RECONSTRUCTING THE BURIED FLOOR OF ATHABASCA VALLES: INCREASED CHANNEL DEPTH ESTIMATES FROM RADAR STUDIES. G. A. Morgan[1], B. A. Campbell[1], L, Carter[2], J. Holt[3], J. Plaut[4] and A. Jasper[5], [1]Center for Earth and Planetary Studies, Smithsonian Institution, MRC 315, PO Box 37012, Washington DC 20013, morganga@si.edu. [2]University of Arizona, [3]University of Texas. [4]Jet Propulsion Laboratory [5]. Pennsylvania State University.

Introduction: The ability of the SHARAD sounder to delineate subsurface structural features has proved pertinent in revealing the morphologic properties of buried Amazonian outflow channels [1]. Morgan et al [1] investigation of the >1000 km long Marte Vallis outflow channel demonstrated that SHARAD data could be used to reconstruct complex channel features that have been embayed by lava flows. The study also provided refined depth estimates of the channel floors. Marte Vallis is not the only Amazonian aged outflow channel on Mars. The Elysium Planitia region contains multiple channel systems, including the >300 km long Athabasca Valles system, which represents the youngest outflow channel on Mars [2-3]. As is the case with Marte Vallis, lava flows have embayed the Athabasca Valles channels. Here we document analysis of SHARAD data that reveal new details of the original channel beds.

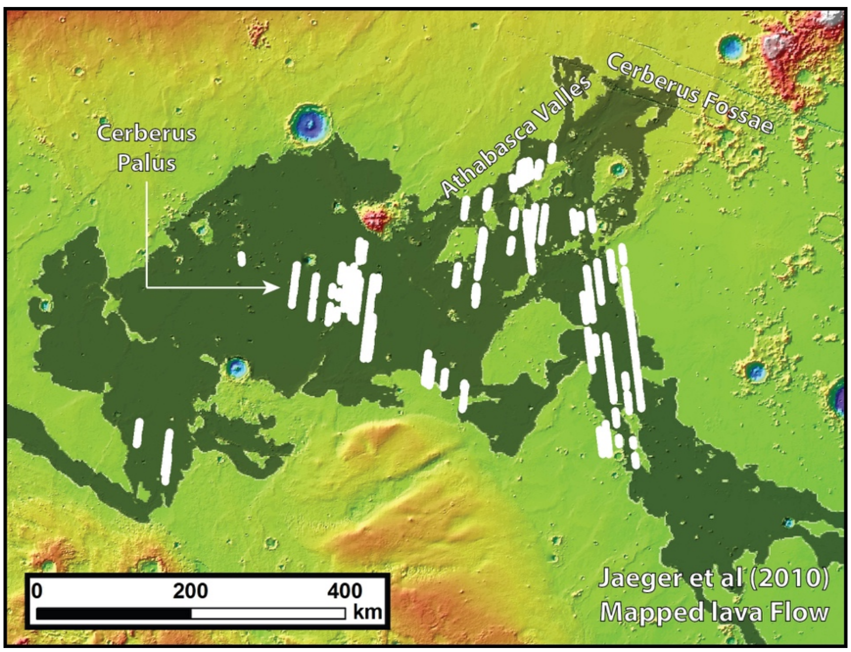

Fig. 1 *The Jaeger et al [9] mapped flow unit within western Elysium Planitia. The white lines represent the locations where subsurface reflectors have been identified with the SHARAD data.*

Athabasca Valles and the Youngest Lava Flow on Mars: Athabasca Valles is situated within northwestern Elysium Planitia. The channels, which are tens of kilometers wide at their greatest extent, emanate from a section of the Cerberus Fossae fracture system and debouch ~280 km to the southwest within the Cerberus Palus basin (Fig. 1). Though several smaller distributary channels also feed off the main channel towards the southeast. Athabasca Valles contains many of the morphological assemblages suggestive of the action of liquid water - such as tear drop shaped islands - that are present within the larger, Hesperian outflow channels surrounding Chryse Planitia. Consequently, the predominant interpretation is that Athabasca Valles was formed through fluvial erosion [2,4-5]. The abrupt opening of the channels directly to the south of Cerberus Fossae argues the floods were sourced from a groundwater reservoir and released to the surface as a result of tectonic extension, possibly associated with dike emplacement [6]. Previous study of Marte Vallis using SHARAD data [7] also identified Cerberus Fossae as the source of the floods. However, due to Cerberus Fossae also serving as a conduit for basaltic eruptions, some authors have suggested the outflow channels were at least partly the product of thermal and mechanical erosion by lava flows [8].

Analysis of Athabasca Valles using HiRISE image data identified lava flow highstands ~50 m above the channel floor [9]. This observation suggests that Athabasca Valles were initially completely filled with lava before the flows drained away leaving only a thin veneer of basalt throughout the channel system [9]. Due to this, multiple hydrological and lava dynamic studies [e.g. 9-10] have considered the current cross section of Athabasca Valles to be a close approximation of the channels prior to the eruption of the most recent lava flows. Further regional mapping by [9] revealed the lavas extend beyond the channels forming a 250,000 km^2 expanse, considered to be the youngest individual lava flow on Mars [Fig. 1].

The age of Athabasca Valles is constrained by the volcanic terrain, within which the channels are cut and the age of the younger lava flow that later embayed the channels. Age estimates of these two volcanic surfaces provide an age range of 10 - 100 Ma [5]. As has been identified from detailed morphological studies of the

Hesperian outflow channels, the formation of Athabasca Valles may not have been a single event, but the result of multiple floods.

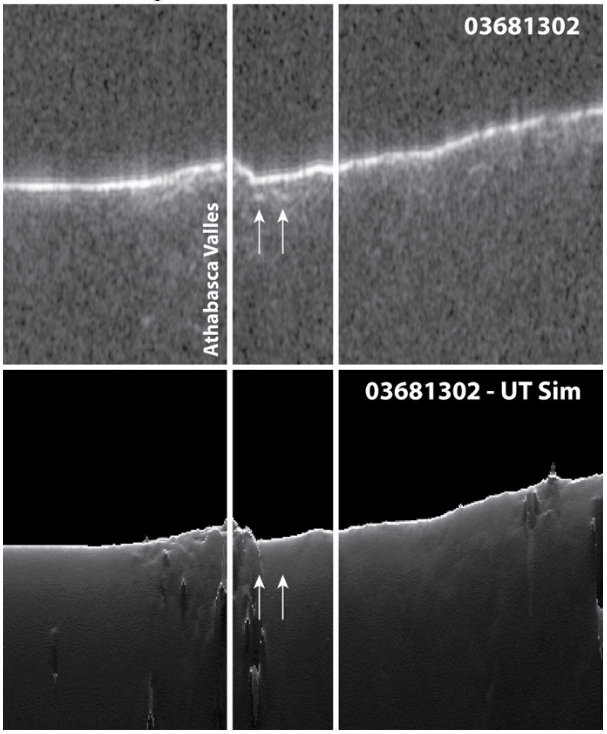

Figure 2 *(Top) Example of a SHARAD radargram from an orbit that has crossed the main channel of Athabasca Valles. The reflector observed within the channel is highlighted by the two arrows. (Bottom) University of Texas clutter simulation of the same radargam. Note the absence of any expected clutter below the channel floor, which argues the reflector in the radargram is a real subsurface feature. See [11] for details on the production of SHARAD clutter sims.*

Application of the SHARAD Radar: SHARAD data are presented as radargrams (Fig 2), displaying round-trip delay time on the vertical axis and along-track distance on the horizontal axis. The radar operates at 20 MHz center frequency (15m wavelength) with a 10 MHz bandwidth, and has a free-space vertical resolution of 15 m, equivalent to a 5 – 10 m vertical resolution for common silicic geological materials [12]. At this wavelength SHARAD is capable of probing hundreds of meters into the subsurface. With synthetic aperture focusing and dependent on the surface roughness, SHARAD has an along track spatial resolution of 300 – 500 m. Such spatial and penetration resolution is optimal for mapping the multiple volcanic subsurface units underlying the thousands of km expanse of Elysium plains [1,7,13], which are estimated to be < 200 m thick [14]. Previous studies using SHARAD data have mapped out buried stratigraphic stacks of volcanic flows [7] in addition to the Marte Vallis channels [1].

The speed of the radar signal below the surface is indirectly proportional to the square root of the dielectric permittivity of the subsurface. As Elysium Planitia is comprised of volcanic terrain we can use laboratory measurements of the permittivity of basalt to convert the round trip time delay of features identified below the surface into depth estimates. In the case where buried channel features are identifiable within the SHARAD radargrams, we can apply this technique to estimate the depth of the channel prior to being embayed by lava.

SHARAD Mapping of Athabasca Valles: We conducted a survey of the ~300 tracks, which comprise the SHARAD coverage of the Jaeger et al [2010] mapped volcanic flow. Clusters of subsurface reflectors were found below several regions of the flow, many of which terminate or dip towards the surface directly below the external boundary of the flow (Fig 1) suggesting they are intrinsically related. We therefore, argue that the reflectors represent the base of the lava flow.

One reason we do not observe reflectors below other parts of the [9] flow unit may be because the base of the lava is too thin to separate from the surface reflector within the range resolution of SHARAD (i.e. < 10 m). Alternatively, there may not be a sufficient dielectric contrast between the lava flow and the underlying material to generate a reflection.

The most significant result of the SHARAD analysis is the identification of reflectors below the current floor of the main Athabasca Valles channel (Fig 1 – 2), which we interpret to represent the original base of the channel. Assuming a dielectric permittivity for basalts of 5 – 9, the reflectors are several tens of meters deep. Whether, these reflectors mark the base of the lava flow within the channel or represent the base of another material which had been deposited prior to the eruption of the [9] flow is uncertain. Nevertheless, the SHARAD analysis suggests that the previous depth assumptions used in flow modeling (both for water and lava) require a revisit.

References: [1] G. A. Morgan et al., Science, 340, 607 (2013). [2] D. M. Burr, et al., Icarus 159, 53 (2002). [3] A. S. McEwen et al., Icarus 176, 351 (2005). [4] D. Berman and W. Hartmann, Icarus 159, 1–17 (2002) [5] J. Plescia, Icarus 164, 79-95 (2003) [6] J. Head GRL, 30, 1577 (2003) [7] G. A. Morgan et al., JGR, 42, 7336 (2015) [8] L, Keszthelyi et al., LPSC #1683 (2014) [9] W. Jaeger et al., Icarus, 205, 230 (2010) [10] N. McIntyre et al., J. Geophys. Res., 117 (2012) [11] P. Choudhary et al., IEEE Geosci. Remote Sensing Lett, 13, NO. 9, (2016) [12] R. Seu et al (2004) Planet Space Sci. 52, 157. [13] L. Carter et al., Icarus, Volume 199, doi:10.1016/j.icarus.2008.10.007, (2009) [14] J. Vaucher et al., Icarus, 204, 418 (2009)