

USING RADAR DATA TO IDENTIFY AREAS OF INTEREST AND PLAN TRAVERSES IN VOLCANIC TERRAINS. R. M. Maj¹, C. D. Neish², M. Zanetti², L. L. Tornabene², ¹The University of British Columbia, Vancouver, BC, Canada (rachel.maj@alumni.ubc.ca), ²The University of Western Ontario, London, ON, Canada.

Introduction: The Craters of the Moon (COTM) basaltic lava field, located in the Eastern Snake River Plain in Idaho is the largest lava field in the contiguous United States. The lava field covers an area of about 1,600 km² and contains up to sixty different lava flows that formed between 15,000 and 2,100 years ago during eight separate eruptive periods [1]. We identified and characterized the surface roughness of various lava flows using multiple remote sensing data sets in order to plan optimal traverses to specific lava flows during the field campaign in August 2016. Routes along smooth surfaces determined from remote sensing data led to the most efficient pathways to select lava flows. A similar approach could be used to explore terrains of varying roughness, such as martian lava flows or lunar impact melt flows.

Remote Sensing Data: We used three remote sensing data sets to identify targets of interest within COTM. They include two radar data sets - AIRSAR L-Band data (24 cm wavelength) collected in March 2003 and RADARSAT-2 C-Band data (5.6 cm wavelength) collected in October and November of 2015 and August 2016. The third data set was Landsat 8 imagery (VNIR) collected in August 2015 (Fig. 1).

We used the circular polarization ratio (CPR) of the two radar data sets to study the surface properties of different lava flows at COTM. CPR is the ratio of the same sense circular polarization to the opposite sense circular polarization, and provides information on the surface roughness at the scale of the radar wavelength. Very low CPR values are indicative of smooth surfaces, such as smooth pahoehoe lava flows or ash in a lava field like COTM. Higher CPR values are indicative of rough surfaces, such as a rubbly lava flow or a lava flow containing natural corner reflectors like large blocks [2]. Vegetation also affects CPR values and can cause complications when studying the surface properties of vegetated lava flows on Earth. In order to minimize the effect of vegetation on CPR values at COTM, Landsat 8 was used to highlight areas with high concentrations of vegetation and eliminate these flows as potential candidates for sample return. A band combination of R: 0.85-0.88 μm , G: 0.64-0.67 μm , B: 0.53-0.59 μm , can be used to identify healthy vegetation as 'red', as it highlights the "red edge" associated with Fe in chlorophyll.

The zonal statistics tool in ArcGIS was used to determine which lava flows contained the greatest difference in C-Band vs L-Band CPR values. This data was used to constrain the size of the radar scatterers, and

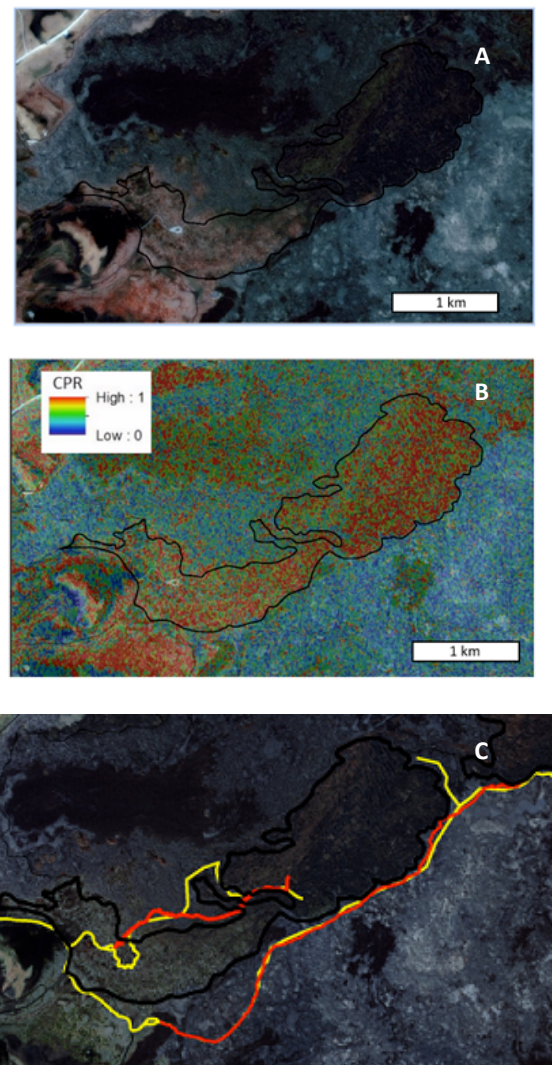


Figure 1: Devils Orchard Flow (outlined in black) as seen at the (a) Landsat 8 colour infrared band combination (VNIR) (b) AIRSAR L-Band CPR (c) Comparison of planned (yellow) and executed (red) traverses to Devils Orchard Flow.

hence, the type of surface texture for each lava flow. This process was carried out for all non-vegetated lava flows mapped by Kuntz et al. [3]. A plot of L-Band CPR vs. C-Band CPR (Fig. 2) in general showed most lava flows in COTM had mean CPR values of about 0.3-0.4 at C-Band and mean CPR values of about 0.5-0.7 at L-Band. Several outliers were identified, however, that had significantly higher CPR at L-Band vs. C-Band [4]. Two lava flows of particular interest - Serrate Flow and Devils Orchard Flow - had much lower CPR at C-Band compared to L-Band. One explanation

for this behavior is a blocky flow with characteristic size scale of ~24 cm, and minimal ~5 cm scatterers [5]. Radar properties are being compared to petrographic data to further investigate this process [6].

Traverse Planning: To test our hypothesis, it was necessary to reach these lava flows during the field campaign planned for August 2016. However, the two geologic units chosen for ground truthing are not easily accessible by foot. There is no existing pathway to the flows, and they were at a distance of 3-6 km from their respective parking lots within the park. The areas of interest could only be accessed by walking over lava flows of varying roughness. CPR was used to plan the safest traverse over these lava flows. Existing roads and hiking trails were located within the park and traced out in ArcGIS. Once the planned traverses reached the end of the hiking trail, L-Band CPR was used to determine the smoothest (and presumably) safest route to the lava flows of interest. COTM contains an abundance of sagebrush, which is also very difficult to walk through and eliminated from traverse planning using the Landsat 8 color infrared band combination. As a result, the planned traverses were longer than a straight path over the lava flows would have

been. The traverse to Serrate Flow was about 5 km in distance as opposed to the shorter 3.5 km straight path to the flow.

Results: We compared the planned traverses to those executed in the field, which were carried out following planned routes while choosing the smoothest and safest looking terrain in real time. We found that those traverses executed in the field did not vary much from the planned traverses (Fig. 1). The regions of low CPR in L-Band were typically smooth pahoehoe flows that were much easier to traverse than the high CPR rubbly and blocky lava flows. A straight path traverse through these terrains took much more time to complete due to the difficulty of navigating the loose and sharp rocks underfoot. Choosing traverses over low CPR lava flows ultimately resulted in less time taken to travel to the lava flows of interest.

We also collected LiDAR data to determine the source of the differing CPR results for these lava flows of interest. We found that the regions of high CPR at L-Band were almost universally blocky lava flows. However, it is not yet clear if there is a preferred block size. Indeed, more recent RS2 data collected in August 2016 points to a higher CPR at C-Band than the data collected in October 2015, suggesting a wider range of block sizes than previously assumed. The reason for this discrepancy is not yet known.

Conclusion: When planning traverses over lava flows of varying roughness, CPR data at L-Band and Landsat 8 color infrared data proved to be the most useful data sets to plan the safest, most efficient routes. Following traverses over lava flows with low CPR ultimately led the team along the most optimal route to the areas of interest. This technique can be used for the navigation of rough terrain in other regions. In particular, radar data will be critical for the future of human exploration of the Moon and Mars.

Acknowledgements: RADARSAT-2 Data and Products © MacDonald, Dettwiler and Associates, Ltd. (2015) – All Rights Reserved. RADARSAT is an official trademark of the Canadian Space Agency.

References: [1] Hughes, S.S. et al. (1999) In: *Guidebook to the Geology of Eastern Idaho*, Idaho Museum of Natural History, Pocatello, ID, pp. 143-168. [2] Neish, C.D. and Carter, L.M. (2014) In: *Encyclopedia of the Solar System 3rd Edition*, Academic Press, London, UK, pp. 1133-1159. [3] Kuntz, M.A. et al. (2007) USGS Map 2969. [4] Zanetti, M. et al. (2016) LPSC 47, Abstract #2429. [5] Bulmer, M.H. et al. (2005) *J. Geophys. Res.-Planet.* 110 (B1). [6] Tolometti, G. D. et al., (2017) LPSC 48.

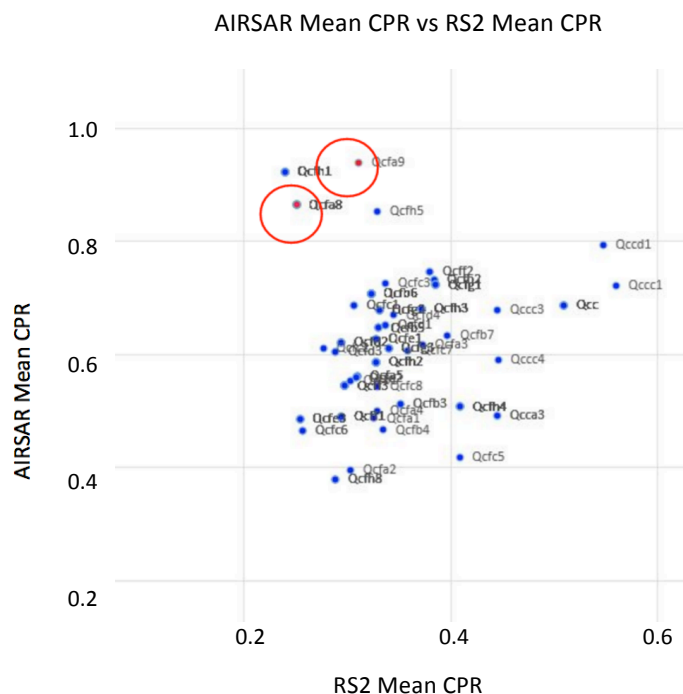


Figure 2: Graph comparing RADARSAT-2 C-Band CPR and AIRSAR L-Band CPR of geologically young lava flows at COTM. Geologic units of interest Serrate Flow (Qcfa8) and Devils Orchard Flow (Qcfa9) are highlighted in red.