ESTIMATING THE COMPOSITIONAL DEPENDENCE OF COSMOGENIC NOBLE GAS PRODUCTION RATES IN E-CHONDRITE SUBSAMPLES USING HIGH-RESOLUTION X-RAY MICRO-COMPUTED TOMOGRAPHY

M. Mijjum[1], D. Blair[1], and M. M. Tremblay[1] [1]Purdue University (550 Stadium Mall Dr., West Lafayette, IN 47906, mmijjum@purdue.edu)

Introduction: Cosmic ray exposure (CRE) ages are a critical tool for constraining the collisional history, orbital dynamics, and parent bodies of different meteorite classes. Accurate knowledge of stable cosmogenic nuclide (^{3}He, ^{21}Ne, ^{38}Ar) production rates is needed to calculate CRE ages. Production rates are primarily a function of shielding and the chemical composition of the sample. Typically, shielding is determined by measuring cosmogenic ^{22}Ne/^{21}Ne [1], while the chemical composition is determined using electron microprobe (EPMA) analyses of representative mineral grains and an estimate of mineral abundances [2].

Motivation: Eugster [3] developed a series of equations for estimating cosmogenic noble gas production rates as a function of shielding depth in L chondrites, which are widely used to calculate CRE ages. To apply these production rate equations to other meteorites, a chemical correction factor 'F' is determined using the weight percentages of target elements present within the meteorite or meteorite class of interest. For cosmogenic ^{3}He, 'F' varies only slightly across different meteorite classes (between 0.97 – 1.01), but it can vary considerably more for ^{21}Ne (0.67 – 1) [3]. Typically, F is calculated using the chemical composition of major minerals determined by EPMA analyses and assuming mineral abundances for the bulk meteorite. However, subsamples of meteorites used for CRE measurements are often small enough that mineral abundances may differ significantly from the bulk meteorite. For example, enstatite (E) chondrites can have significant spatial variability in mineral abundances, especially with increasing petrologic grade [4]. **We are exploring a method to determine subsample specific production rates of cosmogenic noble gas isotopes in meteorites by mapping the volumetric distribution of these minerals using X-ray micro-computed tomography (microCT).** For this initial study we focus on E chondrites, although the approach we will present could be applied to any meteorite class. Understanding the CRE history of E chondrites is important because their chemical composition suggests they formed in the innermost solar nebula, thereby providing unique insight into understanding early solar system environments and processes. MicroCT is a nondestructive technique that leverages X-ray energy attenuation as a function of density. Density variations mapped using microCT can be used to evaluate the volumes and spatial relationships of different mineral grains, inclusions, and pore space within a material. For our purposes, this enables us to determine the volumetric distribution of minerals within a meteorite subsample. E chondrites are predominantly made up of enstatite (3.1-3.3 g/cm^{3}), kamacite (7.9 g/cm^{3}), and anorthite/other feldspars (2.72-2.75 g/cm^{3}). The strong density contrast between these minerals makes identifying their volumetric abundances by microCT readily feasible.

Methods: We prepared subsamples of 6 enstatite (E) chondrites of varying chemical type and petrologic grade from Northwest Africa (NWA) and Caleta el Cobre (CeC) for microCT and subsequent cosmogenic noble gas analyses (CeC 024, CeC 025, CeC 028, NWA 2965, and NWA 6258 (x2)). We cut ~ 0.1 - 0.6 grams from the bulk mass, and removed any weathering crusts. First, we examined each sample to get a qualitative sense of mineral abundances using a scanning electron microscope with energy-dispersive X-ray spectroscopy (SEM-EDS). Using the 3D X-ray microscope at the Purdue University 3D X-Ray Microscope Shared User Facility, we are obtaining CT scans of our specimens with µm-scale resolution. With the microCT data, we will generate 3D renderings of density variations in our samples, which will enable us to determine the volumetric distribution of minerals in each subsample. We will then calculate subsample-specific cosmogenic noble gas production rates using the mineral abundances determined by microCT alongside existing chemical information from EPMA (e.g., [5]). In cases where our subsample has different proportions of enstatite/kamacite/feldspar relative to the bulk meteorite, our microCT approach will lead to more accurate production rate estimates and CRE ages.

Expected Results: Porfido et al. [6] used microCT to obtain quantitative 3D spatial distributions of different minerals in meteorites, but only for the purposes of identifying small-scale textures (i.e., vesiculation). This technique has not yet been explored as a tool for estimating the contribution of different mineral abundances for production rate calculations of cosmogenic noble gases. We anticipate having microCT constraints will improve production rate estimates and therefore CRE age determinations in E-chondrites, which will have applications for other meteorite classes with compositional variance at the subsample level (e.g., lodranites and alcapulcoites [7]).

References: [1] Eberhardt, P. et al. (1966) *Z. Nuturforsch* 21a:414-426. [2] Keil, K. & Andersen, C.A. (1965) *Geochimica et Cosmochimica Acta* 29:621-632. [3] Eugster, O. (1988) *Geochimica et Cosmochimica Acta* 52:1649-1662. [4] Kong, P. et al. (1997) *Geochimica et Cosmochimica Acta* 61:4895-4914. [5] Gattacceca, J. et al. (2020b) *The Meteoritical Bulletin, No. 108* 55:1146-1150. [6] Porfido, C. et al. (2020) *Talanta* 217:121114. [7] Weigel, A. et al. (1999) *Geochimica et Cosmochimica Acta* 63:175-192.