KECK GEOLOGY CONSORTIUM

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

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Dr. Robert J. Varga, Editor
Director, Keck Geology Consortium
Pomona College

Dr. Tekla Harms
Symposium Convenor
Amherst College

Carol Morgan
Keck Geology Consortium Administrative Assistant

Diane Kadyk
Symposium Proceedings Layout & Design
Department of Earth & Environment
Franklin & Marshall College

Keck Geology Consortium
Geology Department, Pomona College
185 E. 6th St., Claremont, CA 91711
(909) 607-0651, keckgeology@pomona.edu, keckgeology.org

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Editor and Keck Director
Pomona College

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JULIA SIGNORELA**,** Franklin and Marshall College
Research Advisor: Andy De Wet

Keck Geology Consortium
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185 E. 6th St., Claremont, CA 91711
Keckgeology.org

VOLCANIC CHANNELS ON ASCRAEUS MONS: FOCUS ON SINUOUS CHANNELS ON THE SOUTHEAST RIFT APRON

JULIA SIGNORELLA, Franklin and Marshall College
Research Advisor: Andy de Wet

INTRODUCTION

Deciphering the water history is important to understanding the geological evolution of Mars and whether it could have sustained life. This research involves studying channel features on the flanks of the Ascraeus Mons volcano, which is a part of the Tharsis province. This province has a specific eruptive history in which the three volcanoes, Arsia Mons, Pavonis Mons, and Ascreaus Mons, shared a magma chamber that migrated from each volcano to the next (Bleacher, et al., 2007). Channel features on Mars, such as the features in Kasei Valles, are generally accepted as evidence for water flowing over the surface in the past (Carr, 1996). However, not all channels are the product of fluvial processes and many can be interpreted as volcanic in origin (Carr, 2006). Numerous sinuous channels exist on the rift apron of Ascreaus Mons and they have been interpreted as either fluvial (Murray et. al, 2010) or volcanic (Garry, 2007) (Bleacher et al., 2010). The channels originate from pits and linear depressions and extend for many 100's of km downslope. Mapping the proximal to distal morphology of the complete channel and determining the relationship with other features on the apron provides evidence for the processes of formation and their relative temporal relationships. Determining these relationships helps to decipher the processes that formed these significant features. This study focused on sinuous channels located on the South-east part of the Ascraeus rift apron (Fig. 1). Observations of analogous features on Hawai'i are also used to provide insights into the processes of formation of these features.

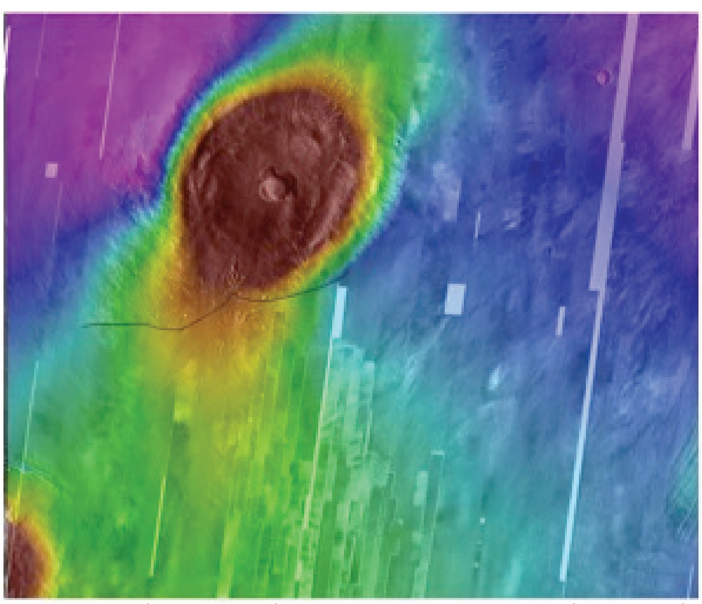

Figure 1. This image depicts Ascraeus Mons volcano and the South rift apron. The study area starts on the SE part of the apron and extends out onto the adjacent plain.

METHODS

The study area is the southeast section of the south rift apron on Ascreaus Mons. Using ArcGIS, high-resolution (18m) THEMIS visible images, combined with HiRISE and CTX images, were geo-referenced onto a lower resolution THEMIS IR Day Mosaic of the study area. Other data, including MOLA topography, was also used in the mapping process in ArcGIS. Initially the major morphological features in the area were examined and classified based on their characteristics such as size, shape, texture, and topography.

Once a classification scheme was created, the features were mapped in ArcGIS. Different features classified and mapped were volcanic vents, impact craters, pits, depressions, and tubes. Volcanic vents are topographically positive features with a negative pit feature at the summit, impact craters are topographically negative, symmetrical, and circular features often with an ejecta blanket surrounding it, pits are topographically negative features, depressions are topographically negative features that appear structurally controlled and parallel to topography, and tubes are topographically positive linear features. Surface lava flows were identified and their flow directions determined. Lava flows are identified as flow lines, which are lines that represent the direction of topographically positive flow features. Sinuous channels are topographically negative meandering features that always flow down slope of topography. All of the features are mapped in the study area on the South-east rift apron of Ascraeus Mons. Several major sinuous channel systems were identified and these became the main focus of the study.

To understand which process, fluvial or volcanic, formed these channels, the source area on the rift apron, located in the northwest section of the mapping area, was mapped in detail. The relationship between vents, pits, depressions, channels, and flow features in the source area was particularly important in understanding how and when the channels formed. A relative time sequence for these features was determined based on crosscutting and superposition relationships.

One particularly well-developed sinuous channel was traced from where it began at the source area on the rift apron to its farthest visible extent, documenting any changes in its morphology. The characteristics of the proximal, medial, and distal areas of the channel were studied using cross-sections and analysis based on MOLA topography and geomorphology.

Volcanic features on Hawai'i are used as analogues to study the features on Mars. The features on Hawai'i are used because the volcanic activity and the morphology of the features are similar to that of Mars. Comparison between volcanic activity on Hawai'i and on Mars provides supporting evidence. On the Big Island of Hawai'i, the features of the Mauna Ulu vent and the Pohue Bay area were studied.

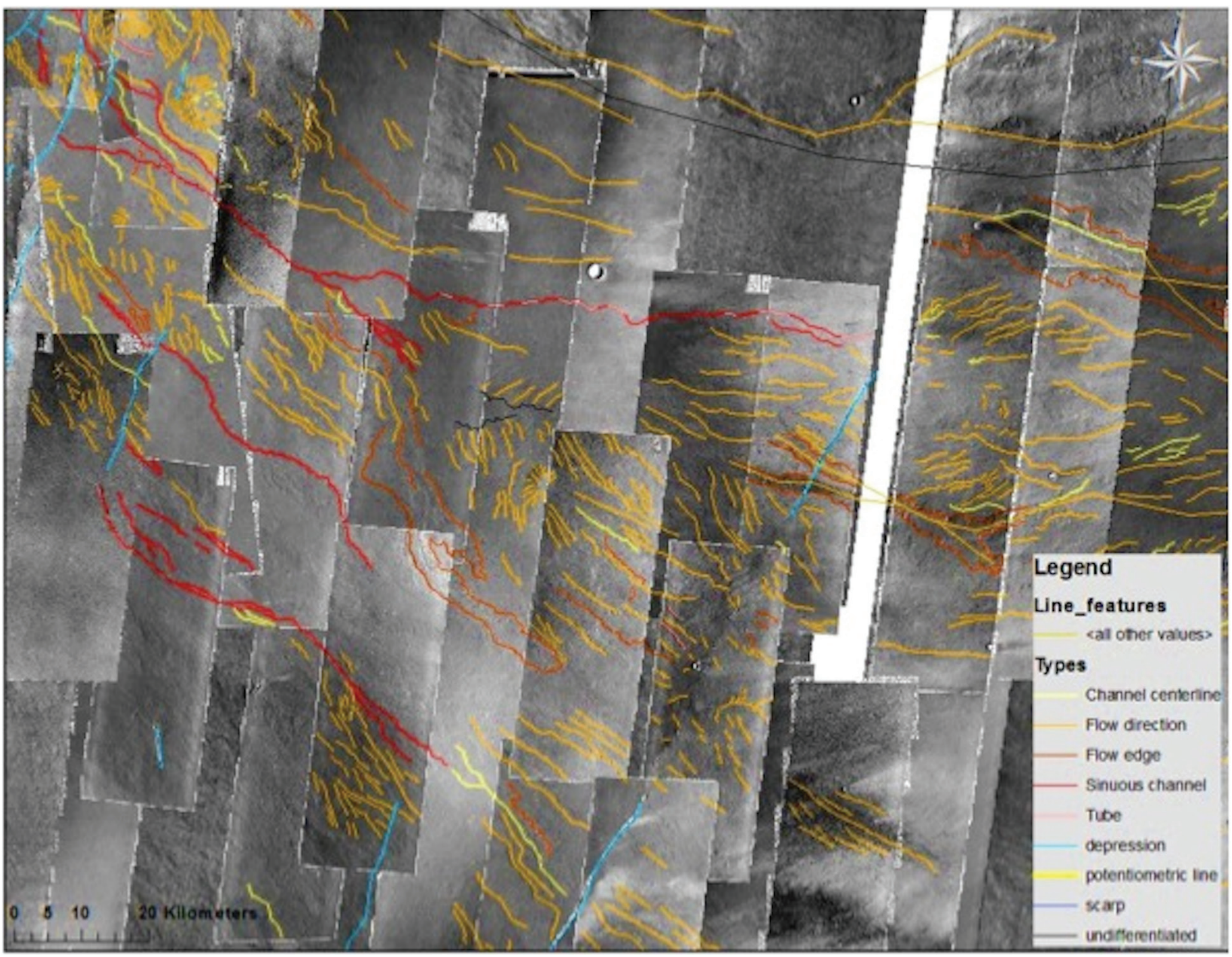

Figure 2. Major channel stemming from depressions in the origin area northwest of the study area (most north red line in image)

RESULTS

Detailed mapping of the prominent sinuous channels in the study area shows a change in morphology through the proximal, medial, and distal sections of each channel. The proximal sections of the main sinuous channels show that these channels typically originate from the depression features on the rift apron. These channels have well-developed sinuous morphology in the proximal sections, but in the medial and distal parts the channel transitions into dispersed, complex flows with roofed over sections and tubes.

One well developed sinuous channel located in the most north end of the study area and originating in the source area of the study area was mapped in detail. In the proximal section, the channel starts off as two well-developed sinuous channels emerging from two separate linear depressions. As the channels move down slope, they merge together. In the medial section, the channel transitions from a well-developed sinuous channel to a channel with roofed over and tubed sections. Then in the distal section, the channel changes to more positive flow features instead of a sinuous channel. Two neighboring channels to the north and south of this one particularly well-developed sinuous channel appear to converge and cover the distal flow sections, so it is not possible to map its full extent (Fig. 2). At this distal section of the channel, the flows coming from the channel appear to inflate as a volcanic feature would (Garry, 2009). Cross sections were made at proximal, medial, and distal sections of the channel measuring the change in topography. The cross sections then were compiled showing the change in topography as the slope changed (Fig. 3).

Determining the relationships between the raised vents, depression, flows, and sinuous channel features in the northwest corner of the study area helped to decipher if this relationship occurs in other areas of the south rift apron of Ascraeus and therefore, determine if a pattern to how these features form exists (Fig. 4). The relationships between the features also inform what process formed them. The superposition relationships mapped in the source area show that the channels and lava flows coming from the depression features have formed most recently and the vents formed before them. It is also clear that the flows come from the depression features and not the raised vents. This shows that the vents could not have formed the recent channel and flow features and therefore the features result from some other process.

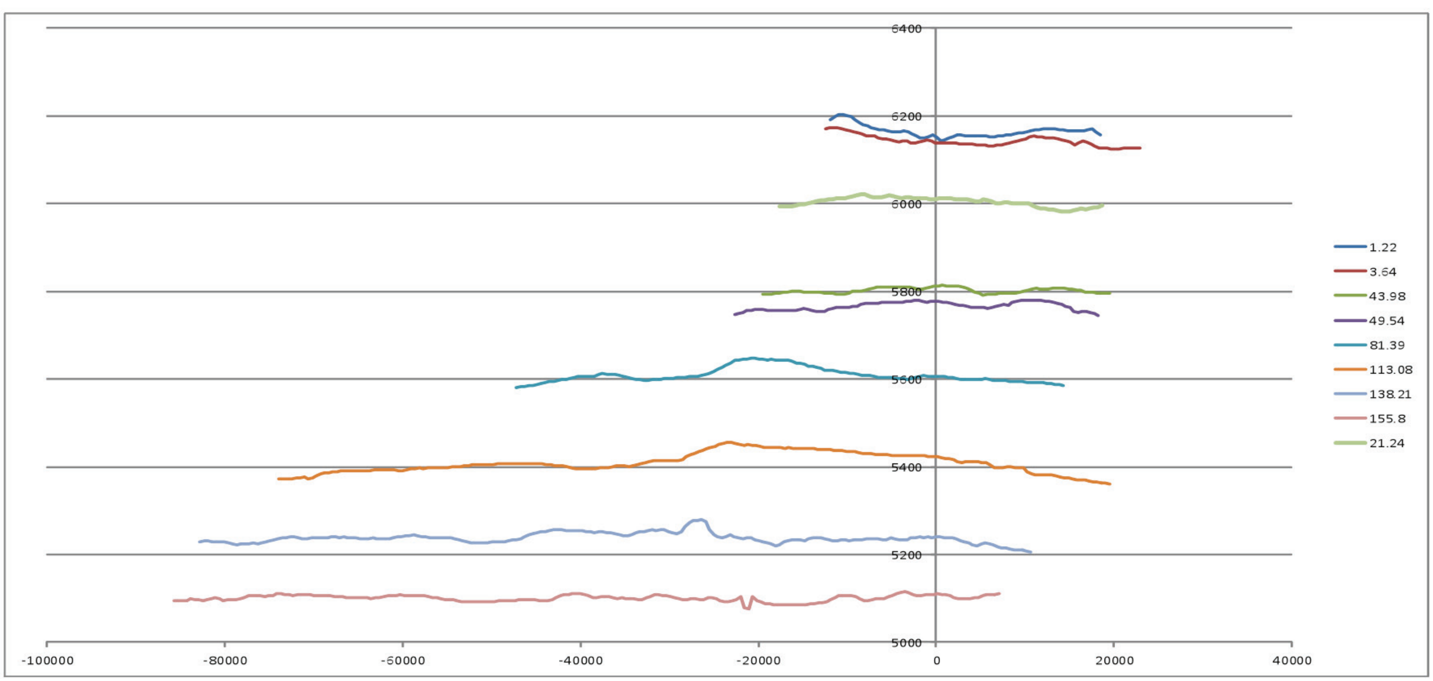

Figure 3. Graph of Slope Gradient of Prominent Channel

The volcanoes on Hawai'i have a similar eruptive style to the volcanoes on Mars since they are low viscosity hot spots. Rift zone eruptions form in weak zones down the flank of the volcano as the magma chamber migrates. The features formed are also similar to features seen on Mars. Flows from Mauna Loa volcano, such as the 1859 Pohue Bay flow and the 1907 flow, and from the Mauna Ulu vent, which is a satellite from the Kilauea volcano, both from the Big Island on Hawai'i, represent good analogues for the study area on the Ascreaus Mons rift apron. The Muliwai a Pele channel from Mauna Ulu vent is an analogue for the proximal section of the major sinuous channel in study area (Fig. 5). An important feature is the volcanic tubes that form from the erupted magma becoming crusted over creating roofed over sections. The tubes create insulation so the heat from the lava cannot escape allowing the lava to flow for a much greater distance than it would without the tubes (Heliker, 2002). Pits often form as negative relief features that collapse into the tube. These features are seen in the Pohue Bay area on the Big Island of Hawai'i. Another volcanic feature found is an inflation, which occurs when the volcanic magma heats below a crusted over section causing it to rise since it cannot move down slope since it is crusted over at the surface.

DISCUSSION

The eruptive style and features formed on Hawai'i are thought to also be occurring on Mars. The raised vents in the study area appear to be the oldest features in that area, but are not the source of significant, long lava channels. The major channels formed after the vents and originate from linear, probably structurally

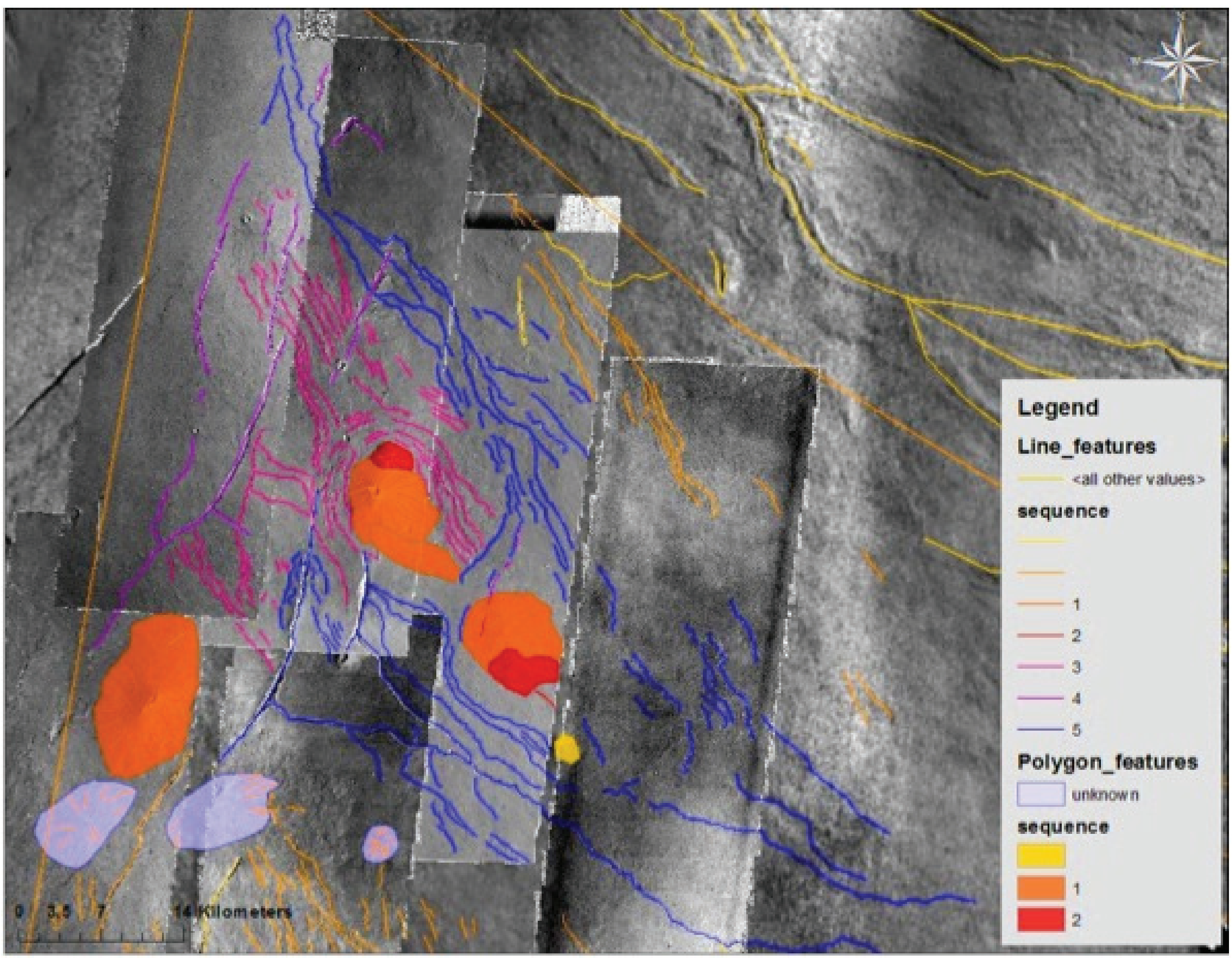

Figure 4. Temporal sequence of features based on crosscutting relationships

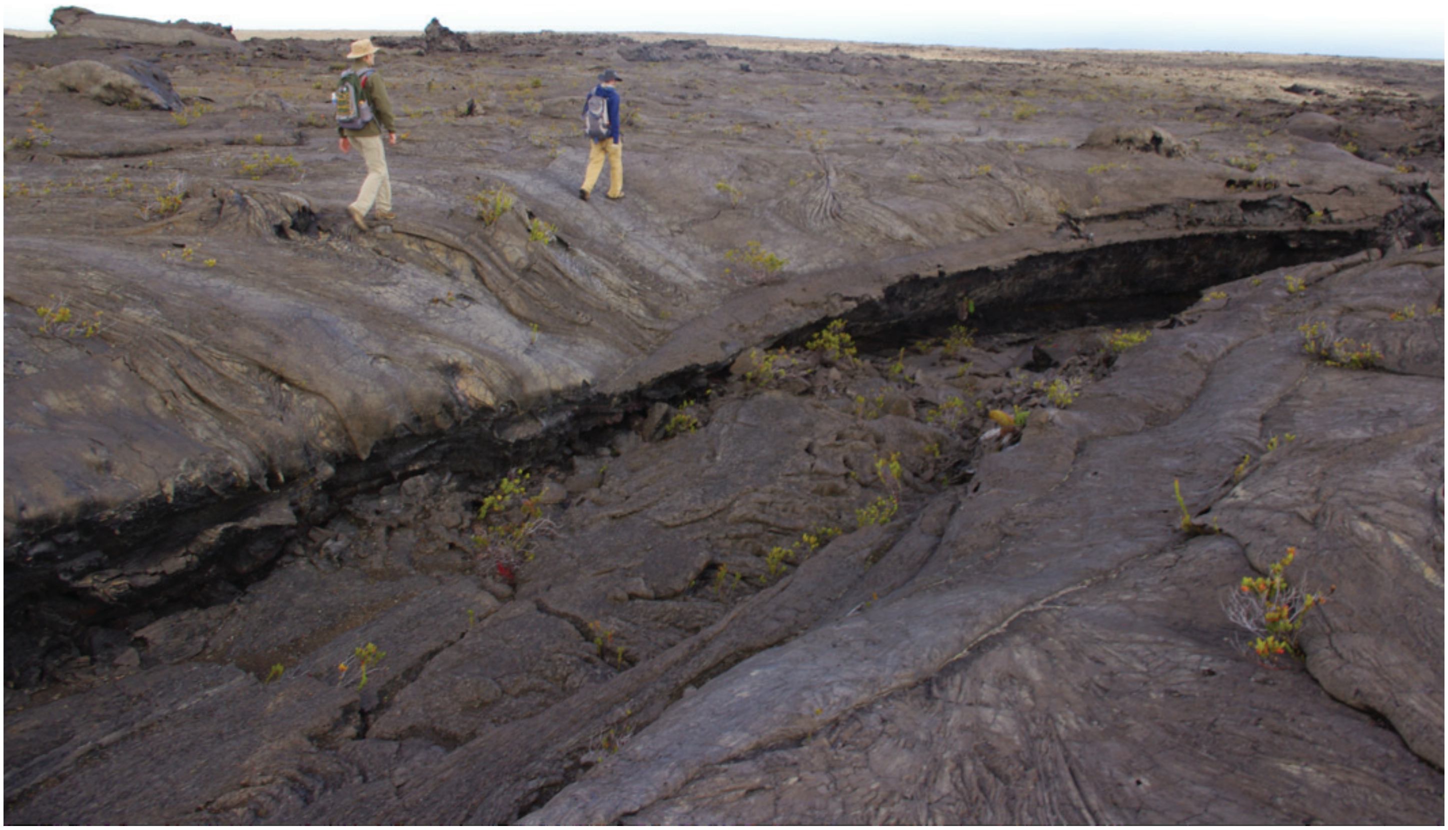

Figure 5. The Muliwai channel from Mauna Ulu vent on the Big Island of Hawai'i as analogue for the incised proximal section of the major sinuous channel in study area

controlled depressions in the area. Determining that the flows originate from depressions and not vents is important because it will help determine what process, fluvial or volcanic, forms the feature. It seems that the depressions are fissure eruptions along the flank of Ascraeus Mons Rift Apron which are similar to fissure eruptions on Hawai'i. So, the magma erupts in the fissures and at a point of weakness breaks out as a major flow, which forms the significant sinuous channels under question. It is possible that the magma in the depressions interacted with the water table creating pyroclastic eruptions. Evidence of this is shown by the morphology represented in the images such as material deposits along side the depressions.

The flows came out of the depressions forming the long sinuous channels that change in morphology to positive flow features. Studying major channels from their proximal to distal sections also helps decipher which process formed the feature. The behavior of the most prominent sinuous channel studied here implies a volcanic origin. At the proximal section, the depressions resemble fissure eruptions from which the prominent flows emerge. Then as a result of the high velocity and high temperature qualities of the flow, the lava creates a channel with levees allowing the large volume of material to funnel through. Then at the medial section, tubes and roofed over sections exist dispersed between the channel. The tubes allow the material to be carried even further down slope as it insulates allowing the lava to remain hotter for longer so it will not cool as quickly. The distal section no longer contains a channel but instead positive flow features, which are morphologically very similar to volcanic flows, especially this prominent channel at the distal section where it inflates. These qualities of the Mars channels are also seen on terrestrial Hawai'ian volcanic features. For example, the proximal section of Muliwai a Pele channel from Mauna Ulu satellite shield on the Big Island of Hawai'i, is analogous to the channels seen in the proximal areas of the sinuous channels on the Ascreaus Mons rift apron. The Pohue Bay flow from Mauna Loa volcano on the Big Island of Hawai'i also exhibits the same characteristics as the channels on Mars as it has roofed over sections, tubes, and collapsed pits. Since the sinuous channel feature originates from depression features instead of the vent features, questions arise. As the analysis of the sinuous channel suggests it is volcanic, why is the most recent volcanic material that forms major flows coming from the depressions without building topographic vents? Did the depression features form due to interaction with the water table below which then allows volcanic material to flow creating the channels? Our current work is focused on this question.

CONCLUSION

The relationships between the vents and depressions as seen in the source area of the study area show the raised vents are older than the depressions and that the prominent channels come from the depressions. The vents represent small intermittent eruptions that produce the topographically positive features whereas the depressions produce a continuous eruption of a large volume of material, which creates the sinuous channels. These depressions result from fissure eruptions similar to fissure eruptions seen on Hawai'i.

The characteristics and change in the morphology of the channel in the study area indicates that the channel is of volcanic origin. The sinuous channels transitions from incised in the proximal section; to tubes, roofed over sections, and collapsed pits in the medial section; to topographically positive features in the distal section. Features from the Big Island of Hawai'i provide analogues for the features seen on the rift apron of Ascraeus Mons proving its volcanic origin. These features were observed in volcanic features from the Big Island of Hawai'i, in areas such as Pohue Bay and Mauna Ulu, suggesting that the Mars channels are volcanic in origin.

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