred from orbital data to vary from almost zero to ~30% [1]. These rock abundances are consistent with images from landers and rovers [J. Keller, priv. comm., 2005]. Several regions on Mars appear to be very rocky or very dusty with some compositional differences [e.g., 2], although more detailed analyses of regions with and without thick dust covers show that even the rockiest regions are still mainly dust [3]. The effects of rocks and soil on gamma-ray fluxes were investigated for several cases [4], although only rocks both much smaller and much larger than neutron-interaction lengths were studied. However, many rocks are of intermediate sizes.

For this study, we did numerical simulations using a 3D code for rocks of various sizes on a martian soil.

Calculations: We did the numerical simulations with the Monte Carlo N-Particle eXtended (MCNPX) code [5]. Our typical models for MCNPX calculations of gamma-ray production rates [6] were spherical with a scale of Mars to model of 1 to 1. However, it is not feasible to hit enough cosmic radiation on a small size (i.e., R=20 cm) rock on such a martian surface. We adapted a box model with reflecting walls that has the same atmospheric features and depth profiles as the spherical MCNPX calculation. This model shows the effect of rock soil mixture without the geometric problems of placing small rocks on the surface of a full sized Mars.

The surface neutron fluxes for cases using reflecting walls and a large sphere were found to be almost identical. Therefore, for the purpose of this calculation, the reflecting-wall model is used. This model has an isotropic radiation source surface at the top of the atmosphere. We used a box with 80 cm dimensions.

We investigated five rock sizes ranging in radii from 5 cm to 30 cm on the surface. We assumed that the rock had almost no water. These rocks cover from 1.2% to 44% of the surface area in our box. The rock is located with its center in the center of the surface, with half of the rock above the ground and half below the ground level. A soil composition of 3% water and a composition similar to the rock for all elements except water and Cl were used. Most elemental concentration ratios of rock to soil are 1.04 except H (0.03), O (0.98), Cl (0.02), and Fe (1.02). The densities for rock and soil were 2.5 g/cm^3 and 1.5 g/cm^3, respectively. We used a standard martian atmosphere with a thickness of 16 g/cm^2. To obtain neutron fluxes around the rock, a cylindrical mesh tally option was chosen with radii from 0.5 cm to 40 cm at 0.5 cm increments. Layers with depths of 0.5 cm were used near the surface.

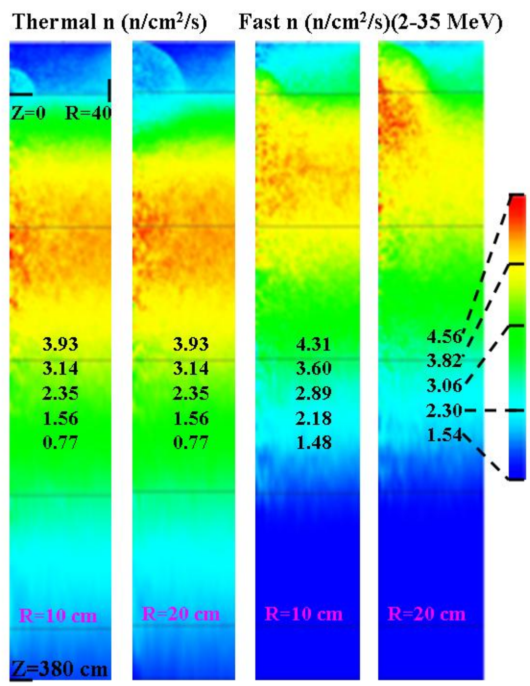

Figure 1. Thermal and fast neutron flux distribution as function of depth of two models of this study.

Results: *Neutron flux:* In Figure 1, the thermal and fast neutron fluxes as a function of radius and depth are shown for the two different rock sizes. These figures indicated that neutron fluxes in the soil mixture with a 10 cm rock didn't change significantly compared those in pure soil, while those with 20 cm rock did change. This indicates that a 10 cm rock at the surface would not significantly change the capture and inelastic gamma ray fluxes at the surface. The effect of rock in soil is seen as a decrease of thermal neutron fluxes surround of the rock while the fast neutrons increased. A significantly high neutron flux for neutron energies of 2-35 MeV region near the rock is observed. This implies that the high fast neutron flux would increase the inelastic gamma ray production rate near the rock portion.

Gamma ray fluxes: Figure 2 shows MCNPX-calculated gamma-ray fluxes above the martian surface with respect to the distance from the center of rocks with radii from 5 to 30 cm expressed as the fraction of the surface area covered by the rock, which range for 1.2% to 44%, respectively. Fluxes for the H 2223 keV and Cl 6111keV gamma rays decrease because H and Cl are less abundant in the rock. Although the rock-to-soil abundance ratio for Si is 1.04, the flux for the Si 1779 keV inelastic-scattering gamma ray increases more with increasing size of the dry rock. The flux for the Fe gamma rays at 7631 and 7645 keV decreases because of lower thermal-neutron fluxes in the dry rock.

Characteristics of elemental ratios: Figure 3 shows the elemental ratios with respect to rock size (and inferred rock abundance) at the martian surface. The ratio of the Fe 7638 keV capture gamma rays to the 1779 keV Si inelastic gamma ray decreases as the rock amount in soil mixture increases. This is due to production rates for capture and inelastic gamma rays with respect to rock amount. When the rock amount increases in a soil/rock mixture, thermal neutron flux relatively decreases while fast neutron flux increases (Figure 2). The Si inelastic line shows that a greater rock portion is related to greater inelastic gamma ray flux (Figure 2).

Conclusion: This study indicated that a dry rock with a radius of 10 cm on a martian-surface soil with a water content of 3% does not significantly contribute to the gamma ray fluxes at the surface. However, a rock having a radius of 20 cm would significantly affect the gamma ray flux at the surface due to the neutron fluxes in the rock being different than the surrounding soil. It was found that rock abundance is associated with both thermal neutron induced gamma ray production and inelastic gamma ray production in opposite ways. Higher rock abundance in soil will contribute in increase of inelastic gamma ray flux, but in decrease of thermal neutron capture gamma ray flux at the surface. Elemental ratios of gamma ray flux at surface of Mars will provide important indication toward the rock abundance of Martian subsurface

References: [1] Christensen P. R. (1986) *Icarus, 68,* 217-238. [2] Evans L. G. et al. (2004) *LPS XXXV*, #1258. [3] Newsom H. E. et al. (2006) *J. Geophys. Res. Planets*, submitted. [4] Squyres S. W. and Evans L. G. (1992) *J. Geophys. Res., 97,* 14,701-715. [5] Walters L. S., (Ed.) (1999), *MCNPX Users Guide, Doc. LA-UR-99-6058*. [6] Kim K. J. et al. (2006) *J. Geophys. Res.*, submitted. This work was supported by the Mars Odyssey project.

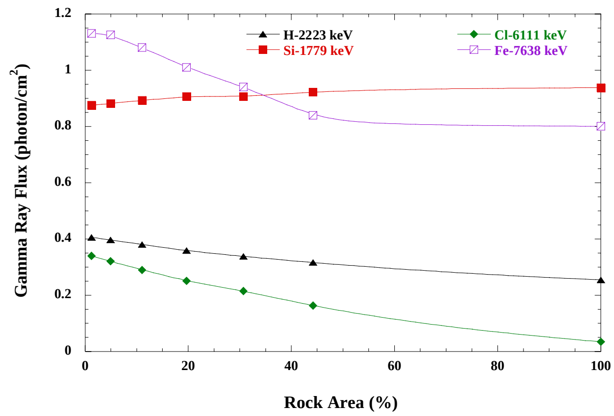

Figure 2. The gamma-ray fluxes calculated for dry rocks with radii of 10 to 30 cm (given as fraction of the total surface area) on a martian surface soil with 3% water. The rock to soil elemental ratios were 1.0 4(Si), 1.02 (Fe), 0.03 (H), and 0.02 (Cl).

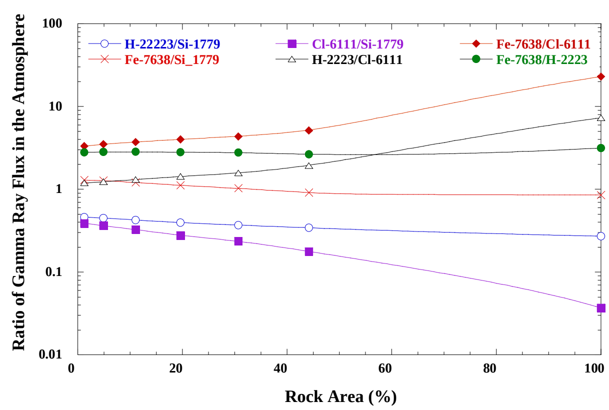

Figure 3. Ratios of gamma-ray fluxes shown in Fig. 2 as a function of rock size.