HYDROTHERMALLY ALTERED STRATIGRAPHY IN THE WALLS OF VALLES MARINERIS. C. E. Viviano-Beck and S. L. Murchie, Johns Hopkins University Applied Physics Laboratory, Laurel, MD <Christina.Beck@jhuapl.edu>.

The Valles Marineris Window: The walls of Valles Marineris (VM) chasma system provides a window into laterally extensive geologic units forming the Noachian- to Hesperian-aged plateau plains assemblage, that record volcanic and sedimentary processes on Mars for over a billion years. Upper parts of the walls are layered, rich in high-Ca pyroxene and presumably basaltic, whereas lower parts are massive, richer and olivine and low-Ca pyroxene, with intruding dikes [1,6]. CRISM data were first used to identify phyllosilicates within the walls, both below and above the upper, layered materials [1, 3, 4]. Lateral variations in the phyllosilicates provide evidence for the processes that formed them. If the phyllosilicates are exposed in laterally continuous deposits, this may indicate they were formed through burial of surficial deposits of phyllosilicates or through hydrothermal alteration at depth along a uniform thermal gradient. If they are discontinuous in distribution, they might be associated with excavation of altered materials from depth, or hydrothermal alteration associated with impact heating at craters [*e.g.*, 2]. Furthermore, mineral variability within the exposed wall units may reveal vertical heterogeneities within the layered units.

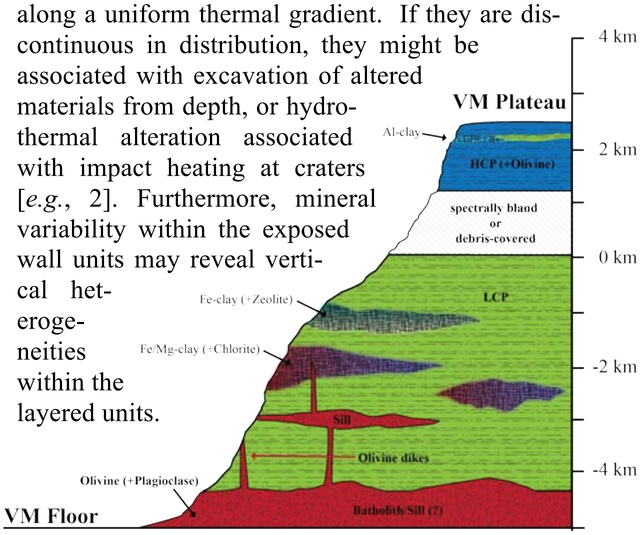

Figure 1. Generalized stratigraphy exposed in E. Coprates walls.

The purpose of this study is to determine the vertical and lateral distribution and mineralogic variability of in the valley walls and floor materials, and to understand how these variations are related to the regional geology surrounding VM.

Stratigraphy Across Coprates Chasma: Flahaut et al. [3] observed that in Coprates Chasma, Mg-rich phyllosilicates were exposed from -2000 to -400 m within the upper section of the Low-Ca Pyroxene (LCP)-rich unit (Figure 1). At the top of the stratigraphic sequence exposed by VM are shallow "plateau phyllosilicates" consisting of Al-phyllosilicate overlying Fe/Mg-phyllosilicates, interpreted to be a pedogenic sequence [4], within or above the layered, High-Ca Pyroxene (HCP)-rich unit [3]. Olivine-rich material occurs at the base of the stratigraphy at the same elevation as the large olivine-rich outcrop identified by [5] in Ganges and Eos Chasma, and may be the source for olivine-rich vertical dikes observed in the stratigraphy in Eastern Coprates [6]. Several locations at the same elevation also show a broad absorption feature centered at ~1.2 μm (Figure 2, top) consistent with Fe^{2+} substitution in plagioclase, *e.g.* [7].

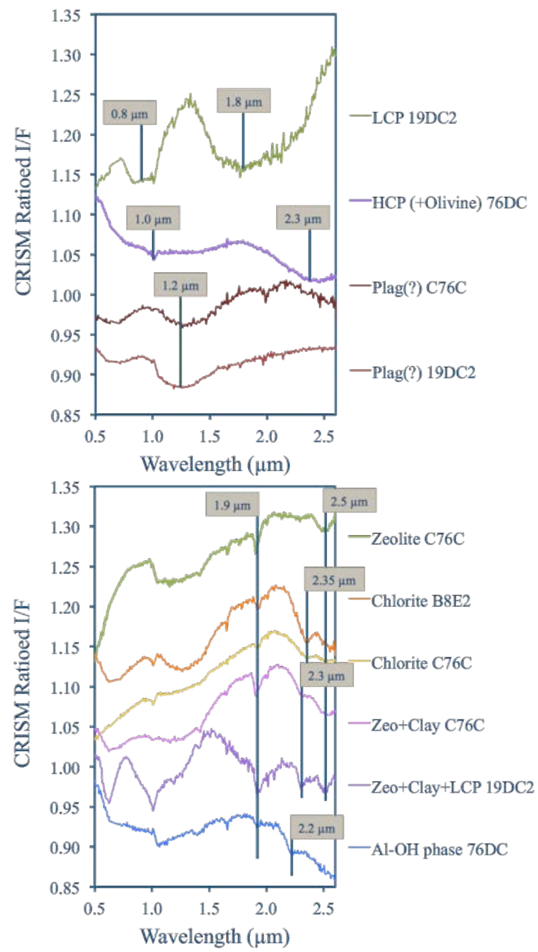

Figure 2. CRISM spectra of representative mineralogy in E. Coprates walls. (top) Primary mineralogy includes plagioclase, high-Ca pyroxene, and low-Ca pyroxene. (bottom) Alteration mineralogy includes zeolite, chlorite, zeolite+clay (or carbonate), and Al-OH material.

Alteration in Eastern Coprates: An area in the Coprates stratigraphy between ~299-305° E, exposes alteration products that are not observed in any other section of the wall. These include zeolite+clay (or carbonate) in the upper section of the LCP unit, where Fe-clay is typically observed, and chlorite in the middle section of the LCP unit, where Fe/Mg-clay is typically observed (Figure 1). Diagnostic absorptions for the identifications are shown in Figure 2 (bottom).

Higher temperature is indicated by the appearance of these minerals, that suggests an enhanced thermal gradient and thermal metamorphism of Fe- and Fe/Mg-clays. If chlorites were formed through the burial diagenesis of smectites, then a relatively uniform increase in chlorite signature would be observed across the phyllosilicates in Coprates. No such signature is observed, suggesting the lateral variability in thermal gradients. Instead, the higher-temperature phases are associated spatially with the olivine-rich dikes. This zone of enhanced thermal activity in the crust may therefore be related to intrusive igneous activity associated with tectonic rifting or the initiation of Tharsis volcanism. We interpret the formation of the chlorite and zeolite to post-date the formation of the altered Noachian LCP-rich unit, and to have occurred as an alteration front associated with the thermal gradients suggested by olivine-rich dikes cutting through the overlying LCP-rich unit. The chlorite and zeolite may have formed contemporaneously with the dikes if formed through thermal metamorphism associated with olivine-rich dike emplacement.

Possible Relation to Tectonics of the Valles Marineris Region: Past attempts to trace the above stratigraphy westward along the walls of Coprates suggest that these units are relatively flat-lying until they disappear where Coprates widens into Melas Chasma. The lack of these units in the walls of western VM were interpreted to be a product of a steeply plunging dip from east to west as a result of tectonic subsidence or "sagduction" via loading of volcanic material [3, 8, 9]. A series of faults just north of the last occurrence of this stratigraphy intersect the wall and appear to reveal a series of down-dropped blocks of the wall material. Detailed mapping of the wall material will be discussed in the full presentation of this work.

The relationship between the region of increased thermal alteration and the greater VM regional geology provides evidence to test proposed tectonic models of the region. South of VM lies the Thaumasia Highland, an arcuate region of elevated Noachian rock. Claritas Rise, the most densely fractured Noachian terrain on Mars [9], lies at its western end. Serpentine-bearing mélange terrain has been identified throughout Claritas [10]. The spectral signature for serpentine can be traced throughout the Thaumasia Highlands and north of E. Coprates (Figure 3). This zone of serpentine-bearing fracture material (Figure 3 dashed region) intersects E. Coprates at the exact point of the observed thermal alteration in the wall mineralogy. Although serpentine has not yet been positively identified in the walls, we hypothesize that the source of the thermal alteration present in the stratigraphy of E. Coprates is genetically linked to serpentinization elsewhere in the Thaumasia Highlands.

The Thaumasia Highlands have been hypothesized to have been formed 1) through lateral movement as a block or slide, 2) as an orogenic fold and thrust belt involving critical taper wedge mechanics, *e.g.* [11, 12]. The occurrence of hydrothermally-altered mineralogy in the highlands is not required by hypothesis 1. Critical taper wedge mechanics indicate that hypothesis 2 requires an unusually low coefficient of friction (μ=~0.1) and nonzero level of pore fluid pressure. Serpentinite fault gouge can reduce friction along thrust faults to as low as μ=0.15 [12] and fluid-driven alteration is required for its formation; thus the presence of serpentine and other high-temperature products throughout this region may indicate that the specific conditions necessary for the Thaumasia Highlands to have formed as a fold and thrust belt existed.

References: [1] Murchie et al. (2009) *JGR*, 114. [2] Frey et al. (2002) *Geophys. Res. Lett.,* 29. [3] Flahaut et al. (2012) *Icarus*, 221, 420-435. [4] Le Deit et al. (2011) *JGR*, 117. [5] Edwards, et al. (2008), *JGR*, 113, E11003. [6] Flahaut et al. (2011) *GRL*, 38, L15202. [7] Wray et al. (2012) *Nat. Geo.*, *5*, 739-743. [8] Quantin et al. (2012) *Icarus*, 221, 436-452. [9] Dohm et al. (2001) *JGR*, 116, 32943-32958. [10] Ehlmann et al. (2010) *GRL*, *37*, L06201. [11] Andrews-Hanna (2009) *Nat. Geo.*, *2*, 248-249. [12] Nahm et al. (2010) *JGR*, *115*, E04008.

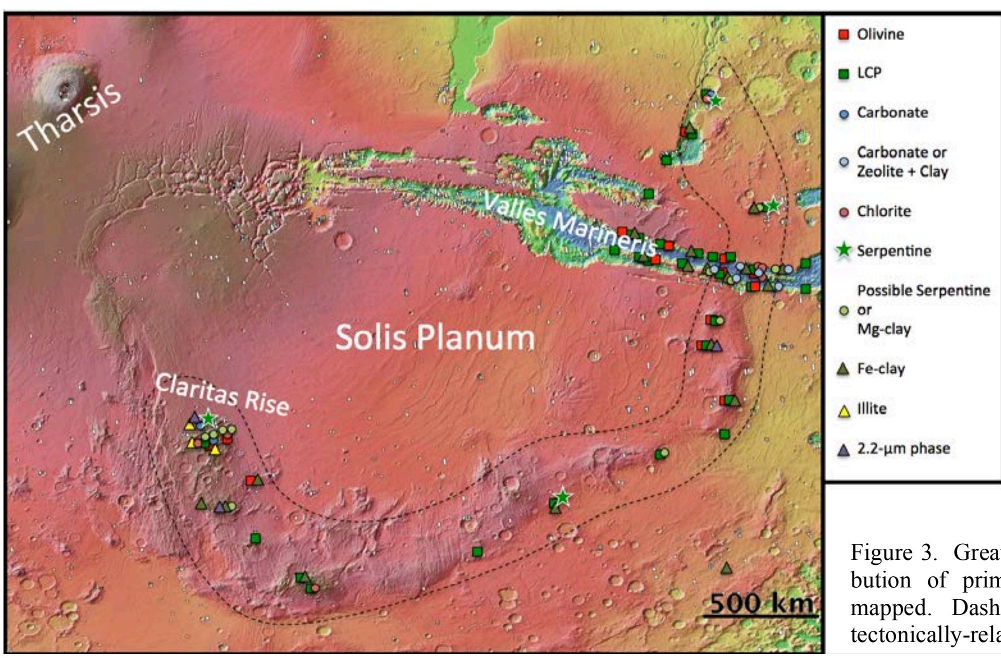

Figure 3. Greater VM region with the distribution of primary and alteration minerals mapped. Dashed line is region of proposed tectonically-related hydrothermal activity.