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JAXA'S *HAYABUSA* SAMPLES OF ASTEROID 25143 ITOKAWA: FIVE YEARS LATER

Takashi Mikouchi, an associate professor of mineralogy in the Department of Earth and Planetary Science at the University of Tokyo (Japan), is studying extraterrestrial samples from the 25143 Itokawa asteroid (Fig. 1). In June 2010, samples of this asteroid were returned by the Japan Aerospace Exploration agency (JAXA)'s *Hayabusa* spacecraft and are currently being investigated to better understand the evolution of the Solar System.

Figure 1 Members of Dr. Takashi Mikouchi's laboratory in front of the field emission gun scanning electron microscope at the University of Tokyo (Japan).

Although some of the returned particles are as large as 300 µm, most are smaller than 50 µm. Following initial analysis by the *Hayabusa* Asteroidal Sample Preliminary Examination Team, the particles are now being distributed to the international community under the International Announcement of Opportunity (referred to as "AO") program.

Particles from asteroid Itokawa are of great scientific interest because they are the first asteroidal materials to be returned to Earth and because they contain important information on the evolution of small objects in the Solar System. A direct link has now, and for the first time, been made between meteorites and their parent asteroid. The particles have also revealed that the original parent body, which was much larger than the present Itokawa asteroid (535 m × 294 m × 209 m) experienced a break-up and a subsequent re-agglomeration into one or more rubble-piles (e.g. Nakamura et al. 2011). Most importantly, some Itokawa particles contain evidence that they were once on the surface of the asteroid and have been affected by space weathering (e.g. Noguchi et al. 2011; Nagao et al. 2011). Such findings would not have been possible from studying meteorite samples alone.

Mineralogical and crystallographic studies were conducted on several Itokawa particles received following the first AO in 2012 (Fig. 2). Synchrotron radiation X-ray sources were used

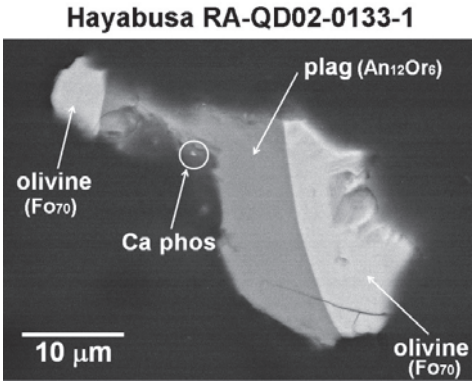

Figure 2 Back-scattered electron image of an analyzed particle from asteroid Itokawa, as returned by the *Hayabusa* spacecraft. Ca phos (calcium phosphate particle); Plag (plagioclase)

to investigate their thermal and shock histories (Mikouchi et al. 2014). At the Super Photon ring – 8 GeV Beam Line 37XU (SPring-8, BL 37XU) facility in Hyōgo Prefecture, Japan (the world's largest synchrotron), an energy-scanning X-ray diffraction (XRD) technique has been developed that can analyze crystals as small as ~1 µm in thin sections (Fig. 3) (Hagiya et al. 2010). Using this technique, plagioclase grains from several Itokawa particles were analyzed and crystal structure refinements were performed revealing that they had undergone high-temperature metamorphism at ~800°C. This result is consistent with initial analyses, which suggested that the original parent body size was greater than 20 km in diameter (Nakamura et al. 2011). X-ray absorption near edge structure (XANES) measurements were carried out at the Photon Factory of the High Energy Accelerator Research Organization (KEK) (using a 5- µm beam on line BL-4A) at Tsukuba (Japan) on the same plagioclase grains to determine their iron valence, which is a good indicator of redox state (Satake et al. 2014). Approximately 50% of the iron in the Itokawa plagioclase crystals is present as Fe^{3+}, suggesting formation under relatively oxidizing conditions. This result is consistent with reports that Itokawa particles show a similarity to LL chondrites, which themselves were formed under relatively oxidizing conditions.

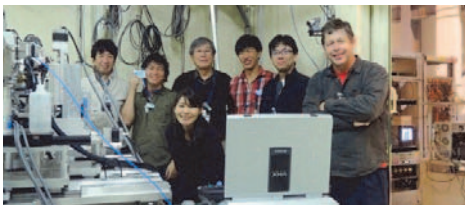

Figure 3 Synchrotron radiation XRD instrument at the Super Photon ring – 8GeV Beam Line 37XU (SPring-8, BL 37XU) facility in Hyōgo Prefecture, Japan

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