RAMAN SPECTROSCOPIC CHARACTERIZATION OF MARTIAN METEORITE ZAGAMI. Alian Wang, Bradley L. Jolliff, Larry A. Haskin, Dept. Earth & Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130. (Alianw@levee.wustl.edu)

We have obtained Raman mineral spectra from a flat slab, about 1.5 × 1.0 × 0.5 cm, of the Martian meteorite Zagami. The sample we studied is of foliated "normal Zagami" [e.g. 1]. Initial Raman measurements were made directly on the rough-sawn surface. Later, one surface of the slab was polished and examined petrographically, then additional Raman spectra were taken to investigate the influence of surface roughness on phase identification.

Two different Raman spectrometers were used for this study. Both gave comparable results. Initial work was done using a S3000 micro-Raman spectrometer (Jobin-Yvon company), which has a spectrograph of Czerny-Turner configuration coupled with a double-monochromator, using a diode-array multichannel detector and a green laser line (514.5 nm, Ar^+) for excitation. Most of the spectra, however, were taken using a HoloLab-5000-633 spectrometer system (Kaiser Optical System Inc.), which has a spectrograph of axial transmissive configuration using a volume holographic grating and notch filters, a CCD detector, and a red laser line (632.8 nm, He-Ne laser). The Kaiser instrument has an automated scanning stage that was used to reposition the sample in the XY plane for sampling along traverses. Both the red excitation laser beam and the backscattered Raman radiation are transferred via optical fibers. Typical Raman spectra of the major and accessory minerals observed in the sample are shown in Fig. 1.

Pyroxene: Pyroxene is the most abundant mineral in Zagami. The Raman spectral pattern of pyroxene is characterized by three spectral regions: (1) near 1000 cm^{-1}, (2) near 670 cm^{-1}, and (3) 400 to 200 cm^{-1} [2]. The frequencies of the Raman peaks in these regions shift systematically with Mg/Fe and Wo content of the pyroxenes. Spectral patterns are different for the three structural types orthorhombic pyroxene, monoclinic pyroxene, and triclinic pyroxenoid. Some 245 pyroxene spectra were obtained in this study of the Zagami meteorite. Nearly all have the spectral pattern of monoclinic pyroxene, but a few have the spectral pattern of orthopyroxene, specifically, the obvious doublet in spectral region 2 with a higher-frequency Raman peak occurring above 670 cm^{-1} plus a characteristic smaller peak just above 230 cm^{-1}. The Raman peak positions of Zagami pyroxenes vary systematically over a range of tens of wave numbers. In Fig. 2, for each Zagami pyroxene spectrum the position of the first peak in spectral region 2 is plotted against the position of the third peak in spectral region 3 (filled symbols). On the same figure data are plotted for lunar pyroxenes whose compositions were determined by electron probe microanalysis (open symbols). The field for the lunar pyroxene is divided into regions of different Mg# [=moles Mg/(moles Mg + moles Fe)]. Points for the Zagami pyroxene spectra lie along the same broad curve observed for lunar pyroxenes [3] and are spread over a range in Mg# from ~0.3 to ~0.6, which is consistent with previous studies [1, 4]. The points for orthopyroxene lie at higher Mg# along with those of lunar orthopyroxene.

Maskelynite: No plagioclase spectra were observed; however, the second most abundant spectra we obtained were of dark, glassy grains. These grains gave weak and broad Raman spectral bands that we attribute to maskelynite, the amorphous form of plagioclase produced by shock, with Raman bands roughly centered 510 cm^{-1} and 1000 cm^{-1}. These band features are typical of glasses consisting of framework silicates and are the same as we have observed for lunar maskelynite.

Phosphates: Two accessory phosphates, whitlockite (merrillite) and apatite, were observed. The Raman spectrum of Zagami whitlockite shows a doublet at 975 and 962 cm^{-1} as the main peak, typical of whitlockite with low concentrations of rare-earth elements, in contrast to whitlockite studied in lunar samples, which has only a single main peak near 968 cm^{-1} and peaks from rare-earth fluorescence [5]. In this Zagami sample, whitlockite occurred as light-colored, narrow grains molded along the edges of maskelynite grains. Only one grain of apatite was encountered, present within a whitlockite grain.

Pyrrhotite: Pyrrhotite was also observed in the sample. Pyrrhotite has more than one structural form; the two forms we have examined gave different Raman spectral patterns. The Raman spectra obtained from the grains in the sample of the Zagami meteorite have a main broad band centered near 430 cm^{-1}, which is similar to the spectrum of magnetic pyrrhotite from Durango, Mexico.

Magnetite: The broad spectral pattern characteristic of magnetite, with only one major peak near 670 cm^{-1} was also observed.

Olivine: From more than three hundred measurement points, no olivine was identified. Raman spectroscopy is highly sensitive to olivine, so we conclude there is none in this particular sample of the Zagami meteorite.

Mineral mode: In total, more than three hundred spots were examined on the unpolished and the roughly polished sawn surfaces of this Zagami sample. Most of the spectra were taken using an objective with a low numerical aperture (20×, NA = 0.4, long working distance) and using an automated scanning procedure. The diameter of the laser beam ranged from ~1 to ~5 μm depending on the precision of the focus, which varied along the traverses as would be expected for a fixed-focus planetary instrument. These scans amount to a point count along traverses on the sample surface with spectra taken at regular intervals of 100 or 200 μm. Spectral quality for mineral identification was essentially the same on the rough-sawn surface as on the polished surface. The maskelynite data from the traverses occurred as high count rate spectra with poorly developed features owing to the fixed counting time used; a shorter counting time would be necessary to obtain better spectra. We presumed in our tabulation that all these spectra were maskelynite.

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In Table 1, the proportions of the different mineral phases obtained from our traverse analyses are compared with mineral modes obtained from other studies on different Zagami samples. The results are similar by both methods.

Table 1. Comparison of mineral mode obtained by this Raman spectroscopic study with previous studies

	This study	*Stolper & McSween (1979)*		*McCoy et al. (1992)*			
				fine grain		*coarse grain*	
Pyroxene	72.5	76.3	69.7	77.7	74.3	76.0	80.4
Maskelynite	21	18.8	24.7	17.6	18.8	18.6	10.3
Mesostasis		1.7	2.6	1.8	3.0	2.1	3.7
Oxides	3.2	2.7	2.8	1.5	1.8	2.0	2.6
Sulfides	0.6	0.5	0.2	0.6	0.4	0.4	0.6
Phosphates	2.7			0.5	0.6	0.5	1.3
Shock melt				0.1	0.9	0.3	0.9

Implications: If these data had been obtained on a rock on the martian surface, we would have recognized that rock as shocked (from the maskelynite) but otherwise unaltered, pyroxene-rich igneous rock with plagioclase as its original second most abundant mineral. We would have observed that the pyroxenes were strongly zoned over short distances, and would conclude that the texture of the rock was basaltic. From the low modal proportion of the whitlockite, the nature of its spectrum, and the absence of rare-earth fluorescence, we would know that the sample was not rich in phosphorus or incompatible trace elements. From the presence of the pyrrhotite and magnetite we could constrain the fugacities of O and S at the time the rock cooled, and from their survival we would know the rock had not experienced an oxidizing, aqueous environment.

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References: [1] Stolper & McSween, 1979, *Geochimica* **43**, 1475. [2] Wang et al., *JGR* **100**, 21,189. [3] Wang et al., LPS 28. [4] Treiman and Sutton, 1992, *Geochimica* **56**, 4059. [5] Jolliff et al., 1996, *LPS XXVII*, 613.

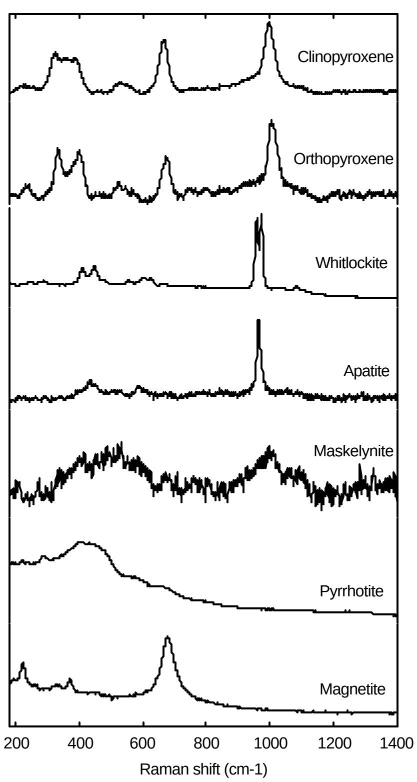

Figure 1. Raman spectra of minerals in a section of “normal” Zagami.

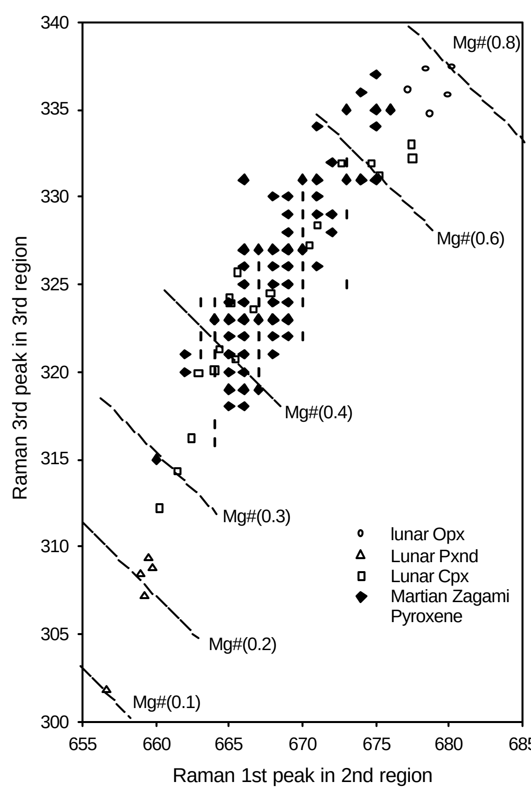

Figure 2. Raman spectral parameters for pyroxenes in Zagami overlain on fields determined from lunar pyroxene.