IDENTIFICATION OF LUNAR ORGANIC COMPOUNDS AND THEIR SOURCES.

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Introduction: Organic compounds may survive beneath the surface or at the poles of the Moon. If so, at least a fraction of such compounds were probably delivered by asteroids and possibly comets. To the extent that inputs of carbon from different sources might vary as a function of geographic location and composition of crustal materials, future studies can advance our understanding of the origins and cycling of organic compounds, carbon, and other biologically significant elements. For example, because the ancient highlands retain pre-3.9 billion-year-old history of the lunar crust, they might contain relatively greater abundances of meteoritic and cometary material than mare basalts that formed later. Earlier investigations indicated that highlands materials might contain more carbon than mare basalts, and such carbon might have meteoritic origins [1]. Polar environments also might be vastly superior for preserving the chemical nature of meteoritic and cometary inputs, not only as water but also as organic and other compounds.

Meteoritic organic carbon: Given our knowledge of meteorite organic carbon we could attempt to answer the question of whether the (possible) organic content of Moon samples matches that of known carbonaceous meteorites. The organic carbon in carbonaceous meteorites is relatively high in abundance and complex in composition [2]; its predominant form is an insoluble phase sometimes called "kerogen-like" or "insoluble organic material". The CI, CM, and CR meteorite classes also include numerous soluble organic compounds (Table 1). A major characteristic of soluble meteoritic compounds (to compare to those found on the Moon) is the diverse and random molecular mixture. For example, over seventy isomeric and homologous amino acid species up to C_8 have been identified in the Murchison meteorite in contrast to just twenty that make up (for example) terrestrial proteins. The chemical analyses of Lunar samples could be conducted with methods including gas chromatography-mass spectrometry (GC-MS) and liquid chromatography-mass spectrometry (HPLC-MS).

Survival of meteoritic compounds on impact with the Moon: The above discussion is based on the expectation that meteoritic and cometary organic compounds survive impacts on the Moon and other solar system bodies, but what experimental evidence supports such an expectation? Impacts among asteroidal objects generate heat and pressure that may have altered or destroyed pre-existing organic matter in both targets and projectiles to a greater or lesser degree depending upon impact velocities. Very little is known about the shock-impact related survival of organic compounds on planetary surfaces. We have studied the effects of shock impacts on selected classes of organic compounds utilizing laboratory shock facilities [3]. Our approach was to subject mixtures of organic compounds (known to be indigenous to carbonaceous meteorites), embedded in a matrix of the Murchison meteorite, to simulated hypervelocity impacts. The molecular compositions of products were then analyzed to determine the degree of survival of the original compounds. Our experiments are correlated with velocities <8 km/sec but are relevant to oblique impacts on planetary surfaces.

Among the classes of compounds tested are: sulfonic acids, phosphonic acids, PAHs, and amino acids. Sulfonic and phosphonic acids were chosen in part because they are very stable (including to oxidation) compared to many other classes of polar organic compounds, thus they may serve as a marker of meteoritic organic input into the Moon. The shock experiments were done in the Experimental Impact Laboratory of the Johnson Space Center, Houston. A 20 mm gun, with its barrel extending into a vacuum chamber (10^{-2} torr), was used to launch the projectile containing the sample at ~1.6 km/sec into various target material. This resulted in the samples experiencing various pressures in the range of 100-400 kb (various pressures translate into various impact velocities). Approximate pressures were 100, 200, 300, and 400kb. After impact, the samples were extracted with water or organic solvents and analyzed by a combination of ion chromatography, HPLC, and GC-MS.

Results: Analysis of the data shows generally that survival of the compounds studied is inversely proportional to shock pressure. However at lower pressures, 100-200 kb, the sulfonic acids show nearly complete survival. There was a significant drop in survival at approximately 300 kb of pressure for all organic sulfur and phosphorous compounds. Pressures of 300-400kb resulted in survivals of approximately 20-30% for one and two carbon compounds, and 0-10% for three and four carbon compounds. For the PAH's, a similar trend is observed as the fraction of surviving compounds decreased with increasing shock pressures. Overall sulfonic acid survival is much greater than that of amino acid or PAH. More detailed analysis of survival rates of individual compounds will be presented. These preliminary results indicate that significant amounts of sulfonic acids, phosphonic acids and PAHs may have survived impacts on the Moon and other bodies at or below 300-400 kb.

References: [1] Des Marais D. J. et al. (1975) Proceedings of the Lunar Science Conference, 6th, 2353-2373. [2] Pizzarello S., Cooper G. W., and Flynn G. J. The Nature and Distribution of the Organic Material in Carbonaceous Chondrites and Interplanetary Dust Particles in *Meteorites and the Early Solar System II*, pp. 625-651. D. S. Lauretta and H. Y. McSween Jr. (eds.), University of Arizona Press, Tucson, 2006. [3] Cooper, G. et al. (manuscript in preparation) Shock Modification of Organic Compounds on Carbonaceous Chondrite Parent Bodies.