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Title:

STRATIFIED COMPOSITION EFFECTS ON PLANETARY NEUTRON FLUX.

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STRATIFIED COMPOSITION EFFECTS ON PLANETARY NEUTRON FLUX. O. Gasnault[1], S. Maurice[2], C. d'Uston[3], and W. Feldman[1], [1]Los Alamos National Laboratory (P.O. Box 1663, MS D466, Los Alamos, NM 87545; gasnault@lanl.gov), [2]Observatoire Midi-Pyrénées (Toulouse, France), [3]Centre d'Etude Spatiale des Rayonnements (Toulouse, France).

Introduction: All the bodies of the solar system that are directly irradiated by the galactic cosmic rays, emit enough neutrons to allow a measurement from space. These leakage neutron fluxes are indexes of the surface composition, depending on the energy of the neutrons [1]. Recent work propose geochemical interpretations of these fluxes: the thermal energy range is sensitive to iron, titanium, rare earth elements and thorium [2, 3], the epithermal energy range is sensitive to hydrogen, samarium and gadolinium [2] and the fast energy range is representative of the average soil atomic mass [4]. Nevertheless these studies make the hypothesis of a composition uniform within the footprint of the spectrometer and independent of depth. We show in this abstract that a stratified composition could change significantly the flux intensity and complicate the interpretation of the measurements.

The neutron leakage flux is a competition between production effects (sensitive at high energy) and diffusion-capture effects (mostly sensitive at low energy). On one hand, it happens to be that the elements which produce the higher number of neutrons in typical lunar compositions are iron and titanium, which have also large cross section of absorption with the neutrons. On the other hand, the maximum of neutron intensity does not occur at the surface but at about 180 g cm^{-2} in depth. Therefore, if we have an iron- and/or titanium-rich soil (important production of neutrons) with a top layer having less iron and/or titanium (i.e. more transparent to the neutrons), we can expect an enhancement of the flux compared to a uniform composition.

Modeling: Computer simulations are used to evaluate the creation of neutrons by galactic cosmic-ray protons and to predict their leakage spectra after transport and moderation processes in the soil. These numerical simulations make use of GEANT [5] code library. Simulations involving low energy neutrons (<1 eV) make use of the GEANT-CALOR [6] interface. The planet surface is modeled as a tube large enough to contain all secondaries without losses (diameter=height=1.2 m and density=3 g cm^{-3}). Here we assume a soil with a typical Apollo 11 mare basalt composition; a layer of ferroan anorthosite (uniform or as a gradient) is added at the surface. The galactic cosmic ray spectrum [7, 8] averaged over a solar cycle is used as input irradiation and injected isotropically onto one point at the surface.

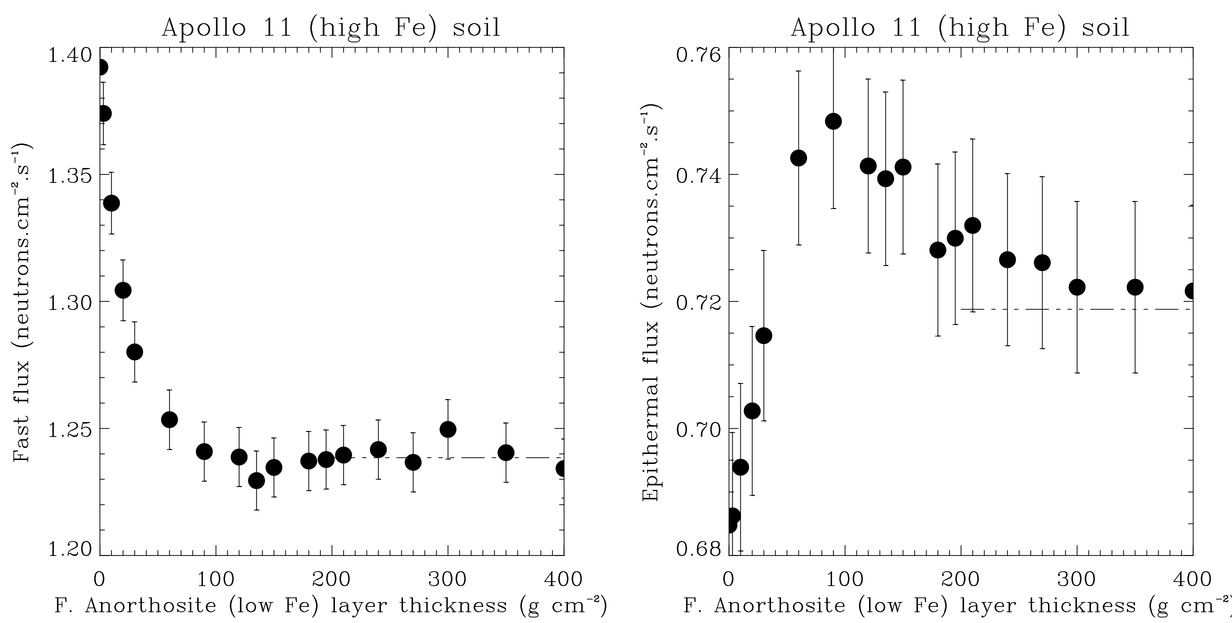

Figure 1. Uniform ferroan anorthosite layer above a uniform Apollo 11 mare basalt.

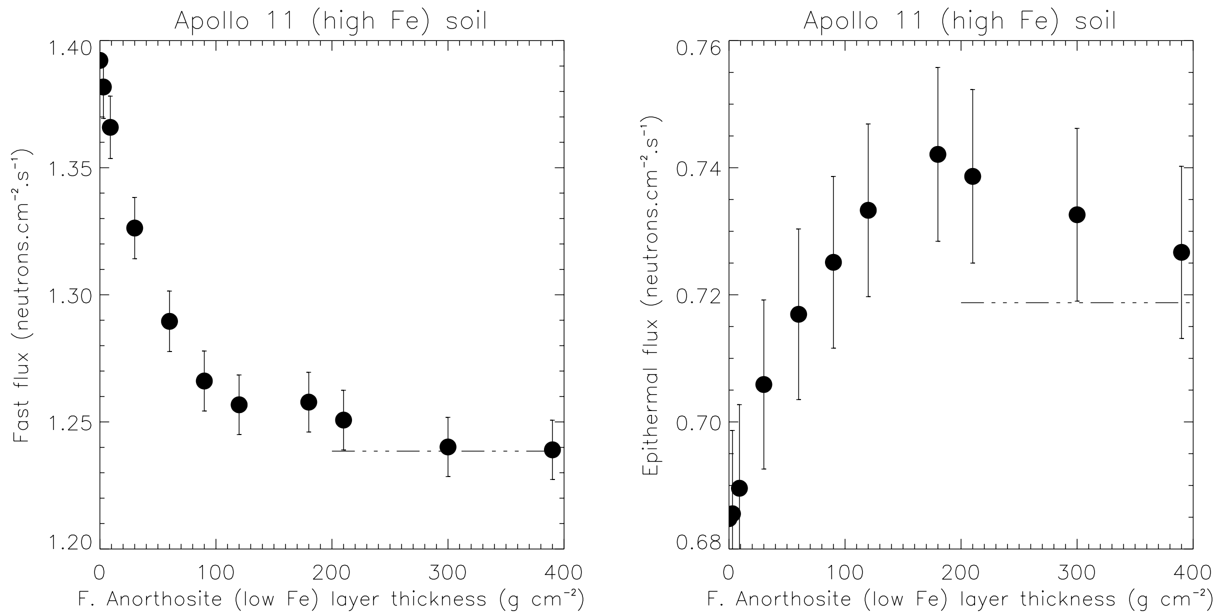

Figure 2. Variation of neutron leakage fluxes in presence of a gradient in the composition.

Results and Discussion:

Uniform ferroan anorthosite layer above uniform Apollo 11 mare basalt. Figure 1 shows the fast and epithermal neutron leakage fluxes when the soil is an Apollo 11 mare basalt (iron-rich) at the surface with a top layer of ferroan anorthosite (iron-poor). The fluxes are shown as a function of the top layer thickness, thus the plots are representative of a uniform Apollo 11 mare basalt toward the left, and of a uniform ferroan anorthosite composition toward the right. The asymptote (dashed line) is the result of a simulation for a pure ferroan anorthosite soil. The fast neutron flux presents a sharp transition from one soil to the other because they are only sensitive to the production effects (in first approximation). The epithermal neutron flux variation is more complicated: when the thickness of the top layer increases, the leakage flux passes through a maximum for a ferroan anorthosite layer of ~100 g cm^{-2} thick. This effect is significant as it represents ~9% increase from the Apollo 11 mare basalt to the maximum, and ~4% increase from a ferroan anorthosite composition.

Gradient. In an attempt to make a more realistic model, the top layer at the surface was subdivided in 10 slices with a composition varying progressively from Apollo 11 mare basalt at the bottom to ferroan anorthosite at the surface. The results are shown in Figure 2. Inspection shows that the maximum enhancement of the epithermal neutron flux now occurs for a thicker layer (~200 g cm^{-2}) and the effect is smaller: ~8% increase from Apollo 11 mare basalt to the maximum, and ~3% increase from the ferroan anorthosite (Figure 2).

Conclusion: We have demonstrated that a stratified composition in a planetary surface affects the neutron leakage flux. In particular, the epithermal flux is enhanced when a layer of iron-poor materials is deposited above an iron-rich soil. This is a 3 to 9% effect, which is theoretically measurable. The maximum deviation from the case of a uniform distribution of soil composition with depth occurs for a 30 or 60 cm thick layer (supposing a density of 3 g cm^{-3}).

It is unlikely that these conditions take place somewhere on the Moon. Work on other soil configurations and other bodies of the solar system are under progress.

References:

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