PROCEEDINGS OF THE TWENTY-SEVENTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

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TECTONIC EVOLUTION OF THE FLYSCH OF THE CHUGACH TERRANE ON BARANOF ISLAND, ALASKA*:*
Faculty: *JOHN GARVER*, Union College, *CAMERON DAVIDSON*, Carleton College
Students: *BRIAN FRETT*, Carleton College, *KATE KAMINSKI*, Union College, *BRIANNA RICK*, Carleton College, *MEGHAN RIEHL*, Union College, *CLAUDIA ROIG*, Univ. of Puerto Rico, Mayagüez Campus, *ADRIAN WACKETT*, Trinity University,

EVALUATING EXTREME WEATHER RESPONSE IN CONNECTICUT RIVER FLOODPLAIN ENVIRONMENT*:*
Faculty: *ROBERT NEWTON*, Smith College, *ANNA MARTINI*, Amherst College, *JON WOODRUFF*, Univ. Massachusetts, Amherst, BRIAN YELLEN, University of Massachusetts
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Students: *SUSAN KONKOL*, Univ. Nevada-Reno, *JESSICA MCHALE*, Mt. Holyoke College, *RYAN SAMUELS,* Franklin & Marshall College, *MEGAN SWITZER*, Colgate University, *HESTER VON MEERSCHEIDT*, Boise State University, *CHARLES WISE*, Vassar College

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Keck Geology Consortium: Projects 2013-2014
Short Contributions— Martian Pāhoehoe Lava Project

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CHRIS HAMILTON, University of Maryland and NASA-GSFC
JAKE BLEACHER, NASA-GSFC
BRENT GARRY, NASA-GSFC

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CHARLES WISE, Vassar College

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ANALYSIS OF CRACK SYSTEMS WITHIN THE MCCARTYS LAVA FLOW WITH POSSIBLE APPLICATIONS TO MARS

CHARLES WISE, Vassar College

INTRODUCTION

The McCartys Lava flow is the youngest basaltic lava flow on the Zuni-Bandera Volcanic Field (ZBVF). Its source is a low shield volcano located at the center of the flow (approximately 25 miles south of the intersection of Interstate Highway 40 and New Mexico Highway 117) (Laughlin et al., 1993). Most of the lava flowed northward, following a pre-existing drainage, reaching as far as the San Jose Valley, as well as southward for about six miles, covering an area of 119 sq. miles (Nichols, 1946). The flow is typically a vesicular porphyritic basalt dominated by large plagioclase phenocrysts within 4 km of the source and olivine phenocrysts at greater distances (Carden and Laughlin, 1974; Laughlin et al., 1993). Dunbar and Phillips (2004) estimated the average cosmogenic 36Cl age for the McCartys flow to be 3.9 ±1.2 ka. Of particular interest is the Lava Falls area, located on the southern edge of the McCartys flow, which is dominated by pahoehoe flows. Topographic features such as plateaus, (containing several concentric and elongate depressions), monoclines, escarpments, and deep cracks have been interpreted as formed by inflation of pahoehoe sheet flows (Mabery et al, 1999; Hon et al., 1994).

This project examines the cracks and crack systems that are part of these topographic features present at Lava Falls using detailed field observations, data differential GPS transects, and geographical information systems (GIS) mapping. Patterns indicative of inflation from these crack data can then be used through remote sensing to identify possible examples of inflation in the Elysium Volcanic Province of Mars.

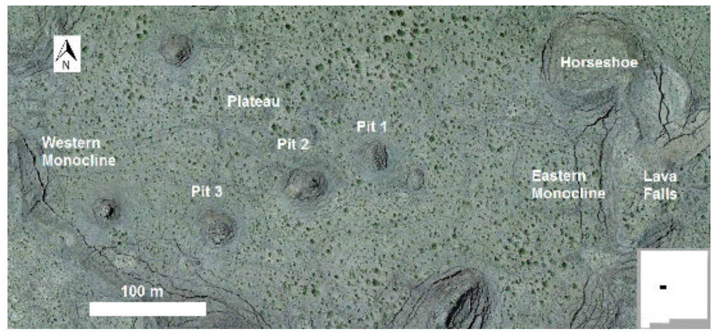

Figure 1 - Lava Falls and surrounding area of the McCartys Lava flow on the Zuni-Bandera Volcanic Field, located within El Malpais National Monument, New Mexico, with major investigation sites identified.

METHODOLOGY

Eight transects were mapped across the Lava Falls area using a differential GPS (DGPS) unit relying on both Real Time Kinematic (RTK) and Post-Processing Kinematic (PPK) processing methods. These transects were accompanied by detailed observations of the transect pathway, including descriptions of lava textures, topography, and measurements of crack widths and crack depths. Transects A, B, C, D, E, and F were measured in and around the topographic feature identified as the Horseshoe in Figure 1. Transects G and K were measured across the plateau from east to west. Transect K also included Pits 1, 2, and 3. The approximate pathways of all transects are shown in Figures 2 and 3, respectively. For Transects A-E, RTK processing was used because the base station was always visible. For Transects G and K, PPK was used because the transect ranges put the rover unit beyond the line of sight of the base station.

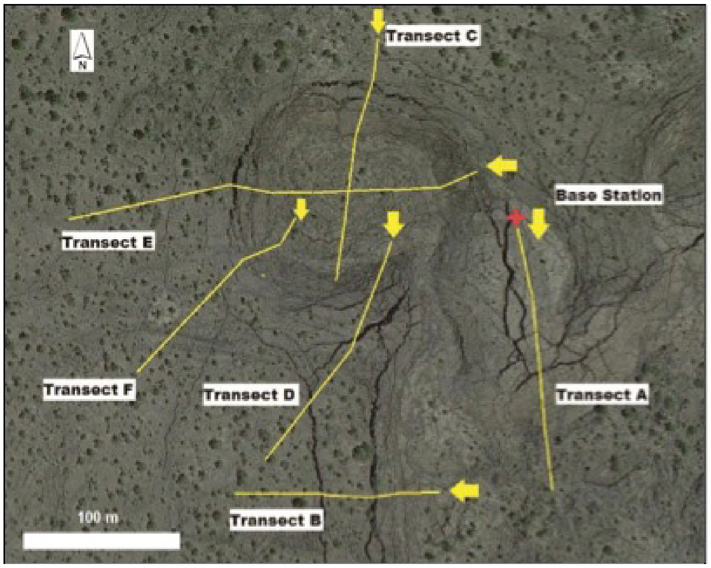

Figure 2 - The DGPS transects mapped at the Horseshoe near Lava Falls, including the base station. Transects A-F were mapped using PPK processing

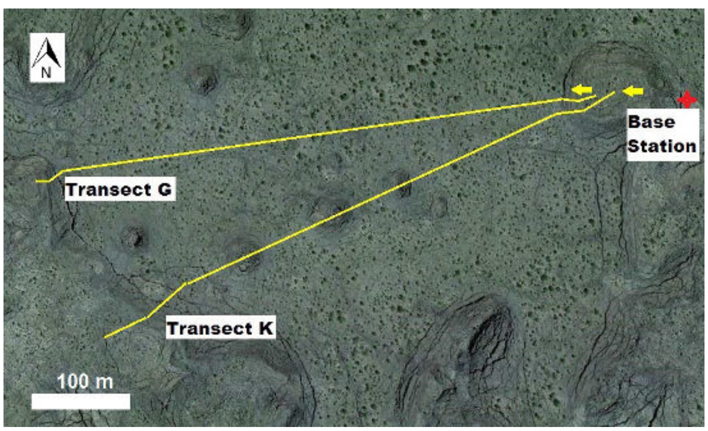

Figure 3 - The DGPS transects mapped from east to west across the plateau from the Horseshoe. Transects G and K were mapped using PPK processing.

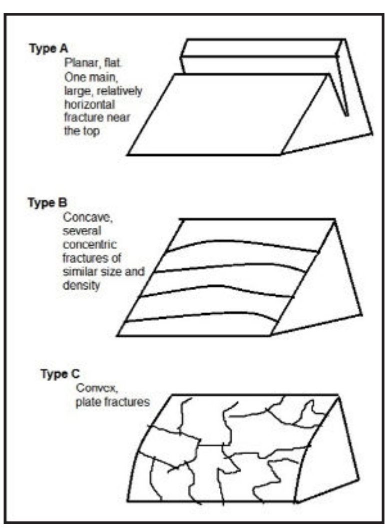

Figure 4 - Cartoon sketch of the three types of crack patterns visible at and around the Lava Falls area.

Additional mapping of the flows was executed by importing base maps and georeferenced images of the McCartys flow into the ESRI ArcMap GIS software package. Shapefiles were used to distinguish cracks, flow margins, and pits. The visual result of this mapping was a rich overview of different crack types, densities, and locations across the plateau and the monoclines in and around the Lava Falls area.

RESULTS

Crack Types

Initial field observations of the various crack systems visible at Lava Falls and the surrounding area allowed for the rough division of these into three broad different categories (Figure 4), determined by Dr. Christopher Hamilton of the NASA-Goddard Spaceflight Center.

ArcMap Mapping

Mapping the crack systems, margins, and pits of the McCartys flow at Lava Falls in ArcMap produced a detailed representation of the area. The ability to distinguish crack densities, crack systems consistent with the three crack patterns, flow margins, and pits is enhanced by the exaggerated representation.

Transect Profiles

Elevation profiles of Transects G and K were generated using the elevations recorded by the DGPS unit in Microsoft Excel. Of note is that the elevations measured in the bottoms of Pits 2 and 3 within Transect K are technically lower than the elevations measured at the base of the Horseshoe and the Western Monocline (Figure 5).

Transect Measurements

The absolute width of the plateau between the base of the Horseshoe and the Western Monocline on Transect G was measured to be approximately 548 meters, while the crustal width across the same area minus the cumulative crack widths on the plateau was approximately 542 meters. This criterion was developed by Walker (1991) for distinguishing between positive volcanic features demonstrating

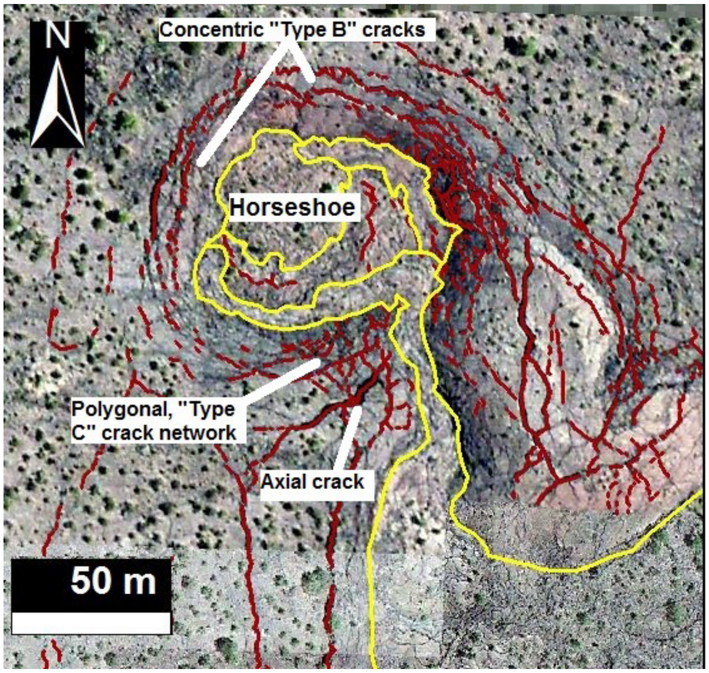

Figure 5 - Map of cracks and flow margins in and around the Horseshoe. Concentric and planar-horizontal fractures of crack pattern Types A and B dominate the flow edges, however, Type C cracks also make up a substantial portion of the margin as well.

fracturing as a result of brittle extension and those demonstrating fracturing as a result of uplift. Hon et al. (1994) also employ a similar method across smooth pahoehoe sheet flows.

ANALYSIS

The crack pattern designations build upon existing definitions for cracks formed as a result of inflation of pahoehoe flows. Hon et al. (1994) noted that the flat, upper surfaces of inflated flow sheets were bound by monoclinal flexures with upper hinges marked by en echelon cracks as deep as 1-2 meters. Several of the en echelon-type cracks we measured on the monoclines of the McCartys flow were much deeper than 1-2 meters, however, sometimes extending as deep at 5-6 meters in an example found on the Western Monocline near the terminus of Transect K. Self et al. (1998) discussed distinguishing inflation pits from collapse pits by looking for horizontal clefts resulting from inflation. Several of these types of cracks were observed within Pits 1-3 within Transect K on the plateau, often resulting in the tilting of blocks into the pits. On pahoehoe sheet flow margins, Hoblitt et al. (2010) described a dominant rifting style of outwardly dipping slabs of lava and a subordinate rifting style of vertical scarps. Both these crack types were observed on the flow margins at both ends; outwardly dipping slabs on the Western Monocline along Transect G, and vertical scarps on the southwest corner of the Horseshoe along Transect D.

The crack system maps in ArcMap demonstrate several important aspects of the location of cracks on the flow (Figure 5). Firstly, crack types A and B are roughly correlated with slope. Type B concentric cracks are primarily observed on curved flow margins or as indicators of inflation pits. Type A cracks dominate the apex of flow margins and represent some of the deepest cracks observed on the flow. Type C cracks are observed both on flow margins and within the flow center on the plateau. Thus Types A and B are thought to be better indicators of inflation histories given their substantial sizes and confinement to either flow margins or inflation pits. Crack density is also greatest at these points.

Following the Walker (1991) and Hon et al. (1994) criterion for analysis of positive topographic volcanic features, a shorter crustal width (542 meters) compared to an absolute width (548 meters) is expected for this plateau where inflation was the primary mechanism of uplift and cracking. However, as Self et al. (1998) note, inflation features can be thought of as the inverse of the topography they cover, hence inflation pits represent topographic highs and smooth, inflated pahoehoe sheets indicate gently sloping, uniform terrain. It is highly interesting that Pits 1 and 2 in Transect K show a lower elevation than the edges of the McCartys flow at the Horseshoe and the Western Monocline (Figure 6). Because the inflation criterion is fulfilled however, this is explainable by the numerous breakouts and complicated smaller flows that have buried the margins of the flow such that their true bases are obscured from view. This suggests that the plateau is more inflated than previously thought and is consistent with observations of very deep en echelon cracks at the flow margins. The deep cracks and the buried flow margins indicate that inflation took place over a longer period of time than originally assumed.

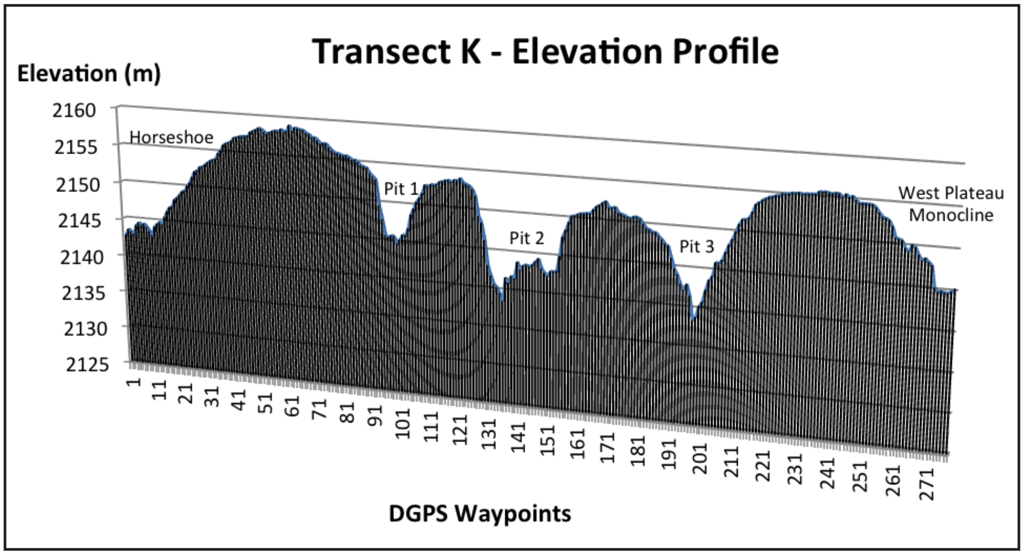

Figure 6 - Elevation profile of Transect K, including the Horseshoe, Pits 1-3, and the Western Monocline. Note the elevations in Pits 2 and 3 are lower than both of the Horseshoe and Western Monocline slope base ones.

MARS

The Elysium Volcanic Province is the second largest volcanic province on Mars and features three main types of volcanic activity: 1) effusion of lava from point sources or vents, 2) effusion of lava from linear sources and fissures, and 3) caldera formation likely associated with lava effusion (Platz and Michael, 2011). Of these, lava effusion from fissures is of particular interest, especially within the Elysium Planitia, located to the east of Elysium Mons. Hamilton (2013) has re-examined the Cerberus Fossae 2 unit, which includes regionally extensive flows that appear to originate from the Cerberus Fossae fracture system and has determined that not only does the Cerberus Fossae 2 unit appear to continue further northwest than previous studies have inferred, but high-resolution Mars Reconnaissance Orbiter (MRO) imagery reveals surface features demonstrating flow characteristics analogous to inflated pahoehoe flows with monoclinal cracks and lava-rise pits. Selecting certain High Resolution Imaging Science Experiment (HiRISE) images from the MRO that show analogous inflation features and mapping crack systems in GIS software could be useful in comparing crack densities and fracture patterns to the work done on the McCartys flow as a means of interpreting these Martian volcanic features as formed by inflation.

CONCLUSION

The combination of DGPS transect mapping, field observations, and GIS mapping of the McCartys flow near Lava Falls provides moderate remote sensing diagnostics indicative of the inflation process. The domination of slopes with particular crack types as well as lava rise pits is an excellent hypothesis to begin mapping of suspected inflation areas within Cerberus Fossae 2 of the Elysium Volcanic Province of Mars, and the combination of crack data analysis across transects and elevation profiles demonstrates that inflation of the McCartys flow was more complex than previously thought and lasted longer. Analysis of the crack systems of the McCartys flow provides insights not only useful for extraterrestrial applications, but also contributes towards the further understanding of terrestrial pahoehoe sheet flows.

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