MID-INFRARED STUDY OF SAMPLES FROM SEVERAL STONES FROM THE SUTTER'S MILL METEORITE.

S. A. Sandford[1], M. Nuevo[1,2], G. J. Flynn[3], and S. Wirick[4], [1]NASA-Ames Research Center, Moffett Field, CA 94035 (Scott.A.Sandford@nasa.gov), [2]SETI Institute, Mountain View, CA 94043, [3]Dept. of Physics, SUNY-Plattsburgh, Plattsburgh, NY 12901, [4]CARS, University of Chicago, Chicago, IL 60637.

Introduction: On April 22, 2012, a fireball was observed over California and Nevada, and the falling fragments of the meteorite were detected by weather radar near small townships in the El Dorado County, California. Some of these stones were collected at Sutter's Mill, in the historic site where the California gold rush was initiated, giving the name to this meteorite. Thus far, 77 pieces of the meteorite have been collected, for a total mass of 943 g, with the biggest stone weighing 205 g [1].

Sample selection: This work presents a preliminary Fourier-transform infrared (FTIR) spectroscopy study of small fragments from two stones of the Sutter's Mill meteorite, SM2 (4.0 g, collected April 24th at coordinates 38.8029°N, 120.9086°W by P. Jenniskens) and SM12 (17.5 g, collected April 27th at coordinates 38.7857°N, 120.9091°W by M. Waiblinger) [1]. We had only a small amount of SM2 and much of this material subsequently proved to contain fusion crust. For SM12, we had enough material to select among available fragments (both with naked eyes and under a microscope) and obtain samples of both fusion crust and non-fusion crust materials.

Methods and analysis: Infrared spectra of fragments from these Sutter's Mill meteoritic samples were recorded with a Nicolet iN10 MX FTIR microscope in the mid-infrared range (2.5–14.8 µm, 4000–675 cm^{-1}). This microscope is capable of analyzing small samples of down to 10 µm in size, and is equipped with a liquid N_2-cooled MCT detector, providing a 4 cm^{-1} resolution. All samples (inner material of the meteorite or fusion crust) were deposited on a clean glass slide, crushed with a stainless steel roller tool, and placed directly on the focal plane of the microscope. IR spectra were collected with the OMNIC software in the reflection mode by averaging 128 scans. Finally, for one fragment of stone SM12, an entire 150-µm size particle was mapped as a mosaic of overlapping 20-µm size windows with a spectral resolution of 4 cm^{-1}.

Results: Preliminary IR spectra of fragments of both stones SM2 and SM12 (non-fusion crust material) show that the mineral composition of those particles is either dominated by silicates or carbonates, or consists of a mixture of both [2,3]. The silicates are characterized by an fairly symmetric feature centered near 1000 cm^{-1} that is characteristic of phyllosilicates. The carbonates display a number of bands, the strongest of which is a broad, intense absorption feature centered near 1450 cm^{-1}. The exact nature of the silicates and carbonates present in this particular stone has yet to be identified, although further analysis may provide information about their elemental compositions.

Figure 1 shows a representative IR spectrum of the inner material of a particle chosen from SM2, in which most of the features are associated with carbonates (2515 cm^{-1}, 1797 cm^{-1}, a broad band centered at 1433 cm^{-1}, 882 cm^{-1}, and 715 cm^{-1}). Features associated with phyllosilicates include a symmetric Si-O stretching mode band centered at 1011 cm^{-1} and several O-H stretching mode bands. The O-H shows up in two forms - a broadband centered at 3415 cm^{-1} that is probably largely due to adsorbed H_2O and a much weaker, narrower feature centered near 3680 cm^{-1} due to structural -OH. SM2 was collected before it rained in the collection area, so its H_2O is original and/or due to atmospheric absorption (note that SM12 was exposed to rain, so its H_2O component must be at least partially terrestrial). Additional features observed in the 2985–2855 cm^{-1} range are due to the symmetric and asymmetric stretching modes of aliphatic $-CH_3$ and $-CH_2-$ groups, suggesting the presence of organics. The relative intensities of these bands are somewhat unusual. Typically, the asymmetric aliphatic C-H stretching bands are stronger than the symmetric

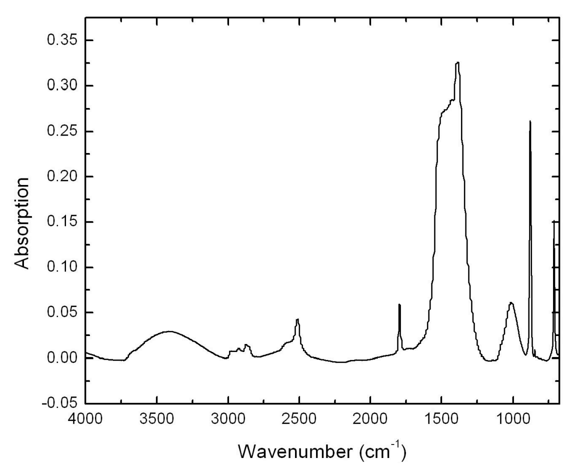

Figure 1. *IR spectrum of a representative fragment of SM2 showing absorption features associated with carbonates and phyllosilicates.*

stretching bands, but in this case the reverse is true (the blended symmetric modes near 2860 cm^{-1} are stronger than the asymmetric bands near 2970 and 2925 cm^{-1}). It is interesting to note that this unusual pattern is well matched by the aliphatic features seen in the spectrum of a terrestrial calcite ($CaCO_3$) standard. Both this observation, and the fact that the strength of the carbonate and aliphatic organic bands seem to correlate between different spectra, suggest the organics are somehow associated with the carbonates.

Samples of the fusion crust of both stones SM2 and SM12 display much simpler spectra that are dominated by a strong silicate feature around 1000 cm^{-1}, much weaker features associated with water, and no bands associated with organics, as expected for a heated material (Fig. 2).

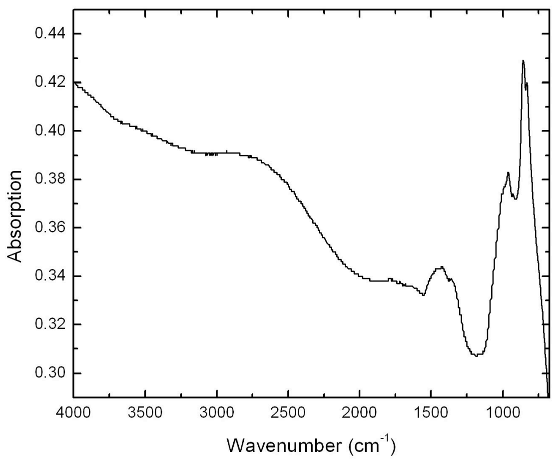

Figure 2. *IR spectrum of a sample of the fusion crust of stone SM12, showing a much simpler spectrum than the inner material of the meteorite.*

As a cautionary point, we note that the spectrum of one particle from SM2 showed a complex IR spectrum indicative of organics, but one very different from normal meteoritic organics or meteoritic IOM. Since SM2 was found in a parking lot where it had been broken into bits after being run over by a car, and since most of the SM2 particles we received were dominated by fusion crust, we suspect this organic material is from a car tire. Not having a sample of the relevant car tire, however, this is currently only a supposition.

IR spectra of samples from stone SM12 show strong similarities with samples from SM2, with bands associated with carbonates, phyllosilicates, and both adsorbed H_2O and structural -OH. Since SM12 was exposed to rain, its H_2O is likely to be at least partially of terrestrial origin. Also, similarly to SM2, some particles are clearly dominated by silicates, while others are clearly dominated by carbonates.

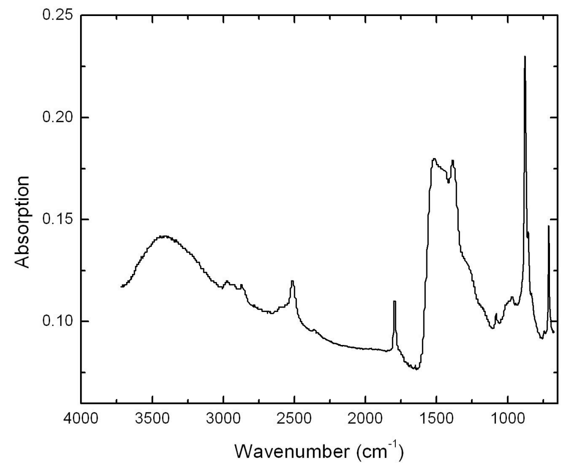

Figure 3. *Average IR spectra obtained by combining the 182 individual mosaic spectra of a ~150 µm grain from SM12 that largely consists of carbonates.*

One of the particles dominated by carbonates from stone SM12 was analyzed by collecting a mosaic of 182 spectra covering the area of the whole particle. These spectra do show some variation from one spot to another, but they are mostly dominated by strong carbonate features near 2515, 1796, ~1455, 879, and 711 cm^{-1}. They also all display an absorbed H_2O band near 3420 cm^{-1}, a weak structural –OH band near 3680 cm^{-1}, and a weak band near 990 cm^{-1} that could be due to phyllosilicates. Features in this particle that are associated with potential phyllosilicates vary in intensity from spectrum to spectrum relative to the carbonate bands, but are always significantly weaker than what is observed in SM2 (Fig. 1). Figure 3 shows the spectrum obtained from averaging all the spectra in the mosaic of this particle and clearly confirms that its composition is dominated by carbonates.

Conclusions: IR spectra of both SM2 and SM12 stones from the Sutter's Mill meteorite show a number of absorption features associated with the presence of carbonates, phyllosilicates, and organics. Though the composition of different particles vary even within a given stone, the composition of our samples of SM2 and SM12 are clearly dominated by carbonates, possibly calcite, with a significant contribution of phyllosilicates. Both the unusual band profile of the aliphatic C-H stretching mode bands and their general correlation with the strength of the carbonate bands suggests the organics and the carbonates are associated in some manner.

References: [1] Jenniskens, P. et al. (2012) *Science, 338,* 1583–1587; [2] Sandford, S. A. (1984) *Icarus*, 60, 115-126; [3] Sandford, S. A. (1986) *Science*, 231, 1540-1541.