STUDY OF WATER CHANNELS AROUND OLYMPUS MONS: ANALYSIS OF THE SURROUNDING TOPOGRAPHY

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ABSTRACT

Images obtained by the THEMIS instrument aboard the Mars Odyssey spacecraft reveal numerous channel systems near Olympus Mons volcano, Mars, which appear to have been cut into the surface by relatively recent water flows. Although the water has long since dried up, the channels formed can still be used to determine changes in ground slope which have occurred since their times of formation. To do this we compared flow directions with current maximum downhill gradients of underlying terrain and noted any inconsistencies between the two. The level of mismatch between indicators of slope indicates that either a large amount of ground deformation has recently occurred in this area, or that the flows were diverted by landforms (most likely glaciers or dunes) that are no longer present.

DISTRIBUTION AND MORPHOLOGY OF CHANNELS

Together with my mentor, I have identified three characteristics of channel systems around Olympus Mons. (1) A single channel to the west of the aureole (at 22.1°N, 208.7°E) that appears to have been a sink of water rather than a source; (2) a single channel system within a lobe of the western aureole deposit (at 25.6°N, 211.67°E); and (3) numerous channels to the SE of the basal escarpment of the volcano that originated from fractures in the young lava plains. Figure 1 shows an example of these channels. The fractures from which these channels originate can either be confined (near-circular) sources or linear fractures. An interesting second attribute of some of these channels is that they are not aligned with the current maximum topographic gradient, despite recent data from detailed crater counts [Basilevsky et al., 2006] that suggest that the lava flows within which the channels are carved may be very young (<25 – 40 Myr). This implies that the ground has either been recently tilted, or that topographic obstacles (such as glaciers) existed at the time that the channels formed. The identification and magnitude of this cause of this mis-match is the central theme of my Space Grant project.

In contrast to the single example of a channel that was discussed by Mouginis-Mark [1990], I have identified numerous long (>50 km long) channels complexes to the SE of the basal escarpment of Olympus Mons (Figure 1). Frequently, these channels are braided, with stream-lined islands along their length. Multiple levels within the channel floor can also be seen in some instances. Several of the source areas show signs of the accumulation of materials along the sides of the fractures so that the source areas have raised rims. The lack of lava flow lobes, or hills with summit pits, allows us to exclude a volcanic origin for these channels and source areas; our interpretation is that they are water-carved channels.
LOCATING WATER CHANNEL SYSTEMS USING THEMIS VIS IMAGES

Early in the project I downloaded from the THEMIS web site, catalogued, and mapped the location of all of the THEMIS images available from years 1-4 of the mission covering the area S.E. of Olympus Mons’ basal escarpment (Fig. 2). This included a total of 384 images – many of which contain ambiguous channel structures that cannot be confirmed to have been formed by water.

![Figure 1 (left): THEMIS VIS image V04311005. This image is the best example of water channels that I have found so far. These channels probably were formed as water rushed out of large cracks in the ground formed under the weight of Olympus Mons. The location of this image is labeled as 1.1 in Figure 2.](image)

![Figure 2 (top right): Summary map for the locations of THEMIS images from year 1 of the mission. The purpose of generating these maps was so that I could easily locate the images I downloaded. Base image is a MOLA shaded-relief version of the topography of the landscape around Olympus Mons.](image)

![Figure 3 (bottom right): Summary map of images found to contain water channels from Years 1 to 4 of the mission. This map allows me to see the regional pattern of images I am studying. Year 1 images are in red, Year 2 in orange, Year 3 in green and Year 4 in blue.](image)

To aid in the task of distinguishing water channels from lava channels we traveled to the Big Island for field work studying some of the lava channels associated with 1800 eruption of Hualalai volcano. With this background in the visual appearances of lava channels I could then identify the THEMIS images containing channels most likely caved by water (Fig. 3). Of these
images, the best examples were selected to be compared with the MOLA elevation data so that further analysis could be made (Fig. 1).

CHANNEL DIRECTIONS AND TOPOGRAPHIC SLOPE

With the help of Harold Garbeil, I was able to identify the channels which do not flow downhill. In order to do this, I used the program written by Harold called MOLAppts, which overlays MOLA elevation data onto THEMIS images containing the best examples of water channels as well as a high level of MOLA coverage. In Figure 4, I show this overlay in the two different ways that I used to study the channel orientation with respect to topography. Figure 4a is a regional view to compare the flow direction to regional gradients. Figure 4b shows a local view, where I investigated the exact relationship between elevation contours and channel orientation. In Figure 4b, it is apparent that the channel floor is parallel to the 1,070 m contour; obviously, the channel should flow straight downhill, so something odd has been identified! Indeed, it had originally been proposed by Mouginis-Mark et al. (1982) that there had been some tilting of the lava flows around Olympus Mons in the recent past due to the load of the volcano; perhaps the water channels had been formed after this tilting took place?

Figure 4: Left (a): Distribution of the seven large channel systems identified to the east of Olympus Mons. Blue arrows show observed flow-paths, and red lines indicate maximum down-slope gradient from the source. Note the mis-match in directions for four of these channels. Outline of Fig. 4b is also shown. Right (b): The source of the channel (located at 16.4°N, 232.6°E) is at the top left of the image, and the channel morphology indicates that the direction of water flow was towards the bottom right. Contours are in red are at 10-meter intervals relative to the MOLA datum. THEMIS image V17029009.

I also checked that the channels really do flow in directions other than straight down-hill. Figure 5a shows my efforts to use a grid of MOLA orbits that cover a channel. I used the program MOLAppts to record individual elevations across this channel. In Figure 5b, I again used MOLAppts, except this time I generated a profile from multiple MOLA orbits to show the direction of flow of the water within the channel. This work was quite time consuming as I had to work with all the individual MOLA orbits on each of the THEMIS images. Using this
technique, I was able to confirm the local slopes and flow directions (Fig. 5a) as well as the geometry of individual channels (Figs. 5b and 5c).

Figure 5. Left (a) MOLA elevation point overlay on THEMIS image V14558021. Image is located to the east of the Olympus Mons aureole, (at 16.1°N, 233.3°E) displaying numerous water channels flowing from S to NW out of a large crack in the ground. Red dots mark the places where I have measured the elevation (in meters). Green open circles mark all the available MOLA shots. Top Right (b): Not all water flow came from the prominent fractures. To the west of the Olympus Mons aureole (at 22.1°N, 208.7°E), very close to the large fresh impact crater called Tooting, is a fracture (at lower left in this image) that has acted as the sink for surface water. Elevations are derived from raw MOLA shots taken from multiple orbits (shown as faint open green circles). Elevations are in meters relative to the MOLA Mars datum. Part of THEMIS image V04574003. Bottom right (c): Graph generated using the Excel program of the elevation points shown in Figure 5b. Data show that the water once flowed from NE of image down into a large crack to the SW. This is the only example of a water channel on Mars that I have found where the crack in the ground is the sink (rather than source) of the water.

DISCUSSION AND IDEAS FOR FUTURE RESEARCH

What could have caused the odd flow directions for the water channels? In Figure 6, I show a landscape just to the east of Olympus Mons where, instead of “normal-looking” lava flows, there is inverted topography and strange unusually smooth margins to the lava flows. These features could either have formed by a lava flow being erupted under a glacier or a sand dune. Glaciers have been proposed as a possible explanation for other landforms within the Tharsis region (Head et al., 2005), and so it is possible that bodies of ice and/or sediment-rich ice were recently found around the base of Olympus Mons volcano. Alternatively, Edgett (1997)
has suggested that there may once have been large volumes of volcanic ash (produced by explosive volcanism on Arsia Mons volcano) in this region. Detailed analysis of Arsia Mons by Mouginis-Mark (2002) also supports the idea that this volcano produced a lot of ash during an explosive phase of its recent history. In either case, the odd channel directions that I have identified would be consistent with the water flowing around obstacles that now no longer exist. Of course, if the water channels also carried sediment, this material would also have been deposited beneath this topography, leaving a similar-looking “mottled” terrain. Further work, including searching for the spatial distribution of this type of landscape is beyond the scope of this project, but offers an interesting new perspective on the origin of the Martian surface that could be productively studied using the high resolution images from the HiRISE experiment currently in orbit on the Mars Reconnaissance Orbiter. I raise the possibility of this type of research in the abstract that I will present at the 7th International Mars Conference (Ambard and Mouginis-Mark, 2007), and hope to produce a peer-reviewed publication on this topic in the coming months with the help of my mentor.

**CONCLUSIONS**

Water channels near Olympus Mons and their odd flow directions can be used to help us understand the changes that have occurred in the area within the past several million years. Channels no longer oriented in a downhill direction either flowed around glaciers or dunes that were later removed, or the channels have been influenced by ground deformation under the weight of the volcano that took place in the relatively recent history of Mars. The model of the water being obstructed by past landforms is consistent with the observed odd surface formations which were most likely formed under ice sheets or sand dunes. Further research should be done...
in this subject (using the recently available very high-resolution HiRISE images) to help shed some light on Mars’ somewhat mysterious past and apparent climate change.

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REFERENCES


