

**INSIGHTS INTO PARENT BODY ALTERATION FROM THE DISTRIBUTION OF WATER AND HYDROXYL IN CARBONACEOUS CHONDRITES.**

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**Introduction:** We are using microscopic Fourier transform infrared spectroscopy ( $\mu$ -FTIR) to examine the spatial relationships of water- and hydroxyl-bearing phases in carbonaceous chondrites. Characterization of the intimate association of hydrous and anhydrous phases may provide evidence for or against in situ (parent body) alteration.

Abundant mineralogical evidence for the aqueous alteration of chondritic materials early in solar system history is present across nearly all major carbonaceous chondrite (CC) groups in the form of hydrated or other secondary phases [e.g., 1 and references therein]. Nominally anhydrous phases result from a lack of aqueous alteration or thermal metamorphism. Models of aqueous alteration typically involve the interaction of anhydrous pre-accretionary phases with water or ice either in the solar nebula or in the parent body, or some combination of both. Many, perhaps even most, observations across chondrite groups would seem to support alteration in the parent body, although there are some data that may be more consistent with nebular processing.

The speciation and distribution of water in carbonaceous chondrites may provide additional constraints on the timing and conditions of alteration. However, water content in meteorites is not readily measured in petrographic context by commonly-used chemical techniques such as electron microprobe or X-ray mapping; rather, its presence is inferred from major element chemical data or measured in bulk by mass spectroscopy [e.g., 2] and it is generally assumed to be present in the nominally hydrous phases as water and/or (oxy-)hydroxyl. However, this may not always be the case, as nominally anhydrous phases can host small amounts of OH<sup>-</sup> and H<sub>2</sub>O. The speciation and distribution of water in all phases can be characterized in petrographic context using  $\mu$ -FTIR.

**Analytical Method:** We use mapping  $\mu$ -FTIR spectroscopy (4000 - 400 cm<sup>-1</sup>, 2.5 - 25  $\mu$ m) to detect the fundamental stretching modes of water (H<sub>2</sub>O), which can be centered over a broad region from 3800 - 3000 cm<sup>-1</sup> (~2.63 - 3.33  $\mu$ m). In a crystalline structure, minerals with hydroxyl (OH<sup>-</sup>) also exhibit a sharp spectral feature near 3700 cm<sup>-1</sup> (2.7  $\mu$ m). Using the fundamental vibrational modes at longer wavelengths, we can confirm and further characterize the phases in which the hydration occurs (e.g., silicates, carbonates, oxides, etc.). Finally, by collecting maps on thin sections, our mineral maps can be compared with chemical maps and used to guide additional analyses (e.g., TEM).

**Samples:** Here we focus on CCs of petrologic types 1 and 2. Among those types, the nature and variations in degree of aqueous alteration exhibited by CM chondrites is well documented [e.g., 2], making CMs a logical choice. CRs generally exhibit less aqueous alteration than CMs and offer differing components for study such as amorphous silicate matrices and low-Ca pyroxene. Combining available petrologic and chemical data with our focus on type 1 and 2 CM and CR chondrites, we identified six thin sections that comprise our initial suite for  $\mu$ -FTIR analysis (classifications are from [2]/[3]/[4]): "Murchison (CM1.6/2/2.5), Allan Hills 83100 (CM1.1/1/2), La Paz Icefield 02277 (CM1.4/1/2.0), Graves Nunataks 06100 (CR\*/2/2.5 - heated, no classification reported by [2]), La Paz Icefield 02342 (CR2.5/2/2.8), and Grosvenor Mountains 95577 (CR1.3/1/2.0). In addition, we are measuring spectra of progressively heated samples of Murchison [5] to observe the effects of post-alteration heating.

**Preliminary Results:** Our reconnaissance-scale maps (300  $\mu$ m/pixel) demonstrate that there is discernible spatial variation in the strength of spectral features associated with H<sub>2</sub>O and OH<sup>-</sup>. In the bulk meteorite spectra (i.e., map averages), these features generally become weaker with increasing petrologic type (as previously observed in powdered meteorite spectra), indicating that local-scale variability in our maps can be interpreted reliably (we take care to distinguish between indigenous hydration and phases resulting from terrestrial weathering). We are particularly focused on identifying any nominally anhydrous phases that exhibit features of hydration or intimate associations of phases that would require alteration to have occurred on the parent body. The H<sub>2</sub>O feature in bulk spectra of heated Murchison samples decreases in strength with increased temperature as expected and is no longer visible after heating to ~600-700°C; map data show spatial variability in this feature as well. Currently we are measuring areas of interest in all of our samples at high spatial resolution (10-25  $\mu$ m/pixel) and quantifying measured hydration features (e.g., band positions, strengths, and areas).

**References:** [1] Krot, A. N. et al. (2006) *Meteorites and the Early Solar System II* 525-553. [2] Alexander, C. M. O'D. et al. (2013) *Geochimica et Cosmochimica Acta* 123:244-260. [3] Rubin, A. E. et al. (2007) *Geochimica et Cosmochimica Acta* 71:2361-2382. [4] Harju, E. et al. (2014) *Geochimica et Cosmochimica Acta* 139:267-292. [5] Matza, S. D. and M. E. Lipschutz (1977) *LPS VIII*, 628-630.