EVIDENCE FOR AN EXTENDED CARBONATE-BEARING UNIT IN THE COLUMBIA HILLS OF GUSEV CRATER, MARS. Steven W. Ruff[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287-6305, steve.ruff@asu.edu.

Introduction: The recent discovery of outcrops rich in Mg-Fe carbonates (16-34 wt%) in the Columbia Hills has provided an example of the role of near-neutral pH water there [1]. The Comanche carbonate outcrops are at the base of Haskin Ridge (Fig. 1) and initially were thought to represent an isolated occurrence. But now spectral evidence from the Spirit rover's Miniature Thermal Emission Spectrometer (Mini-TES; ~350-2000 cm^{-1}) indicate a larger range for this material, possibly including McCool Hill (Fig. 1).

Comanche Stratigraphy: Although found at the base of Haskin Ridge, the Comanche outcrops appear to be the stratigraphically highest unit of a set of olivine-rich volcaniclastic rocks that mantle the ridge [2; 3]. Upslope and down section from Comanche are olivine-rich outcrops known as Algonquin class (Fig. 1). [4] demonstrated that a Mini-TES spectrum of Comanche is well modeled as a combination of the spectral character of average Algonquin class rocks with the addition of Mg- and Fe-rich carbonates. This leads to the idea that Algonquin class outcrops were enriched in carbonates, perhaps via hydrothermal alteration or precipitation from an evaporating brine.

Comanche Extended: Between the Algonquin and Comanche outcrops is a set of flat outcrops most clearly imaged by Spirit's Panoramic Camera (Pancam) (Fig. 1, left). Mini-TES spectra of these outcrops are similar to one another and notably intermediate in spectral character between average Comanche and Algonquin spectra (Fig. 2, left). Spectral modeling of one example known as Apache using the same library of end members as that of [1] with the addition of an average Algonquin and Comanche spectrum is shown in Fig. 2 (right). The Apache spectrum is remarkably well modeled as a mixture of 70% Comanche and 30% Algonquin after normalizing for contributions from dust, blackbody, and spectral slope. This result suggests that outcrops on Haskin Ridge that are spatially intermediate between Comanche and Algonquin outcrops also are mineralogically intermediate.

Evidence of this spectrally intermediate rock unit is present elsewhere in the Columbia Hills. While Spirit was positioned closer to McCool Hill, Pancam imaged a hill slope littered with relatively rounded and gray boulders, some of which appear to have reached the base of the hill (Fig. 1, right). Mini-TES observed two m-scale examples known as Amery and Gurruchaga. Spectrally they are notably similar to the intermediate class described above (Fig. 2, left). These two spectra were initially described as similar to those of the olivine-rich Seminole outcrops further up Haskin Ridge ([5]), but this was prior to a proper correction for dust accumulated on the Mini-TES pointing mirror. All the spectra shown in this abstract have been corrected according to the approach shown by [6]. The corrected spectra of Amery and Gurruchaga include features at low wavenumbers that better match the Mg-rich olivine present in Comanche and Algonquin rather than Seminole.

Discussion: The stratigraphic position of the spectrally intermediate outcrops on Haskin Ridge is consistent with the idea suggested by [4] that Comanche outcrops are the result of carbonate enrichment of olivine-rich Algonquin class. In this view, a unit of Algonquin class rock was stratigraphically highest at the time carbonate alteration occurred, but only the uppermost portion of this unit was altered to the degree observed in the Comanche outcrops. In between the stratigraphically lower unaltered Algonquin outcrops and higher Comanche outcrops, there now appears to be a unit that has been altered by carbonates, but to a lesser degree than Comanche. Using the spectral model results that the intermediate unit is equivalent to 70% Comanche and 30% Algonquin, this unit may contain as much as 24 wt% Mg-Fe carbonate based on the results of [1].

Summary: Spectra from Mini-TES show outcrops from Haskin Ridge and boulders from McCool Hill that are spectrally intermediate between those of olivine-rich Algonquin class outcrops and carbonate-rich Comanche outcrops. This is consistent with a process that produced a gradient of carbonate enrichment that is now exposed by erosion and a carbonate-rich unit more extensive than the smaller exposure of the Comanche outcrops.

References: [1] Morris, R. V., et al. (2010), Science, 329, 5990, 421-424, 10.1126/science.1189667. [2] McCoy, T. J., et al. (2008), J. Geophys. Res., 113, E06S03, 10.1029/2007JE003041. [3] Crumpler, L. S., et al. (2011), J. Geophys. Res., 116, E00F24, 10.1029/2010JE003749. [4] Ruff, S. W. (2011), Lunar Planet. Sci., XLII, abstract #2708, [5] Ruff, S. W., et al. (2007), Lunar Planet. Sci., 38, Abstr. #2063, [6] Ruff, S. W., et al. (2011), J. Geophys. Res., 116, E00F23, 10.1029/2010JE003767.

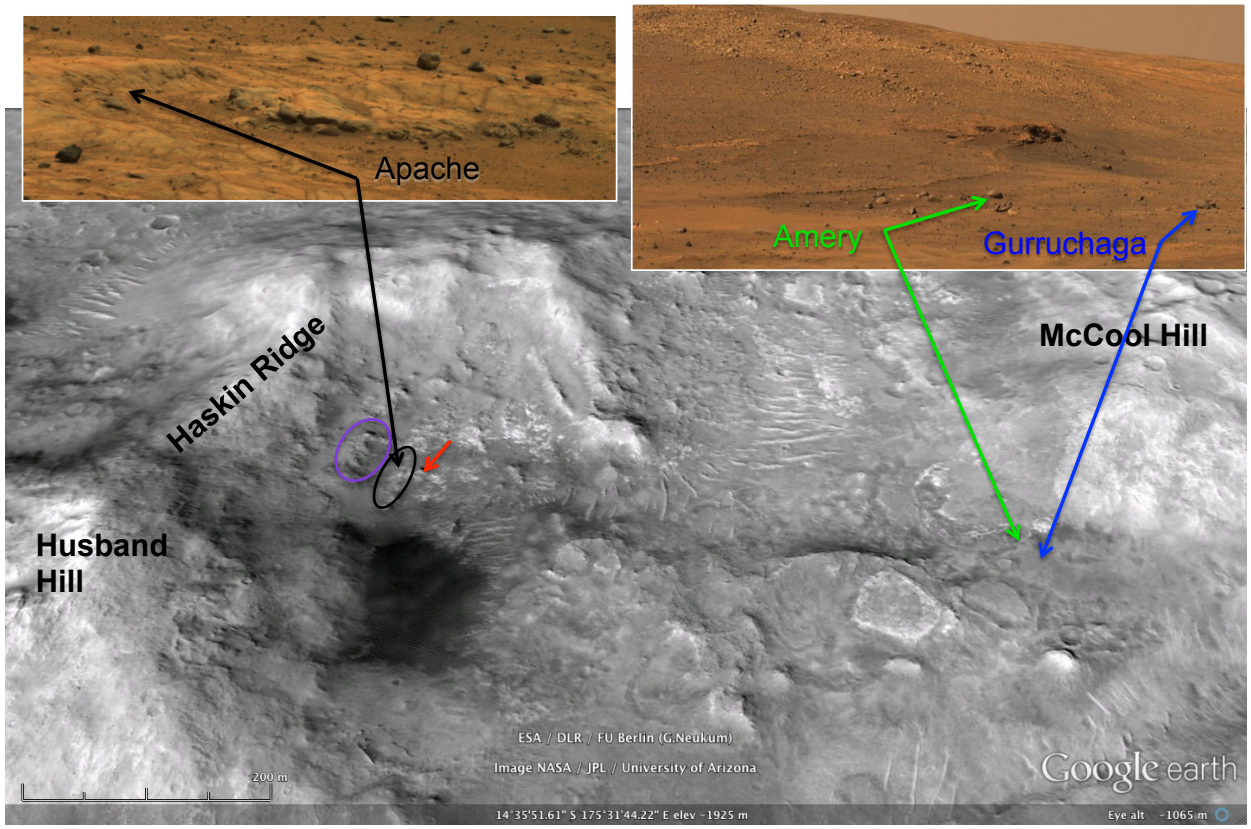

Figure 1. Inner basin of the Columbia Hills. HiRISE image (north is left) shows the context of features described in the text including Algonquin (purple oval), Comanche (red arrow), and intermediate (black oval) outcrops. Left Pancam inset shows outcrop containing Mini-TES target on Apache outcrop. Right Pancam inset shows two boulders from McCool Hill that are spectrally similar to the intermediate outcrops on Haskin Ridge.

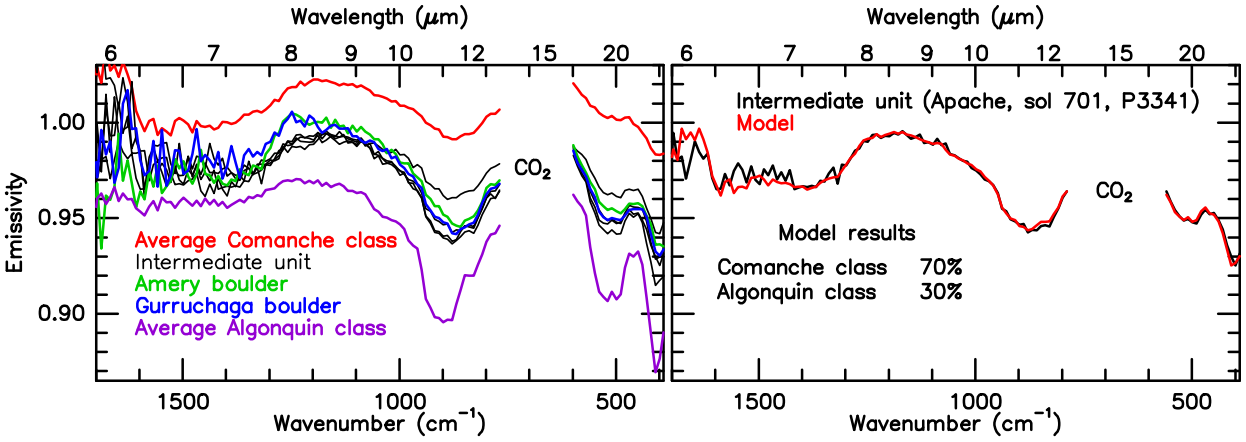

Figure 2. Mini-TES spectra of materials on Haskin Ridge and McCool Hill color-coded to Figure 1. Left: Spectra (black lines) from outcrops stratigraphically intermediate between the Algonquin and Comanche outcrops also are spectrally intermediate between the average spectra of these two outcrops (shown vertically offset). Two boulders from McCool Hill have Mini-TES spectra (Amery, sol 1078, P3810; Gurruchaga, sol 1059, P3802) that closely resemble the intermediate outcrops. Right: Modeling of the intermediate unit produces a remarkably good fit with just Comanche and Algonquin spectral components after normalization for non-geologic spectral components.