THE PHYSICAL NATURE OF THE UPPER MARTIAN CRUST. J. L. Bandfield[1], C. S. Edwards[2], B. D. Brand[1], D. R. Montgomery[1], [1]Earth and Space Sciences, University of Washington, [2]School of Earth and Space Exploration, Arizona State University.

Introduction: The basic processes that form the crust of a planet are a fundamental aspect of planetary development that establishes a basis for shaping more detailed investigations. One view of the upper martian crust is that it is primarily composed of lava flows that may or may not have been subsequently disrupted by the creation of a mega-regolith through impact events. Previous studies have established that the much of the martian upper crust is mechanically weak [1-3]. The notion of a mega-regolith that has been highly fractured and disrupted has often been invoked as the cause of this weakness.

Here we reexamine the paradigm of a martian crust dominantly composed of effusive lavas (disrupted or otherwise) in light of more recent high resolution visible and thermal infrared observations. We find that the upper ~2-10 km of the pre-Hesperian martian crust (where exposed) is inconsistent with a mega-regolith composed of fractured, highly cohesive blocks such as what may be derived from lava flows or well-cemented sandstones. Rather, the upper martian crust is more typically composed of poorly consolidated, particulate materials. Highly cohesive material akin to what might be derived from lava flows is volumetrically much less substantial, but appears to have become more common later in martian history.

Valley Systems: The stratigraphy of the upper several km of the Valles Marineris system dominantly displays repetitive bedding where more resistant layers are separated by 10's of layers of less resistant, thinner layers (Fig. 1). The more resistant layers display a rough texture at meter scales and produce boulders; however, the blocks do not persist more than several hundred meters down slope. This suggests that the blocks are composed of weakly consolidated materials that disaggregate under minimal down-slope transport. Thermal inertia values derived from THEMIS nighttime temperature data are relatively low and also indicate the dominance of weakly consolidated materials (Fig. 1).

High thermal inertia, blocky, olivine-rich basalts are clearly present within Valles Marineris and are exposed in a relatively thin, but laterally extensive layer near the base of the canyon system [4]. The layers within this cliff-forming unit are thick and laterally continuous to sinuous, and produce abundant boulders that collect at the base of the scarp ~1000m lower in elevation. These high-strength materials are consistent with effusive volcanism and are easily distinguished from particulates and weakly consolidated layers.

High-strength materials are typically absent from the vertical extent of other valley walls, such as in Ares Valles, Ganges Chasma, and Kasei Valles. However, it is common for laterally extensive exposures of high thermal inertia materials to be present on the valley floors, which may be indicative of a high-strength layer that exerts a control on depth of incision.

Craters: Craters within the southern highlands also display distinctive thermophysical properties consistent with low strength and poorly consolidated particulates (Fig. 2). These walls often appear to be mantled with material locally derived from the easily eroded walls. The adjacent floors of craters within many regions of the southern highlands display an abrupt transition to elevated values of thermal inertia [5] and highly fractured surfaces consistent with high-strength rock exposures (Fig. 2). Most regions within the southern highlands also have crater morphological characteristics consistent with materials of yield strengths between that of wet soil and weak sedimentary rocks (and also consistent with highly fractured bedrock), whereas lowland craters are consistent with higher strength and less fractured rocks [1,3,6].

Nighttime THEMIS temperature data show elevated nighttime temperatures associated with small (<5 km) diameter craters in the same regions where larger crater morphologies are consistent with

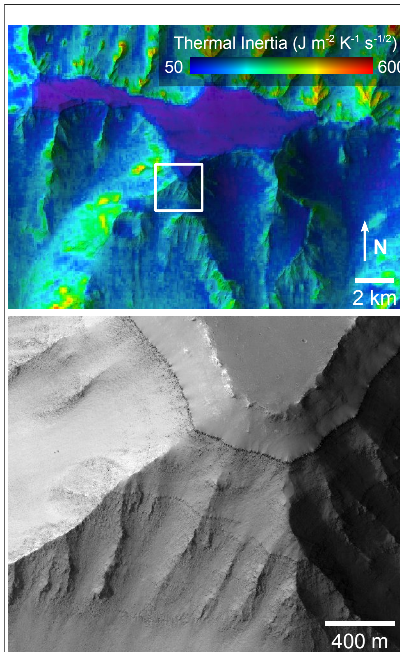

Fig. 1. (top) Thermal inertia data within Coprates Chasma derived from THEMIS data (CTX data used for shading). Thermal inertia values remain low across the 4.5 km elevation range despite the exposure of layering on steep slopes. (bottom) Layered exposures are visible in HiRISE data near the canyon rim. The few boulders present do not persist downslope, indicating that they are weakly consolidated and easily broken down.

high strength crustal materials. Outside of these regions small craters do not display elevated nighttime temperatures, indicating that highly cohesive, high-strength materials are largely absent or deeply buried. The regions dominated by these high strength materials are all of Hesperian age or younger. These observations indicate a crust dominated by poorly consolidated materials in older regions, while younger regions are often dominated by higher strength rocks.

Landing Sites: The Mars Exploration Rover (MER) investigation within the Columbia Hills provides a close-up view of what may be typical highlands materials and stratigraphy in a region that was otherwise resurfaced by younger Hesperian lavas. A complex array of lithologies are present, but most consist of weakly consolidated clastic materials. These rocks have a lower thermal inertia than materials such as volcanic blocks [7] and are interpreted as ejecta and/or volcaniclastic materials that drape local topography [8,9].

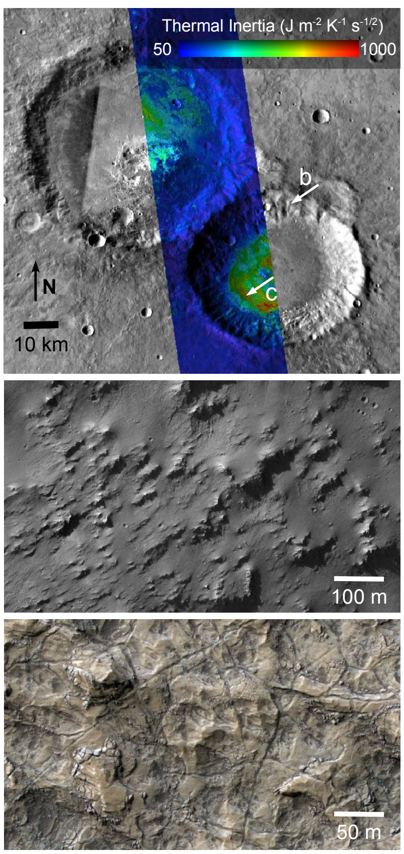

Fig. 2. (top) THEMIS derived thermal inertia centered near 46.5E, 25.0S. High thermal inertia materials are located within crater floors but are largely absent from the crater rims. (middle) HiRISE images display crater wall materials that lack significant fractures, rocks, or other features that would indicate the presence of high-strength materials. (bottom) Crater floors often display highly fractured blocky materials.

The presence or absence of rocks at the landing sites appears to be linked to the presence or absence of a regional high thermal inertia rocky layer similar to that discussed here. Where a blocky, high thermal inertia layer is present, lander and rover images show abundant blocks on the surface. These blocks are presumably derived from nearby craters that tap this layer. Weaker materials, such as volcaniclastic or sedimentary deposits, are not likely to survive ejection or secondary impact processes intact.

Discussion/Conclusions: Much less than 1% of the martian surface is composed of surfaces dominated by high strength rocks and exposures of materials such as blocky lava flows are extremely rare [5]. Extensive regions completely lack exposures of high strength rocks. Where we have the ability to probe the martian subsurface through craters, canyons, and other topographic features, THEMIS, CTX and HiRISE observations suggest the martian crust is typically mechanically weak and composed of weakly consolidated particulates.

By comparison, in the case of the Moon, younger craters expose blocky materials buried underneath the regolith, resulting in block-dominated crater floors, walls, and ejecta with high thermal inertias relative to the surrounding terrain [10]. In contrast, the blocky surface of Venus may be an example of the surface of a lava-dominated planet without significant space or aqueous weathering processes. Our sampling of martian rocks, either as ejecta blocks on the surface or as martian meteorites, would be restricted to materials strong enough to survive ejection and subsequent impact. This implies that we may have a highly biased sampling of martian crustal materials that are not representative of the bulk of the martian upper crust.

If the upper crustal materials are not dominated by lava flows or other high strength materials, what is the origin of the martian upper crust? Given that these deposits are generally basaltic in composition, volcaniclastic materials, primary or reworked, are good candidate materials consistent with these characteristics. Certainly aeolian and aqueous deposits may be present or even dominant as well.

Regardless, the martian crust represents a style of planetary development and evolution that is unique from the other planets, and has implications both to the evolution of volcanism as well as the geomorphological development of the surface.

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