INVESTIGATING L-AMINO ACID ENANTIOMERIC EXCESS IN CM AND CR CARBONACEOUS CHONDRITES.
E. T. Parker[1], J. C. Aponte[1], C. M. O'D. Alexander[2], D. Foustoukos[3], J. P. Dworkin[1], and D. P. Glavin[1] [1]Solar System Exploration Division, NASA Goddard Space Flight Center, Greenbelt, MD U.S.A. 20771, [2]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC U.S.A. 20015, [3]Geopghysical Laboratory, Carnegie Institution of Washington, Washington, DC U.S.A. 20015

Introduction: Meteorites contain many soluble organic compounds, including amino acids. These species provide clues about parent body processes and chemical reactions that may have contributed to the production of extraterrestrial biomolecules [1–3]. Non-protein amino acids, such as isovaline (Iva), are of primary interest because these compounds are less likely to be a result of terrestrial contamination and therefore can be valuable indicators of extraterrestrial formation [4]. Furthermore, the enantiomeric compositions of meteoritic amino acids with chiral centers can help elucidate the origin of homochirality on Earth, or elsewhere, and be associated with the degree of aqueous alteration experienced on the parent body.

Previous explorations of type 2/3 CR meteorites have shown significant L-Iva excesses are not present in the least aqueously altered CR chondrites [3]. However, analyses of aqueously altered type 1 CM, CR, and CI meteorites, and some aqueously altered CM2 meteorites, have revealed significant L-isovaline excesses of up to ~18% [4-6]. These findings corroborate the hypothesis that aqueous alteration of the meteorite parent body was necessary for the amplification of small, initial L-excesses of Iva [4] in these meteorites.

While CM2 meteorites, such as Yamato-791198 (Y-791198), have been studied for amino acids [7], a comprehensive investigation of amino acid enantiomeric excesses in Y-791198 has yet to be reported. Such an investigation is necessary to determine if the aforementioned hypothesis is consistently observed in other carbonaceous chondrite groups.

In the present exploration, we are focusing on 5 different Antarctic meteorites: Y-791198 (CM2), EET 96029 (CM2), MIL 090657 (CR2), LAP 02342 (CR2), and GRA 95229 (CR2). These meteorites were analyzed for a wide array of amino acids, and the analyses were compared to that of two different samples of the non-Antarctic Murchison meteorite (the most abundant and well-studied type 2 CM chondrite): 1) Murchison USNM 54512, and 2) Murchison from the Chicago Field Museum of Natural History. In addition to searching for a range of amino acids, the analyses is particularly focused on Iva enantiomeric abundances.

Experimental: Samples were prepared for analysis by 1) hot-water extraction, 2) acid-vapor hydrolysis, 3) desalting, and 4) pre-column derivatization with *o*-pthaldialdehyde/*N*-acetyl-L-cysteine (OPA/NAC) [5]. OPA/NAC is a fluorescent derivative that enhances specificity for, and sensitivity to, primary amino groups and chromatographically separates amino acid enantiomers. Analyses were performed via ultraperformance liquid chromatography with fluorescence detection, and time-of-flight mass spectrometry [8]. Aliquots of the bulk powders have been analyzed for their H-C-N abundances and isotopes to determine relative degrees of alteration [9].

Results and Discussion: Preliminary results indicate L-Iva excesses in the samples studied here are as high as ~18%. Additional measurements will be made to more precisely constrain the L-Iva excesses and their associated measurement uncertainties.

Recent analytical method development, combined with improved access to enantiopure, non-protein amino acid standards (*e.g.*, β-aminobutyric acid (β-ABA), and β-aminoisobutyric acid (β-AIB)) have improved our capacity to explore the possibility of meteorites providing L-excesses of additional non-protein amino acids. Future work will focus on determining if L-excesses of ABA and AIB isomers exist in CM and CR carbonaceous chondrites.

Implications: The experiments performed here evaluate the suggestion that aqueous alteration is necessary for the amplification of small, initial L-excesses of amino acids, namely Iva, in carbonaceous chondrites. The results will improve our understanding of the formation of L-excesses of chiral amino acids in CM and CR meteorites that have experienced limited aqueous alteration. This analytical approach could be useful for implementation to investigate if L-amino acid excesses exist in pristine regolith returned from the asteroids Bennu (NASA's OSIRIS-REx mission) and Ryugu (JAXA's Hayabusa2 mission).

References: [1] Botta, O. et al. (2002) *Orig. Life Evol. Biosph.*, 32, 143. [2] Burton, A. S. et al. (2012) *Meteoritics & Planet. Sci.*, 47, 374. [3] Elsila, J. E., et al. (2016), *ACS Central Sci.*, 2, 370. [4] Glavin, D. P. and Dworkin J. P. (2009) *Proc. Natl. Acad. Sci.* DOI: https://doi.org/10.1073/pnas.0811618106, 2009. [5] Glavin, D. P. et al. (2010) *Meteoritics & Planet. Sci.*, 45, 1948. [6] Burton, A. S. (2013) *Meteoritics & Planet. Sci.*, 48, 390. [7] Shimoyama, A. and Ogasawara, R. (2002) *Origins of Life Evol. Biosph.*, 32, 165. [8] Glavin et al. (2006) *Meteoritics & Planet. Sci.*, 41, 889. [9] Alexander C. M. O'D. et al. (2013) *Geochim. Cosmochim. Acta*, 123, 244.