GEOLOGIC AND MINERALOGIC MAPPING TO DETERMINE THE ORIGIN OF CLAY MINERALS IN RITCHEY CRATER, MARS. V. Z. Sun[1] and R. E. Milliken[1], [1]Dept. of Geological Sciences, Brown University, RI, 02912, Vivian_Sun@brown.edu.

Introduction: Ritchey Crater [28.5˚S, 51˚W] is a ~90 km diameter post-Noachian crater located at a boundary between Noachian-aged plains to the east and Hesperian-aged ridged plains to the west [1]. The crater exhibits diverse morphology, mineralogy, and numerous fluvial features. Visible-near infrared CRISM data indicate the presence of olivine, pyroxene, and hydrated silicates throughout the crater [2], and low-calcium pyroxene and hydrated silicates are prominent in the central uplift [2,3]. Current paradigms suggest that clay formation on Mars was largely restricted to the Noachian [4,5], but clays in Ritchey provide an excellent location to test this hypothesis because they occur in different geologic units that post-date and pre-date the impact event; in addition, the impact itself sampled both Hesperian and Noachian terrains. Previous studies have shown that the central uplift of Ritchey has accessed massive fractured bedrock from a depth of ~9 km [3,6], and this Noachian-age material is overlain by several kilometers of layered Hesperian materials [6] that may be exposed in the crater wall/rim.

Detailed morphologic and mineralogic mapping of Ritchey and its interior deposits can help to determine if the clays are more consistent with a detrital origin (fluvially reworked clays from Noachian or Hesperian units) or if they are also consistent with an authigenic origin, in which case they could have formed in the Hesperian or possibly Amazonian by *in situ* alteration of primary minerals exposed in the crater walls and central peak. We investigate this by using visible imagery (HiRISE and CTX) to map morphologic units and fluvial features in the crater that can be integrated with independent mineralogical maps derived from CRISM data. Stratigraphic relationships between morphologic units, mineralogic boundaries, and fluvial features are then assessed to constrain depositional processes and the relative timing of events within Ritchey Crater.

Methods: Geomorphic and fluvial features were mapped in ArcGIS using CTX images in conjunction with HiRISE images where available. CRISM data (14 FRT and 3 HRL targets) were processed with the CRISM Analysis Tools (CAT) in ENVI, using the "volcano scan" atmospheric correction, division by cosine of incidence angle, and a destriping correction to suppress noise and column bias. Regions rich in olivine (OL), low-Ca pyroxene (LCP), and Fe/Mg clay minerals were mapped using spectral parameters described by [7], and regions of positive detections were then mapped as shapefiles in ArcGIS. The mineralogy indicated in the parameter images was verified by analyzing spectral ratios (spectral average from a 'mineral-rich' region was divided by the spectral average from a 'dusty' or 'bland' region in the same image) (Fig. 1). Olivine was identified by its characteristic broad 1 μm absorption, low-Ca pyroxene by broad 1 and 2 μm absorptions, and Fe/Mg clays by 1.4, 1.9, and ~2.3 absorptions.
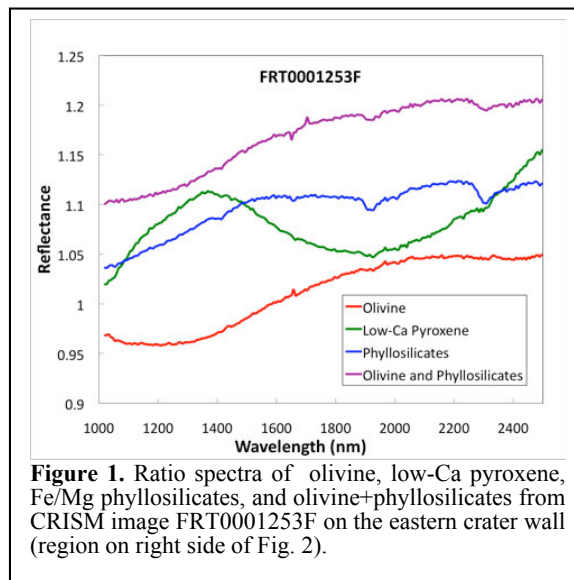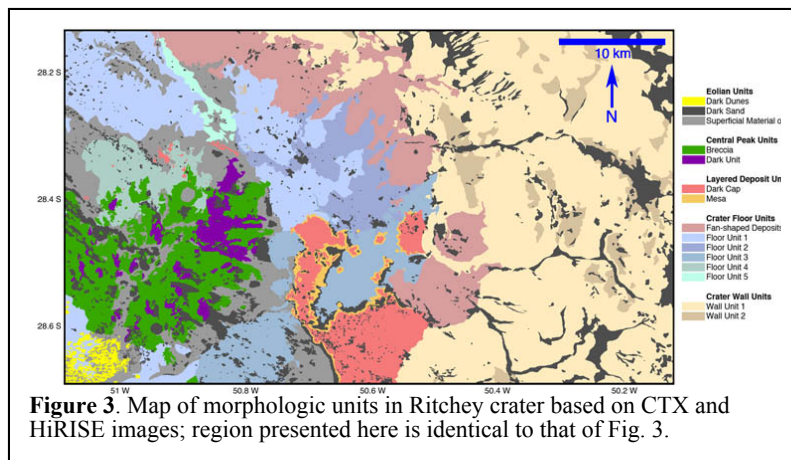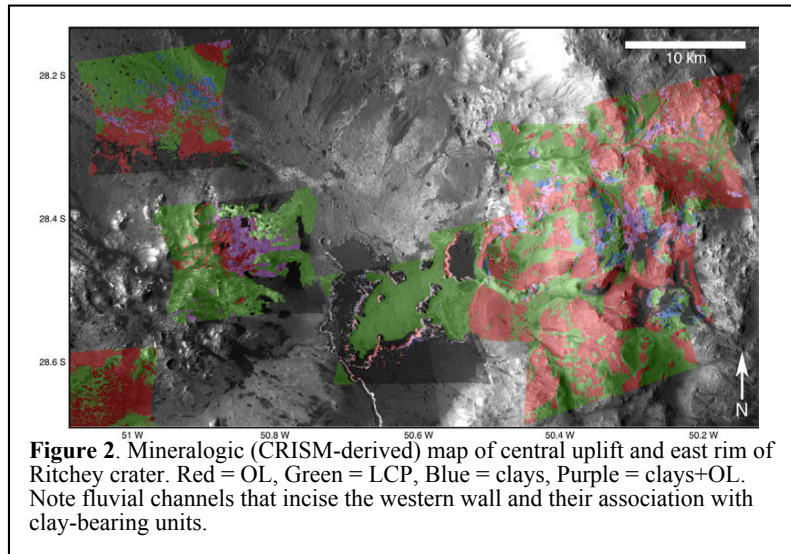

Figure 1. Ratio spectra of olivine, low-Ca pyroxene, Fe/Mg phyllosilicates, and olivine+phyllosilicates from CRISM image FRT0001253F on the eastern crater wall (region on right side of Fig. 2).

Results: Fluvial channels are abundant along the crater wall and rim, with some possible evidence for fluvial incision in the central uplift. Of the three spectral parameters, OL and LCP are the predominant minerals in all 17 CRISM images, and clays were detected in all but one image. Similar to previous studies, the central uplift contains olivine, LCP, and hydrated minerals [2,3], where the spectral shape of the latter may indicate the presence of mixed-layer chlorite/smectite [8]. The crater walls and rim contain abundant pyroxene and olivine signatures as well as Fe/Mg clays (Fig. 2). Although complete CRISM coverage does not exist for the walls, the clays appear to be most areally extensive along the northern and eastern portions, which have been fluvially incised. Channels and alluvial fans are also present along the western wall and crater floor, but clay occurences are very localized in this region. The crater floor exhibits OL, LPC and, in the north, clay signatures.

The primary morphologic units are the crater wall and floor, the central peak, dark dunes, stratified deposits (consisting of a light-toned mesa unit capped by a more resistant and heavily cratered dark unit), and covered sections (Fig. 3).

Figure 2. Mineralogic (CRISM-derived) map of central uplift and east rim of Ritchey crater. Red = OL, Green = LCP, Blue = clays, Purple = clays+OL. Note fluvial channels that incise the western wall and their association with clay-bearing units.

Figure 3. Map of morphologic units in Ritchey crater based on CTX and HiRISE images; region presented here is identical to that of Fig. 3.

Alternatively, the clays may be from strata that post-date the older crater, were excavated by the formation of Ritchey, and then fluvially transported to the crater floor; we cannot rule out either of these hypotheses.

The clay detections are not confined to specific stratigraphic horizons, but rather they are dispersed among LCP and OL signatures in the crater wall materials, much of which likely represents Hesperian-aged terrain. Thus, another alternative is that the clays in the wall of Ritchey were formed *in situ* by post-impact alteration of primary minerals (e.g., OL) in Hesperian lava flows. Such alteration could have been contemporaneous with the period(s) of fluvial incision. However, clay signatures are not commonly detected in the proximal or distal sediments associated with the fluvial systems. This may be the result of clays being volumetrically 'diluted' by mixing with non-clay components as the fluvial systems integrate sediment from different lithologies.

Conclusions: Clays in Ritchey are consistent with Fe/Mg smectite or mixed-layer chlorite/smectite. These clays are often mixed with olivine, possibly because they are the result of olivine alteration. Clays in the central uplift and crater walls may represent excavated, pre-impact clays; the central uplift clays are likely Noachian, but geologic mapping suggests at least some of the wall materials are Hesperian in age. In addition, the assocation between primary minerals and clays in the crater wall, their proximity to fluvial channels, and their occurrence in strata that post-date the impact event suggest authigenic clay formation cannot be ruled out. If true, the rocks in Ritchey may provide access to Martian clay deposits formed in different time periods for which Mars is believed to have experienced very different and distinct climatic conditions.

The central peak is largely composed of lighter-toned, pyroxene-dominated breccia and darker olivine-rich units. Clays in the central uplift may be mixed with olivine or represent Fe-rich clays given their overlap with the OL spectral parameter (Fig. 2). Dark dunes to the southwest of the central uplift are olivine-bearing, and this is the only region of the crater that lacks detectable clays in current CRISM coverage. Stratified deposits that post-date the impact event occur in the SE portion of the crater interior, and the dark capping unit exhibits only weak pyroxene features, similar to Martian dust. However, the underlying, light-toned mesa unit contains both OL and clays. Moderate-toned units on the crater floor exhibit LCP signatures, but compositions of lighter portions in the NE are unknown due to lack of CRISM data (e.g., center of Fig. 2).

Discussion: Ritchey is superimposed on an older, similarly-sized crater to the E-SE that lies primarily in Noachian-age terrain. Therefore, clays in Ritchey may have been excavated by two impact events and fluviallly reworked to form deposits on the floor of Ritchey.

References: [1] Skinner, J. et al. (2006), *LPSC 37*, #2331; [2] Milliken, R.E. (2007), *MSL 2nd Landing Site Wkshp*; [3] Quantin, C. et al. (2012), *Icarus 221*, 436-452; .[4] Bibring, J.-P. et al. (2006), *Science 312*, 400-404; [5] Poulet F. et al. (2005) *Nature, 438,* 623-627 [6] Caudill, C. et al. (2012), *Icarus 221*, 710-720; [7] Pelkey, S. et al. (2007), *JGR 112*, E08S14; [8] Milliken et al. (2011), *LPSC 42*, #2230.