Scientific Strategy of Landing Site Selection for Hayabusa2

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Introduction: The Japanese C-type asteroid sample return mission, Hayabusa2, was launched on December 3, 2014. The spacecraft is scheduled to arrive at the asteroid 162173 Ryugu on July 2018 [1]. During its 18-month stay, remote-sensing observations will be carried out by the on-board instruments, Optical Navigation Camera (ONC), Near Infrared Spectrometer (NIRS3), Thermal Infrared Imager (TIR), and Light Detection and Ranging (LIDAR) [2]. Based on the data from global mapping of the asteroid surface at 20 km in altitude, the three landing sites for collecting the asteroid samples, including the crator created by Small Carry-on Impactor (SCI), will be determined. It is therefore very important to work out a strategy in the landing site selection from the operational, scientific, and safety perspectives, and it is particularly essential to interpret the remote sensing data through the comparison with the spectra of meteorites and asteroid sample analogues. In 2014, the working groups on meteorite groups, asteroidal alteration, organic materials, and grain sizes, have been newly organized, respectively, for establishing the method to characterize the asteroid surface materials from the observation data and for selecting the most scientifically-valuable landing site.

The Potential Candidates for the Landing Sites: The search of water and organics from the asteroid is one of the significant goals of Hayabusa2 and it is a high priority to collect the less-altered materials. Several potential combinations of the three landing sites are suggested;

Combination 1: The least altered material (e.g., CR3 chondrite), aqueously-altered material (e.g., CM2, CI1, or CR2), and thermaly dehydrated material (e.g., heated CM)

Combination 2: The least altered material, aqueously-altered material, and unknown (or exotic) material

Combination 3: Space weathered material and the least weathered material (the crator created by SCI)

Combination 4: Three different CR3- or CM2-like materials

According to the comparison between the grand observation of Ryugu [3, 4] and the laboratory experiment [5], a major part of the asteroid surface is presumed to be heated (and/or space-weathered). Nevertherless, it is likely that heterogeneities in alteration degrees and grain sizes in several tens-meter scale are observed for the small asteroid like Ryugu (about 900 m), and collecting the samples including less-altered parts, such as crators, will be expected. This approach will enable linking the results from remote sensing, ground-based observation and sample analyses.

Strategy of characterizing the asteroid surface materials: The reflectance spectra of meteorites are well reflected by mineralogical and petrologic variations within and across meteorite groups, and the flowcharts to apply the meteorite classification to the asteroid Ryugu are summarized for the individual instruments.

ONC: In case that a 0.7-μm absorption band derived from serpentine is observed in visible reflectance spectra, the material can be identified CM-like. In case that the band is not observed, the degree of reflectance based on 6 bands classifies into the three groups; i) less altered (e.g., CR3, CR2, CI1), ii) space weathered or dehydrated CM, and iii) others (e.g., CV, CO, CK). The reflectance at 0.39 μm derived from total carbon contents distinguishes among the three primitive groups [6] . Eventually, ONC can distinguish up to six meteorite groups.

NIRS3: A 3-micron absorption feature in near infrared spectra due to hydrated minerals can classify into the three groups; i) primitive groups or space-weathered CM, ii) heated CM, iii) others (e.g., CV, CO, CK).

TIR: Since the optimum grain size for the safe landing and sampling efficiency is the level of mm, the thermal inertia (I = about 200 or less) [7] corresponding to the size range will be extracted.

ONC has the highest spatial resolution of 2 m/pixel, while its data downlink takes the longest time (7 days). Thus it will be efficient to apply NIRS3 and TIR first for the rough characterization of Ryugu with the topographic data from ONC, then apply the spectral data from ONC for the conclusive characterization. The actual spectral features of asteroids will be complex due to the mixtures of chemical and physical features (e.g., chemical compositions and grain sizes) and multiple processes on asteroid parent body. Further accumulation of reflectance spectra for various groups of meteorites as well as experimentally heated/space weathered meteorite samples will be required.

References: [1] Yoshikawa M. et al. 2014. *Proc. IAC* 3:2285–2290. [2] Tachibana S. et al. 2014. Geochemical J. 48, 571-587. [3] Binzel R. et al. 2001. Icarus 151, 139-149. [4] Vilas F., 2008. *Astron J.* 135, 1101-1105. [5] Hiroi T. et al. 1996. *MAPS* 31, 321-327. [6] Hiroi T. et al. 2016. Abstract #1084. 47th Lunar & Planetary Science Conference. [7] Okada et al. 2014. Abstract #1201. 45th Lunar & Planetary Science Conference.