EVALUATING THE EFFECTS OF IMPACTS ON ORGANICS IN ASTEROIDAL AND COMETARY SIMULANTS.
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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 [1–3]. Research exploring prebiotic chemistry on Earth has focused primarily on hydrothermal and atmospheric (Miller-Urey) processes leading to the formation of biologically relevant compounds [e.g., 4, 5]. Impact-driven chemical evolution has largely been overlooked, despite the impressive inventory of prebiotically relevant compounds and simpler precursor compounds known to exist on comets and meteorites. Beyond evolution of exogenous organics and their precursors, collisional processes also provide 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 [6] means that impacts could have played a critical role in life's emergence, but, due to experimental and analytical challenges, the experiments performed to date have sampled only a fraction of the parameter space relevant to prebiotic chemistry [7–11].

Our experimental work will systematically examine 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. Parameters of interest include: the modal composition of this regolith, including variable silicate matrices; ratios of ices, silicates, and amino acids; and impact velocities/shock pressures. To determine whether amino acid and peptide formation are more efficiently catalyzed by different mineral substrates during impact events, we will vary the composition and amount of silicate matrix. In these experiments, we will employ a mixture of amino acids that represents the major functional group chemistries and will use isotopically-labeled reagents (e.g., deuterated amino acids) to mitigate contamination.

Methods: Samples containing CM chondrite meteorite regolith simulant (Deep Space Industries) materials were spiked with solutions containing a suite of deuterated amino acids ranging from 1:10 amino acid:meteorite simulant to 1:100,000 by mass. The resulting samples (~100 mg each) were freeze-dried and packed into target assemblies and subjected to shock-reverberation pressures ranging from 11.3 – 31.5 GPa (Table 1); a subset was also prepared that did not contain amino acids to serve as negative controls. The post-impact samples will be extracted for amino acids and peptides using established methods for processing meteorite impact samples by liquid chromatography-mass spectrometry [e.g., 12], and residual solid materials will be analyzed by X-ray diffraction (XRD), scanning electron microscopy (SEM) and/or transmission electron microscopy (TEM) to investigate mineralogical changes.

Table 1. Parameter space of impact experiments performed with CM chondrite regolith simulant.

Amino acid to simulant ratio	Mass of simulant used	Pressure (GPa)
0:1	102	11.3
1:10	109	11.5
1:1,000	96	12.0
1:100,000	104	12.7
0:1	106	19.8
1:10	111	20.6
1:1,000	97	22.1
1:100,000	109	21.3
0:1	97	24.7
0:1	101	30.2
1:10	110	24.8
1:10	95	28.9
1:1,000	96	30.1
1:1,000	105	30.5
1:100,000	99	26.0
1:100,000	110	31.5

Results: Preliminary experiments were performed to develop optimal sample preparation and post-impact handling techniques. Figure 1 shows backscattered electron (BSE) images of freeze-dried montmorillonite clay material that was spiked with amino acids pre-impact and post-impact (~5 GPa). Analyses of the organics in the CM-simulant samples are currently underway.

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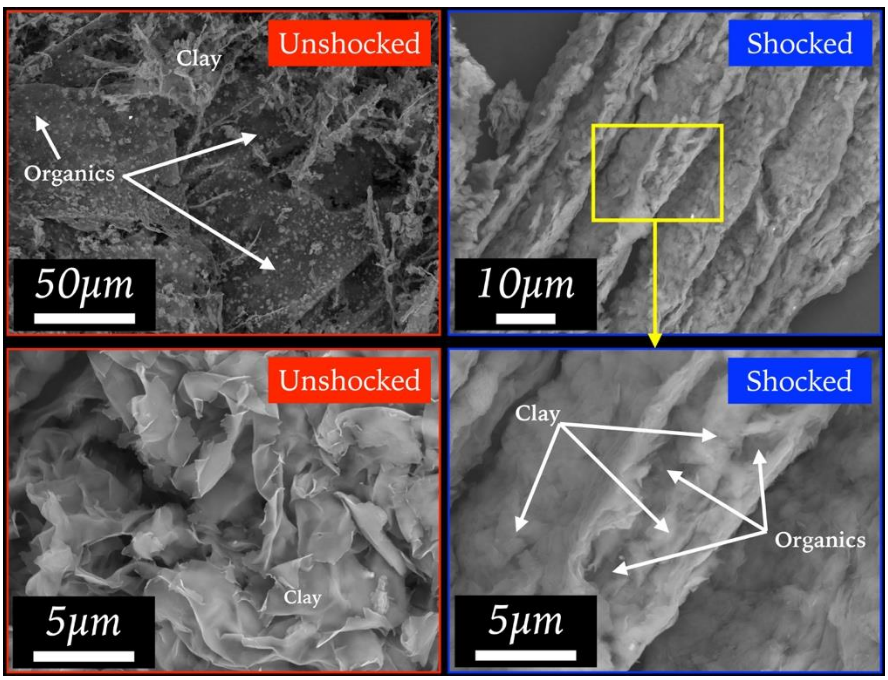

Figure 1. BSE images of pre- (left) and post-impact (right) mixtures of amino acids and montmorillonite clay. Samples were impacted at ~4.9 GPa with the Flat-Plate Accelerator in the Experimental Impact Laboratory at NASA JSC. The textures of components have changed; the organics are more intimately associated with the clay in the shocked, relative to unshocked, samples.