GEOLOGY OF THE REULL VALLIS REGION OF MARS: EVIDENCE FOR MID-NOACHIAN SHEET FLOODS.

P. T. Leth[1] and A. H. Treiman[2], [1]Pomona College (Dept. Geology, 650 N. College Way, Claremont, CA 91711; pleth@pomona.edu), [2]Lunar and Planetary Institute (3600 Bay Area Blvd, Houston, TX 77058; treiman@lpi.jsc.nasa.gov).

Viking Orbiter images of the Reull Vallis (41.6°S, 258.3°W) show a complex scene that includes horizontal rock strata exposed in the valley walls, parallel remnants of plains mantle units and an apparently anomalous re-entrant structure which we call the Pomona Vallis (44°S, 258.5°W) (see Fig. 1). These features reveal an intricate history, including a large sheet flood, possibly originating from the Pomona Vallis, which stripped and scoured Reull Vallis and its surroundings.

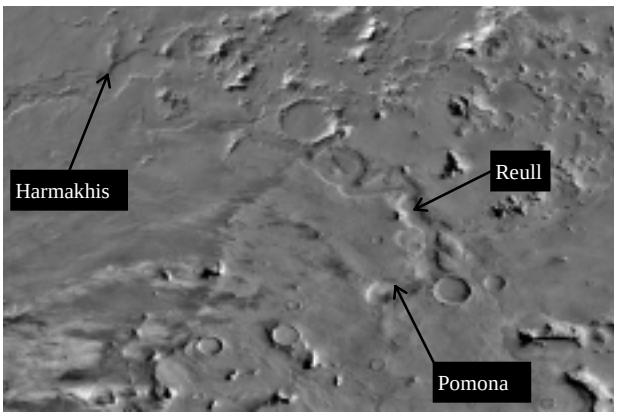

Figure 1: Overview of Reull Vallis Region (MDIM; lat = [-47,-37], lon = [253,268]; frame width = ~700km).

Methods - To unravel the geologic history of the Reull Vallis region, we first assembled a photo mosaic of orthographically projected images (VO frames 329S21-31; 235m/pixel) and mapped topographic units. This allowed us to locate time-stratigraphic contacts between different units, and to obtain a broad view of the surrounding terrain. Red, green and blue filter images that were cleaned and radiometrically and geometrically corrected with PICS and ISIS software packages, were then registered together to obtain full color images for the upper Reull Vallis/ Pomona Vallis region (VO frames 126A08,16,22,24; 160m/pixel) and the lower Reull Vallis/Harmakhis Vallis region (VO frames 124A45,51,56, 57; 140m/pixel). Shadow lengths were measured to get approximate heights of several mountains.

Results: COLOR - The Martian surface in and around the Reull Vallis is nearly monochromatic, as if the surface were composed of a single reddish material. Almost all color differences seem to be brighter and darker variants of the same rusty hue, caused perhaps by changes in slope and solar illumination. Only the dark wind streaks on the leeward sides of minor topographic rises (e.g. craters and hills) have significantly different color. The colors of the streaks are consistent with mixtures of the reddish material with $\leq$20% dark gray material (visible albedo ~5%). The basement units of the plains sequence exposed in the valley walls appear to be more yellowish than other materials, but the difference is not significant.

STRATIGRAPHY - From our geologic mapping, we can outline the following units in the history of Reull Vallis. The sequence was used to construct a detailed geologic history (see below).

	upper	transient wind streaks
Amazonian	middle	lobate debris aprons
	lower	Harmakhis and Dao floor deposits
	upper	northern plains fluvial deposit
Hesperian	middle	impact ejecta blankets
	lower	
	upper	plains mantle unit
Noachian	middle	two thick basement units of the plains sequence (exposed in valley walls)
	lower	Hellas crater rim massifs; mountains

Figure 2: Stratigraphy of Reull Vallis region.

A GEOLOGIC HISTORY OF THE REULL VALLIS REGION OF MARS - Geologic history of the Reull Vallis starts with the Hellas Basin impact event in the Early Noachian, since all previous morphology was either destroyed by the impact or covered by its ejecta blanket. Currently the rugged massifs of the crater rim unit have vertical relief of up to 4km, as determined by shadow measurements.

The Beds: By the Middle to Late Noachian [1] the low-lying areas of the pre-Reull landscape had been covered by a thick sedimentary sequence, including at least two widespread, thick (~1km each) layers now exposed as two distinct steps in the Valley walls (especially Pomona; see Figure 3) and an overlying, thin (~200m) mantle unit which is currently found in dissected fragments west and northeast of Reull Vallis. The nearly complete burial of two large craters of 120km and 100km diameters, just southwest of Reull, indicates that the sedimentary sequence is 2-3km thick, based on known depth/diameter relationships for Martian impact craters [2]. In addition to Pomona, the thick layers are also exposed clearly in a 40km long stretch of Reull Vallis about 100km downstream from Pomona, and in a 50km long stretch of Reull just before its terminus near Harmakhis. Although layers cannot be traced continuously from one exposure to another, all exposures show similar stratigraphy, lithologic properties and weathering patterns which suggest that the same laterally-extensive layers are exposed in each locality. The layers are of constant thickness and show no obvious cross-bedding or other internal structure. Their fluted weathering pattern on north facing slopes suggests that they are loosely lithified and friable, possibly consistent with volcanic ash (see Figure 3), although the exact origin and nature of this sequence, whether volcanic, aeolian or fluvial, is not known. Emplacement as volcanic ashfall or ash flow tuff during multiple episodes of eruption of Hadriaca Patera is possible, considering that the steplike form on the western Hadriaca caldera rim could be interpreted as resulting from a series of caldera collapse and eruption stages [3]. Shortly after lithification, regional compression and/or subsidence of the sequence produced a series of east/west trending wrinkle ridges.

The Flood: In the Early to Mid-Hesperian, a large near-catastrophic flood, emerging roughly 120km southwest of the north-trending bend in the proto-Reull Vallis, may have scooped out Pomona Vallis. The waters subsequently roared downhill toward Hellas Planitia, focusing their strength perhaps along a proto-Reull Vallis, deepening and widening the valley to roughly its current breadth and depth. Evidence in the form of a large erosional field suggests that the waters also flowed over the plains southwest of Reull Vallis in a sheet

flood which stripped and plucked the wrinkle ridges and upper mantle unit of the plains sequence. As far as 400km west of Pomona Vallis, remnants of the mantle deposit are aligned parallel to slight topographic undulations and the inferred direction of flood flow (west), indicating that even though the remnants are not streamlined, the unit was likely plucked out of the ground as the flood passed laterally. By ~300km west of Pomona Vallis in the erosional field, valleys and streamlined landforms become more common, while masses of the mantle deposit become rare. These observations are consistent with increasing flow velocity as the flood descended over topographic lips on its way towards the Hellas basin floor. The flood, however, was likely not as catastrophic as those which emptied from Ares and surrounding valleys into Chryse Planitia, since streamlined flood plain features are not as well developed.

Evidence that Pomona Vallis was the source of the flood is circumstantial. The Vallis sits near the highest and easternmost edge of the eroded surface which radiates downstream toward Hellas Planitia [4]. The above-mentioned parallel ridges and undulations all converge on this edge. While there is no obvious chaotic terrain on the floor of Pomona Vallis, as there is in many catastrophic outflow channel heads, its floor is much more lumpy and uneven than the smooth, lineated floor of the main Reull Vallis. A few bean-shaped lumps on the floor of Pomona Vallis are parallel to the valley walls, suggesting that some erosive agent flowed down-canyon. Also, Pomona's position as a short and abrupt tributary of Reull Vallis suggests that it has a separate, younger origin.

The cause and source of water for the Pomona Vallis flood are uncertain, although the melting of large blocks of ground ice by some external source, such as coeval volcanism in Tyrrhena Patera, has been suggested [1,5]. The catastrophic release of confined, high pore-pressure groundwater, emerging as an enormous artesian spring initiated by some disruption event such as meteorite impact or crustal faulting, is also possible.

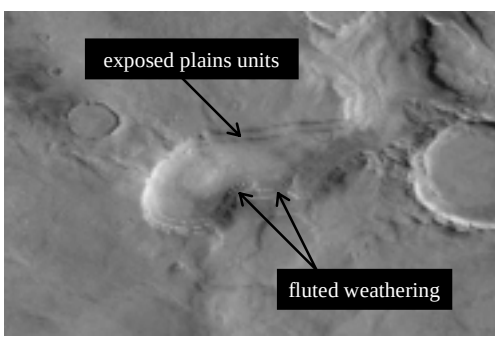

Figure 3: Pomona Vallis (MDIM; lat = [-45,-43], lon = [257,260]; frame width = ~120km).

Following the catastrophic Pomona Vallis flood, the then-fluvial Reull Vallis entered its fretted channel stage [6-8], probably in the Mid-Hesperian. Promoted by subsurface groundwater sapping, debris in upper Reull Vallis could have begun to flow slowly downslope. At a rate as small as a few millimeters per year, the debris flow could have swept down-valley, slowly obliterating all evidence of a previous fluvial history, such as canyon bottom stream channels, streamlined basement features (e.g. teardrop/media-lemniscate islands) and narrow V-shaped cross-sections, in much the same way that terrestrial valley glaciers alter mountainous terrain. The mouth of Reull Vallis may have filled with debris at one time, but subsequent debris flows from highland massifs have since covered the region. Reull Vallis today is a classic fretted channel: broad (~20km), deep (~1.5km), and boxy with few tributaries and with numerous longitudinal ridges and/or medial streaks which parallel the valley.

Throughout the Hesperian, meteorite bombardment of the region continued. The ejecta blankets of several impact craters (2-30km in diameter) overlie the stripped mantle and plains sequence west of the Vallis. Around the end of the Hesperian, a large fluvial flow from an undetermined source in the Dao Vallis/Hadriaca Patera region closed off the lower end of Reull Vallis and laid a thick (volcanic or sedimentary?) deposit over the lower northwestern limits of the Pomona flood plain. This surface appears to be younger than the stripped plains to the south because it has fewer impact craters. In the Early Amazonian a catastrophic flood from Harmakhis Vallis created a large (60km wide) outflow channel head and streamlined topography (e.g. teardrop islands) downstream. Harmakhis shows no signs of fretted terrain, perhaps because of the distance of its head from the highlands or its relatively young age.

The Early Amazonian was also characterized by frequent debris apron formation from the Noachian basin rim massifs. These lobate debris aprons are interpreted as talus, emplaced by either ice creep [5] or rapid debris avalanches, perhaps triggered by meteorite impacts.

Evolution of the Reull Vallis landscape continues to this day. Plastic flows from slopes near the convergence of Pomona and Reull Valles appear to be infilling the Valles. The absence of impact craters on its floor and the lack of a depositional fan at its mouth suggests that debris in Reull Vallis may have only recently stopped flowing. The transient wind streaks suggest a present-day wind direction from the northeast (N70E), which agrees well with the Mars general atmospheric circulation model [1]. The current monochromatic surface is likely due to a thick (few-mm ?) dust cover, distributed during dust storms [6].

Conclusions - No one theory suffices to describe all observed features in and around Reull Vallis. The landscape has been affected by several episodes of flooding, deposition and erosion. Pomona Vallis is interpreted to be the source of the large sheet flood since all flood features (mantle stripping and streamlined islands) appear to originate from this area.

References - [1] Tanaka K. & Leonard G. (1995) *JGR*, *100*, 5407. [2] Strom R., Croft S. & Barlow N. in *Mars*, ed. by Kieffer H. et. al. (1992), 383. [3] Crown D. & Greeley R. (1993) *JGR*, *98*, 3431. [4] USGS Map I-2160. [5] Crown D., Price K., & Greeley R. (1992) *Icarus*, *100*, 1. [6] Carr M. *The Surface of Mars.* (1981). [7] Carr M. (1995) *JGR*, *100*, 7479. [8] Carr M. *Water on Mars*. (1996).