ORIGIN OF CLAY MINERALS IN MARTIAN CENTRAL PEAKS: EVIDENCE FOR POST-NOACHIAN CLAY FORMATION. V. Z. Sun[1] and R. E. Milliken[1], [1]Dept. of Geological Sciences, Brown University, RI, 02912, Vivian_Sun@brown.edu.

Introduction: Martian Noachian (≥3.6-3.9 Ga) rocks record a period of widespread aqueous alteration and clay mineral formation on Mars that is purported to have largely ceased by the Early Hesperian [1,2]. One piece of evidence for this paradigm comes from detections of clay minerals in central peaks of impact craters that are conventionally interpreted to represent ancient altered Noachian crust excavated from depth [3,4,5]. However, recent studies of Hesperian impact craters (e.g., Holden [6], Toro [7], Ritchey [8]) have determined that in some cases these clays likely formed *in situ* post-impact, indicating clay formation in the Hesperian or younger. Here we expand these previous studies by examination of other craters. By correlating mineralogy with geomorphology and stratigraphy, we assess whether the clays formed pre- or post-impact. When possible, we also determine if clays may be associated with impact melt, as has been observed in Ritchey crater [8]. In particular, we focus on clays in post-Noachian craters to better constrain the period and lateral/vertical distribution of clay formation on Mars.

Methods: Craters were selected for study if their central peaks were clearly visible and had both CRISM and HiRISE coverage. Crater ages were estimated by crater counts from CTX images within the crater's continuous ejecta (1 crater radius) and by superposition of geologic units. Mineralogy was analyzed from 1-2.6 μm using CRISM data and was correlated to geologic units determined from HIRISE images. All datasets were integrated in ArcMap GIS for analysis.

CRISM data were processed using the CRISM Analysis Tools in ENVI, including atmospheric, photometric, and destriping corrections. Hydrated and mafic mineralogy were assessed with the default spectral parameters as described in [9], which can indicate the presence of various hydrated and mafic minerals. Spectral ratios were analyzed by dividing a region of interest (ROI) by a spectrally 'bland' region in the same image. Individual ROIs (<100s pixels) were independently analyzed and, when representative of the same mineralogy, averaged together to produce higher quality ratio spectra. Pixel-by-pixel analyses were also used to determine detailed mineralogic boundaries and subtle variations in mineralogy.

Results: A global survey shows that almost ~25% of candidate central peaks exhibit hydrated mineralogy in default CRISM parameter maps, typically Fe/Mg clays (D2300; Fig. 1). However, some may be false positives, and 'non-detections' may have hydrated minerals that are not apparent in the default parameter maps. Manual, detailed analysis is needed to determine the true number of central peaks exhibiting clays. All of the craters described in detail hereafter (starred in Fig. 1) are along

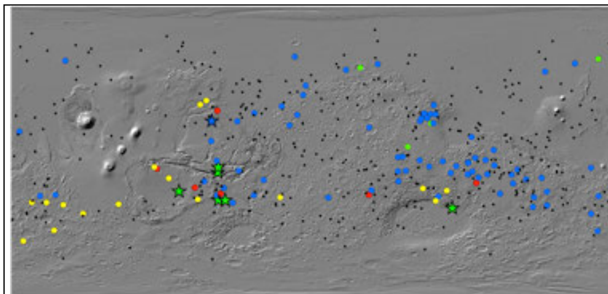

Figure 1. Global survey of 462 central peaks with CRISM and HiRISE coverage. Red(7): positive BD1900 parameter, blue(74): positive D2300 parameter, yellow(16): positive BD2210, green(11): positive BD2210 and D2300. Stars indicate craters studied in detail for this work thus far.

the Noachian-Hesperian boundary or younger and span ages from 3.81 to 3.13 Ga. They all also exhibit Fe/Mg clay (Fig. 2) and hydrated silica (with the exception of Pompeii) signatures at their central peaks. Unnamed craters are referred to by their CRISM ID.

Uplifted Clays: FRT00016D57 (23.1°S 78.6°W) is a 3.4 Ga, 28 km crater with central uplift strata interpreted to be Hesperian lava flows [5,10] uplifted from ~2.7 km depth. Clays are distinctly associated with exposures of uplifted strata (Fig. 3a), providing clear evidence of pre-impact, clay-bearing materials at depth.

Clays of Uncertain Origin: FRT00005C7C (28.4°S 55.1°W) is a 3.43 Ga, 17 km crater with uplifted stratified units, a brecciated region, and likely impact melt deposits. None of these are definitively associated with clays. Thus, central peak clays may have formed post-impact, but excavation from depth cannot be ruled out and their origin/age is ambiguous.

Elorza (8.8°S 55.2°W) is a 3.68 Ga, 42 km crater uplifting both massive and layered units [5]. Two distinct clay signatures are present in the central pit (Fig. 2). The massive units, interpreted to be ancient Noachian bedrock, appears as unaltered LCP (Fig. 3b); clays cannot be distinctly linked to a specific geologic unit. The presence of fluvial channels and deposits throughout the crater and clays in the region around Elorza indicate a possible detrital or pre-impact origin.

Post-Impact Clays: Craters in this group show clear evidence of unaltered and massive uplifted units superposed by clay-bearing units emplaced post-impact. FRT00017B42 (11.8°S 55.5°W) is a 3.81 Ga, 16 km crater uplifting LCP-rich bedrock, with clays associated with clast-rich regions (Fig. 3c) that could be interpreted to be impact melt.

Ritchey (28.5°S 51°W) is a 3.46 Ga, 75 km crater uplifting LCP-rich bedrock, and clays at the central peak are distinctly associated with a brecciated impact melt draping the bedrock (Fig. 3d) [8].

Majuro (33.3°S 84.3°E) is a 3.41 Ga [11], 44 km crater uplifting olivine-rich bedrock that appears to be draped by a clay-bearing, post-impact deposit (Fig. 3e). The origin of the clay-bearing unit is uncertain as its draping quality implies an impact melt or airfall deposit, but a large fan deposit may also have transported detritus to the central peak [11].

Pompeii (19°N 59.1°W) is a 3.13 Ga, 30 km crater uplifting LCP-rich bedrock that is overlain by a clay-bearing post-impact unit (Fig. 3f). There is no evidence for fluvial activity in or around the crater, indicating the clays could have formed *in situ*. At 3.13 Ga, Pompeii is the youngest crater discussed here and may provide the best evidence thus far of Late Hesperian or Amazonian clay formation.

Conclusions and Future Work: This evidence shows that clays in some crater central peaks represent post-impact formation rather than excavation of older altered materials from depth, although some craters are ambiguous or consistent with clay excavation from depth. Post-impact clays in Hesperian central peaks are particularly interesting, as in some (but not all) cases they are associated with putative impact melt deposits. These results indicate clay formation was a continued and important process during the Hesperian and possibly Amazonian, though whether such formation required impact-generated heat/fluid circulation or was the result of near-surface weathering requires more detailed study. Ongoing work will continue to extend this study to all central peaks with CRISM and HiRISE coverage to determine the extent of post-Noachian clay formation and the crustal distribution of ancient clays.

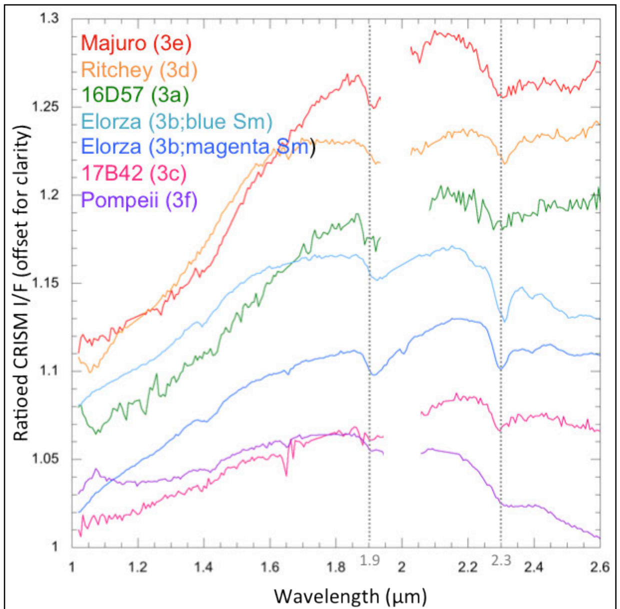

Figure 2. Select spectra of clay minerals at central peaks of craters in Figure 3.

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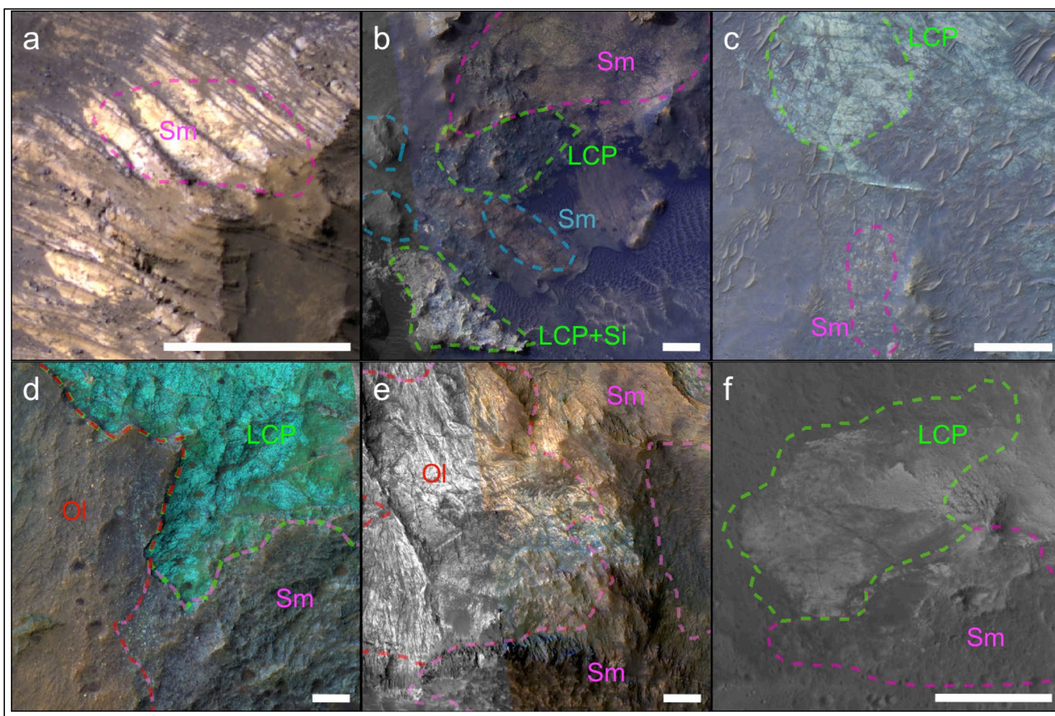

Figure 3. HiRISE images of central peaks with mapped CRISM mineralogy overlaid. (a) uplifted clays at 16D57;(b) two clay types of sedimentary or uncertain origin at Elorza;(c) clays in a clast-rich region at 17B42; (d) clays in impact melt at Ritchey; (e) clays in putative impact melt at Majuro; (f) clays in post-impact unit at Pompeii. Sm: Fe/Mg smectite, LCP: low-Ca pyroxene, Ol: olivine,Si: hydrated silica. Scale bars indicate 100 m.