EXTRATERRESTRIAL AMINO ACIDS IN IRON METEORITES. J. E. Elsila[1], J. P. Dworkin[1], D. P. Glavin[1], and N. M. Johnson[1] [1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, Email: Jamie.Elsila@nasa.gov

Introduction: Studies of the organic content of meteorites are important in astrobiology, providing information about the potential delivery to Earth of molecules relevant to the origin of life. Many of these studies have focused on amino acids, which are essential to terrestrial life as the monomers of proteins and enzymes. The primary target of these analyses have been carbonaceous chondrites, primitive meteorites containing ~3-5 wt% carbon; amino acids have been detected in varying abundances and distributions in representatives of all eight carbonaceous chondrite groups, as well as in ungrouped carbonaceous chondrites, ordinary and R chondrites, ureilites, and planetary achondrites [1 and references therein].

Iron meteorites have been postulated to be the cores of differentiated planetessimals and make up ~5% of falls to the Earth, yet could have also been a source of prebiotic material. Searches for amino acids in iron meteorites have not previously been reported, perhaps because of the difficulties in preparing these samples for extraction or because of the low expectation of organics forming or surviving in such environments. Here, we report the first analyses of amino acids in iron meteorites as well as in both the iron and silicate portions of a pallasite.

Methods: We analyzed ~1-2 g samples of three iron meteorites as well as both the iron and silicate components of a pallasite: Campo del Cielo (IAB), Canyon Diablo (IAB), Cape York (IIIAB) and Imilac (pallasite). Organic analysis of stony meteorites typically begins by grinding a sample in a mortar and pestle to create a fine-grained powder that can then be extracted by a solvent (typically water). The cohesion and malleability of iron meteorites renders them impossible to grind using the same methods; instead, iron samples for this study were processed in a $N_{2(l)}$-chilled ball mill. Processing of the iron meteorite samples by this method produced flakes and grains from the embrittled metal. Imilac was first disaggregated in a mortar and pestle to separate iron and silicate fractions; the iron was ground in the ball mill and the silicate was powdered in a mortar and pestle. After processing, all samples were then extracted for 24 hours in ultrapure water. Extracts were split into two fractions, with one portion undergoing acid-vapor hydrolysis (3 hours at 150 °C in the presence of 6N HCl). Both unhydrolyzed and hydrolyzed portions were derivatized using *o*-phthaldialdehyde/N-acetyl-L-cysteine and analyzed via ultraperformance liquid chromatography with fluorescence detection and time-of-flight mass spectrometery (LC-FD/ToF-MS) [2,3]. Procedural blanks of fused silica processed in the ball mill were also prepared and analyzed.

Results: Amino acids were detected in all samples, including both the iron and silicate portions of the pallasite, but not in the procedural blanks. Some amino acids appear to result from terrestrial contamination, with an excess of L-proteinogenic compounds. However, we observed many amino acids that are not common in the biosphere. In particular, a series of non-proteinaceous five carbon (C5) amino acids was detected in the iron samples (Fig 1). Overall amino acid abundances were low (typically <100 ppb), with over half of the abundance in the unhydrolyzed extracts in the form of glycine and <10 ppb in the C5 amino acids. The two IAB iron meteorites had roughly similar amino abundances, with the IIIAB and pallasite containing lower abundances; abundances in the silicate portion of the pallasite were lower than in the iron portion.

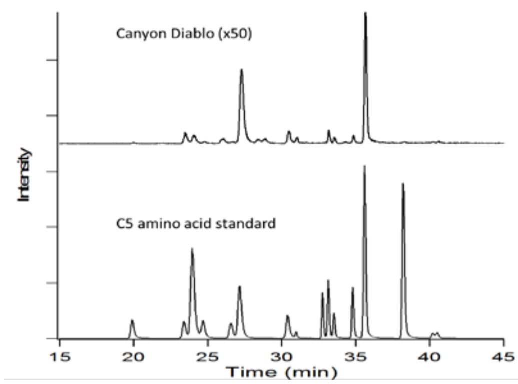

Fig. 1. Representative LC-FD/ToF-MS single positive ion chromatogram of the mass corresponding to derivatized C5 amino acids for the unhydrolyzed Canyon Diablo meteorite extract (top, x50) and a C5 amino acid standard mix (bottom).

These results open new areas of study on the organic content of these meteorites, as well as the potential origin of their amino acids. Surface-catalyzed reactions of gases have been suggested to form amino acids on metal surfaces [4-6], but it is not yet known if that mechanism could result in the distribution of compounds observed here. This discovery of amino acids in iron meteorites adds to the known sources of organic delivery to the early Earth.

References: [1] Elsila J. E. et al. (2016) *ACS Central Science*, *2*, 370-379. [2] Glavin D. P. & Dworkin J. P. (2009) *Proc. Natl. Acad. Sci. U. S. A.*, *106*, 5487-5492. [3] Glavin D. P. et al. (2006) *Meteorit. Planet. Sci.*, *41*, 889-902. [4] Burton A. S. et al. (2012) *Meteorit. Planet. Sci.*, *47*, 374-386. [5] Pizzarello S. (2012) *Meteorit. Planet. Sci.*, *47*, 1291-1296. [6] Yoshino D. et al. (1971) *Geochim. Cosmochim. Acta*, *35*, 927-938.