Q-TYPE ASTEROIDS: POSSIBILITY OF HAVING NON-FRESH WEATHERED SURFACES. S. Hasegawa[1], T. Hiroi[2], K. Ohtsuka[3], M. Ishiguro[4], D. Kuroda[5], T. Ito[6], and S. Sasaki[7], [1]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (3-1-1 Yoshinodai, Chuo, Sagamihara, Kanagawa 252-5210, Japan, hasehase@isas.jaxa.jp). [2]Brown University, Providence, USA. [3]Tokyo Meteor Network, Japan. [4]Seoul National University, Korea. [5]Kyoto University, Japan. [6]National Astronomical Observatory of Japan, Japan. [7]Osaka University, Japan.

Introduction: There was a major problem that there are almost no main-belt asteroids that have the characteristics of an ordinary chondritic surface over the past 40 years. Asteroids having nature of ordinary chondrites which are the most recovered meteorites on the Earth were present in some near-Earth asteroids, but was not found in the main belt asteroids.

As a way to solve this dilemma about difference in color of between S-complex asteroids and ordinary chondrites, solutions were suggested. It is the idea that color of S-complex asteroids was altered from those of ordinary chondrites by 'space weathering' process. Returned samples by the Hayabusa spacecraft proved that composition of the Sq-type asteroid 25143 Itokawa is ordinary chondrite materials LL5/6 [1,2,3] and that nanophase iron particles causing spectral reddening/darkening are produced on Itokawa [4]. Although Itokawa particles cleared on the origin of the S-complex asteroids, which has been the conundrum for 40 years, it is important to notice that "a NEW MYSTERY" of the space weathering process appeared by them as shown next.

Conventionally, the time scale of the space weathering was considered to be about 1 Myr from results with laboratory experiments and spectroscopic observations of S-complex asteroids in the families [5,6]. However, combination of these results using cosmochemical [7], crater counting [8], and spectral analysis [9] for Itokawa particles indicates that the space weathering age of the surface of Itokawa will be in the order of around thousands of years.

The asteroid surface matures from a refreshing ordinary chondritic surface to an S-complex asteroid like surface by the space weathering process. As this is an irreversible process, several models have been proposed to create a Q-type asteroid like surface. A model was proposed that the regolith on the surface of the S-complex asteroids is peeled off during close encounter with the planet, and the unweathered subsurface materials is exposed and becomes the Q-type asteroid. However, the time scale required for these formation models is more than several million years, and if the time scale of the space weathering is around thousands years, it is not so easy to explain the surface formation of Q-type asteroids in those models.

Therefore, we propose a new model that Q-type asteroids are composed of large particles undergoing "the space weathering process".

Methods: The spectral reflectance of ordinary chondrites with controlled both particle size and the degree of the space weathering are performed for verification of reproduction in spectra of Q-type asteroids under space weathering condition. According to the method pioneered by [10], 7-ns pulse-laser irradiation experiments were performed on chip and pellet samples of ordinary chondrites. Since the powder are blown off by laser irradiation, pellets were prepared instead of the powder sample. Reflectance spectra of the chip, powder, and pellet samples were measured using the bidirectional spectrometer at Reflectance Experiment Laboratory (RELAB) located in Brown University [11] or the Bunko-Keiki DRS-25 spectrometer at University of Tokyo or Mizusawa VLBI Observatory of National Astronomical Observatory of Japan. The incidence and emergence angles are set to 30 and 0 degrees as the standard viewing geometry, and the data were collected over the wavelength range of either 0.3–2.6 μm or 0.25–2.5 μm at every 5 nm interval. Spectra data over the common wavelength range (0.3-2.5 μm) between the two spectrometers were used for this study.

For studying Q-type asteroids, it is necessary to remove samples with spectra that are not unique to ordinary chondrites. For this purpose, the meteorites were classified using the Bus-DeMeo taxonomy [12,13].

Results: The spectra of 21 ordinary chondrite meteorites were obtained under each of the three surface conditions: chip, 125–500 μm, and < 125 μm. Space-weathering experiments were conducted on 12 out of the 21 samples. Based on the classification results, in this study, spectral comparisons were performed for 15 meteorites.

Initially, the effect of the particle size on the spectra was examined for the meteorite samples before space weathering. Increasing the particle size of ordinary chondrites resulted in the appearance of more blue-sloped spectra (Figure 1). The mean spectral slope of 125–500 μm powders was consistent with that of the chips, within the standard deviation. This indicates that the spectral slope is influenced by the presence or absence of particles of approximately 100 μm or less.

Figure 2 shows that the increase in the degree of space weathering toward that of ordinary chondrites leads to the appearance of more red-sloped spectra. The spectra of weathered ordinary chondrites composed of particles below 125 µm had reddish slope, but the slope of the weathered chip spectra tended to be flat. Based on the Bus–DeMeo taxonomy, the results of laboratory experiments on space weathering demonstrated that ordinary chondrites without particles smaller than 125 µm can be established as Q-type asteroids, even with space weathering [14].

Discussions The mechanism to release less than 100 µm particles from the asteroid surface layer in 10^3 yr is required. There are several candidates for that mechanism: centrifugal force, electrostatic acceleration, and/or solar radiation pressure. These forces can be considered as a mechanism to release particles smaller than 100 µm and it has been found that they can be applied to Q-type asteroids less than 0.5 km in diameter with very small perihelion or less than 0.3 km in diameter [14].

However, these mechanisms can't explain release of small particles on the asteroids with large perihelion such as Mars crossing asteroids. This may imply the need for other mechanisms to escape particles smaller than 100 µm from the asteroid surface, otherwise additional concepts to make spectrum of Q-type asteroids.

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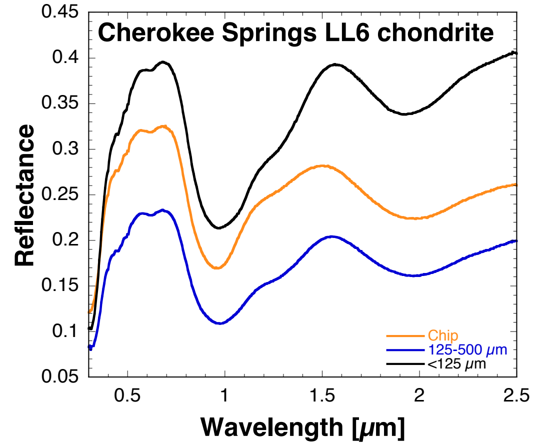

Figure 1. Sample spectra for ordinary chondrites measured at incidence angle: 30 degrees and emergence angle: 0 degrees.

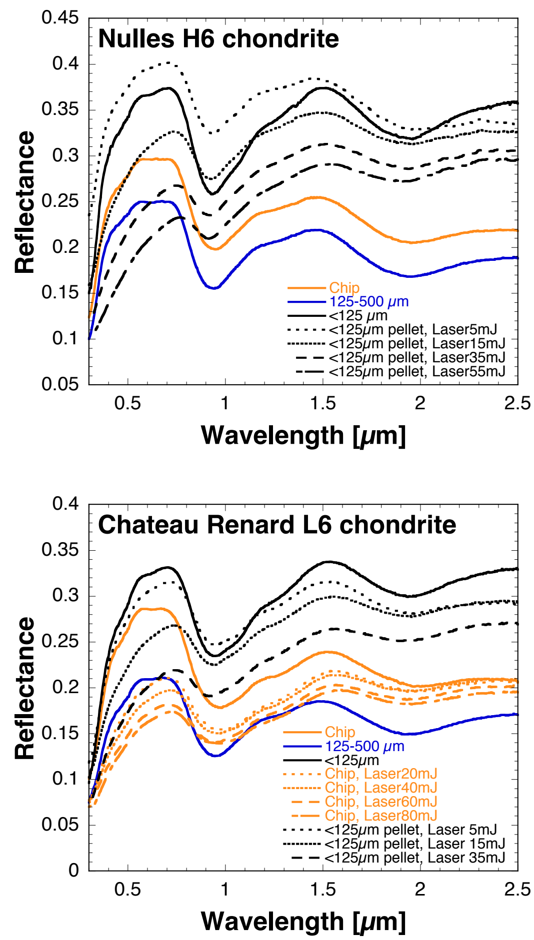

Figure 2. Spectra with space weathering process for ordinary chondrites measured at incidence angle: 30 degrees and emergence angle: 0 degrees.