INVESTIGATING THE EFFECTS OF COSMIC RAY EXPOSURE ON AMINO ACIDS IN METEORITES: IMPLICATIONS FOR FUTURE SMALL BODY SAMPLE RETURN MISSIONS.

D. P. Glavin[1], A. A. Pavlov[1], J. C. Stern[1], J. E. Elsila[1], A. M. Parsons[1], J. P. Dworkin[1], H. L. McLain[1,2], D. S. Lauretta[3], H. C. Connolly Jr.[4], and K. Nakamura-Messenger[5]. [1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, E-mail: daniel.p.glavin@nasa.gov, [2]Catholic University of America, Washington DC 20064, [3]University of Arizona, Tucson, AZ 85721, [4]Kingsborough Community College, Brooklyn, NY 11235, [5]NASA Johnson Space Center, Houston TX 77058.

Introduction: Carbonaceous chondrites represent a very primitive class of meteorites that contain 2-5 wt% organic carbon, most of which is from organic matter thought to represent some of the oldest and least altered organic material in the Solar System [1]. The solvent-extractable organic carbon in these meteorites contains a variety of different classes of organic compounds with a range of abundances up to several hundred parts-per-million. Many recent studies of the soluble organic component of carbonaceous meteorites have focused on amino acids since these prebiotic molecules are the monomers of proteins and enzymes found in all life on Earth. Over 80 different amino acids have been identified in the CM Murchison meteorite and hundreds of amino acids with up to nine carbons have been detected in this meteorite [2].

The NASA OSIRIS-REx asteroid sample return mission scheduled to launch in 2016 will return to Earth at least 60 g of material from the near-surface (top few cms) of the near-Earth B class asteroid Bennu in 2023. The spectra of Bennu are consistent with a CI or CM meteorite [3]. Exposure of the surface of airless bodies, like Bennu, to solar and galactic cosmic radiation could lead to significant modification and destruction of organic material. Energetic particles and their secondaries can penetrate and deposit energy up to 4 meters in depth regardless of the asteroid's chemical composition, porosity and water content [4]. Therefore, to maximize the chances of returning organic-rich material from the surfaces of asteroids and comets, it is imperative that future missions identify regions on the surfaces of these bodies that have experienced the least amount of space weathering and exposure to cosmic radiation. Here we present amino acid results from recent experiments on γ-ray exposed samples of the Murchison meteorite and discuss *in situ* data that will be collected by OSIRIS-REx to characterize variations in space weathering across the surface of Bennu.

Murchison Irradiation Experiments: A 15 g fragment of the Murchison meteorite was crushed to a powder and homogenized by mixing. Three separate aliquots (~ 1 g each) of the meteorite powder were transferred to individual glass test tubes and sealed at ~ 50 mtorr air. Two of the samples were then exposed to γ-radiation doses of 1 MGy and 2 MGy (a 2 MGy dose is equivalent to ~ 1 million years of cosmic ray exposure at 2 cm depth on an asteroid such as Bennu) at room temperature using a ^{60}Co source, while the third sealed sample was not exposed to γ-radiation. For comparison, a dried amino acid standard containing many of the same amino acids found in Murchison was subjected to the same radiation doses. After exposure, the total abundances of amino acids in acid-hydrolyzed hot-water extracts of the standards and the Murchison samples were chromatographically determined [2] and compared to the amino acid abundances in the non-exposed samples. We found that on average ~30% of the amino acids in the 2 MGy exposed Murchison sample were destroyed. The amino acid destruction rate in Murchison was similar to the pure dry amino acid standards exposed under the same conditions (Fig. 1), and in agreement with previous γ-radiation studies of pure amino acids [5]. Our data are consistent with theoretical predictions that minerals or insoluble organic matter in meteorites cannot shield amino acids from cosmic radiation.

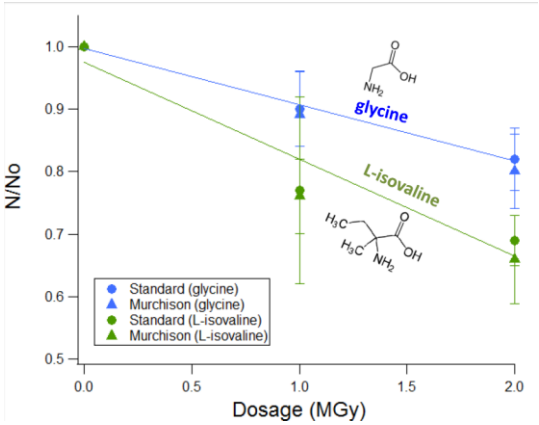

Fig. 1. Comparison of the decomposition of glycine and L-isovaline measured from extracts of an irradiated dry standard and an irradiated portion of the Murchison meteorite represented as the fraction of amino acid recovered intact (N/No) as a function of γ-radiation exposure.

Space-Weathering Effects: Previous studies of S-asteroids have suggested that reddening of surface spectra obtained from these asteroids compared to la-

boratory spectra of ordinary chondrites could be explained by space weathering, with bluer regions associated with fresh young craters and recently exposed surfaces [6]. However, current published literature on space weathering of low albedo objects such as Bennu is inconclusive about the spectral effects of space weathering.

For the OSIRIS-REx mission, a variety of indicators from the *in situ* remote sensing measurements will be used to assess the probability of space weathering on the surface of Bennu including visible and infrared spectral continuum slope and band depth, x-ray fluorescence, normal reflectance albedo and color ratio maps, crater and boulder proximity, regolith particle size, and surface slopes [7]. In addition, the surface morphology including evidence for recent impacts will be important in identifying locations on the surface of the asteroid that represent the least altered material. These measurements will feed directly into the Bennu Sample Site Selection process for Science Value, which will be expressed as an Integrated Science Value Map.

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