EXPLORING THE MINERALOGY, PETROLOGY, AND ISOTOPIC COMPOSITIONS OF GIBEON AND NWA 4759 (CV3) THROUGH MULTIPLE ANALYSIS TECHNIQUES.

E. Driscoll[1], E. S. Bullock[1], M. K. Jordan[1], T. D. Mock[1], S. M. Vitale[1], J. Wang[1], C. R. Wilson[1], J. Yang[1] , [1] Earth and Planets Laboratory, Carnegie Institution for Science, Washington, DC USA.

Introduction: Analyzing the chemical and physical characteristics of stony and iron meteorites provides valuable information about the processes and conditions present in the early solar system through to planetary formation. Chondrites, composed of undifferentiated planetary material, contain some of the most primitive matter that formed in our solar system. Once the molten cores of planetesimals, iron meteorites supply insight into the processes by which planetary objects form, differentiate into layers, and react to impacts. We fully characterized two meteorite samples – a carbonaceous chondrite (NWA 4759) and an iron meteorite (Gibeon) – to investigate their elemental and isotopic compositions, degree of terrestrial alteration, and consistency with previously published analyses. Each analytical technique provides a piece of the puzzle in understanding these samples.

Instrumentation and Methods: We collected data using a wide variety of techniques to build a rigorous profile of each meteorite's makeup and history. Backscattered and secondary electron images, as well as basic compositional data via energy dispersive spectroscopy (EDS), were obtained on a Zeiss Auriga field emission SEM. Further imaging was conducted on a JEOL JXA-8530F field emission electron microprobe analyzer (EPMA), which also provided quantitative compositional data via spot analysis and element maps. A high spatial-resolution compositional analysis of the matrix in a region 60 µm x 55µm was performed on a Helios G4 PFIB CXe DualBeam. A Cameca NanoSIMS 50L ion probe collected isotopic data to search for presolar grains. Two inductively-coupled plasma mass spectrometers – a Nu Plasma II and a ThermoFisher iCAP Q – were used to gather isotopic and elemental data from sample solutions of each meteorite; purified Fe sample solutions were obtained using ion exchange chromatography and analyzed on the Nu Plasma II. All analyses were performed at the Carnegie Earth and Planets Laboratory.

Compositional and Isotopic Results: We gathered the following data on the two meteorite samples using the above techniques,.

NWA 4759. NWA 4759 was identified to be a CV3 chondrite. Its bulk Mg/Si ratio is 1.06, which places it within the classification guidelines of a carbonaceous chondrite [2]. It contains large (0.1-1.5 mm) chondrules with abundant matrix and shows very little pre-terrestrial aqueous or metamorphic alteration. EPMA point analysis of NWA 4759 shows that SiO_2 makes up 41.7% of the total chondrule mass, MgO is 39.3%, Al_2O_3 is 4.56%, and FeO is 12.0%. Chondrules, characterized with respect to their elemental compositions and cations, were shown to consist mainly of olivine (63% of analyzed grains) and pyroxene (33%). Spinel grains, indicative of relict calcium-aluminum-rich inclusions (CAIs), are present in small quantities (4%). The matrix is comparatively rich in SiO_2 (34.9%) and MgO (26.5%) [3], and contains Na-rich regions in addition to abundant carbon (Figure 1).

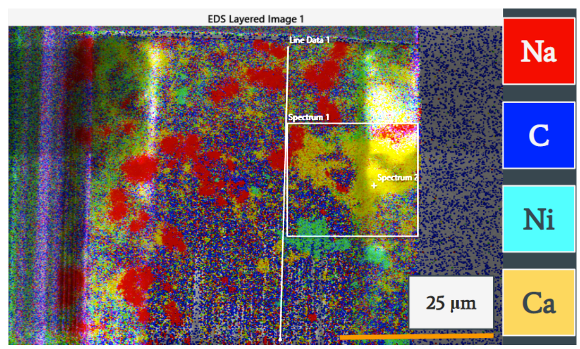

Fig. 1. Layered elemental EDS data from a FIB thin-section of NWA 4759 matrix.

Features of interest include a patch of Ca-sulfate crystal growth, which occurred over a two-day period between sample preparation and SEM analysis (Figure 2). This feature likely resulted from exposure to water during the polishing process, similar to a Ca-sulfate patch reported in an Ivuna sample [4]. The sample as a whole has been extensively terrestrially altered, as shown by the brown staining in the matrix (visible in the hand sample), thin-iron-rich veins cross-cutting the sample, and the alteration of iron metal to iron oxides. As a result, after examining ^{12}C, ^{13}C, ^{16}O, ^{17}O, ^{18}O, ^{28}Si, and $^{27}Al^{16}O$ in the sample's matrix via nanoSIMS, presolar grains were undetectable – any presolar grains that may have once been present had been altered beyond identification. We ran the same isotopic analyses on Asuka 12169 (CM), a less altered sample, and were able to locate plentiful presolar grains. Our characterization of NWA 4759 largely corresponded with previously published analyses, with the exception of the identification of a fusion crust of thickness 50-150 µm (Figure 3) and the scarcity of large CAIs [1].

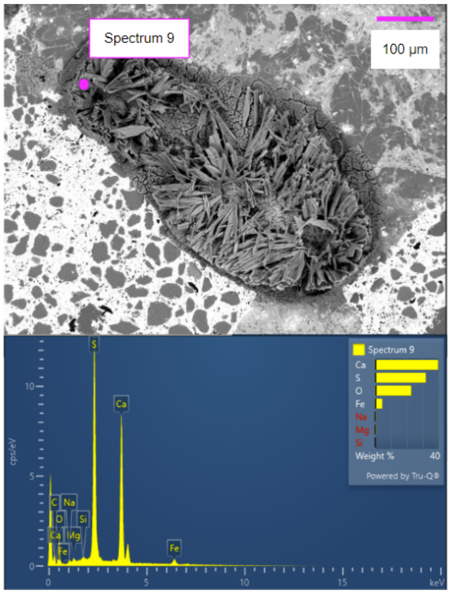

Fig 2. Top: BSE image of a Ca-sulfate crystal growth image near the edge of an indium-mounted piece of NWA 4759. Bottom: EDS data displaying elemental composition (S- and Ca-rich).

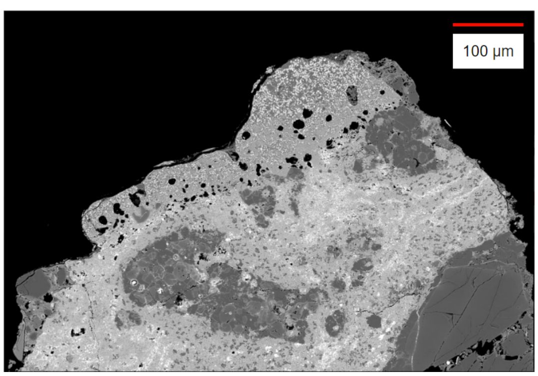

Fig. 3. BSE image of epoxy-mounted NWA 4759, displaying the fusion crust.

Gibeon. The iron sample was found to have a Ni composition of 10.1% based on ICP-MS data. Its Widmanstätten pattern is visible upon first inspection, and the sample has lamellae of width 100-300 µm. Taenite veins and spots were present throughout the sample, extending into its heavily oxidized surface region. The combination of Ni percentage and bandwidth led to a classification of IVA. Like most IVA meteorites, it can be accurately described as a fine octahedrite [5]. This sample, similar to the chondrite, underwent terrestrial alteration – its rusted surface corroborates previous evaluations that it has been subjected to environmental weathering since prehistoric times [6].

Conclusion: The carbonaceous chondrite was identified to be a CV3 meteorite with substantial terrestrial alteration, no intact presolar grains, and a minor amount of fusion crust visible. NWA 4759's chondrules consist predominantly of olivine and pyroxene grains. Minor amounts of spinel suggest the presence of CAIs. Our analysis largely agreed with previous characterizations, but had key differences, including the presence of a fusion crust and a lack of large, easily identifiable CAIs [1]. The iron meteorite was identified as a fine octahedrite of the IVA group. Like the chondrite, the iron sample was subjected to terrestrial weathering, resulting in an oxidized surface layer of 200-300 µm thickness. The use of multiple correlated techniques allows us to build up a broader picture of each meteorite's individual history.

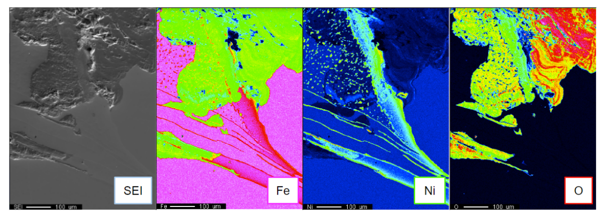

Fig. 4. Four maps of the same region of Gibeon. 1) SEI image, 2) Element map of Fe, 3) Element map of Ni, 4) Element map of O.

References: [1] (2022) *LPI Meteoritical Bulletin Database: NWA 4759.* [2] G.W. Kallemeyn and J.T. Wasson (1981) *Geochimica et Cosmochimica Acta (GCA): Carbonaceous chondrite groups,* 1217-1230. [3] H. Y. McSween and S. M. Richardson (1977) *GCA: Composition of carbonaceous chondrite matrix,* 1145-1161. [4] A. J. King et al. (2019) *GCA: Terrestrial modification of the Ivuna meteorite*. [5] A. E. Rubin et al. (2022) *GCA: IVA iron meteorites as late-stage crystallization products, 331,* 1-17. [6] (2022) *LPI Meteoritical Bulletin Database: Gibeon.*