

EFFECTS OF METAL FRACTION, PETROLOGIC TYPE, TEMPERATURE, AND PARTICLE SIZE ON VNIR SPECTRA OF ORDINARY CHONDRITE METEORITES

M. E. Gemma^{1,2,3,*}, K. A. Shirley⁴, T. D. Glotch⁵ and D. S. Ebel^{2,1,3}

¹Department of Earth and Environmental Sciences, Columbia University, New York, NY, 10027, USA. ²Department of Earth and Planetary Sciences, American Museum of Natural History, New York, NY, 10025, USA. ³Lamont-Doherty Earth Observatory, Palisades, NY, 10964, USA. ⁴Atmospheric, Oceanic, and Planetary Physics, University of Oxford, Oxford OX1 3PU, UK. ⁵Department of Geosciences, Stony Brook University, Stony Brook, NY, 11794, USA. *mgemma@amnh.org

Introduction: Establishing links between the plethora of meteorite samples in collections on Earth and the parent body asteroids they originated from is a valuable outcome of past (NEAR-Shoemaker, Hayabusa, Dawn), present (Hayabusa2, OSIRIS-REx) and future (Lucy, Psyche) space missions [1]. Sample return missions (Hayabusa, Hayabusa2, OSIRIS-REx) provide much needed context for the study of relevant extraterrestrial samples, and by utilizing these specimens of asteroids in the laboratory, we can supply detailed chemical, mineralogical and petrological information for reference libraries of materials relevant to asteroid missions [2,3]. Laboratory-based spectral analysis of well-characterized meteorite samples can be applied to more quantitatively analyze asteroid remote sensing data in conjunction with returned samples. Previous work has evaluated the spectral features of ordinary chondrite material [2], and revealed the individual effects of temperature and grain size on the visible and near-infrared (VNIR) spectra of silicate [4,5] and meteorite [6] powders. In this work, we examine the combined effects of physical variables (temperature, particle size) and chemical variables (petrologic type, metal fraction) on VNIR spectra of ordinary chondrite meteorite powders.

Sample Selection: Six ordinary chondrite falls spanning the full range of equilibrated petrologic types were sourced from the American Museum of Natural History (AMNH) meteorite collection: Soko-Banja (LL4), Mangwendi (LL6), Mount Tazewright (L5), Suizhou (L6), Jilin (H5), and Zhovtnevyi (H6).

Methods: Bulk chondrite samples (~2-6 cm³ volumes) were first scanned using AMNH's computed tomography scanner, with resolutions ranging from 6-11 microns/voxel, to characterize their 3D structure and determine the abundance of optically opaque (metal and sulfide) phases. These samples were subsequently mapped for the X-ray intensities of ten major and minor elements at 4 microns/pixel resolution, over a sufficient area (~1 cm²) to characterize mineralogy in a 2D slice [7]. Element maps were linearly combined to determine the mineralogy of each individual pixel in every map, enabling quantitative determination of the relative mineral abundances in each meteorite [8]. Samples were then powdered and sieved to four different size fractions (25-63 µm, 63-90 µm, 90-125 µm, 125-250 µm) to capture the spectral diversity associated with asteroid regoliths dominated by various grain sizes. Each individual size fraction for each meteorite was characterized via X-ray diffraction (XRD) to assess the distribution of metal grains across the size fractions, in case of preferential size sorting of metal grains during sieving. VNIR spectra of the ordinary chondrite material were then measured under simulated asteroid surface conditions (defined as ~10⁻⁶ mbar, -100°C chamber temperature, and low intensity illumination) at a series of temperatures chosen to mimic near-Earth asteroid surfaces. These reflectance spectra were collected in increments of 10°C, over the range 10°C to 100°C.

Results: The VNIR spectra show minimal variation in both major absorption bands across the simulated near-Earth asteroid temperature regime. Spectral changes due to particle size are consistent across samples, with the smallest and largest grain sizes having the highest reflectance. Previous spectral investigations of ordinary chondrites [3] removed the metal fraction from the powdered meteorite sample. Notably, we retained the metal fraction in our powders instead of analyzing the silicate fraction only. In our measurements, we observe distinct offsets in spectral features when compared to analyses of purely silicate fractions. XRD analysis shows that the largest size fraction of nearly every sample contains relatively more metal, likely due to the retention of metal nuggets in the largest size fraction during sieving. The more petrologically pristine samples (e.g., LL4) from each ordinary chondrite group display relatively shallower band depths than their more petrologically altered counterparts (e.g., LL6). The band depths shift to higher wavelengths as temperature, grain size, and petrologic type increase. Spectral studies of meteorites combined with detailed petrologic analysis of the samples greatly enhance interpretation of current and future planetary remote sensing data sets. Importantly, understanding the spectral contribution of the metal fraction will aid in investigations of metal-rich mission targets such as asteroid 16 Psyche. This work continues an effort to develop a comprehensive spectral library of materials in conditions relevant to airless bodies and contemporaneous asteroid missions.

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