DIVERSE MINERALOGIES IN TWO TROUGHS OF NOCTIS LABYRINTHUS, MARS. C. M. Weitz[1], J. L. Bishop[2], P. Thollot[3], N. Mangold[3], and L. H. Roach[4]. [1]Planetary Science Institute, 1700 E Fort Lowell #106, Tucson, AZ 85719, weitz@psi.edu; [2]The SETI Institute&NASA-Ames Research Center, Mountain View, CA 94043; [3]Lab. Planétologie et Géodynamique de Nantes, CNRS et Univ. Nantes, 44322 NANTES Cedex, France; [4]Frontier Technology, Beverly, MA 01915

Introduction: Several troughs within Noctis Labyrinthus contain layered beds and hydrated minerals [1, 2, 3], but only the two analyzed in this study have extensive exposures of diverse mineral phases. Both troughs contain an assortment of hydrated minerals that are generally associated with layered, indurated light-toned outcrops near the lowest elevations within each trough. A stereo pair of HiRISE images covering each trough was used to produce a Digital Terrain Model (DTM) [4]. CRISM spectral parameter maps were then co-registered and overlain on each DTM to aide in the interpretation of stratigraphic relationships.

In this study, we map and focus on units that are layered in HiRISE images and/or have spectral features in CRISM data. Units are defined and mapped based upon morphology and mineralogy as follows: Light-toned Layered (LTL), Light-toned (LT), Light-toned Draping (LTD), Medium-toned Layered (MTL), and Medium-toned (MT), with mineralogy listed in association with a unit if known.

Results: *TROUGH 1:* In the southwest portion of the trough (Fig. 1), unit LTL(FeSm) is confined within valleys along the walls, indicating it is a draping unit and, consequently, one of the youngest units. Other exposures in the trough have numerous beds that drape over pre-existing material. CRISM spectra of this unit are consistent with the Fe-smectite (FeSm) nontronite.

Exposures of MT(HdSi) occur along massive blocky wallrock slopes with no evidence of layering. The unit appears morphologically the same as the adjacent wallrock, albeit slightly brighter, suggesting it represents alteration of the underlying substrate. The CRISM spectra for this unit are consistent with hydrated silica (HdSi).

LT(Db) is a ~20-m thick massive light-toned bed near the top of a mound composed of an indeterminate stack of light-toned beds seen only in the eastern portion of the trough (Fig. 1). A CRISM spectrum of the unit shows a hydration feature at 1.9 μm and an enigmatic doublet (Db) between 2.2 and 2.3 μm, with one band at 2.20-2.23 μm and the second band at 2.26-2.28 μm. Explanations for a similar doublet found in Ius Chasma include mixtures of two phases such as montmorillonite or hydrated silica with Fe-smectite or jarosite [5]. Spectra of acid-leached Fe-smectite [6] and poorly crystalline Fe–SiO_2 bearing precipitate [7] produced in the laboratory also share a doublet similar to that observed in CRISM spectra.

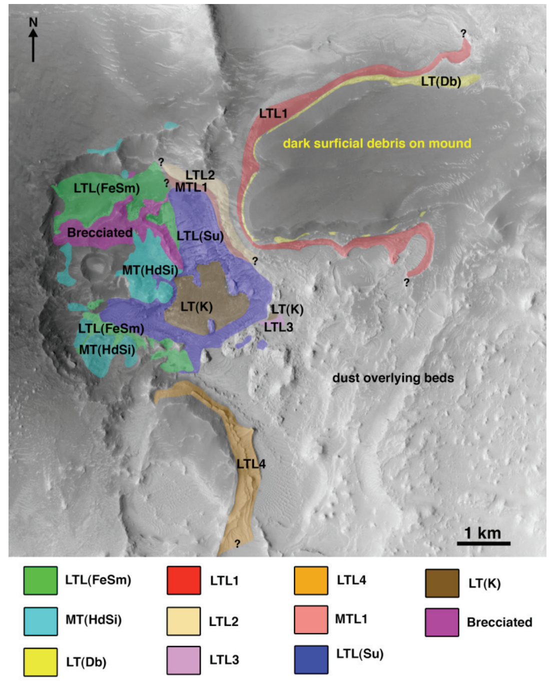

Figure 1. Geologic map of units in Trough 1.

LTL1 consists of dozens of light-and medium-toned beds that vary in thickness. A CRISM spectrum averaged across the entire strata has broad absorptions centered at 1.9 and 2.25 μm, but no other absorptions enable a specific identification. LTL4 is comprised of similar light-and medium-toned beds. CRISM spectra for LTL4 display broad absorptions centered at 1.9 and 2.25 μm, similar to those for LTL1.

LTL2 represents a stack of dozens of light-toned beds that lack spectral features in CRISM data. LTL3 is a small outcrop of fractured light-toned beds. Spectra from the unit have absorptions at 1.95 and 2.23 μm, consistent with a hydrated but indeterminate mineral. MTL1 is interbedded between units LTL2 and LTL(Su) (Fig. 1). The medium-toned layered unit is spectrally neutral in CRISM data.

LTL(Su) generally has polygonal fractures that produce loose-lying blocks on the surface. CRISM spectra suggest multiple polyhydrated and monohydrated sulfates (Su), including kieserite, szomolnokite, ferricopiapite, and melanterite. Several spectra of LTL(Su) also have an unusual narrow 2.23 μm absorption that could imply partial oxidation and dehydration of ferric sulfates [8-13].

Much of LTL(K) appears polygonally fractured, with bright fractures surrounding darker interiors. A small exposure of this unit in the southeastern portion of the trough (Fig. 1) is located ~20 m above the same unit on the trough floor. CRISM spectra are consistent with Al-rich clays, with a good match to an Al-smectite and kaolinite (K) mixture, halloysite (kaolinite+H_2O), or beidellite.

TROUGH 2: There are several large outcrops and smaller patches of unit LTD that drape along an inner wall in the eastern portion of the trough (Fig. 2). CRISM spectra show a 2.2-2.28 μm doublet and another absorption at 2.02 μm.

Unit MTL is medium-toned and layered, but lacks spectral features in CRISM data. Erosion along a portion of MTL reveals several interbedded light-toned layers (LTL1). Spectra of LTL1 are consistent with hydrated silica/opal and/or Al-clays and possibly a sulfate (Fig. 2). Stratigraphically below MTL and LTL1 is a ~30 m thick stack of finely layered predominantly light-toned beds (LTL2). Spectra averaged across the unit suggest mixtures of opal/hydrated silica and/or Al-clays, possible sulfates, and a 2.23/2.28 μm doublet.

LTL3 is a mixture of light- and dark-toned beds, although the overall appearance of the unit is light-toned. CRISM spectra support mixtures of minerals, including sulfates and the 2.22/2.27 μm doublet phase. LTL4 appears to contain only light-toned beds. CRISM spectra show only weak features including broad absorptions near 1.9 and 2.2 μm.

LTL5, LTL(FeSm1), LTL(FeSm2), and LTL6 all reside in the northeastern portion of the trough (Fig. 2). From CRISM spectra, minerals within LTL5 include opal and/or Al-clays. LTL(FeSm1) represents a light-toned layered unit with all beds sharing a similar lithology. The spectrum for the unit is consistent with an Fe/Mg-rich smectite. LTL(FeSm2) has a similar spectrum to LTL(FeSm1) but lies a few meters below the elevation of LTL(FeSm1) and appears morphologically different with numerous heterogeneities between beds, which is why we distinguish the two units. LTL6 is comprised of small exposures of light-toned beds below LTL5 that lack spectral features.

Additional upper units towards the center of the study area include a light-toned bed that contains opal-bearing material, LTL(Op), and below it a unit with possible sulfates (LTL(Su)), followed by LTL7 composed of mixtures of the 2.2-2.3 μm doublet and jarosite. The middle unit LTL8 consists of dozens of interbedded light- and medium-toned beds with unknown, indeterminate mineralogies.

At the bottom of the strata exposed within the trough are units LTL9, LT(FeSm), and LTL10 (Fig. 2). LTL9 has a mineralogy consisting of possible sulfates, opal/hydrated silica and/or Al-clays, and kaolinite.

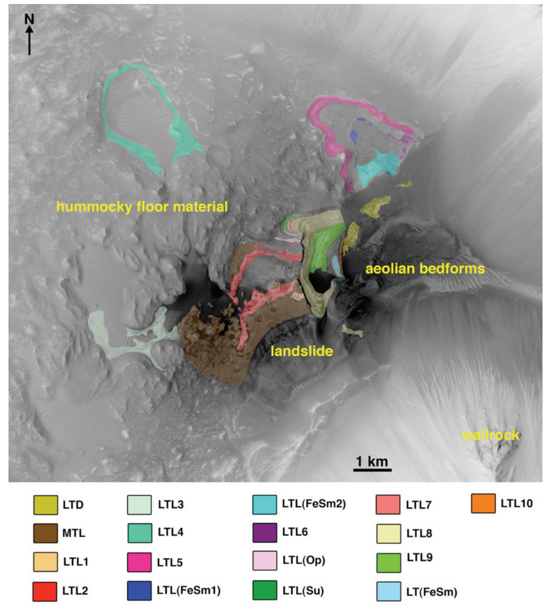

Figure 2. Geologic map of units in Trough 2.

About 10 m below this unit is LT(FeSm). LTL10 has an unknown mineralogy, but can be distinguished in spectra and morphology from the Fe-smectite unit LT(FeSm) directly above.

Discussion: The diverse hydrated minerals in these two troughs support numerous hydrologic and/or depositional events in localized environments spread over time. Many of the units appear to pre-date the current trough shapes, and are only visible because of continued extension, collapse, and erosion. Groundwater infiltration, perhaps associated with Tharsis volcanism, is a plausible source for the water that deposited the hydrated units. These units may underlie more of the Noctis Labyrinthus region than is observable today, deposited locally in smaller ancestral basins that subsequently became partially or completely buried. The age of Noctis Labyrinthus troughs is thought to be Late Hesperian to Early Amazonian [14] and the hydrated units within the troughs are likely this age as well.

References: [1] Mangold et al. (2010) Icarus, 207, 265–276; [2] Weitz et al., 2010 Author E. F. et al. (1997) *Meteoritics & Planet. Sci., 32,* A74. [3] Thollot et al. (2010) *LPS XLI,* #1873. [4] Kirk et al. (2008) JGR, 113, doi:10.1029/2007JE003000. [5] Roach et al. (2010) *Icarus, 206*, 253–268. [6] Madejová et al. (2009) Vib. Spect., 49, 211-218. [7] Tosca et al. (2008) LPI Contrib. 1441, #7030. [8] Swayze et al. (2008) US Geol. Surv. Circular, 8–13. [9] Milliken et al. (2008) *Geology* 36(11), 847–850. [10] Bishop et al. (2009) *JGR* doi:10.1029/2009JE003352. [11] Morris et al. (2009) *Lunar Planet. Sci., XL*, #2317. [12] Lichtenberg et al. (2010) JGR doi:10.1029/2009JE003353. [13] Wray et al. (2010) JGR doi:10.1029/2010JE003694. [14] Scott and Tanaka (1986) USGS Misc. Inv. Series Map I-1802-A.