SPECTRAL PROPERTIES OF INTERIOR DEPOSITS OF VALLES MARINERIS FROM ISM IMAGING SPECTROSCOPY.

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Introduction. The interior of the Valles Marineris chasma system exhibits a variety of deposits including landslides, "layered materials," and floor deposits [1,2]. Several genetic mechanisms have been proposed for the layered materials, including formation as erosional remnants of wall material [3], eolian deposits [4,5], subaerial lava flows [6], fluvial sediments [6], and lacustrine subaqueous pyroclastic [5] or carbonate deposits [7]. The floor deposits have been interpreted as downfaulted plateau plains or layered materials, covered by eolian, volcanic, or fluvial material [1,2,5,8,9]. These interior deposits were imaged by the ISM spectrometer on *Phobos* 2, which obtained 128-channel, 0.77-3.16 µm spectra with 20-km resolution covering much of the chasma system (Figure 1). Preliminary analysis of ISM data for this region was carried out by Erard *et al.* [10]. Here we report first results of more detailed investigation of the interior deposits of Valles Marineris, based on analysis of the spectral properties of independently mapped geologic units. First we summarize the physical geology of the interior deposits, and present a geologic map depicting units mappable at the scale of ISM resolution. Then we describe the units' spectral properties, and compare them with materials outside the chasmata. Finally, we discuss implications for the origin of the interior deposits.

Geology of the Interior of Valles Marineris. The structural framework of the chasmata consists of materials derived from surrounding plateau plains and their basement. These include *chasma-wall material* exposed on steep slopes, *channel materials* scoured by flowing water, and *chaotic materials* consisting of jumbled blocks formed by collapse of preexisting terrain. The interior deposits are classified into three groups (listed below in order of decreasing relative age), mapped in Figure 1.

(a) "*Layered materials*" form plateaus standing up to 5 km above the chasma floor. Most occurrences consist of alternating lighter and darker strata 10's to 100's of m thick [5]. In some locations the lighter and darker strata appear to be differentially erodible. For example, in Melas Chasma, portions of the layered materials are topped by a flat dark stratum which caps a steep escarpment to the north. Underlying materials exposed on gentler slopes have a mottled albedo pattern and a rounded to undulatory surface. In contrast, in Eos Chasma, a large plateau of "layered material" possesses a mottled, undulatory surface like that in Melas Chasma but lacks distinctive albedo layering [5].

(b) *Landslides* consist essentially of the same material as the chasma walls [11].

(c) *Chasma floor materials* are divided into three distinctive units. (*i*) The *smooth unit* exhibits a low albedo and a smooth surface on a several-km scale, although smaller-scale positive- and negative-relief features including dunes are common [8]. (*ii*) The *rough unit* consists of low-albedo positive relief features including knobs, parallel ridges, lobate flow-like features, and closely-spaced mesas [cf. 9]. (*iii*) The *rolling unit* is composed of deposits with a smooth to undulating surface, similar in appearance to "layered material" in Eos Chasma and on the gentler slopes of the plateau in Melas Chasma. The materials have a low to mottled albedo, and occur marginal to the layered materials in Melas and Eos Chasma. Small-scale relief is generally absent, suggesting mantling of a preexisting surface. A number of closed, rimless depressions in the chasma floor material have irregular shapes not easily explained by an impact origin [9]. The most conspicuous grouping is located at 9°S,77°W, where the rolling unit in Melas Chasma contacts the smooth unit to the west. Lucchitta [9] has interpreted similar structures as volcanic calderas.

NIR Spectral Properties of the Interior Deposits. Major spectral variations exhibited by Martian surface materials in ISM data include brightness, spectral slope between 1.79 and 2.39 µm, and strength of a broad 3-µm water absorption. Previous analyses of these parameters and of the strength of the 1.0-µm mafic silicate absorption have demonstrated that surfaces outside the chasmata are dominated spectrally by two types of material: bright, hydrated material with a relatively flat spectral slope (laterally mobile "dust") and dark, less hydrated material with a relatively blue spectral slope and stronger 1-µm mafic silicate absorption ("mafic rock") [10]. Recent improvements in calibration of ISM data [12] permit more exact characterization of the shape and position of the 1.0-µm silicate feature and extraction of compositional information based on these parameters.

Large parts of the interior deposits are low-albedo and lack an optically thick dust cover. Among these dark surfaces, large landslides in Melas and Ius Chasma and the rough and smooth units of chasma floor material exhibit a blue spectral slope and weak water absorption typical of "mafic rock." In contrast, the rolling unit is unlike both "dust" and "mafic rock": the low albedo and strong 1-µm absorption are accompanied by both a flat spectral slope and a strong water absorption. Layered materials are spectrally heterogeneous. Those in eastern Candor Chasma are bright and hydrated like "dust", but with a bluer spectral slope. Dark, resistant strata capping layered material in Melas Chasma resemble "mafic rock" in their blue spectral slope and weak water absorption. Exposures of underlying material, as well as layered material in Eos chasma, resemble the adjacent rolling chasma-floor deposits in their flat spectral slope and strong water absorption.

0.77-1.51 µm spectra of type locations of low-albedo interior units are shown in Figure 2 (with locations indicated in Figure 1). All exhibit a mafic silicate absorption centered at <1.0 µm whose general shape is indicative of high-Ca pyroxene, consistent with identification in previous analyses of a 2.1-2.2 µm high-Ca pyroxene absorption [10]. However there is a large degree of variability in the shape and position of the 1-µm band. The rough and rolling chasma-floor units and the cap rock of layered material in Melas Chasma have very deep absorptions with band minima at <0.94

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μm. The rolling and rough units have symmetric bands, but the cap rock exhibits broadening towards longer wavelengths suggestive of an additional mafic component (e.g., olivine, glass). The smooth chasma-floor unit and layered material in Eos Chasma also have deep symmetric absorptions, but with band minima near 0.96 μm. All of the low-albedo interior materials that were examined here have stronger absorptions at shorter wavelengths (6-8%, ≤0.96 μm) than do dark areas just outside the chasmata in Lunae Planum (Figure 2) and in Syrtis Major [12] (2%, 0.99 μm).

Implications for the Origin of the Interior Deposits. The spectral properties of the smooth and rough units of chasma floor material are interpreted to indicate relatively anhydrous pyroxene-bearing volcanic rocks, supporting earlier interpretations based on photogeology of an origin by basaltic volcanism [8,9]. The spectral heterogeneity of the layered and chasma-floor deposits is suggestive of a variety of compositions and/or histories of surface alteration, but morphologic and spectral resemblances of some of the units suggest a possible common origin. The spectral distinctiveness of layered and chasma floor materials from both landslides and the surrounding plateau plains suggests a distinctive range of compositions, dominated by neither "dust" nor typical "mafic rock".

These results do not support an origin for layered materials as remnants of wall material or by lateral transport of "dust" or "mafic rock" from outside the chasmata. The deep mafic absorptions and the strong water absorptions in many of these materials, plus their spatial association with caldera-like depressions, are consistent with an origin of some layered materials as subaqueous mafic pyroclastic deposits: terrestrial analogs are poorly coherent and thus erodible, widely dispersed, and contain pyroxene in association with hydrated minerals [13,14]. However presence of the resistant, relatively anhydrous strata in Melas Chasma suggests a possible additional role for emplacement of basalt as sills or flows. On the basis of these results, we tentatively hypothesize that layered materials in Melas and Eos Chasma formed as subaqueous mafic pyroclastic deposits intercalated with basaltic flows and/or sills, and that some of the adjacent floor materials formed by downfaulting and/or lateral transport and redeposition of the layered materials.

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Figure 1 (below). Surficial geologic map of interior units of Valles Marineris. Numbers show type locations of units.
Figure 2 (right). Spectra of type locations of the interior units. Numbers identify locations of the spectra in Figure 1.