EXPERIMENTAL HEATING OF A HYDRATED CARBONACEOUS CHONDRITE TO SIMULATE SOLAR RADIATION HEATING OF 3200 PHAETHON.

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Introduction: 3200 Phaethon is a 6-km size, near-Earth B-type asteroid with an orbital period of 1.43 yr. and a rotation period of 3.6 hours [1]. It is a target asteroid of the Japanese DESTINY$^+$ mission. It is also a near-Sun asteroid whose perihelion distance from the Sun is 0.14 au and therefore the surface material is heated intensively up to 700 °C by solar radiation [2] and the surface properties and the spectrum would have changed during heating. Phaethon shows blue to flat spectra and the spectral shape is similar to those of CI/CM chondrites that experienced aqueous alteration and subsequent heating [2]. Phaethon is also known as the parent body of the Geminid meteor shower, which can be observed every mid-December, but it remains unknown how the Geminid meteoroid-size aggregates (mm-size aggregates) were formed on the surface of Phaethon. Spectroscopic observation shows that some Geminid meteors have already depleted their sodium abundances before entering the Earth's atmospheric [4]. CI/CM chondrites contain abundant phyllosilicates. Various experimental studies investigated heating and dehydration of CI/CM chondrites [e. g., 3], however, in those experiments, a meteorite powder sample was transferred to another container after heating for spectral measurements and during the transfer the sample surface was disrupted. Therefore, the reflectance spectra of the heated sample surface could not be measured. Therefore, in order to study spectral changes by the solar radiation heating of primitive asteroids such as Phaethon, the sample surface should remain undisturbed during heating and subsequent spectral measurements. We have carried out such heating experiments of a carbonaceous chondrite.

Experimental methods: A powder sample (particle size < 77 µm) of the Murchison CM chondrite was heated to 400, 700, 900 and 990 °C in vacuum for the duration of 50 hours at IW oxygen fugacity. After heating at each temperature, without explosure to the atmosphere, reflectance spectra of the same surface area of the Murchison sample was measured for wavelength range from 0.4 to 15µm . This enabled us to study the precise changes of the reflectance spectra caused by radiation heating. In addition to spectral changes, we observed the sample surface with an optical microscope, examined mineralogical changes by synchrotron X-ray diffraction (S-XRD), and measured elemental composition by FE-EPMA.

Results and Discussion: Many aggregates larger than original particle size (< 77 µm) start to form at 400°C, grow to several-hundred µm in size at 700°C, and finally up to 1mm at 900°C. S-XRD of an aggregate indicates that phyllosilicate serpentine starts to decompose at 400 °C, serpentine decomposition is complete and secondary olivine form (thus dehydration is complete) at 700 °C, and metallic iron crystallizes at 900 °C. Polished sections of 1-mm size aggregates from the 990 °C-heated sample was analyzed to study the internal texture and chemical composition by FE-EPMA. The observations showed that the 1-mm size aggregate consists of loosely-packed smaller particles with approximately < 50 µm in size. The small particles are probably original powder particles that were rich in Fe-rich serpentine, but now consisting of anhydrous Mg-rich olivine, low-Ca pyroxene, and spherical metallic irons of typically <1 µm in size. As for the elemental composition, sodium and sulfur, which were present at ~0.5 wt % and ~6 wt%, respectively, in the matrix of unheated Murchison, are lost from the 990 °C-heated sample due to evaporation.

Spectral analysis indicates that the heating causes flattening and bluing of the spectra. 3µm absorption feature of serpentine becomes smaller at 400 °C and disappeared by dehydration at 700 °C, which is consistent with the mineralogical analysis. The reflectance at 0.55 µm decreases from 4.5% to 2.6% by heating at 400 °C, but turns to increase to 8.3% at 990 °C. Spectral comparison indicates that Phaethon is still bluer than the experimentally heated Murchison samples. This suggests that Phaethon surface material would be larger grain size and suffered significant space weathering, both of which tend to change the spectra towards a blue colour [e. g., 5].

These observation clearly indicates that solar radiation heating induces dehydration of phyllosilicates and evaporation of Na and S as well as formation of mm-size aggregates by shrinkage and sintering of pre-existing small phyllosilicate particles on the surface of asteroids. Along with mineralogical and grain-size changes of the surface material, overall reflectance spectra become much bluer and 3µm absorption feature disappears. We suggest that the mm-size aggregates would be released from Phaethon surface thus becoming Geminid meteoroid material when Phaethon passes its perihelion.

References: [1] S.F. Green et al. (1985) *Monthly Notices of the Royal Astronomical Society* 214:29–36. [2] K. Ohtsuka et al. (2009) *Publications of the Astronomical Society of Japan* 61:1375–1387. [3] T. Hiroi et al. (1996) *Meteorics & Planetary Science* 31:321-327 [4] J. Borovicka et al. (2005) *IAU symp.* [5] C. Lantz et al. (2017) *Icarus* 285:43-53.