

**COORDINATED SPECTROSCOPIC AND PETROLOGIC INVESTIGATION OF LAP 04840: FIRST RESULTS OF INFRARED, THERMAL AND RAMAN SPECTROSCOPY.** R. Klima<sup>1</sup>, C. Pieters<sup>1</sup>, J. Sunshine<sup>2</sup>, T. Hiroi<sup>1</sup>, J. Bishop<sup>3</sup>, M. Lane<sup>4</sup>, D. Dyar<sup>5</sup> and A. Treiman<sup>6</sup>, <sup>1</sup>Brown University, Providence RI ; <sup>2</sup>University of Maryland; <sup>3</sup>SETI Institute; <sup>4</sup>Planetary Science Institute; <sup>5</sup>Mt. Holyoke College; <sup>6</sup>LPI; Rachel\_Klima@Brown.edu.

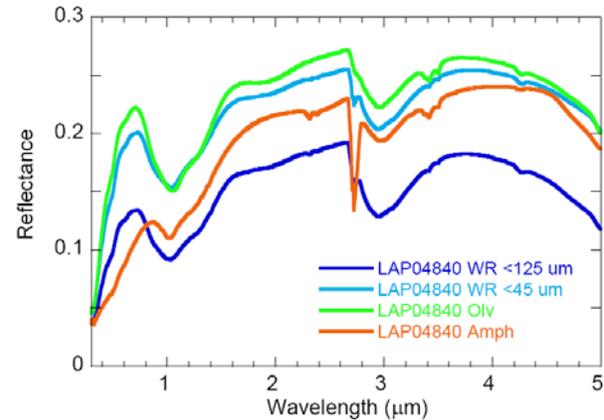
A number of studies have shown that a joint approach integrating petrography, Mössbauer, infrared spectroscopy and other related methods to the investigation of a single sample provides insight into planetary materials beyond what can be inferred from any of the individual techniques alone [e.g. 1-4]. We present the initial results of optical, thermal and Raman spectroscopy in a coordinated petrographic and spectroscopic investigation of the amphibole bearing R-chondrite LAP 04840. The associated mineralogy and petrography [5] Mössbauer spectroscopy [6], and metamorphic conditions [7] are also described in this volume.

**Sample Preparation and Handling:** A 1.147 gram chip of LAP 04840 was obtained from the Meteorite Working Group (MWG) through the Astromaterials Acquisition and Curation Office, JSC. After thin sections were made, half of the chip was sent to M. Lane for collection of thermal emission spectra. The second half was sent to Mt. Holyoke where it was ground under distilled water and mineral separates of olivine and amphibole were handpicked from the bulk. The particulate samples were sent to the RELAB at Brown University and sieved to <125  $\mu\text{m}$  (bulk) and <45  $\mu\text{m}$  (bulk and mineral separates) size fractions for bidirectional and FTIR spectroscopic measurements. The particulate samples were then sent to M. Lane for further thermal emission spectra, and finally returned to D. Dyar for collection of Mössbauer spectra.

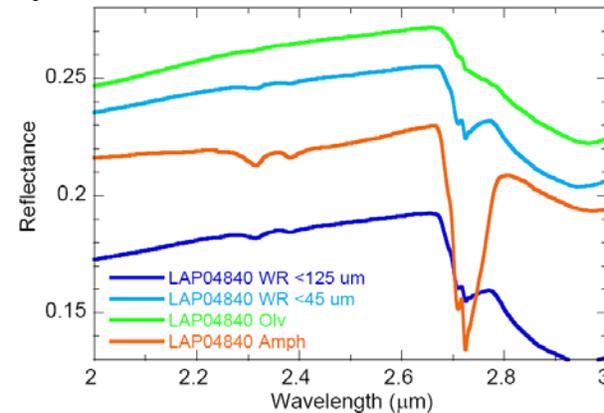
**Visible and Infrared Reflectance Spectra:** Bidirectional reflectance spectra were collected from 0.3-2.6  $\mu\text{m}$  at 5 nm resolution using a halon reference standard. Diffuse reflectance spectra for the wavelength range of 1.3-50  $\mu\text{m}$  were collected in a purged ( $\text{H}_2\text{O}$  and  $\text{CO}_2$  free) environment using a Pike diffuse reflectance attachment on a Thermo-Nicolet Nexus Fourier transform infrared (FTIR) 870 spectrometer (off-axis biconical geometry). The diffuse reflectance spectra were measured relative to a gold reference standard, scaled to the bidirectional reflectance spectra and spliced between 1.73-1.78  $\mu\text{m}$ .

Shown in Fig. 1 are near-infrared spectra of the LAP04840 meteorite bulk powders and mineral separates. Crystal field absorption bands caused by  $\text{Fe}^{2+}$  are present in all spectra near 1  $\mu\text{m}$ . In the bulk and olivine separates, these absorptions are primarily caused by  $\text{Fe}^{2+}$  in the M1 and M2 sites of olivine. A slight band near 1.9  $\mu\text{m}$  indicates that some pyroxene is also present.  $\text{Fe}^{2+}$  in the accentric M4 amphibole site produces a strong absorption near 0.96  $\mu\text{m}$ . A weaker absorption near 1.17  $\mu\text{m}$  has been attributed to  $\text{Fe}^{2+}$  in the M1, M2 and M3 sites [8]. The bands near 1 and 1.15  $\mu\text{m}$  in the amphibole separate are likely to be dominated by these amphibole absorptions, though some contamination

from olivine is possible. The visible/NIR reflectance spectra of terrestrial hornblendes are usually dominated by a strong  $\text{Fe}^{2+}$ - $\text{Fe}^{3+}$  charge transfer, which often completely obscures the crystal field transitions near 1  $\mu\text{m}$ . The LAP04840 amphibole separate does have a lower reflectance at visible wavelengths than the bulk samples and olivine, though the  $\text{Fe}^{2+}$ - $\text{Fe}^{3+}$  charge transfer is far weaker than in most terrestrial hornblendes.



**Fig. 1.** Near-IR spectra of LAP04840 bulk rock and mineral separates.

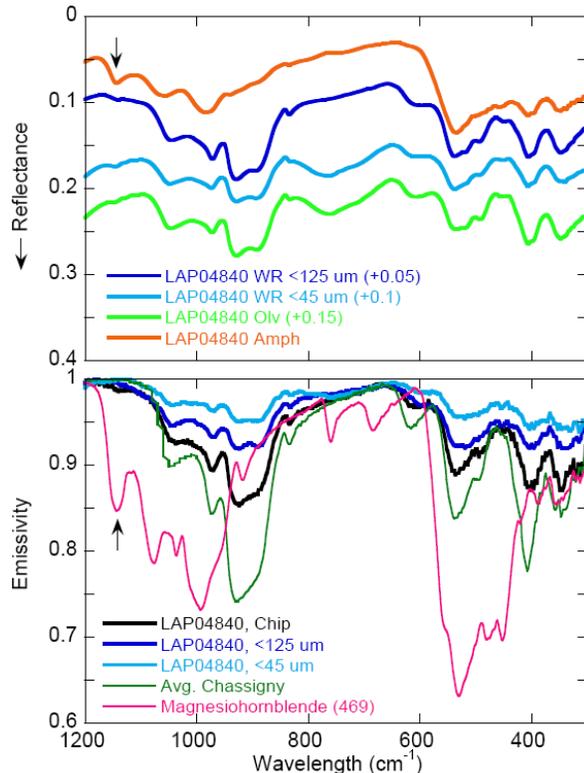


**Fig. 2.** Close-up view of fundamental  $\text{OH}^-$  stretch ( $\sim 2.7 \mu\text{m}$ ) and  $\text{OH}^-$  combination overtones (2.3-2.4  $\mu\text{m}$ ).

The bulk samples and amphibole separate all show evidence for  $\text{OH}^-$  fundamental stretches, as well as combination overtones between the  $\text{OH}^-$  stretch and metal- $\text{OH}^-$  bends. A closer view of these vibrational features is presented in Fig. 2. These features suggest our amphibole separate is also the likely host of biotite. The olivine separate appears to contain some amphibole or biotite, based on the presence of a very weak  $\text{OH}^-$  stretch. In the bulk samples and amphibole separate, the strength of the combination overtones increase proportionally with the strength of the fundamental  $\text{OH}^-$  stretch. The <125  $\mu\text{m}$  size fraction appears to contain

stronger amphibole features than the <45  $\mu\text{m}$  fraction. This is supported by the stronger  $\text{Fe}^{2+}$ - $\text{Fe}^{3+}$  charge transfer in the spectrum of the <125  $\mu\text{m}$  bulk.

Mid and far-IR reflectance spectra of the bulk and mineral separates are presented in Fig. 3 (top panel). These spectra have been inverted for comparison with the emissivity spectra (lower panel). As in the near-IR, the bulk and olivine separate spectra are dominated by olivine features. A feature attributed to amphibole near 1150  $\text{cm}^{-1}$ , highlighted by an arrow in Fig. 3, is weakly discernible in the olivine and bulk spectra. This feature is strongest in the <125  $\mu\text{m}$  spectrum, again suggesting that there is a larger proportion of amphibole in that size fraction.



**Fig. 3. (Top)** Mid- and far-IR reflectance spectra of LAP04840 bulk rock and mineral separates. Spectra are inverted for comparison with thermal emission spectra and offset for clarity. **(Bottom)** Thermal emission spectra of LAP04840 chip and bulk powders. For comparison, a spectrum of Chassigny [9], courtesy of V. Hamilton, and a spectrum of Magnesiohornblende WAR-0354 from the ASU spectral library [10] are included.

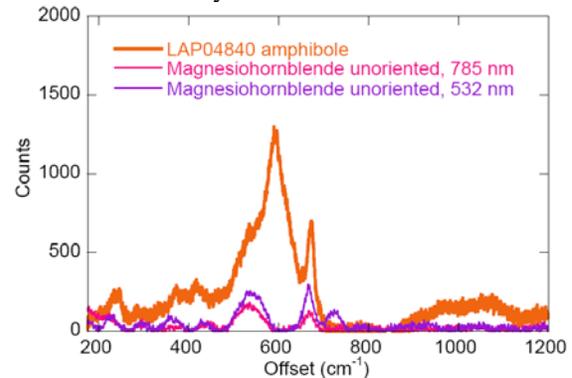
**Thermal Emission Spectra:** Thermal emissivity data were acquired at Arizona State University's Mars Space Flight Facility using a Nicolet Nexus FT-IR interferometer, modified for emission measurements. The samples were heated to and maintained at  $\sim 80^\circ\text{C}$  and the data were collected over the spectral range of 240 to 2000  $\text{cm}^{-1}$ .

Thermal emission spectra of the LAP04840 chip and bulk particulates are presented in the bottom panel

of Fig. 3. Spectra of Chassigny [9] and magnesiohornblende [10] are included for comparison. Both size fractions and the chip are dominated by the spectral features of olivine. The feature observed at 1150  $\text{cm}^{-1}$  is weakly observed in the chip and <125  $\mu\text{m}$  size fractions.

**Raman Spectra:** Raman spectra were taken with the Horiba HR-LabRam Raman microscope at ARES division, Johnson Space Center, using red He-Ne laser light (632.8 nm). Grains within the thin section that had been identified as amphibole by EMP and optical analyses were targeted with a  $\sim 5$   $\mu\text{m}$  beam spot size.

A Raman spectrum of LAP04840 amphibole is presented in Fig. 4. The spectrum is consistent with magnesiohornblende, but Raman spectra of amphiboles vary widely [11] because the chemical compositions of amphiboles varies widely.



**Fig. 4.** Raman spectrum of amphibole in LAP04840 compared with RRUFF library spectra of Magnesiohornblende, RRUFF ID R070003.

**Implications:** The bulk spectra of LAP04840 are dominated by olivine at all IR wavelengths, though the presence of amphibole is evident in the near-IR between 2-3  $\mu\text{m}$  and in the mid-IR near 1150  $\text{cm}^{-1}$ . If the LAP04840 lithology is pervasive on the surface of its parent body, it could be distinguished at either wavelength range.

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**References:** 1. Dyar, M.D. et al. (2005) *JGR*, 110, E09005, doi:10.1029/2005JE002426. 2. Treiman, A.H. et al. (2007) *JGR*, 112, in press. 3. Mayne, R. et al. (2006) LPSC XXXVI, Abstract #1796. 4. Taylor, L.A. et al. (2001) *JGR*, 106, 27,985-28,000. 5. McCanta, M. et al. (2007), this volume. 6. Dyar, M.D. et al. (2007), this volume. 7. Treiman, A.H. et al. (2007), this volume. 8. Burns, R.G. (1993) Cambridge University Press, 551pp. 9. Hamilton, V.E. and Christensen, P.R. (2005) *Geology*, 33, 433-436. 10. Christensen, P.R. et al. (2000) *JGR*, 105, 9735-9739. 11. See the CalTech Raman site, <http://minerals.gps.caltech.edu/FILES/raman/Index.htm>