

SUMMARY OF REGIONAL MARTIAN GEOLOGIC HISTORY FROM IN SITU STRATIGRAPHIC MEASUREMENTS IN THE COLUMBIA HILLS, GUSEV CRATER, MER SPIRIT ROVER. L. Crumpler¹ and Athena Science Team. ¹New Mexico Museum of Natural History & Science, 1801 Mountain Rd NW Albuquerque, NM, 87104, USA, larry.crumpler@state.nm.us.

Introduction: Correlation of stratigraphic sections measured along the Columbia Hills transect by Spirit detect a secular trend in lithology and alteration products that arguably represent the detection of some regional and global trends in the geologic environments and history of Mars. The stratigraphic succession is characterized by an earliest wet impact-dominated period, followed by early volcanic ash-dominated sequences, then later extensive mechanical erosion of the landscape, later lava, and, later still, epicyclic and surficial excursions in climate.

Measured Stratigraphic Sections: At least 60 m of vertical stratigraphic section was examined within the Columbia Hills. Where benches, ridges, and ledges were traversed on the flanks of Husband Hill, the dip of local outcrop layers, or structural surfaces, generally exceeded the topographic slopes. From this general arrangement of bedding planes, the Columbia Hills are interpreted to have a approximately antiformal structure, that is, older materials are generally exposed at

higher elevations. This general attitude is modified at the highest elevations by local caps of higher, more resistance stratigraphic units. The summary stratigraphic results for the four principal study areas are shown in Figure 1 and correspond to breaks in the lateral correlation between the western most margin (“West Spur”), the northwest slopes of Husband Hill, the high western slope of Husband Hill near the summit (“Western Husband Hill”), and the north slope of a ridge jutting eastward from the west side of Husband Hill (“Haskin Ridge”). The attitude of bedding planes in all four areas have been well determined [1].

Local Record of Regional Volcanism: Several sources of pyroclastic fall deposits in the Columbia Hills include proximal volcanic vents [2], and volcanic vents on the crater floor, although the latter would be unidentifiable if present because of the burial of the crater floor by late lava flows. Another source is more far field. Gusev crater lies within a volcanic province extending across the highlands-lowlands boundary that

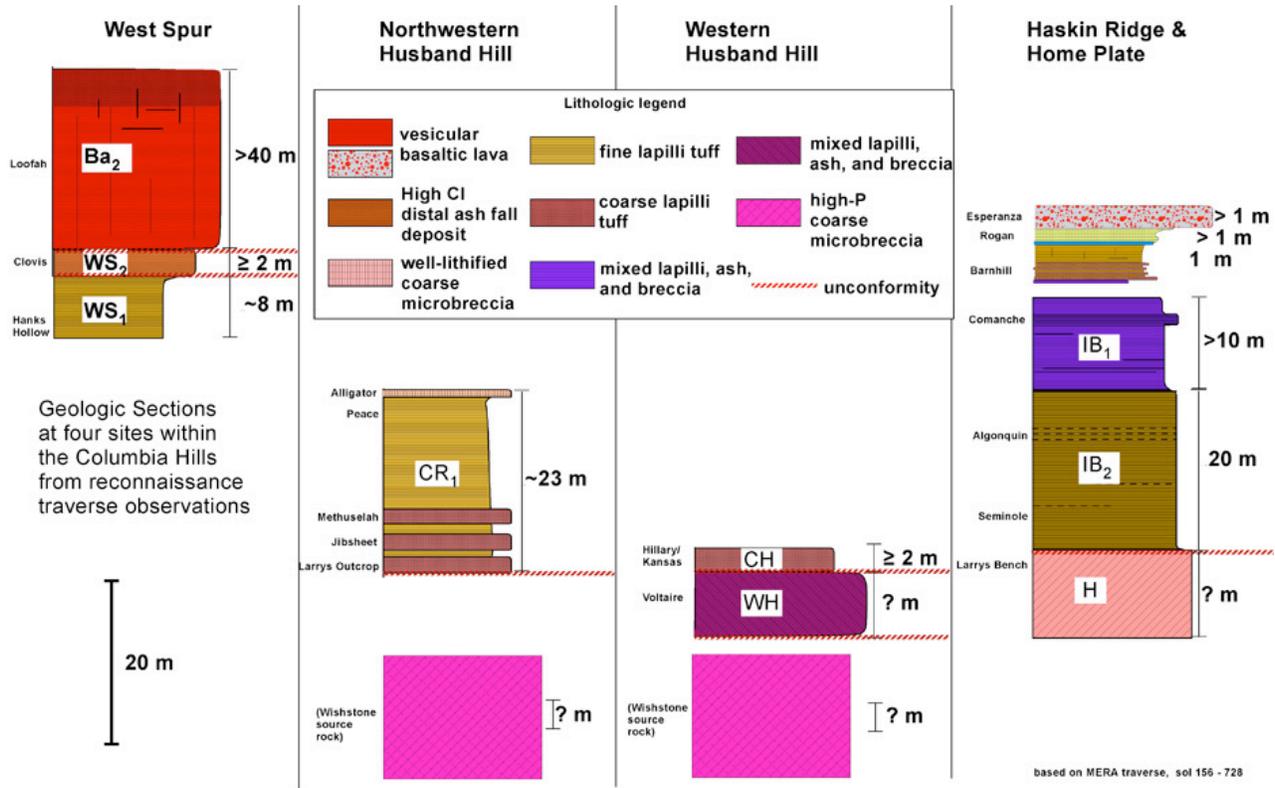


Figure 1. Measured stratigraphic sections at four locations along the traverse through the Columbia Hills. The total apparent section is about 60 m. Early impactites and microbreccias are followed in succession by thick lapilli tuffs, fine ash fall deposits, and late basaltic lava flows. A significant erosion unconformity post-dates the high-Cl ash of West Spur (“Clovis” outcrop, unit WS₂) unconformity.

contains several vents, some poorly known such as Apollinaris Tholus and Zephyria Tholus, in addition to the better known Apollinaris Patera to the north. The more explosive (plinian and sub-plinian) character of highland volcanoes in general [e.g., 3] makes them a candidate for deposition of some relatively thick air fall deposits on the floor of Gusev Crater, draping the Columbia Hills precursor massif in several blankets of ash. It has been shown that lapilli fall deposits approaching the petrographic character of lapilli tuffs observed in several Columbia Hills outcrops may be transported up to several hundred kilometers under certain conditions [4] so all the coarser lapilli tuffs need not be local.

In Situ detection of gross changes in Martian climate with time: Casting these *in situ* results in terms of some regional events, we offer the following historical interpretation of the regional geology: Early deposits resulted from impactite-dominated, fall deposits, some regional tectonism, and high apparent rock water environments resulting in isochemical alteration of ash-size fraction glass deposits. This was followed by mostly volcanic-ash and lapilli-dominated fall deposits originating from any of several highland volcanic sources, and this by continued wet alteration of protoliths. A significant period of high energy mechanical erosion and development of epiclastic deposits and thick mantles of float followed. The lava flows were comparatively late in the overall stratigraphic sequence, despite significant, Hesperian age crater abundances. Although late in the sequence, regional volcanism was early in Martian geologic history. Subsequent to regional volcanism, most of the remaining geologic history was one of continued lower water activity in cyclic climatic events. The record of these events is preserved in the form various cohesive and salty soils and growth of sulfate varnishes.

In Situ Sample of Medusae Fossae?: The outcrop Clovis and the cap rock of West Spur in general is interpreted as a fundamentally basaltic volcanic ash (size fraction) fall deposit bearing abundant normative pyroxene, but enriched in Cl (1.4 wt %) and Br [5, 6, 7]. This deposit is somewhat altered given that nanophase iron oxides, goethite, and hematite, and high (0.72) Fe^{3+}/Fe_T [8] are characteristic. If the Upper Cap Rock of West Spur (WS₂) is a volcanic ash, then the nanophase iron oxides may also represent the results of substantial alteration of the glassy component. The reported RAT grind energy of 4 to 9 J mm⁻³ [7] is consistent with a weakly cohesive fine ash (<0.063 mm size).

The chlorine enrichment of Clovis is notable given that Keller *et al* [9] found the equatorial area immediately north of Gusev Crater to be enriched in chlorine

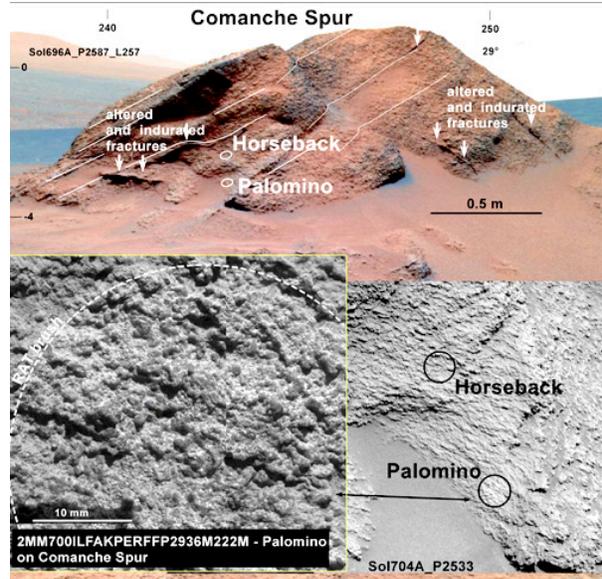


Figure 2. Based on MI targets (Palomino and Horseback) on Comanche Spur, the outcrop is a lapilli tuff steeply dipping down the north flank of Husband Hill. Significantly it is moderately high in the stratigraphic section, yet is estimated [13] to consist of up to 30 percent (Mg,Fe)-carbonate, possibly as a cement. The view azimuth is a few degrees south of the actual strike. Part of unit IB₁, Haskin Ridge section.

in an area restricted to the Medusae Fossae Formation [10], a broad equatorial region of thick layered mantling deposits [11, 12]. The average value of 1.4 wt% as determined from APXS measurements in Clovis class rocks [6] falls within the 1 wt% Cl enrichment contour of Keller *et al* [9]. The proximity of Gusev Crater to the region over which Medusae Fossae Formation occurs and the chlorine anomaly makes the Clovis-class material (unit WS₂) a viable candidate as a distal outlier of the Medusae Fossae Formation. Based on the pre-Ma'adim Vallis age of Medusae Fossae, this would mean that *the Clovis cap rock of West Spur records the climate pre-dating the principal fluvial events of Gusev Crater and that many of the sections observed by Spirit also pre-dated Ma'adim Vallis.*

References: [1] [McCoy *et al.* (2008) *J. Geophys. Res.*, 113, E06S03. [2] Squyres *et al.* (2007) *Science*, 316, 738. [3] [3] Greeley, R. *et al.* (2000) in *Environmental Effects on Volcanic Eruptions: From Deep Oceans to Zimbelman*, T.K.P. Gregg, Kluwer, 75-112. [4] Wilson and Head, 2007, LPSC XXXVIII, 1117. [5] Gellert *et al* (2006) *J. Geophys. Res.*, 111, E02S05. [6] Ming *et al* (2006) *J. Geophys. Res.*, 111, E02S12. [7] Squyres *et al.* (2006) *J. Geophys. Res.*, 111, E02S11. [8] Morris *et al.* (2008) *J. Geophys. Res.*, 113, E12S42. [9] Keller *et al.* (2007) *J. Geophys. Res.*, 111, E03S08. [10] Newsom *et al.* (2007) *J. Geophys. Res.*, 112, E03S121. [11] Mandt *et al.* (2008) *J. Geophys. Res. Planets* 113, E12011. [12] Kerber and Head, (2010) *Icarus* 206, 669-684. [13] Morris *et al.* (2010). *Science*, 329, 421.