

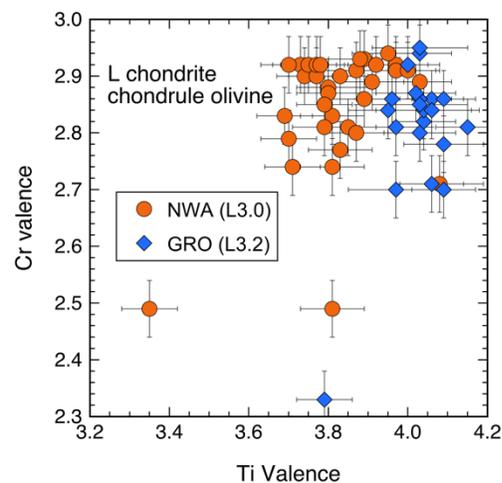
RESPONSE OF Cr and Ti VALENCES IN CHONDRULE OLIVINE TO THE ONSET OF METAMORPHISM IN ORDINARY CHONDRITES.

S. B. Simon¹, S. R. Sutton^{2,3}, and A. J. Brearley⁴. ¹Institute of Meteoritics, University of New Mexico, Albuquerque, NM 87131 (sbs8@unm.edu). ²Dept. of the Geophysical Sciences, The University of Chicago, Chicago, IL 60637; ³Center for Advanced Radiation Sources, The University of Chicago; ⁴Dept. of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131.

Introduction: An important indicator of the pristinity of chondrites is the abundance and distribution of Cr in ferroan olivine chondrule phenocrysts. As first shown by [1], olivine in the least metamorphosed ordinary and CO chondrites has relatively high, uniform Cr₂O₃ contents. With increase in grade from 3.0 to 3.1, standard deviations of analysis populations increase, and with further metamorphism through type 3.2, both Cr₂O₃ contents and standard deviations of analysis populations decrease. This relationship is a major diagnostic tool in the classification of low-grade chondrites, but the process that causes this behavior is not understood. Neither the valence of Cr in the olivine nor the phases that Cr redistributes into with the onset of metamorphism are known. The initial results of our study of Cr and Ti valences in olivine in low-grade chondrites [2] showed that Cr and Ti in olivine in ALHA 77307 (CO3.0) are reduced compared to Kainsaz (CO3.2). For comparison with results for CO chondrites [2], we measured Ti and Cr valences in olivine in type IIA chondrules in two L chondrites, NWA 7731 (type 3.0) and GRO 95544 (type 3.2).

Methods: One polished thin section of each sample was mapped with a scanning electron microscope. Chondrules and isolated grains were selected for study and their fayalite contents determined by energy-dispersive analysis. Valences of Cr and Ti plus Ti coordination data were obtained by X-ray absorption near edge structure (XANES) spectroscopy. XANES spectra were collected using the GSECARS X-ray microprobe in fluorescence mode, with a 1 μm X-ray beam. The valence of Ti was determined following the results of [3], who demonstrated that Ti K-edge XANES spectra of pure Ti⁴⁺-bearing minerals fall into distinct valence-coordination clusters on a plot of pre-edge peak intensity vs. energy. The valence of Cr was determined using Fe-free glass standards with Cr³⁺ or Cr²⁺ as in [4]. For all but three analytical spots, spectra were collected at four different orientations and then merged to minimize orientation effects. Reported valences, between 2 and 3 for Cr and between 3 and 4 for Ti, are averages for the analytical volumes.

Results: Thus far analyses are only available for olivine in chondrules. As illustrated in Fig. 1, differences were found between NWA 7731 (NWA) and GRO 95544 (GRO). Valences of Ti tend to be reduced in NWA chondrules relative to GRO. The mean valence of Ti in NWA is 3.83±0.13 and the mean for GRO is 4.01±0.10. In contrast, the samples have very similar Cr valences; in most grains 15-20% of the Cr is divalent. The “outliers” with reduced Cr in NWA are phenocrysts (Fa₁₀₋₁₅) with hopper crystal morphology in a large (~3.5 mm diameter) porphyritic chondrule. The GRO outlier is a phenocryst in a chondrule fragment with a sulfide rim. Other grains analyzed in these chondrules have typical valences. Proportions of Ti cations that are in tetrahedral coordination are correlated with Ti valence. GRO olivine tends to have higher proportions (average 30±8%) than NWA (average 22±5%).



Discussion: In both of the 3.0-3.2 chondrite pairs investigated so far, Ti in chondrule olivine in the type 3.0 is reduced compared to that in the type 3.2. In ALHA 77307 chondrule olivine, both Ti (average valence 3.51±0.13) and Cr (avg. 2.69±0.07) are reduced compared to Kainsaz (CO3.2) [2] and compared to the present samples.

The clear presence of Ti³⁺ in chondrule olivine indicates that at least some chondrules had reduced precursors. Divalent Cr is present in all chondrule olivine analyzed thus far. Simple loss of Cr³⁺ relative to Cr²⁺, to perhaps form chromite, is not indicated for either the CO [2] or the present samples. A difference between the COs and the Ls, possibly related to differences in their olivine compositions, matrices and/or parent body environments, is that in the COs, either exsolution of Cr from olivine was accompanied by oxidation, or Cr²⁺ preferentially exsolved relative to Cr³⁺, but neither is the case for the Ls. The L3.0 and L3.2 olivine have essentially identical Cr valences; the diffusive losses of Cr²⁺ and Cr³⁺ must have occurred at similar rates. In the L chondrites, valences of Ti and Cr responded differently from each other to the first stages of chondrite metamorphic processes.

References: [1] Grossman J. N. and Brearley A. J. (2005) *Meteoritics & Planetary Science* 40:87–122. [2] Simon S. B. et al. (2017) 80th Annual Mtg. Meteoritical Soc. Abstract #6323. [3] Farges F. et al. (1997) *Phys. Rev. B*, 56, 1809-1819. [4] Goodrich C. et al. (2013) *Geochimica et Cosmochimica Acta* 122:280-305.