Scientific importance of the sample analyses of Phobos regolith and the analytical protocols of returned samples by the MMX mission

Wataru Fujiya[1], Yoshihiro Furukawa[2], Haruna Sugahara[3], Mizuho Koike[4], Ken-ichi Bajo[5], Nancy L. Chabot[6], Yayoi N. Miura[7], Frederic Moynier[8], Sara S. Russell[9], Shogo Tachibana[10], Yoshinori Takano[11], Tomohiro Usui[3], and Michael E. Zolensky[12]
[1]*Ibaraki University,* [2]*Tohoku University,* [3]*Institute of Space and Astronautical Science, JAXA,* [4]*Hiroshima University,* [5]*Hokkaido University,* [6]*Johns Hopkins University Applied Physics Laboratory,* [7]*Earthquake Research Institute, University of Tokyo,* [8]*Institut de Physique du Globe de Paris, CNRS,* [9]*Natural History Museum,* [10]*UTOPS, University of Tokyo,* [11]*Japan Agency for Marine-Earth Science and Technology,* [12]*NASA Johnson Space Center*

The Martian Moons eXploration (MMX) mission by JAXA is a sample return mission from a Martian moon, Phobos, aiming at collecting >10 g of the regolith materials on Phobos. The touchdown operations are planned to be performed twice at different landing sites. The regolith materials will be collected using coring (C-) and pneumatic (P-) sampling systems [1]. We, Sample Analysis Working Team (SAWT) members, are now designing the analytical protocols of returned Phobos samples [2].

The origin of the Martian moons is unclear, but there are currently two favored formation scenarios: (i) the in-situ formation (giant impact) scenario [e.g., 3], and (ii) the captured asteroid scenario [e.g., 4]. If Phobos formed by giant impact, then the Phobos building blocks were likely heated to high temperatures (ca., ~2000 K), and the returned samples will consist of igneous and/or glassy materials produced by the solidification of melt or the condensation of gas [5]. On the other hand, If Phobos is a captured asteroid, then the returned samples would be primitive materials like carbonaceous chondrites as inferred from Phobos' surface spectra resembling D-type asteroids [e.g., 6]. Observations of the returned samples under an optical microscope, quantitative analysis of their chemical compositions, and isotope measurements of, e.g., O, Ti, and Cr, can distinguish between the above formation scenarios, and characterize the Phobos endogenous materials [e.g., 7].

In the case of the giant impact scenario, the volatile loss accompanied by the giant impact can be evaluated using the isotopic compositions of moderately volatile elements like Zn [8]. Radiometric dating by, e.g., Pb-Pb and Rb-Sr systematics, will provide chronological information about the giant impact event [9]. In the case of the captured asteroid scenario, analyses of organic matter, bulk H and N isotopic compositions, and presolar grain abundance will provide insights into the primitiveness of the Phobos endogenous materials. The timing when the Martian gravity captured Phobos can be constrained by the combination of Ar-Ar dating of the returned samples and the crater counting of the Phobos' surface [10]. In either formation scenario, the sample analyses mentioned above can shed light on the material transport in the solar system and the delivery of volatiles to the terrestrial planets.

It should be noted that the Phobos' regolith may contain materials ejected from Mars by impact throughout the Martian history [11]. The Martian materials on Phobos may include fragile ones like sedimentary rock, which cannot be found in Martian meteorites commonly shocked by >5 GPa [12]. These Martian materials will provide crucial information about the surface evolution of Mars. Furthermore, biomarkers or even potential microorganisms could be detected in the Martian materials on Phobos, although MMX has no concern about viable Phobos organisms to be returned [13]. We plan to design the analytical protocols of the returned samples to detect such Martian materials in curation procedures before they are processed for further analyses.

References

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