IN-SITU PRODUCTION OF ORGANIC MOLECULES AT THE POLES OF THE MOON. S.T. Crites*[1], P.G. Lucey[1], and D.J. Lawrence[2] [1]Hawaii Institute for Geophysics and Planetology, 1680 East West Road, POST 602, Honolulu, HI 96822 [2]Space Department, JHU/APL, Laurel, MD *scrites@hawaii.edu

Introduction: Samples returned by the Apollo missions showed no trace of organic materials. However, the poles of the Moon are utterly unlike the equatorial regions, and the LCROSS impactor detected a range of organic compounds including C_2H_4, CH_3OH, and CH_4 [1]. These compounds may have been delivered directly by comets, or they may have developed in situ from simple ices or even solar wind implanted materials. If these compounds developed in situ the poles of the Moon provide an opportunity to test models of inorganic synthesis that can be applied to many surfaces in the solar system and interstellar clouds. Production of organics in situ requires the presence of the relevant elements (combinations of C, H, O, and N), sufficient mobility of elements to react with one another, and an energy source to drive reactions. This project is to assess the galactic cosmic ray protons flux in the lunar regolith as a potential energy source and contribute to an assessment of the plausibility of production of organics on the Moon from in-situ inorganic material.

Presence and mobility of elements: Because of the low obliquity of the Moon, regions in topographic lows at the poles are permanently shaded from sunlight and measurements from the Diviner Lunar Radiometer have confirmed the extremely cold nature of some of these regions [2]. The temperatures are low enough to trap even very volatile ices such as CO_2, but these low temperatures can also inhibit ion mobility. However, indirect illumination by light reflected off local topographic highs as well as the bombardment of the lunar surface by meteorites create temperature variation in the top 20 cm of regolith and expose icy material to a range of depths and temperatures.

Energy source: In addition to the presence of organic elements and temperature cycling, an energy source is needed to break bonds and enable reactions. Possible energy sources include scattered interstellar Lyman alpha UV radiation and galactic cosmic ray protons. However, Lyman alpha is confined to the optical surface and erodes surface ice [3], so we investigate the deeper penetrating protons in the upper few centimeters where ices are better protected from loss. Laboratory measurements have demonstrated that energetic protons can stimulate organic synthesis in simple mixtures of C, H, O, and N-bearing ices. For example, a column density on the order of 10^{17} molecules/cm^2 of CH_3OH was produced from an H_2O + CH_4 ice mixture after an irradiation dose of 10 eV/molecule, and rose with increasing dose to about 17 eV/molecule [4].

Results and discussion: We use the particle transport code MCNPX to calculate proton flux from cosmic rays at the poles of the Moon to determine a dose rate from protons to compare to the laboratory measurements of Moore and Hudson [4]. Our model provides flux of both protons and electrons across the energy spectrum resulting from galactic cosmic rays with depth in the lunar regolith. To compare directly to Moore and Hudson's experiment, we calculate the time required to accumulate the fluence of 1.5 x 10^{15} p/cm^2 reported by Moore and Hudson [4] as being approximately equal to a dose of 17 eV/molecule. Moore and Hudson's experiment used a beam of 1MeV protons, so for this first approximation we consider only the 1 MeV protons from galactic cosmic rays. Using our maximum flux of 0.009 p/cm^2-s for 1MeV protons (Figure 1), we calculate that 5.28 By are required to accumulate this fluence. This time is an upper limit for time required to accumulate a dose capable of initiating organic synthesis, since there are 100x more protons available, and most are of higher energy. Hudson and Moore [5] report that there is a peak in efficiency for stopping power of protons at 1 MeV, so these may be the most effective. However, the abundant higher energy protons also contribute to the radiation dose accumulated by ices in the regolith. Our results suggest that in-situ production of organics at the poles of the Moon may be plausible for timescales on the order of magnitude of the ages of the polar cold traps, if the effects of higher energy protons are taken into account.

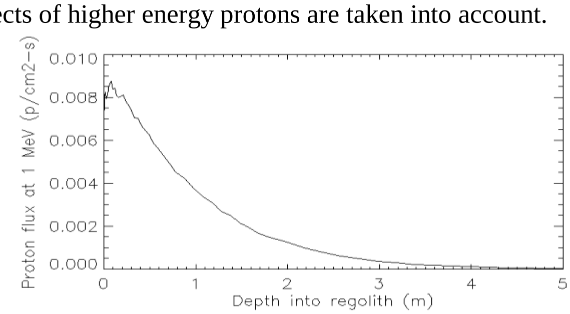

FIGURE 1: Flux of 1 MeV protons only with depth in the lunar regolith

References:

[1] Colaprete, A, and 16 co-authors (2010), Science, 330, 463-467. [2] Paige, DA, and 26 co-authors (2010), Science, 330, 479-482. [3] Morgan, TH and DE Shemansky (1991), J. Geophys. Res. 96(A2), 1351-1367. [4] Moore, MH and RL Hudson (1998) Icarus, 135(2), 518-527. [5] Hudson, R.L., and M.H. Moore (1995), Radiat. Phys. Chem., 45(5) pp 779-789.