CHEMICAL COMPOSITION OF QUEEN ALEXANDRA RANGE 97008: AN ORGANIC-RICH UNEQULIBRATED ORDINARY CHONDRITE. M. Yesiltas[1] and T. D. Glotch[1], [1]Department of Geosciences, Stony Brook University 255 ESS Building, Stony Brook, NY 11794-2100. mehmet.yesiltas@stonybrook.edu

Introduction: The synthesis and origin of organic molecules are highly relevant to the question of how life arose on Earth. Various types and amounts of organic molecules are found in meteorites, especially in carbonaceous chondrites [1], although to a lesser extent, some primitive ordinary chondrites also contain organic molecules in their compositions [e.g., 2]. Unequilibrated ordinary chondrites with low thermal metamporphic grades, for instance, are relatively unprocessed and still retain signatures of their thermal and aqueous alteration histories that their parent bodies have undergone. Therefore, this group of meteorites offers great potential for investigating the structure, type, and distribution of organic matter in order to understand the formation and evolution of such organic molecules. As part of an ongoing work, we investigated the organic chemical compounds *in-situ* in Queen Alexandra Range 97008 (QUE 97008), an unequilibrated ordinary chondrites.

QUE 97008 is an L3.05 type meteorite with shock stage of S2 and weathering grade of A [3].

Sample: The meteorite sample studied here was received from the NASA Antarctic Meteorite Curatorial Facility in the form of a chip, which was subsequently ground down to micron size grains using an agate mortar and pestle set.

Micro-FTIR Imaging: We performed synchrotron-based micro-FTIR imaging spectroscopy of QUE 97008 in the mid-infrared region (3800 – 850 cm^{-1}) with high spatial resolution using the IRENI beamline of Synchrotron Radiation Center at University of Wisconsin in Madison [4] before the decommissioning of the facility. IRENI consisted of a Bruker Hyperion 3000 IR microscope and a Bruker Vertex 70 FTIR spectrometer with a commercial focal plane array. We used a 74× magnification objective, and the effective pixel size was 0.54 × 0.54 μm^2, providing spatially resolved images that are diffraction-limited at all wavelengths. Spectral resolution was 4 cm^{-1}, and 128 scans were co-added. A sample-free region of the diamond window was used for the collection of reference spectra.

FTIR-ATR Spectroscopy: FTIR attenuated total reflectance (ATR) experiments were conducted in the Infrared Laboratory of California Institute of Technology. The spectra were collected in the far-infrared region (800-50 cm^{-1}) using a Pike ATR apparatus in a Nicolet Magna 860 FTIR spectrometer with 4 cm^{-1} spectral sampling resolution and in an atmosphere purged of H_2O and CO_2.

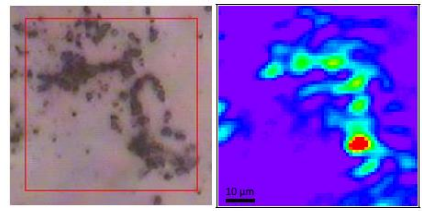

Figure 1. Visible (left) and infrared (right) images of the studied meteorite grains. The infrared image represents absorbance at 2921 cm^{-1}, and colors represent absorbance, red being the heighest.

Results: Figure 1 presents the visible micrograph as well as the infrared absorbance image at 2921 cm^{-1} of multiple micron-sized QUE 97008 grains obtained via micro-FTIR imaging. The average infrared absorbance spectrum, shown in Figure 2, displays signatures of anhydrous silicates such as olivine and pyroxene between 1080- 880 cm^{-1}, C-H bending in CH_3 in aliphatics near 1359 cm^{-1}, C=O stretching in carbonates between 1475-1450 cm^{-1}, C=C stretching at 1535 cm^{-1}, H-O-H bending in water or C=C stretching in aromatics at 1640 cm^{-1}, C=O stretching in ketone at 1743 cm^{-1}, C-H stretching in aliphatics between 3000-2800 cm-1, and finally O-H stretching between 3700-3000 cm^{-1}. Sharp features between 2400-2300 cm^{-1} are due to atmospheric CO_2.

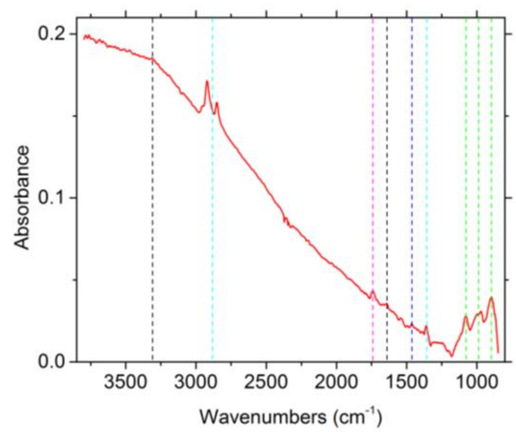

Figure 2. Average absorbance spectrum of QUE 97008 obtained by masking the sample-free regions in the infrared image in Figure 1 and averaging the signal coming from only the sample. Vertical lines indicate positions of silicates (green), aliphatics (cyan), carbonates (blue), OH (black), and carbonyls (purple).

Infrared spectra extracted from individual hot-spots ("islands") shown in the infrared image of Figure 1 reveal organic-rich and organic-poor grains. For example, the third spectrum from the bottom in Figure 3 has the strongest C-H stretching peaks between 3000-2800 cm^{-1} among all spectra but there is almost no silicate band between 1080-880 cm^{-1}, indicating that the corresponding grain is dominated by aliphatics.

CH_2 and CH_3 bands at 2921 cm^{-1} and 2952 cm^{-1} can be used to roughly estimate the mean aliphatic hydrocarbon chain length [5]. The CH_2/CH_3 absorbance band intensity ratios of QUE 97008 grains studied here span a range of 2.6 to 4.95, indicating presence of mixture of different types of aliphatic hydrocarbons. This is consistent with large variations of the carbon peak parameters [6]

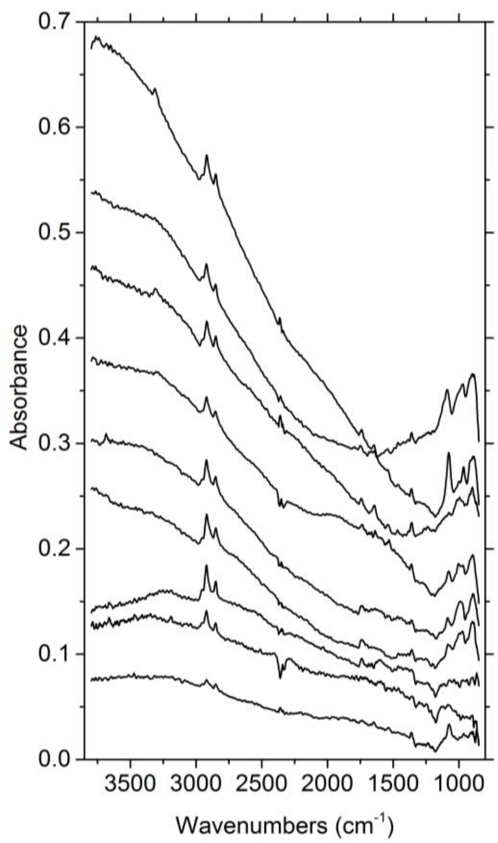

Figure 3. Absorbance spectra of individual "islands" shown in the infrared image of QUE 97008 in Figure 1. Spectra are offset for clarity.

To our knowledge, there are no far-infrared spectra of QUE 97008 in the literature, so we present it for the first time (Fig. 4). In this spectral region, QUE 97008 presents multiple absorbance bands due to silicates. Band centers of these prominent features appear at 500, 405, 340, 273, and 216 cm-1.

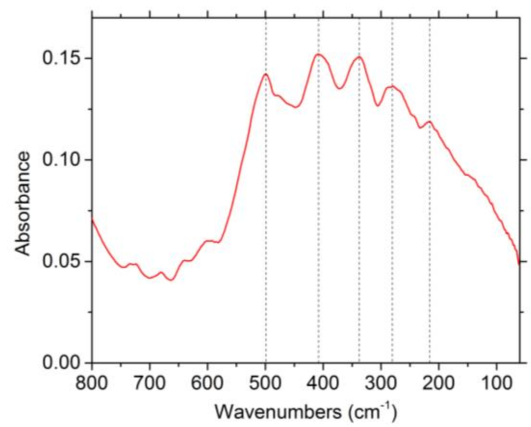

Figure 4. FTIR-ATR spectrum of QUE 97008 in the far-infrared region.

Conclusions: FTIR microspectroscopy is a powerful technique for the study of extraterrestrial materials. When coupled to synchrotron, signatures of organic matter can be detected *in-situ* without any chemical treatment. We studied an unequlibrated ordinary chondrite, QUE 97008, for detection and identification of its organic and inorganic constituents. The mineralogy and organic content of QUE 97008 suggests minimal thermal metamorphism in the parent body, and no aqueous alteration. In a future study, we will (i) generate integrated infrared images of individual chemical functional group in order to study correlations between various chemical components through their distributions in the meteorite grains (ii) perform micro-Raman imaging experiments in order to study the carbon content and its degree of disorder for the same meteorite. Results of such analyses will potentially help us better understand the history of the parent body of this meteorite.

References: [1] Ehrenfreund and Charnley. (2000) An. Rev. of A&A. 38, 427-483. [2] Grady et al. (1989) MAPS 24, 147-154. [3] Wang et al. 2007 GCA 71, 1062-1073. [4] Nasse et al. (2011). Nature Methods, 8, 5, 413-416. [5] Igisu (2009) Precambrian Research 173, 19-26. [6] Starkey et al. (2013) MAPS, 48, 1800-1822.

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