MAJOR AND TRACE ELEMENT COMPOSITION OF CARBONACEOUS CHONDRITES: INSIGHT INTO THEIR ALTERATION HISTORIES. P. Haenecour[1], L. R. Smith[1], M. Neuman[2], P. Koefoed[2], K. Wang[2], and K. Dominik[1]. [1]Lunar and Planetary Laboratory, The University of Arizona, Tucson, AZ, USA. [2]Department of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University in St. Louis. (Email: haenecour@arizona.edu)

Introduction. As remnants of the early solar system, asteroids give us the opportunity to study the original materials that formed the planets in the protoplanetary disk. Carbonaceous chondrites are samples from asteroids that are divided into groups of CI, CM, CR, CO, CV, CK, CH, CB, CY and CL chondrites. Laboratory measurements of their chemical compositions provide constraints on the composition and differentiation history of planetary reservoirs [1, 2]. CI chondrites are rare chondrites that almost entirely consist of fine-grained materials, and their relative bulk chemical compositions closely match the solar photosphere, attesting to their primordial chemical composition [1]. Virtually all other known planetary materials, i.e., other groups of meteorites, the terrestrial planets and the Moon are significantly depleted in volatile elements (e.g., Na, K, Zn, S, Cd) relative to CI.

Carbonaceous chondrites were affected by secondary processing, including both heating and aqueous alteration, on their host asteroid, e.g. [3]. The presence of hydrous minerals in many carbonaceous chondrites provides evidence of low-temperature hydrothermal alteration on asteroids [4]. The response of primary fine-grained materials to secondary alteration is important for understanding active processes on the surfaces of and within their parent asteroids in the early solar system. For example, thermal metamorphism played an important role in alteration, *e.g.*, melting, volatile loss, metasomatism, and driving hydrothermal processing.

Table 1. Samples used in this work.		
Meteorite Name	*Type*	*Fall/Find*
Orgueil (MNHN 234)	CI1	Fall
Allende (SRM powder)	CV3	Fall
Murchison	CM2	Fall
Sutter's Mill	CM2	Fall
Kolang	CM2	Fall
Tarda	C2-ung.	Fall
Aydar 003	CM1/2	Find
NWA 8534	CM1/2	Find
Jbilet Winselwan	CM2	Find
Northwest Africa 10574	CM2	Find
Daoura 003	CM2	Find
Sueilila 003	CV3	Find
Northwest Africa 801	CR2	Find
Chwichiya 002	C3.00-ung.	Find
Additional Standard Materials: Bituminous coal (NIST 8499), Coal Fly ash (NIST 1633a), Fish Clay (FC-1 04-01), Oil-rich Green River Shale, anthracite, San Carlos Olivine, Serpentine		

Constraining the effects of alteration processes on carbonaceous chondrites is critical to understanding past and ongoing processing of asteroids. As part of a broader effort to address this question, we report initial

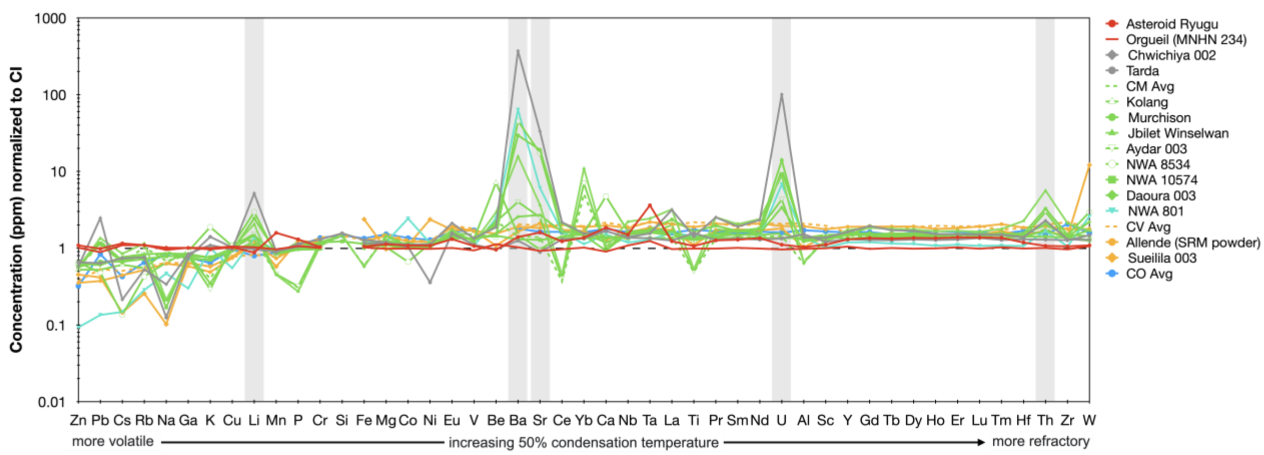

Fig 1. Measured abundances of elements in Orgueil, Allende, Kolang, Aydar 002, Murchison, NWA 8534, Jbilet Winselwan, NWA 10574, Tarda and Chwichiya 002 normalized to CI chondrite values and compared with samples from asteroid Ryugu [5] and average CM, CO, and CV [1,6,7].

data on the bulk abundance of major and trace elements in carbonaceous chondrites.

Samples and Methods. We selected a series of carbonaceous chondrite falls and finds from different petrologic types, especially focusing on aqueously-altered meteorites (Table 1). We also selected standard materials (e.g., carbonaceous- and volatile-rich) to investigate the effect of heating on their chemical compositions. Samples of each meteorite were first ground and homogenized using a mortar and pestle. Apart from Orgueil and Allende, we used at least one gram of sample to prepare each powder. Aliquots of approximately 40-50 mg of the powdered meteorites were then dissolved in mixtures of double-distilled HNO_3 and HF on a hotplate at ~150 ºC for one week. Samples were then dried down and redissolved in concentrated HNO_3, then 7M HCl, and finally 2% HNO_3 for analysis. Solutions of the dissolved samples were prepared at dilution factors of about 5,000 (for minor and trace elements) and 50,000 (for major elements) to achieve concentrations of individual elements in the range required for measurement in pulse counting mode. Elemental concentrations were determined using a quadrupole-ICP-MS (Thermo Fisher Scientific iCAP Q ICP-MS) at Washington University in St. Louis. The instrument was tuned, calibrated, and left to stabilize prior to all analyses. Samples were run in kinetic energy discrimination (KED) mode using the USGS reference materials BHVO-2, BIR-1, and BCR-2 for liner calibrations and an internal standard of 5 ppb In to correct for signal drift. After the instrument was tuned and had stabilized over the course of a few hours, samples were run using an internal standard of 5 ppb In to correct for signal drift during analyses. Each sample was measured multiple times at each dilution factor to improve accuracy.

Fused beads of each meteorite sample will also be made to measure their chemical compositions with electron microprobes (EPMA) both at Washington University in St. Louis (JEOL JXA-8200) and at The University of Arizona (Cameca SX-100 Ultra).

Results & Discussion. Allende, Kolang, Aydar 002, Murchison, NWA 8534, Jbilet Winselwan, NWA 10574, Tarda and Chwichiya 002 show the typical depletions in volatile elements relative to CI chondrite values (Fig. 1). As previously reported by [2], all meteorites found in hot desert (e.g., Chwichiya 002, NWA 8534, Jbilet Winselwan, NWA 10574 and Aydar 002) exhibit clear evidence of terrestrial weathering with enrichments in Sr, Ba, U and light rare earth elements (LREE) and depletion in highly mobile alkali elements (Na, K, and Cs) relative to meteorite falls (Fig. 1 & 2a). Unlike all hot desert finds, Tarda does not exhibit significant signs of terrestrial weathering. Despite being characterized by high presolar abundances and exhibiting only localized aqueous alteration [8], the bulk chemical composition of Chwichiya 002 shows that it experienced extensive terrestrial weathering. At the meeting, we will further discuss the major and trace element compositions and how they compare with the EPMA measurements of the fused meteorite beads.

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References: [1] Lodders (2021) Space Science Reviews 217:44. [2] Braukmuller et al. (2018) GCA 239, 17–48. [3] Scott and Krot (2014) Treatise on Geochemistry (2nd Edition), Vol. 1, pp. 65-137. [4] Wadhwa et al. (2020) Annu. Rev. Earth Planet. Sci. 48: 233–58. [5] Yokoyama et al. (2022) Science, 10.1126/science.abn78. [6] Lodders & Fegley (1998) Oxford University Press. 371 p. [7] Lodders et al. (2003) ApJ 591 1220. [8] Smith et al. (2023) LPSC LIV.

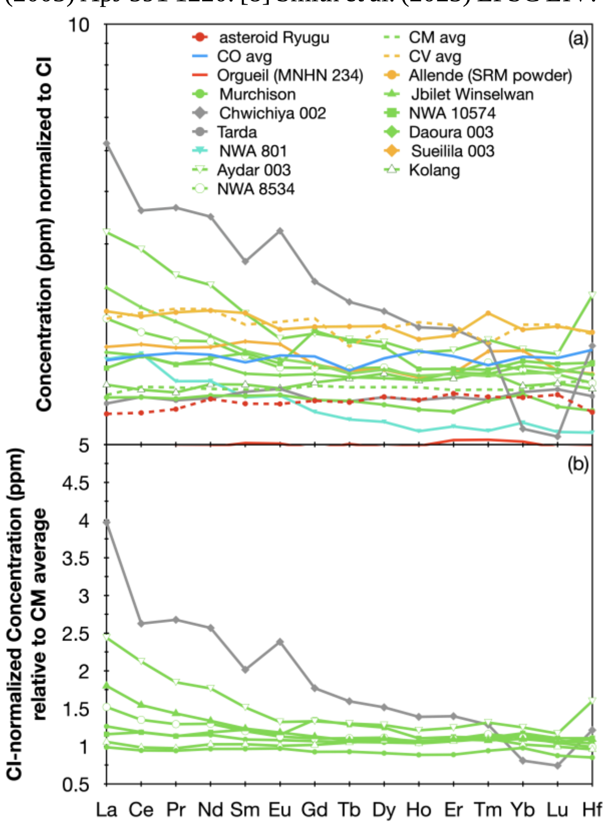

Fig. 2: (a) Rare Earth Element (REE) concentrations (ppm) normalized to CI chondrites for 13 carbonaceous chondrites, samples from asteroid Ryugu [5] and average CM, CO, and CV [1,6,7]. (b) CI-normalized REE concentrations of CM chondrites normalized to the CM average.