ALADDIN: PHOBOS-DEIMOS SAMPLE RETURN

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Aladdin is a Discovery-class mission to explore and return samples to Earth from multiple, well-characterized locations on two small bodies, the Martian moons Phobos and Deimos. Aladdin is to be launched in January 2001, with samples returned from both bodies to Earth in November 2003 (Fig. 1). Addressing fundamental questions about the origin and evolution of small bodies, remnants of the building blocks of the solar system [1], requires comprehensive analyses of their mineralogical, elemental, and isotopic composition to a level of detail that is only possible using sophisticated instruments of terrestrial laboratories. Aladdin's hyperspectral remote sensing instruments will characterize the geologic context of the returned samples. The integrated geophysical and compositional analyses enabled by Aladdin will determine whether these small dark bodies share a common origin with Mars, or are vestiges of primitive objects from the outer solar system that delivered volatiles and organics to the inner solar system. Either result has enormous implications for evolution of the terrestrial planets.

Unlike other low-albedo small bodies, Phobos and Deimos are known sufficiently for clear science questions to be posed and for a well thought-out investigative strategy to be formulated. Both satellites are low in albedo (6–7%) and have morphologic features, such as infilled craters, indicative of a surface layer of regolith. The satellite densities are uncertain but clearly much lower than those of the terrestrial planets; contradictory satellite masses implying densities in the range of 1.4–2.2 g/cm^3 have been reported [2-4]. Spectral properties are surprisingly heterogeneous for such small bodies, and hint at a possible link to the outer solar system. Most of Phobos's surface is occupied by a "redder" unit which has the reddest spectrum of nearly all small bodies. This unit exhibits no evidence for abundant H_2O, suggesting a highly desiccated surface [5]. Paradoxically, the two best spectral analogs to the redder unit (Fig. 2) are completely different and imply drastically different origins and history for Phobos. The first is highly space-weathered silicates, similar to lunar or mercurian soils in steepness of the near-infrared (NIR) continuum. Heavily space-weathered ejecta from Mars could possibly account for these properties. The more widely recognized spectral analog is D-type asteroids, primitive and probably organic-rich bodies that dominate the outer solar system. The remainder of Phobos's surface consists of a dark, less red or "bluer" unit that forms the interior and ejecta of Stickney, Phobos's largest crater (Fig. 3a). The formation of Stickney likely exposed different material at depth, but its composition and relation to the redder unit are unknown. Deimos's surface is generally comparable in color to Phobos's bluer unit, but like Phobos it exhibits hemispheric differences in color and it is also highly desiccated [6,7]. Albedo variations are highly organized around the moon's blocky shape: low-albedo regions occupy the "facets"; bright streamers originating on the intervening "ridges" trend downslope into facets (Fig. 3b) [8].

The low densities, low albedos, and spectra of the satellites are consistent with those expected for primitive bodies of the outer solar system [9]. To resolve whether Phobos or Deimos is a captured body, or whether the moons consist of material native to the Mars system, and whether they have the same or different origins, we need comprehensive, unambiguous measurements of the compositions and geologies of both moons. This can be achieved only with return of samples from both moons, from sites whose geologic contexts are well established so that global implications of sample science can be inferred.

Phobos and Deimos also hold evidence for basic processes that have affected the surfaces of primitive small bodies. Despite their similar bulk properties, the two moons have starkly different surfaces. At scales of kilometers and less, Deimos is much smoother, possibly indicating a thicker regolith layer. Phobos is criss-crossed by a system of grooves, which are not present on Deimos [2]. On Phobos, color and albedo features are correlated with specific craters [5], yet on Deimos albedo features are believed to arise from downslope regolith movement [8]. Understanding these differences is fundamental to characterizing processes that have shaped small bodies, and this requires both comprehensive geologic characterization and return of samples from key locations.

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Aladdin takes its name from its "flying carpet" sample collector, which flies through and sweeps up particles released by artificial impacts targeted at specific areas on Phobos and Deimos. Sampling sites are shown in Fig. 3. On Phobos, these include (a) representative "redder" regolith and (b) "bluer" Stickney ejecta, which samples material from depth. Deimos sampling targets include both lower- and higher-albedo regolith. An onboard dust detector confirms successful collection of the samples. Aladdin's mission profile includes repetitive satellite encounters, supporting an integrated science strategy. More distant encounters are devoted to spectral mapping and stereo imaging to characterize surface units, shape, and topography, and to documenting the geologic contexts of sample sites so that global implications of the samples can be inferred. Close encounters are devoted to sampling, very high resolution coverage of the sample sites, and definitive mass determinations. When not utilized for study of the satellites, Aladdin's NIR imaging spectrometer will be trained on Mars to map the surface mineralogy of key sites of high scientific interest.

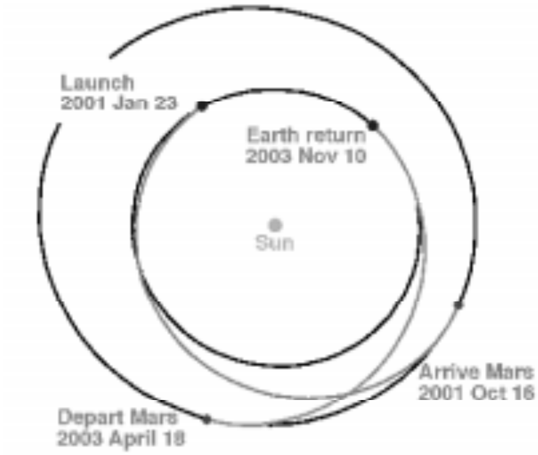

Fig. 1. Aladdin's orbit allows sample return from both Martian moons within three years after launch.

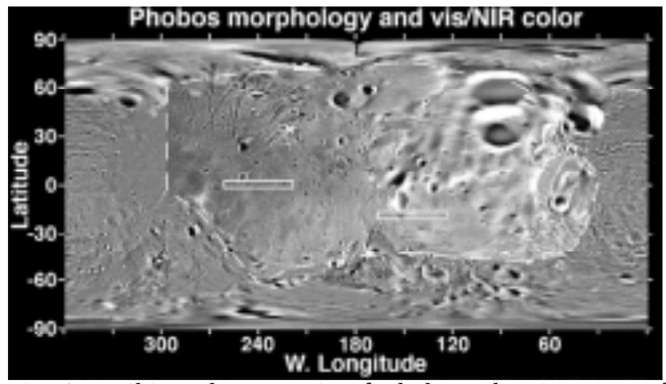

Fig. 3a. Viking photomosaic of Phobos, showing area of color imaging from Phobos 2 (dashed outline). Within the outline, redder areas are represented as darkened and "bluer" areas as brightened. Rectangles enclose the highest-resolution Aladdin imagery; sample sites are centered in the rectangles.

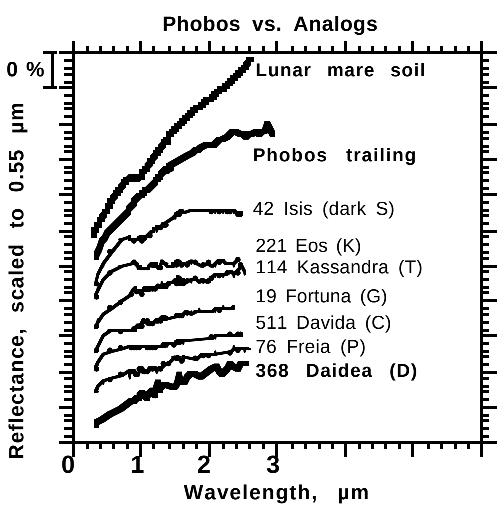

Fig. 3b. Viking albedo map of Deimos, overlain on a Viking photomosaic. The rectangle encloses the highest-resolution Aladdin imagery; sample sites (white dots) include a high-albedo streamer (right) and low-albedo regolith (left).

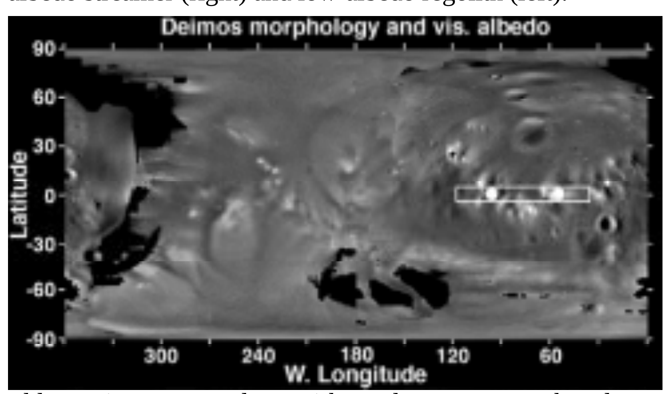

Fig. 2 (at left). Phobos 2 spectrum of Phobos's redder unit, compared to with analog spectra. The closest similarities are to D asteroids and space-weathered silicate assemblages.

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