LAVA COILS IN CONTEXT: DYNAMICS OF THE ATHABASCA VALLES LAVA FLOW. A. J. Ryan[1], C. W. Hamilton[2], and P. R. Christensen[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ (andy.ryan@asu.edu), [2]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ.

Introduction: Athabasca Valles is an extensive outflow channel that contains some of the best-preserved surface textures and lava flow morphologies on Mars. It is thus one of the most widely studied regions on the planet [e.g., 1,2,3]. Although the origin and nature of the surface materials that now coat Athabasca Valles and its distal flow members have been debated, the majority of observations (e.g. platy-ridge flow morphologies, rootless cones, lava coils) are indicative of a volcanic origin [1,3,4,5].

Orbital observations and flow modeling suggest that low-viscosity lava emanated from the Cerberus Fossae fissures, flowed through Athabasca Valles, and ponded in the Cerberus Palus basin [5]. The flow unit in its final and present state is only a few meters thick in the proximal portions of Athabasca Valles. Ring- and mound-shaped landforms, similar to hydrovolcanic rootless cones, are common on these flow surfaces [5].

Downstream of Athabasca Valles' main channels, the flow morphology gradually changes to a platy-ridged volcanic flow featuring large, rubbly crust fragments that are interpreted to have been fragmented and rafted atop a fluid interior [6]. The now-solidified flow surface between these rubbly plates is characterized by meter-scale polygons with raised centers and other less regular meter-scale topographic undulations. This polygonal terrain is sometimes punctuated by spiral/whorl patterns, similar in morphology to terrestrial lava coils, that are unique to the Athabasca Valles flow unit [4] (Fig. 1.). Here we discuss an updated model for the formation of the coils as well as our current knowledge of their regional distribution. The crustal motion and lava coil distribution in Cerberus Palus allow us to reconstruct the flow history here with very high fidelity.

Cerberus Palus Formation Model: The rubbly plates in Cerberus Palus are similar to auto-brecciated "rubbly pahoehoe" surfaces present in the Icelandic 1783–1784 Laki eruption [6,7]. Similarly on Mars, we expect that a wide sheet flow initially advanced across Cerberus Palus. As the flux of lava continued in the flow interior, the surface crust was compressed against the brittle flow front. The brecciation from this stress led to a jumbled, rubbly surface. This process continued, eventually producing a nearly continuous crust atop a massive lava lake, spanning much of Cerberus Palus. This crust was not necessarily a rigid plate but more likely consisted of interlocking angular pahoehoe blocks bound to an interior flow skin [7].

The surface was later disrupted such that the rubbly crust was fragmented, rafting portions of crust down channel atop a molten interior. The source of this disruption may be related to a large up channel pulse of lava, leading to inflation and fracturing of the flow crust in Cerberus Palus and renewed flow further down channel. Alternatively, the surface disruption could have been caused by a sudden drainage of fluid lava that was previously confined in Cerberus Palus as a perched lava pond [c.f., 8]. This latter hypothesis is more consistent with the flow direction inferred from the rubbly plate geometry.

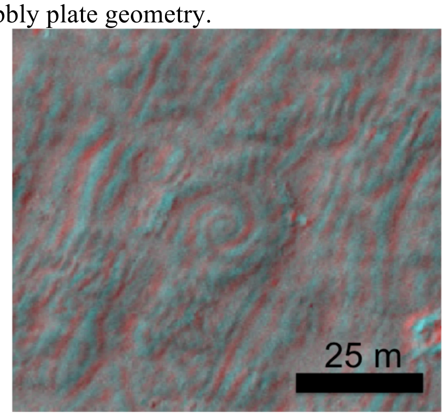

Figure 1. A well-preserved lava coil on Mars in Cerberus Palus (red/cyan anaglyph). Location is left-most star in Fig. 3. HiRISE stereo pair: ESP_027649_1850_ESP_027372_1850.

As the rubbly flow surface was disrupted, fluid lava was exposed in rift zones. These exposed lavas immediately began solidifying to eventually produce crust patterned with high-centered polygons similar in scale and morphology to terrestrial counterparts on stagnated ponds in channelized flows and lava lakes. In several locations, the rubbly crust was rifted apart in a manner that produced spreading center-like zones on the surface of the newly exposed, crust forming lava. The polygonal crust also appears to have been rifted and translated across a fluid interior, much like the rubbly plates.

Lava Coils Formation and Distribution: The lava coils in Cerberus Palus are somewhat different than their terrestrial counterparts, particularly in terms of scale. Terrestrial lava coils are typically less than a meter in diameter but may be as large as 10 meters. Martian coil counterparts are as large as 100 m in some cases, but are present down to the limits of discernment in HiRISE full-resolution imagery (1–2 meters).

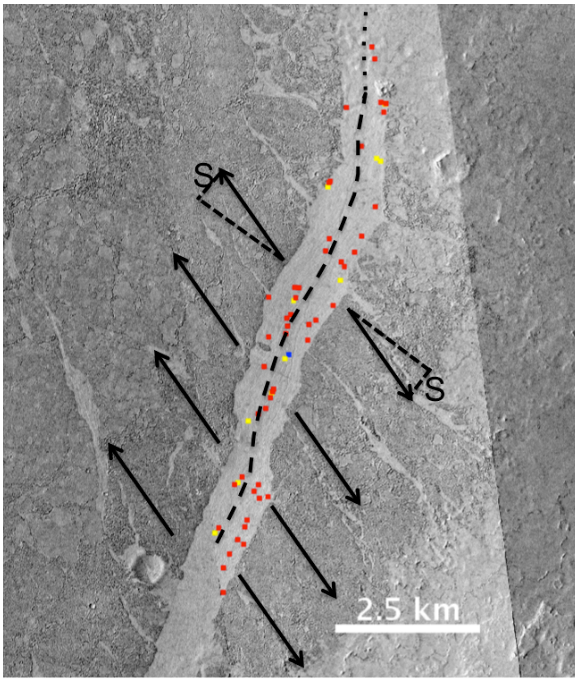

Figure 2. HiRISE ESP_028084_1845 over CTX mosaic. The terrain within a rift in the rubbly crust in Cerberus Palus contains numerous lava coils, indicated by color markers. Red = clockwise spiral in; blue = counterclockwise; yellow = too degraded or small to tell. Arrows show direction of rubbly crust motion inferred from crust edge geometry. Two arrows are broken into directional force components to illustrate the shearing component "S". Shear is right lateral, which would produce clockwise coils.

Martian coil size and context suggest that their formation mechanism is different from that of terrestrial coils. On Earth, lava coils typically form along the margins of channelized flows due to shear. Their handedness has been recognized as a convenient indicator of shear direction, thus facilitating flow mapping even when original flow channels are obscured by later modification [9]. The coils on Mars are not in or near any channelized flows. They have been identified exclusively in zones of flow stagnation and ponding. Their abundant distribution primarily along the distal southern margin of Cerberus Palus may be associated with, particularly, the low kinetic energy in the flow.

We expand on the hypothesis that the lava coils in Cerberus Palus formed in lava lake spreading centers [4]. In this model, new crust is generated as the rubbly plates rift apart in a manner similar to mid-ocean ridges or spreading processes observed on active lava lakes in summit calderas on Earth. Laboratory models of spreading centers have shown that spiral-shaped crustal patterns can form when the direction of spreading is *not* perfectly perpendicular to the axis of the spreading ridge [10]. The handedness, or orientation, of the spiral is related to the direction of the shear force component in such a system (Fig. 2).

The locale, orientation, and frequency of lava coils in the Cerberus Palus crustal rift zones are consistent with the crustal spreading laboratory model [10], suggesting that they too may have formed in a spreading center. Fig. 3. shows that the direction of the shear force vector and the orientation of the observed lava coils are in good agreement. These observations indicate that the martian lava coils formed in a manner that has yet to be well documented in a natural system on Earth, despite their apparent similarities with terrestrial lava coils.

References: [1] Plescia (1990), *Icarus*, 88, 465-490. [2] Murray et al. (2005), *Nature*, 434, 352-356. [3] Jaeger et al. (2007), *Science*, 317, 1709-1711. [4] Ryan and Christensen (2012), *Science*, 336, 449-452. [5] Jaeger et al. (2010), *JGR*, 205, 230-243. [6] Keszthelyi et al. (2004), *G3*, 5, Q11014. [7] Guilbaud et al. (2005), *Geol Soc Am Spec Pap 396*, 81-102. [8] Haack et al. (2006), *JGR*, 111, E06S13. [9] Peck (1966), *USGS Prof Pap 550B*, 148-151. [10] Katz et al. (2005), *New J. Phys.*, 7,

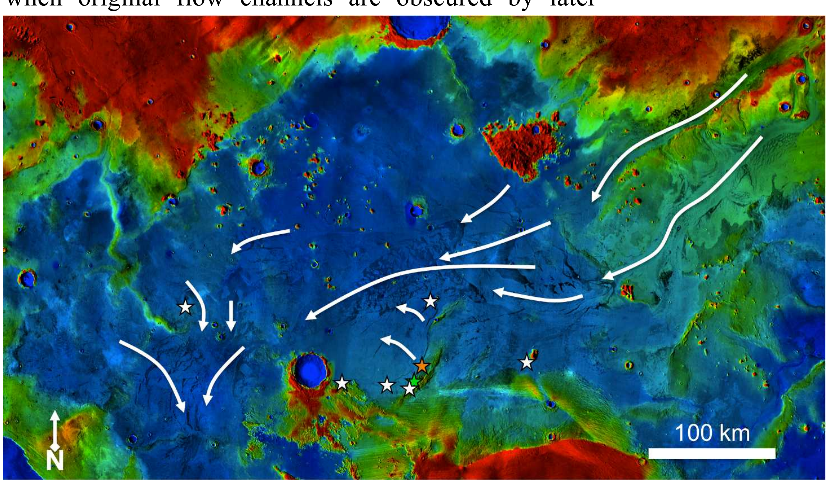

Figure 3. Cerberus Palus. THEMIS day IR with MOLA colorized elevation. The margin of the flow unit is roughly demarcated by color transition from blue to green. Athabasca Valles enters from northeast. Arrows indicate direction of rubbly crust motion, as determined by crust geometry, during flow disruption event. Stars show location of HiRISE images that contain lava coils. Orange star is Fig. 2. Green star image used in [4]. ~600 lava coils have been identified in total.