EPSC Abstracts
Vol. 5, EPSC2010-683, 2010
European Planetary Science Congress 2010

Phobos investigations using the CHOMIK device (Phobos Sample Return mission)

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1. Introduction

Phobos is very likely a captured martian satellite. The main reason for this widely held belief is that its spectral properties (albedo and spectral slope) are typical of C- or D-type asteroids, i.e., the types populating the outer parts of the Main Belt and the regions beyond.

Very little is known about the capture event, however. Orbital stability of a captured object requires dissipation of energy, and one possibility - supported by the spectral similarity between Phobos and Deimos - is capture of a binary asteroid. The timing of this event is completely open. It is possible that the late stages of formation of the planet involved building blocks with an origin in the C/D-type asteroid region [5]. Another period in the distant past, when captures of C/D-type asteroids would have been particularly likely is the Late Heavy Bombardment about 3.9 Gyr ago. But a more recent capture, although *a priori* not a high-probability event, is not excluded for the reason that tidal interactions between Phobos and Mars are presently causing the rapid decay of Phobos' orbit and the likely destruction of the object within a time scale of ~10 Myr only.

2. CHOMIK science issues

A unique geological penetrator CHOMIK (Figure 1) dedicated for the Phobos Sample Return mission will be designed and manufactured at the Space Mechatronics and Robotics Laboratory, in Space Research Centre of the Polish Academy of Sciences (SRC PAS) in Warsaw. CHOMIK is based on the well known MUPUS instrument developed for the Rosetta mission to comet 67P/Churyumov-Gerasimenko [2]. One of the most important goals of the mission is to collect a soil sample from Phobos and deliver it to Earth. The sample will be collected from the surface of the satellite by the Polish penetrator and deposited in a container that is going to land in 2014 in Kazakhstan encased in the Russian re-entry capsule. Apart from sampling, CHOMIK will perform thermal and mechanical measurements of Phobos' regolith [6].

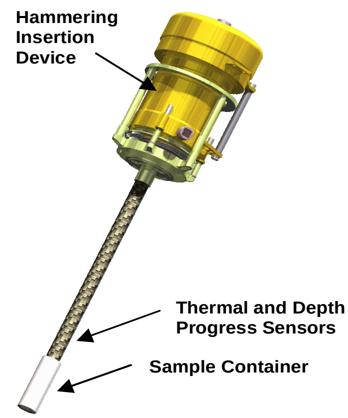

Figure 1: CHOMIK insertion device.

2.1 Thermal measurements

Recently, space probes have brought IR spectrometers that performed *in situ* spectral mapping of comet 9P/Tempel 1 (NASA, Deep Impact) and asteroid (2867) Steins (ESA, Rosetta). Combining this with the accurate shape models obtained from the imaging provided an opportunity to derive surface temperature maps with good precision and thus a long-awaited test of the standard thermal models.

The CHOMIK experiment on the Phobos Sample Return mission provides an excellent opportunity to obtain a new kind of *in situ* data, i.e., the temperature itself as a function of rotational phase both at the surface and at some slight depth. Therefore, the thermal inertia may be derived, thus providing ground truth for the thermophysical models. A time sequence of temperature measurements by the thermal conductivity sensor and the surface temperature sensor (Figure 1) will provide the necessary data. For a passive experiment, using the heat input by the varying insolation, the vertical separation of 20 mm between the sensors is in the range of the expected thermal skin depth for a ~8h spin period. The solar zenith angle as seen from the ground where CHOMIK stands should also be measured as a function of time, and imaging of the surrounding surface would provide a framework for estimating the influence of self-heating, shadowing and scattered sunlight. From the active experiment also to be performed, the heat conductivity will be measured, and combining this with the thermal inertia, the product of density and specific heat will be determined, thus constraining the porosity of the material.

2.2 Phobos sample investigations

Whatever the dynamical history of the Mars-Phobos-Deimos system, the clear association with C/D-type asteroids makes it geochemically highly interesting. Such objects include the parent bodies of carbonaceous chondrites, which are rich in water of hydration (up to ~10% of water by mass), consisting largely of phyllosilicates. Thus, the inclusion of their material during the build-up stage of the terrestrial planets is seen as the most likely origin of the Earth's water, and the water on Mars, too. Not all of these asteroids seem to have undergone the melting of ice, which caused the aqueous alteration and hydration of original minerals seen in carbonaceous chondrites. Ice still exists in some of them, as was recently found in the large object (24) Themis [1]. Therefore, it cannot be excluded that the interiors of Phobos and Deimos are ice-rich and that ice exists not very deep below the surface. The low density measured for Phobos (~1.9g/cm^3) is often interpreted to mean a large degree of porosity, but may also indicate a partly icy composition.

Recent imaging has indicated the Phobos surface to be covered by a regolith layer; the size distribution of rock fragments within this layer was estimated by Kuzmin et al. [4]. Independently of this, it may be foreseen that there is a mixture of material original to Phobos itself, which should be the dominant component as judged from the spectra, and pieces of martian surface rocks that have been knocked off due to impacts and landed on Phobos. The Kaidun meteorite, which is thought to come from Phobos, has a composition that is consistent with this picture [3]. Planned experimental analysis using meteoritic material (i.e. carbonaceous chondrites) allows us to choose an adequate analysis framework for the Phobos sample.

A combination of mineralogical characterization and radiometric dating should provide the means to read the history of Phobos, and perhaps to see during which period it was captured. It should also be noted that the sampling of a primitive object - like Phobos seems to be - is the key to understanding much of the evolution of the Solar System.

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