THERMAL EMISSION SPECTROSCOPY OF UNPOWDERED METEORITES. J. W. Ashley[1], P. R. Christensen[2]; [1]Lunar Reconnaissance Orbiter Camera, [2]Mars Space Flight Facility, School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287-3603 (james.ashley@ser.asu.edu).

Introduction: Mid-infrared thermal emissivity spectra have been obtained for 46 whole-rock (unpowdered) meteorites broadly representing most chondritic and achondritic groups. This work includes and expands upon that of [1]. The library should find applicability with ground-based, orbital, fly-by, lander, and sample-return asteroid research. Nine of the samples are C chondrites, representing CB, CH, CK, CM, CO, and CV types; and 25 are ordinary chondrites representing the H, L, and LL groups with petrologic types ranging from 3 through 6. The achondrite suite consists of one each of a eucrite, ureilite and howardite. The stony-iron group consists of two pallasites and three mesosiderites. Three spectra of undifferentiated chondritic fusion crusts are included, as is a thoroughly oxidized iron meteorite spectrum. Measured surfaces were either cut slabs or rough hemispherical surfaces from bulk samples. Samples were provided through the Center for Meteorite Studies at Arizona State University, the NASA Antarctic Meteorite Working Group, Johnson Space Center, and from private collections. All spectra will eventually be accessible through the Arizona State University Spectral Library website of the School of Earth and Space Exploration's Mars Space Flight Facility (http://speclib.asu.edu).

Background: Rock and mineral spectral libraries representing the types of materials likely to be encountered during planetary exploration, assessment, and mapping projects are required to interpret the data produced by these instruments [2-5]. These have been prepared for major rock-forming minerals [2], sulfate and sulfate-bearing minerals, [6], altered basaltic tephras [7], additional salt minerals [8], salt cements [9], olivines [10], and iron oxides [11]. As thermal emission spectroscopy finds application to more primitive (less geochemically evolved) planetary materials, however, an expansion of these libraries to include meteorites (as samples of these parent bodies) is required. In particular, the Origins Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-REx) Thermal Emission Spectrometer (OTES) instrument will benefit from having meteorite spectral libraries when this mission performs its orbital mapping of near-Earth asteroid 1999 RQ_{36}.

The genetic relationships of meteorites to their (primarily) asteroidal parent bodies has, with few exceptions, long been a problem for meteorite/asteroid research [12]. Spectroscopic efforts have been made to link individual meteorite groups to specific asteroid parent bodies with some success [e.g., 13, 14]. However, most asteroid spectroscopy studies are in the VNIR [15], and consist of reflectance measurements. Many meteorite spectroscopic analyses have therefore also focused on the VNIR spectral range [e.g., 16-18]. One recent study successfully correlated TIR spectra for the HED association of meteorites with spectra collected for the asteroid Vesta using Mid-Infrared Asteroid Spectroscopy (MIDAS) and Infrared Space Observatory (ISO) spectrometers [14].

Methods: Spectra were collected at the Mars Space Flight Facility Spectroscopy Laboratory at Arizona State University using the spectrometer setup outlined in [4]. This includes a modified Nicolet Nexus 670 FTIR spectrometer equipped with a cesium iodide beamsplitter, and an uncooled, deuterated triglycine sulfate detector. Samples are heated for a minimum of 24 hours in a gravity convection oven at or near a temperature of 80° C (maintained during measurement with a sample heater) to drive off adsorbed water, achieve isothermality, and increase signal strength. Spectra are taken at ambient pressure across the 2000 to 200 wavenumber (~ 5 to 50 μm) mid-infrared spectral range. A total of 270 scans at a sampling of two wavenumbers are made and averaged by the spectrometer to produce an interferogram. The spectrometer and sample chamber are purged with nitrogen to minimise the absorption effects of atmospheric H_2O and CO_2, and to remove particulates.

Preliminary Results: As expected from known mineralogies, many meteorite types display moderate to wide variability in the depth, position, and shape of prominent absorption features, making them readily distinguishable from each other in the TIR. For example, though mineralogies are similar, high spectral diversity is observed between the three chondrite classes C, O, and E.

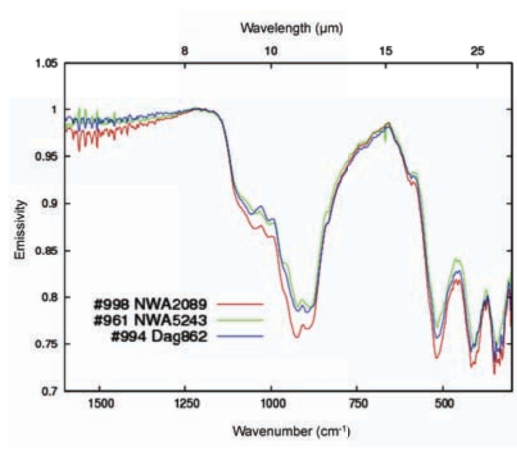

Figure 1. Spectra representing the thre ordinary chondrite groups H (Dag862), L (NWA5243), and LL (NWA2089). All three meteories are finds of petrologic type 3 (least thermally metamorphosed).

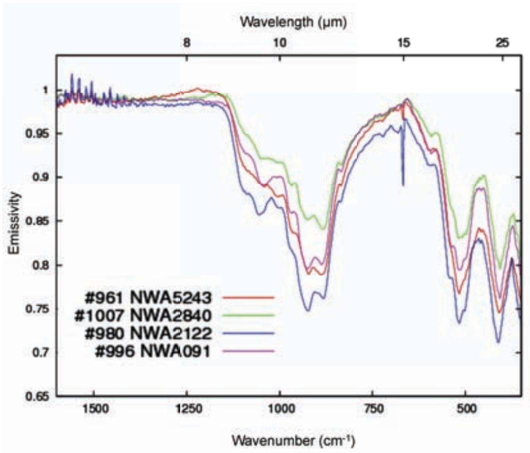

Figure 2. The effects of petrologic type on spectra among L chondrites appear to be more dramatic than those for group among ordinary chondrites; NWA5243 (L3), NWA2840 (L4), NWA2122 (L5), NWA091 (L6).

Remarkable consistency is observed among the ordinary chondrite groups (H, L, and LL; Figure 1), which are generally regarded as representing separate parent bodies [e.g., 12]. However, minor differences are observed between the various petrologic types for group L chondrites (Figure 2). This may be due to recrystallization and grain coarsening in the higher petrologic types. The Antarctic samples tend to show lower spectral contrast than non-Antarctic samples, which may be due in part to weathering effects.

Well-defined spectra among the C chondrites include those for Allende, NWA1694, NWA2918, Sayh al Uhaymir (SAU) 290, Gujba, and Isheyevo, representing the CV, CK, CO, CH, and CB groups, respectively (Figure 3). The spectra for the CM and CB C chondrites NWA5376 and Bencubbin have lower spectral contrast. Considerably more diversity is observed among the C chondrites than for the O chondrites, particularly within the Si-O stretching band region (~900-1200 wavenumber). Again, these variations are not unanticipated based on known carbonaceous chondrite group mineralogies. The spectra for the three CB meteorites show notable decreasing emissivity values toward their lower wavenumber ends. This could be a contribution from the high elemental iron-nickel fraction of these three meteorites present in sub-equal proportions with silicates and clearly visible in hand specimen.

Linear deconvolution models were applied to select meteorites from the library to calculate volumetric mineral abundances using the methods outlined in [4]. The RMS error range of 1.15 to 1.33 among the highest spectral contrast spectra are considered only moderate fits at best, and could be the results of differences between library end-members and the mineralogy of meteoritic silicate minerals, the fine-grained nature of many chondritic matrices, and/or the presence of metal grains.

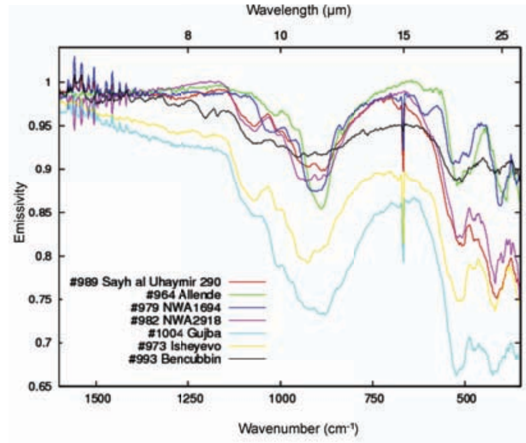

Figure 3. Carbonaceous chondrite spectra. The carbonaceous chondrites exhibit more dramatic differences among their groups than the ordinary chondrites in the thermal infrared. Represented are a CO3.0 (NWA2918), CV3.2 (Allende), CH3 (SAU290), CK3 (NWA1694), and three CB meteorites Gujba (CB), Bencubbin (CBa), and Isheyevo (CH/CBb).

Our findings also demonstrate the utility of TIR spectroscopy for making preliminary (and perhaps definitive) meteorite classification determinations. The method can be applied quickly to many samples in a single laboratory session. Several immediate and future uses for these TIR meteorite spectra and spectra yet to be added to the database are anticipated.

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