METEORITE HILLS 00639 AS AN ANALOGUE METEORITE OF ASTEROID 162173 RYUGU BASED ON SPACE WEATHERING SIMULATIONS OF CARBONACEOUS CHONDRITES. T. Hiroi[1], R. E. Milliken[1], K. M. Robertson[1], H. Kaiden[2], K. Misawa[2], R. Shimana[3], S. Sasaki[3], M. Matsuoka[4], T. Nakamura[5], K. Kitazato[6], E. Tatsumi[7], S. Sugita[8], K. Ohtsuka[9], [1]Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912, USA (takahiro_hiroi@brown.edu), [2]National Institute of Polar Research, Japan, [3]Osaka University, Japan, [4]JAXA Institute of Space and Astronautical Science, Japan, [5]Tohoku University, Miyagi, Japan, [6]The University of Aizu, Fukushima, Japan, [7]Instituto de Astrofísica de Canarias, España, [8]University of Tokyo, Japan, [9]Tokyo Meteor Network, Japan.

Introduction: In order to derive the surface compositions of C-complex asteroids, we have been simulating space weathering of carbonaceous chondrite (CC) samples [1] using pulse-laser irradiation according to the method developed by [2], as well as visible and near-infrared spectral surveys of CC chips from both the Japanese and US collections [3, 4].

The Hayabusa2 spacecraft recently rendezvoused with asteroid 162173 Ryugu and obtained visible (Vis) and near-infrared (NIR) reflectance spectra using its onboard instruments ONC-T and NIRS3 [5, 6].

In this paper, Meteorite Hills (MET) 00639 is studied as one of the spectrally closest meteorites of the surface material of Ryugu based on the results of space weathering simulations of other CCs.

Experimental: Samples of Orgueil and Ivuna (CI1), Yamato (Y)-793595 (CM2), Dhofar 225 and El-Quss Abu Said (CM-an), and Tagish Lake were used in the experiments. Each CC sample was ground, dry-sieved to <125 μm, and pressed into a pellet in a copper dish of about 1 cm in diameter (depending on sample) and 1 mm in depth. Pulsed YAG laser irradiation [2] was performed over an area of 8 mm in diameter in vacuum. Reflectance spectra were measured either at Osaka University or the NASA RELAB facility [7]. However, not all samples were measured beyond wavelengths of 2.5 μm due to the lack of an on-site FTIR spectrometer at the pulse-laser irradiation facility.

Method: Using the reflectance spectra over the wavelength range of 0.3-3.2 μm, approximately corresponding to those of the Hayabusa2 instruments, spectral changes due to pulse-laser irradiations were examined using simple ratio spectra for different types of meteorites and amounts of laser energy.

Optimizing a fractional power of the ratio spectra to extrapolate laser energy, the spectra of MET 00639 samples were converted to fit Ryugu spectra.

Results: Shown in Fig. 1 are reflectance spectra of all measured samples. After dividing the spectra of laser-irradiated samples by untreated sample spectrum, their applicability in fitting an average Ryugu spectrum when combined with spectra of MET 00639 samples was examined. As a result, ratio spectra of irradiated anomalous CMs (Fig. 2) were chosen as the best candidates.

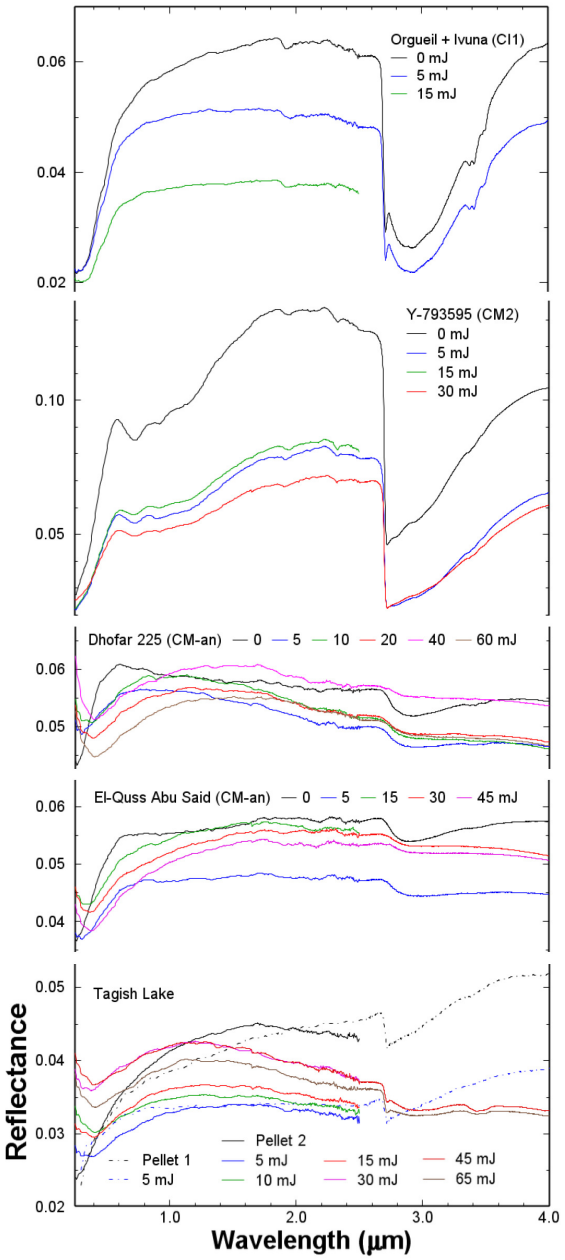

Fig. 1. Space weathering simulation using pulse laser irradiation on carbonaceous chondrite pellets.

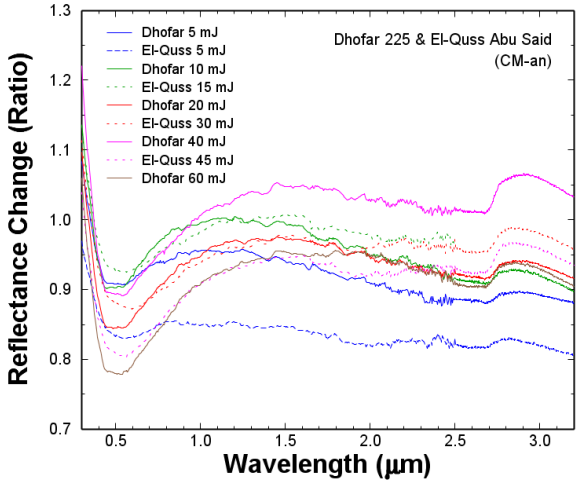

Fig. 2. Changes (ratio) in reflectance spectra by pulse-laser irradiation of dehydrated CM chondrites in Fig. 1.

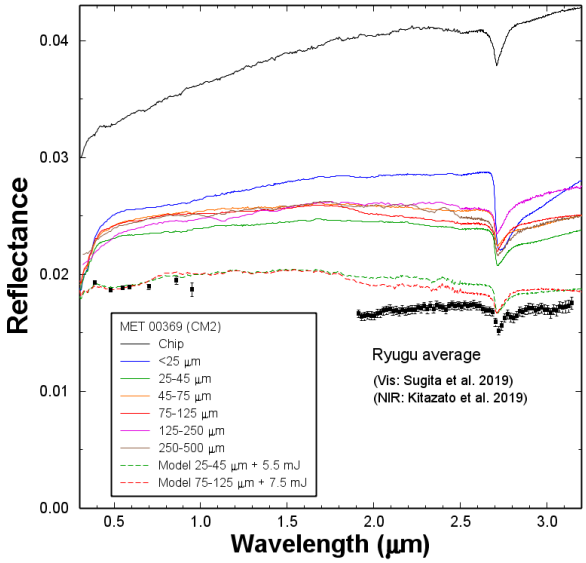

Fig. 3. Reflectance spectra of MET 00639 samples, and their modeled spectra to fit average spectra of asteroid Ryugu.

Although all the ratio spectra calculated from reflectance spectra shown in Fig. 1 exhibit a similar UV upturn (as seen in Fig. 2), the ratio spectra of the anomalous CM chondrites show a minimum around 0.5 μm and increase toward longer wavelength before nearly flattening.

Among the ratio spectra in Fig. 2, spectrum of El-Quss Abu Said irradiated at 5 mJ in energy (blue broken line) was the most suited for modeling with spectra of some MET 00639 powders to match the Ryugu spectrum in brightness, UV upturn, and the 2.7 μm absorption band position and shape. The results are shown in Fig. 3. Spectra for the 25-45 and 75-125 μm MET 00639 samples with low degrees of space weathering (5.5 and 7.5 mJ, respectively) fit Ryugu spectra most closely.

Discussion: This model using reflectance spectra of MET 00639 powders assumes that the surface of Ryugu is mostly covered with fine particles or dust that is below the highest resolution of Hayabusa2 cameras, even on apparently bare surfaces of rocks.

Ryugu's ejecta (supposedly containing finer particles) produced by Hayabusa2's sampling or creation of an artificial crater are darker than its average surface, similar to how spectra of powders of MET 00639 are darker than an intact chip (Fig. 3).

In addition, lower gravity on Ryugu compared with the laboratory setting is expected to result in higher porosities on the asteroid surface. This could further darken the spectra, implying the actual degree of space weathering on Ryugu could be less than derived here. The reason why the actual samples of MET 00639 were not employed in our pulse laser irradiation experiments is that simply pressing their powders to make pellet samples artificially brightens them by decreasing porosity. Regardless, these experiments are currently in progress.

Because these meteorite spectra were measured in an ambient air, adsorbed water results in the 2.7 μm band being expanded longward, particularly evident in the finest <25 μm sample spectrum. Therefore, the model spectra based on those of 25-45 and 75-125 μm samples also show their 2.7 μm band slightly expanded longward.

Conclusions: The meteorite MET 00639 is a close spectral analogue to Ryugu in that samples of it are:

1) among the darkest meteorites,
2) similar in 2.7 μm band position and shape,
3) similar in Vis-NIR spectra if space-weathered, and
4) darker when measured as powders versus as a chip.

Whether Ryugu is actually composed of similar material to MET 00639 will become clear after Hayabusa2 returns samples to Earth at the end of 2020.

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References: [1] Hiroi T. et al. (2013) *LPS XLIV*, Abstract #1276. [2] Yamada M. et al. (1999) *Earth Planets Space 51*, 1255. [3] Hiroi T. et al. (2013) *Antarct. Meteorites 36*, Abstract #1276. [4] Hiroi T. et al. (2017) *LPS XLVIII*, Abstract #1086. [5] Sugita S. et al. (2019) *Science 364*, 252. [6] Kitazato K. et al. (2019) *Science 364*, 272. [7] http://www.planetary.brown.edu/relab/.