INFRARED SPECTROSCOPY OF SAMPLES FROM MULTIPLE STONES FROM THE ALMAHATA SITTA METEORITE. S. A. Sandford,[1] S. N. Milam,[1,2] M. Nuevo,[1] P. Jenniskens,[2] and M. H. Shaddad[3]. [1]Astrophysics Branch, NASA-Ames Research Center, Moffett Field, CA 94035 USA, [2]SETI Institute, Mountain View, CA 94043 USA, [3]Department of Physics, University of Khartoum, Sudan.

Introduction: On 7 October 2008, the asteroid 2008 TC3 entered the Earth's atmosphere, exploded at 37km altitude, and created a strewn field of stones, now known as the Almahata Sitta meteorite, in the Sudan desert. Preliminary analysis of one of these stones showed it to be a unique polymict ureilite [1]. Here we report on 39 mid-infrared transmission spectra taken from 26 different stones collected from the strewn field.

Samples and Measurement Techniques: Because the total available material for most of the stones examined were small, only limited samples were available for this study. Typical sample sizes obtained were in the 5–10 mg range, although a few were smaller due to lack of available material. In many cases a spectrum was measured from only a single sample from a particular stone. In other cases enough material was available from a stone to make multiple samples and measurements. Care was taken to ensure that selected samples were free from contaminants and fusion crust.

The material in most of the meteorites consisted of a dark, porous/friable matrix, often with visible embedded crystals. The crystals were generally sub-mm in size, although larger crystals were occasionally seen. The samples from most stones looked qualitatively similar and wherever possible an attempt was made to select and use samples that were representative of the material available from each stone.

It is worth noting that the olivine-pigeonite aggregates in ureilites are typically 0.1–2.0 mm in diameter (see [2]), but domains as large as 7 mm have been reported. While the material in Almahata Sitta #7 is anomalously fine-grained, this was not true for all the stones from which samples were obtained. Some samples contained larger individual mineral grains in the matrix. Thus, there exists the possibility that some of the samples described here could be dominated by local heterogeneities and therefore fail to be representative of the original stone as a whole. Where possible, we have prepared and measured multiple samples from the same stone to help assess the extent of this issue.

The samples were prepared using the standard KBr pellet techniques described in Sandford [3]. In general, samples of a few mg were mixed with 100 times their mass of KBr and then ground mechanically for 2 minutes in an all-steel ball mill. Approximately 100 mg of the resulting powder was then compress in a 1.5 cm diameter die at 1.1×10^8 Pa for 1 minute to make a thin pellet suitable for IR transmission measurements. The resulting variability in sample density and column depth between the various meteorite sample pellets is expected to be on the order of 1%.

IR spectra were taken using a Bio-Rad Excalibur Fourier transform infrared spectrometer equipped with a Globar source, a KBr beamsplitter, and a liquid nitrogen-cooled mercury-cadmium-telluride detector. Spectral from 7000 to 450 cm^{-1} (1.43–22.2 μm) were measured at a resolution of 1 cm^{-1}, which is more than adequate to resolve mid-IR mineral bands. It was generally possible to obtain spectra with signal-to-noise ratios of ~0.2% in a modest number of scans. The number of scans used was therefore usually determined by selecting a scan time that provided good cancellation of atmospheric H_2O and CO_2 bands by the background spectrum. No additional corrections for telluric gases were made to the spectra.

Results: The ureilite spectra show a number of absorption bands including a complex feature centered near 1000 cm^{-1} (10 μm) due to Si–O stretching vibrations (Figures 1-3). The profiles of the silicate features fall along a mixing line with endmembers represented by Mg-rich olivines and pyroxenes, and no evidence is seen for the presence of phyllosilicates. The relative

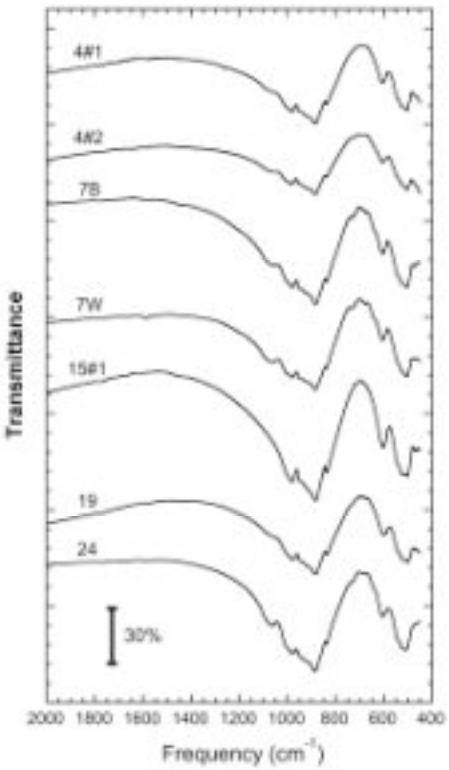

Figure 1: IR spectra from 2000 to 450 cm^{-1} (5.0–22.2 μm) of some of the olivine-rich samples of Almahata Sitta.

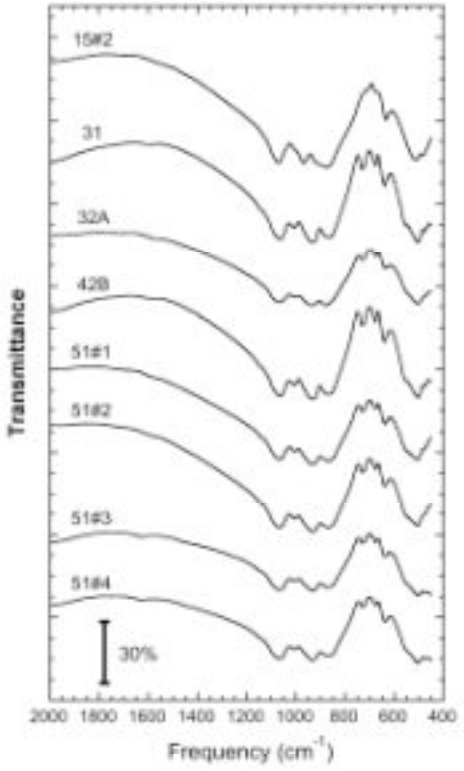

Figure 2: IR spectra from 2000 to 450 cm^{-1} (5.0–22.2 µm) of pyroxene-rich samples of Almahata Sitta. The spectrum of sample 15#2 is unique and matches that of enstatite.

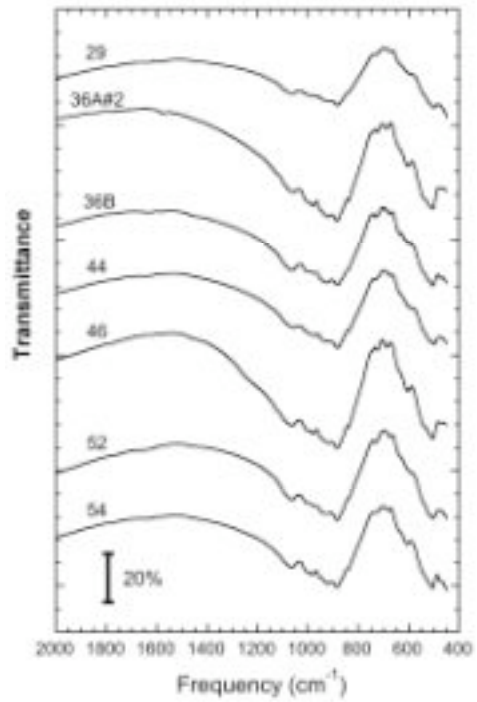

Figure 3: IR spectra from 2000 to 450 cm^{-1} (5.0–22.2 µm) of samples of Almahata Sitta that show mixtures of olivines and pyroxenes.

abundances of olivine and pyroxene show substantial variation from sample to sample and sometimes differ between multiple samples taken from the same stone. Analysis of a mass-normalized coaddition of all our ureilite spectra yields an olivine:pyroxene ratio of 74:26, a value that falls in the middle of the range inferred from the infrared spectra of other ureilites. Both the predominance of olivine and the variable olivine-to-pyroxene ratio are consistent with the known composition and heterogeneity of other ureilites.

The precise positions of the principle absorption bands of olivine provide a measure of the Mg/Fe ratio in the mineral. Comparison of the peak positions of the olivine bands in the Almahata Sitta spectra with those from mineral standards indicate the olivines are very Mg-rich, consistent with the known mafic nature of this mineral in ureilites. With one exception (15#2), the spectra dominated by pyroxene are consistent with an assignment to pigeonite, in agreement with the mineralogy of many ureilites and Almahata Sitta stone #7. One unique sample, 15#2, yielded a pyroxene spectrum most consistent with assignment to enstatite.

Variations in the colors of the KBr pellets and the intensities of the silicate feature relative to sample mass indicate a significant contribution from additional materials having no strong absorption bands, most likely graphitized carbon, diamonds, and/or metal.

Conclusions: We have obtained 39 mid-infrared (4000–450 cm^{-1}; 2.5–22.2 µm) transmission spectra taken from 26 different stones from the Almahata Sitta meteorite. The strongest absorption in the spectra consist of a complex feature centered near 1000 cm^{-1} (10 µm) attributed to Si–O stretching vibrations in silicates. The profile of the silicate feature varies from sample to sample; all the spectra are dominated by mixtures of olivines and pyroxenes. Mixtures span the entire range from nearly pure olivine to nearly pure pyroxene. The mass weighted average spectrum of all the ureilite samples yields an olivine:pyroxene ratio of 74:26, which falls in the middle of the range reported for other ureilites. The predominance of olivine and the variable olivine-to-pyroxene ratio (both within and between stones) are consistent with the known composition and heterogeneity of other ureilites.

Variations in the intrinsic strength of the silicate feature and its surrounding infrared continuum indicate the variable presence of material with no strong infrared absorption bands. The most likely candidate for this infrared-neutral material is graphitized carbon, but diamond and metals could contribute.

A more detailed description of these results has been submitted to *MAPS* [4].

References: [1] Jenniskens P., et al., 2009, *Nature* 458:485–488. [2] Berkley J. L., 1986, *Meteoritics* 21:169–189. [3] Sandford, S. A., 1993, *Meteoritics* 28:579-585. [4] Sandford, S. A., et al., *MAPS*, submitted.