SYNCHROTRON X-RAY FLUORESCENCE ANALYSIS OF TRACE ELEMENTS IN FOCUSED ION BEAM PREPARED SECTIONS OF CARBONACEOUS CHONDRITE IRON SULFIDES (CM AND CR) AND ASSOCIATED METAL (CR)

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Introduction: Recent studies have proposed that a population of sulfide grains in carbonaceous chondrites formed in the solar nebula by sulfidization (reaction of condensate Fe,Ni-metal with nebular gas [e.g., 1]) or crystallization (cooling of sulfide melts within chondrules produced during the chondrule-forming flash heating event [e.g., 2, 3]). The study of such grains can enhance our understanding of the earliest conditions within the solar nebula.

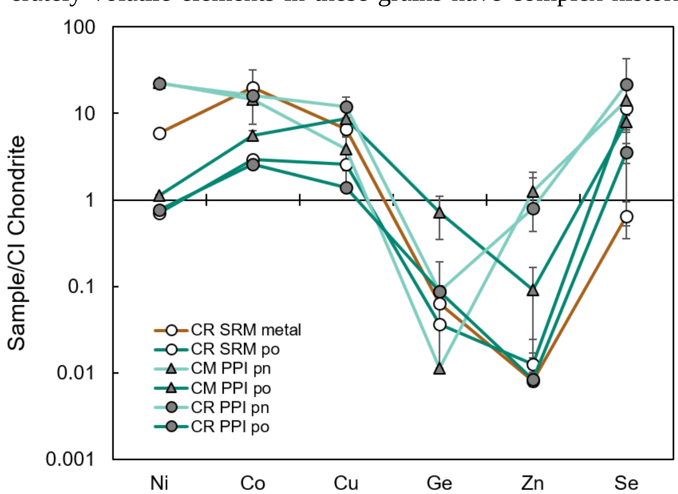
The purpose of this work is to evaluate trace element abundances in primary iron sulfides and associated metal, which we have identified in previous work [4]. Such data have the potential to provide insight into the primary nebular trace element signatures of sulfides and the potential to determine the partitioning behavior of trace elements between coexisting sulfides and Fe,Ni metal. The study of trace element abundances and behaviors in sulfides of chondritic meteorites is a largely unexplored topic. Additionally, the analysis of trace element abundances from Focused Ion Beam (FIB)-prepared sections extracted from polished thin sections is a newly developed technique.

Methods: The meteorites studied for this work include: CM2 QUE 97990, CR2 QUE 99177, and CR2 EET 92042. For a more comprehensive explanation of the textural groups discussed (PPI = pyrrhotite-pentlandite intergrowth grains, referred to as COMP grains previously; SRM = sulfide-rimmed metal grains), see [4]. Microscopic scale imaging of the textures and preparation of FIB samples were performed using the FEI Quanta 3D FEGSEM/FIB at the Dept. of E&PS, UNM. The major and minor element compositions of the phases were obtained using a JEOL 8200 EPMA in the Institute of Meteoritics at UNM.

Trace element analyses of the phases were obtained using the SXRF Microprobe at GSECARS beamline (13-ID-E) at the Advanced Photon Source (ANL). Using FIB sections allowed us to avoid issues with beam overlap of adjacent phases and achieve high spatial resolutions (~2 µm) with expected detection limits from 100 ppb to 1 ppm [5]. SXRF analyses were carried out on FIB sections of grains that were previously characterized by SEM and EPMA. We collected between 4 and 7 spectra using spot analyses for each of our 6 FIB sections. EPMA analyses were used for standardization where Fe acted as the internal sensitivity reference for high-energy (i.e., 19 keV) analyses.

Preliminary Results: CM and CR chondrite pyrrhotite and pentlandite all contain Ni, Co, Cu, Ge, Zn, and Se. CR chondrite metal, in association with pyrrhotite, also contains Pb. The accompanying figure illustrates the abundances of these elements where each line represents an average for a grain subsequently normalized to CI chondrite [6]. The elements are listed in order of increasing volatility. The error bars (1σ) depict the intragrain heterogeneity.

The trends of CM and CR chondrite sulfides, including both pyrrhotite (po) and pentlandite (pn), are remarkably similar. This is further evidence for a primary nebular origin for CM sulfides, given the ample evidence for nebular formation of CR sulfides [e.g., 1]. The pyrrhotite of the PPI grains, and of the SRM grain, appear similar. The moderately volatile elements in these grains have complex histories. Contrary to expectations, Ge and Zn are depleted relative to CI in all sulfides and metals analyzed, but Se, which is more volatile, is significantly enriched. This suggests that Ge and Zn may have been depleted during thermal processing in the solar nebula, but Se was enriched in a later, lower temperature stage in the formation of both metal and sulfide. Future work will address the cosmochemical ramifications of these observations.



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