Experimental studies on the effect of impact processes on the formation and evolution of amino acids

Eve L. Berger[1], Aaron S. Burton[1], Christopher J. Cline II[1], Mark J. Cintala[1], Elizabeth B. Rampe[1], Aaron B. Regberg[1], Carina Lee[2,3], Susan M. Lederer[1]. [1]NASA Johnson Space Center, Houston TX 77058 (eve.l.berger@nasa.gov); [2]Jacobs JETS II contract – NASA JSC, Houston TX 77058, [3]Texas State University, San Marcos TX 78666

Introduction: A critical step in the emergence of life on Earth was the synthesis of larger organic molecules from simple building blocks such as NH_3, CO_2, H_2O, and CH_3OH. The presence of amino acids and other complex organics in comets and meteorites demonstrates that widespread organic synthesis likely occurred across the early solar system. Building on previous work [e.g., 1-3], we systematically explore impact-driven chemical evolution of exogenous organics and their precursors. Collisional processes may also have provided a source of energy for the formation of more complex organics from endogenous building blocks. The high flux of impactors to Earth immediately prior to and during the origins of life suggests that impacts could have played a critical role.

Key Questions:

1) How are the formation and evolution of amino acids affected by the presence of a mineral matrix during cometary and asteroidal impacts onto the early Earth?
2) Do some minerals (e.g., phyllosilicates) provide a more robust protective framework or reactive surface site for amino-acid formation and/or polymerization?
3) Does the abundance of ices and/or amino acids relative to that of the mineral matrix affect the formation and evolution of amino acids?
4) Are there impact velocities/shock pressures at which formation or polymerization of amino acids is favored or precluded?

Experimental Approach: This study systematically examines the conditions under which amino acids and other organic molecules can form, be polymerized, and/or be destroyed during impact events into particulate regolith simulants. Variable parameters include the modal composition of this regolith (silicate matrices, ratios of ices, silicates, and amino acids) and impact velocities/shock pressures.

Impacts experiments were performed using the two-stage light-gas gun (LGG), vertical gun (VG), and flat-plate accelerator (FPA) in the Experimental Impact Lab at JSC. FPA experiments were performed over a range of shock pressures (11.3-31.5 GPa) using CM chondrite simulant mixed with amino acids at ratios of 0:10, 1:10, $1:10^3$, and $1:10^6$ (amino acid:host). Techniques for mixing cometary ices have been optimized and test runs have been performed using the LGG (see figure below).

Panel 1: Preparation of cometary ice mix (H_2O, CH_4, MeOH, CO_2). **Panels 2 and 3:** Cometary ice mixture pre-and post- LGG impact.

Analysis: Post-impact, samples are heated in water to extract amino acids and peptides. Extracts are characterized via liquid chromatography-mass spectrometry (LC-MS) and the mineralogies of solid residues are characterized using X-ray diffraction, scanning electron microscopy and transmission electron microscopy. Additional LC-MS and mineralogical analyses are underway.

References: [1] Peterson et al 1997 *GCA* 61:3937. [2] Blank et al 2009 *Orig. Life Evol. Bios.* 9:943. [3] Martins et al 2013 *Nature Geosci.* 6:1045 [4] Sugahara and Mimura 2015 *Icarus* 257:103.

Acknowledgments: NASA ROSES Exobiology