EARLY HiRISE OBSERVATIONS OF ATHABASCA VALLES: A LAVA-DRAPED CHANNEL SYSTEM.

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Introduction: Athabasca Valles is a complex channel system located at ~9°N, 156°E in the Elysium Planitia region of Mars [1]. It begins at the Cerberus Fossae (an array of volcano-tectonic fissures), continues southwest, largely in distributary form, for ~300 km, and terminates at Cerberus Palus, a ~500-km-wide basin at the distal end of the main channel. The paucity of impact craters on the channel floor indicates a surface age of 1.5-200 Ma, which is exceptionally young for Mars [2]. Most researchers agree that Athabasca Valles was carved into a thick sequence of lava flows by catastrophic floods, but its more recent geological history is controversial. Competing hypotheses describe the current channel floor as (a) the icy or desiccated dregs of a sediment-rich aqueous flood that froze [3], (b) an explosively devolatilized CO_2- and/or H_2O-rich debris flow [4], (c) a primary flood-carved surface, perhaps with patches of ice-bearing sediments [5, 6], (d) a glaciofluvially eroded surface [7], or (e) solidified lavas that postdate aqueous flooding [8, 9]. Recently acquired High Resolution Imaging Science Experiment (HiRISE) images resolve this controversy.

HiRISE Data: The HiRISE camera, onboard the *Mars Reconnaissance Orbiter* (MRO) spacecraft, is returning spectacular pictures of the surface of Mars. As of early January 2007, HiRISE had acquired five images of Athabasca Valles. Collectively, they show that the flood-carved channel system was resurfaced by a lava sheet flow that issued from the same fissure system as the earlier floodwaters. Subsequently, the region was mantled by a relatively high-albedo layer that has since been stripped away by eolian processes.

The region north of the Cerberus Fossae is covered by overlapping, arcuate flows with rough (and consequently dark) terminal edges (Fig. 1). These near-vent flows appear to have been remarkably fluid as they were emplaced. Cross-cutting relationships record an age progression wherein the flows nearest the fissure are younger than those farther north. In places buried flow fronts show through younger and stratigraphically higher flows, attesting to their exceedingly thin nature (Fig. 1). Where shadow measurements can be made, the flow fronts are less than 1 m tall. We hypothesize that these flows were emplaced during a fissure eruption along the Cerberus Fossae. Pulses of very fluid lava traveled uphill for short distances, forming thin, brittle crusts as they did so. The rough leading edges probably evolved as the gravity-driven reversal of flow direction disrupted the brittle crusts on individual flows. The entire flow sequence captured in this image appears to have formed during the waning stages of the fissure eruption, as progressively smaller flows were emplaced closer to the source.

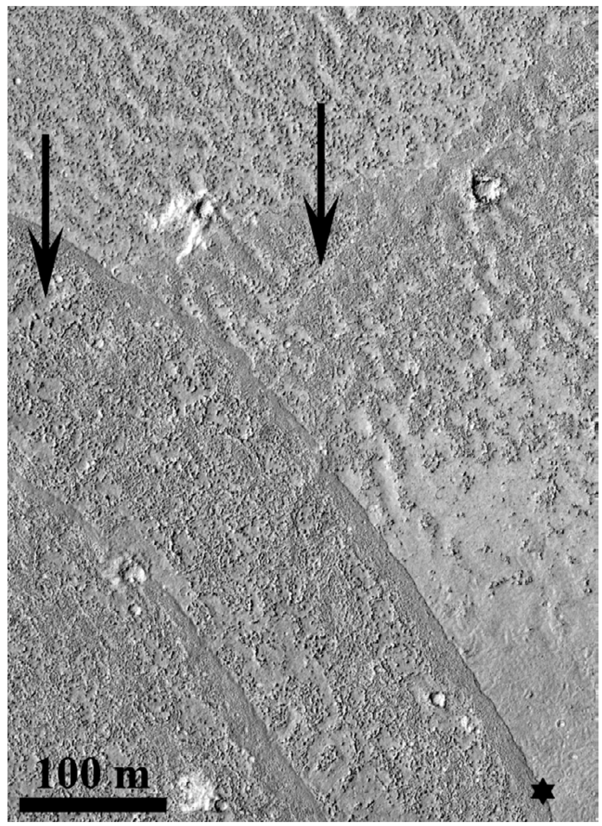

Figure 1. Thin, overlapping flows north of the Cerberus Fossae in HiRISE image PSP_001408_1900. Traces of buried flow fronts are indicated by arrows, and a star marks the location where a flow front height of <1 m was measured. Two bright-rayed Zunil secondary craters are visible, one between the arrows and the other to the right of the scale bar.

Using datasets that provide good regional coverage, such as THEMIS and MOC, these lava flows can be traced from the source region along the Cerberus Fossae, through Athabasca Valles, and, ultimately, into Cerberus Palus and eastern Elysium Planitia. The flows are also readily visible in all HiRISE images acquired to date over these areas. Thus, the channel floor is not a primary erosion surface with a heterogeneous mantling of sediments.

The lavas in Athabasca Valles exhibit two dominant surface textures: polygonal and platy-ridged. It appears that the difference between the two is only surficial, with the crust on platy-ridged lavas having endured a complex strain history (Fig. 2). Numerous 10-100-m-scale ring/mound landforms (RMLs) occur on the flows, both where they are polygonal and platy-ridged. These are hydrovolcanic constructs similar to terrestrial rootless cones (a.k.a. pseudocraters) [10]. Associated structures, such as wakes and moats, are diagnostic of RML formation atop the thin, brittle crust of an active lava flow. The observed continuum of wake morphologies indicates that the crust rafted downstream while the steam sources remained fixed to the substrate. Broken and tilted slabs at moat perimeters coupled with surface-age constraints indicate that the crust can support prominent overhangs for $\geq 10^6$ years without sublimating or disaggregating, which precludes a lithology of ice or ice-cemented sediments. Impact craters that have excavated the flows are commonly ringed by boulder-strewn ejecta blankets, which indicate a rocky lithology consistent with lava.

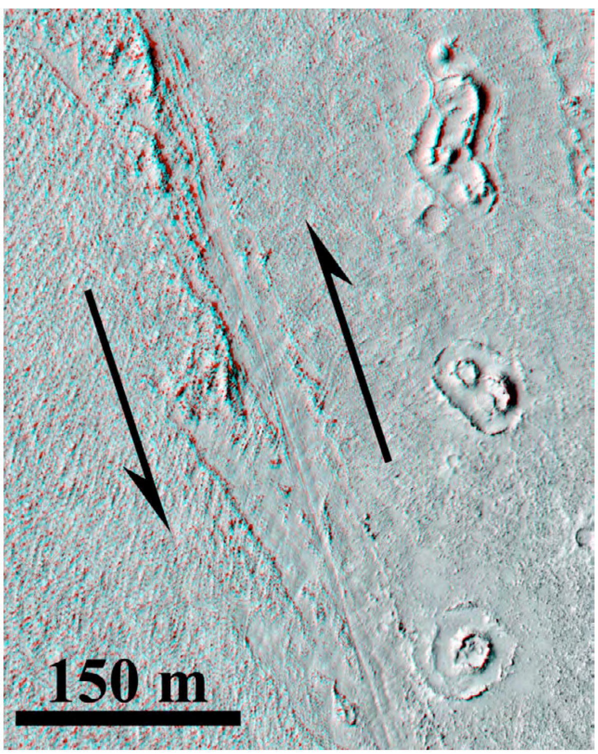

Figure 2. Anaglyph from stereo images PSP_001540_1890 and PSP_001804_1890. A shear zone separates platy-ridged lavas in the center of the channel (left) from polygonal lavas at the channel margin (right). Black arrows indicate relative offset. RMLs are visible on the right.

HiRISE images show that the lava sheet flow deflated as fluid in its interior drained downstream into Cerberus Palus. This process left Athabasca Valles draped by a thin layer of lava, but largely preserved the earlier flood-carved topography. A low mesa near the center of HiRISE image PSP_001606_1900 has RMLs on its surface and fractures around its perimeter. The RMLs indicate that lava topped the mesa, and the fractures appear to have formed where the brittle crust broke as it was draped over the underlying topographic feature. In other areas, boulder chains are probably composed of slabs of crust that were stranded on flood-carved terraces along the channel margins during deflation. Although the channel system is almost entirely draped by lava, patches of primary flood-deposited materials may still be exposed at the surface. Low-centered polygons can be seen atop some streamlined mesas (e.g., PSP_001540_1890). These are similar to ice-related polygons at higher latitudes, and they may have formed in freezing flood sediments.

Bright-rayed Zunil secondary craters pepper the floor of Athabasca Valles, from its near-vent region to its most distal reaches [2]. HiRISE shows that the bright rays are wind-swept, positive-relief features. Similar bright material can be found in the lees of topographic obstacles. These are apparently remnants of a widespread, light-toned mantling deposit that was stripped away except in places where it was armored by impact processes or sheltered from the wind.

Conclusions: HiRISE images show that the flood-carved channel system at Athabasca Valles is almost entirely covered with a thin coating of lava. The lava flow was both voluminous and extremely fluid. In several places it topped high-water marks before draining out and thinly draping the channel system. The drained lavas continued downstream, ponding in Cerberus Palus and eastern Elysium Planitia. The former is the site of a purported equatorial “frozen sea” [11], which is, instead, a solidified body of lava. After the lavas were emplaced, the region was covered by a layer of bright and friable material. The Zunil impact event occurred while this bright deposit mantled Athabasca Valles. Later, the bright material was largely removed by eolian erosion, leaving the channel system as we now see it.

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