**THERMAL HISTORY OF SUTTER'S MILL CM CARBONACEOUS CHONDRITE FALL FROM WATER-ABUNDANCE AND THE STRUCTURE OF ITS ORGANIC MATTER .** P. Beck[1], A. Garenne[1], Q.-Z. Yin[2], L. Bonal[1], E. Quirico[1], B. Schmitt[1], G. Montes-Hernandez[3], G. Montagnac[4], R. Chiriac[5], F. Toche[5]. [1]UJF-Grenoble 1 / CNRS-INSU, Institut de Planétologie et d'Astrophysique de Grenoble (IPAG) UMR 5274, Grenoble, F-38041, France, beckp@obs.ujf-grenoble.fr. [2]Department of Geology, University of California at Davis, Davis, CA 95616. [3]Institut des Sciences de la Terre (ISTerre), OSUG/CNRS, UJF, BP 53X, 38041 Grenoble, France.[4]Laboratoire de Géologie, UMR 5276, Ecole normale supérieure de Lyon. [5]Université de Lyon, Université Lyon 1, Laboratoire des Multimatériaux et Interfaces UMR CNRS 5615.

**Introduction:** The Sutter's Mill (SM) meteorite fall was observed in the sky of California on 22nd April 2012. Petrographical, mineralogical and chemical characterization of fragments recovered within only a few days after the fall revealed definitive affinities to the CM family, a carbonaceous chondrite class, with some unique features hitherto unknown among CM [1].

This fall is of great importance since many minerals described in CM are sensitive to terrestrial residence (sulfides, phyllosilicates) and because CM meteorites contain soluble and insoluble organic compounds, primitivity of which can be altered over very short periods.

Sutter's Mill is a regolith breccia composed of both heavily altered clasts and highly reduced xenoliths [1]. Here we present a detailed investigation of a fragment of SM18 (one of the many SM fragments recovered). We characterize the water content and the mineralogy by infrared (IR) and thermogravimetric analysis (TGA) [2] and the structure of the organic compounds by Raman and Infrared spectroscopy [3-4].

**Infrared spectroscopy.** About 30 mg of sample have been powdered, out of which 1 mg was extracted and diluted in KBr for measurement in transmission geometry (extinction spectra). The spectra were measured with a Vertex 70 (Brüker) infrared spectrometer covering the 2 to 25 µm spectral range. For each sample, 3 measurements have been performed after heating the pellets successively to 25°C, 150°C and 300°C. The transmission spectra of SM shows that the mineralogy of the sample is dominated by a mixture of phyllosilicate and olivine. SM shows an intense peak at 11.2 µm indicative of olivine (Fig. 1). Among all CM and metamorphosed CM we studied, SM18 shows one of the most intense olivine signature, and therefore a low proportion of phyllosilicate minerals.

**Thermogravimetric analysis.** A separate aliquot of the initial powder was used for TGA. TGA experiments were performed with TGA/SDTA 851e Mettler Toledo under the following conditions: sample mass of about 15 mg, platinum crucible of 150 µl, heating rate of 10 °C.min$^{-1}$, and inert $N_2$ atmosphere of 50 ml.min$^{-1}$. The TGA curve of SM reveals a total mass loss of about 7.4 wt%, of which 2.0 wt % occur below 200°C (i.e. adsorbed and mesoporous water). The amount of water contained in phyllosilicate is estimated ~3.2 wt %. This value is quite low with regard to other CM chondrites that typically range from 6 to 12 wt %. However, the value found is in the range obtained for metamophosed CM (<1 wt % to 10 wt %).

**Raman spectroscopy.** Raman measurements with a 514 nm excitation were performed on raw matrix grains with a LabRam HR800 (Horiba Jobin Yvon) implemented with a single dispersive grating, housed at Laboratoire de Géologie de Lyon (ENSL/UCBL). Raman spectra are devoided of fluorescence, and show broad G and D carbon bands whose spectral characteristics point to a thermal event different dissimilar from long duration thermal metamorphism as experienced by type 3 chondrites. We infer the action of a short duration high-temperature event, presumably trigerred by collisions.

**Infrared spectroscopy of the IOM.** Insoluble organic matter was isolated from bulk rock using the setup described in [4]. IOM grains were crushed between two diamond windows to obtain a typical sample thickness of ~1 µm. Infrared transmission spectra were measured with an infrared microscope (Brüker/Hyperion 3000) at IPAG, under vacuum to remove any spectral contribution by adsorbed water.

With respect to other unheated CMs, such as Murchison [4], infrared spectroscopy shows evidence of a higher $CH_2/CH_3$ ratio together with a decreased abundance of carbonyl functional groups. These chemical features point to the effect of a heating event.

**Discussion**. The four methods used in this study suggest that SM18 was significantly heated. Sutter's Mill has been classified as a regolith breccia and therefore the clast studied (SM18) cannot be seen as representative of the whole meteorite.

If compared to unheated CMs, the abundance of olivine in SM suggest that phyllosilicates were partially dehydrated. We exclude the possibility of the dry accretion of anhydrous silicates, as a thermal processing is unambiguously testified by the composition and structure of organic matter. Furthermore the high abundance of magnetite in SM18 [1] suggest that an oxidation process took place at some point of its geological history [1].

Dehydration of phyllosilicates can be produced by short or long duration heating (at temperature >300°C) as well as by shock loading. The Raman results tend to support this latter hypothesis. Because carbonaceous chondrites are porous samples, impact energy can be efficiently dissipated in the form of compaction and heating.

Shock wave experiments performed on fragments of the Murchison CM chondrite revealed that a significant volatile lost (20-40 % $H_2O$ and $CO_2$) can occur at reatively low shock pressure (≈10 GPa) [5]. At higher shock pressure (>20 GPa) localized melting occurs (melt pockets and shock veins) [6]. The infrared spectra of the IOM is also in agreement with the shock heating hyposthesis, with an increased $CH_2/CH_3$ ratio, that has been observed in shock recovery experiments performed on Murchison [7].

**Conclusion:** Fragment SM18 of Sutter's Mill was significantly heated (T>300°C) leading to a severe dehydration of the phyllosilicates. The heat source favored is impact induced-heating from Raman observations.

**References:** [1] Jenniskens, P. et al. (2013) Science 338,1583-1587. [2] Beck, P. et al. (2013), this meeting. [3] Quirico et al., 2003, MAPS. 38, 1-17 [4] Orthous-Daunay et al., Icarus in rev. [5] Tyburczy, J.A. et al. (2001) EPSL 192, 23-30. [6] Tomeoka K. et al. (1999) GCA, 63, 3683-3703. [7] Beck, P. et al. (2011) Met. Soc. Meet. London. Abstract [8] Rubin et al. (2007), GCA 71, 2361-2382.

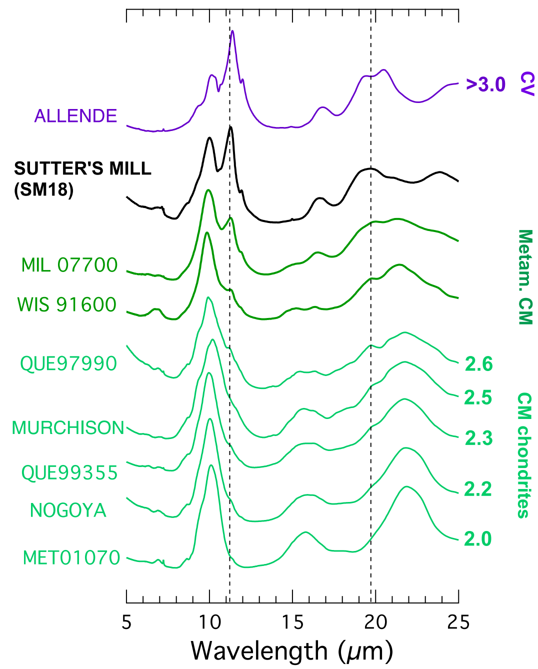


**Figure 1:** Transmission spectra of selected CM chondrite (green), metamorphosed CM (MCM – dark green) and a CV chondrite (Allende). The spectra of CV are dominated by olivine, while that of heavily altered CM by a saponite-like phyllosilicate. The presence of a 11.2 μm feature (olivine) appears to be correlated with the aqueous ateration scheme of [8]. SM shows an intense olivine feature.

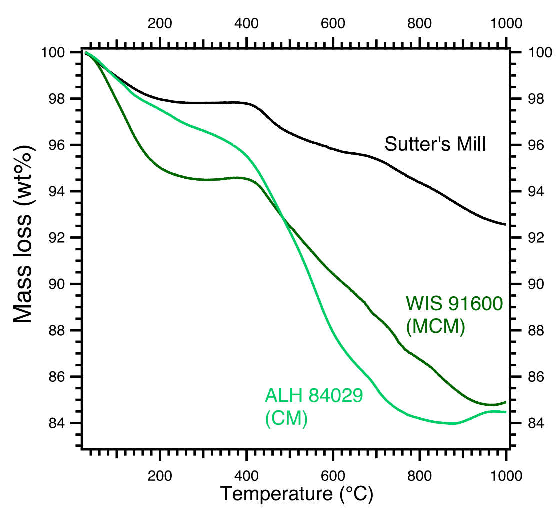


**Figure 2**: TGA curves of Sutter's Mill, WIS 91600 (MCM) and ALH 84029 (CM). The TGA curve of Sutter's Mill reveals a clear depletion in water with respect to regular CM.