MORPHOLOGY AND ERUPTIVE PROCESSES OF THREE VOLCANIC RIFT VENTS IN THE THARSIS PROVINCE, MARS. S. Tyson[1], L. Wilson[1,2] and P.J. Mouginis-Mark[2] [1]Environmental Science Dept., Lancaster University, Lancaster LA1 4YQ, UK (L.Wilson@Lancaster.ac.uk), [2]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i, Honolulu HI 96822, USA.

Abstract: Three young (<100 Ma) volcanic vents and their associated lava flows within the Tharsis Volcanic Province, Mars (17.9° N, 246.8° E) are identified in Mars Odyssey THEMIS images. Geometrical measurements and detailed morphological analyses of 12 lava flows are used to estimate erupted volume, volume flux and duration of each eruptive episode.

Background: The three well-preserved vents are arranged en echelon with a common strike and may well represent the surface manifestations of a common feeder dike at depth. (Fig. 1). They lie ~100 km to the east of a fissure system identified previously [1, 2].

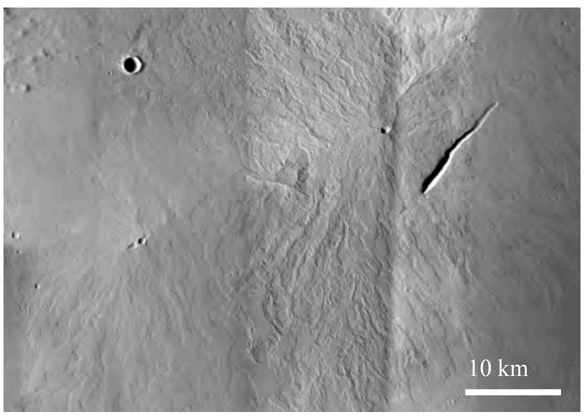

Figure 1. Composite of THEMIS visible images V05459019, V17665024, V19200011, V13971010, V18264018, V10277007, V21047002, V14570021, V20111007 and V20423046 showing the study area centered on 17.9° N, 246.8° E.

The system comprises three morphologically different vents and extensive lava fields covering ~2800 km^2. Vent 1 (Fig. 2a) has two craters, a circular crater with a diameter of 800 m and a prominent raised rim, and a more elongate vent which is 1300 m long and ≤500 m wide. It is probable that the raised rim represents preserved welded spatter. Vent 2 (Fig. 3) is a perched lava lake above a primary vent with a long-lived channel draining its western side. The channel remains un-drained or has roofed over to form a tube. The lava lake has a diameter of ~2000 m and the channel is on average 750 m wide. Two collapse pits are visible in the lake surface formed when the lake was drained from below; drainage most likely occurred via a tube within the roofed-over channel. Many layers of overflows are also evident. Vent 3 (Fig. 2b) is a single crater with a diameter of ~1100 m, again with a raised lip. Layering can clearly be seen within the crater suggesting a composite cone built from flows, welded spatter and tephra. A ridge ~50-150 m wide and ~3800 m long strikes ~NE from the crater. The ridge has lava flows originating at several points along its length and could represent either an open spatter rampart or an inflated tube feeding ephemeral vents. The ridge terminates at an elongate perched lava pond.

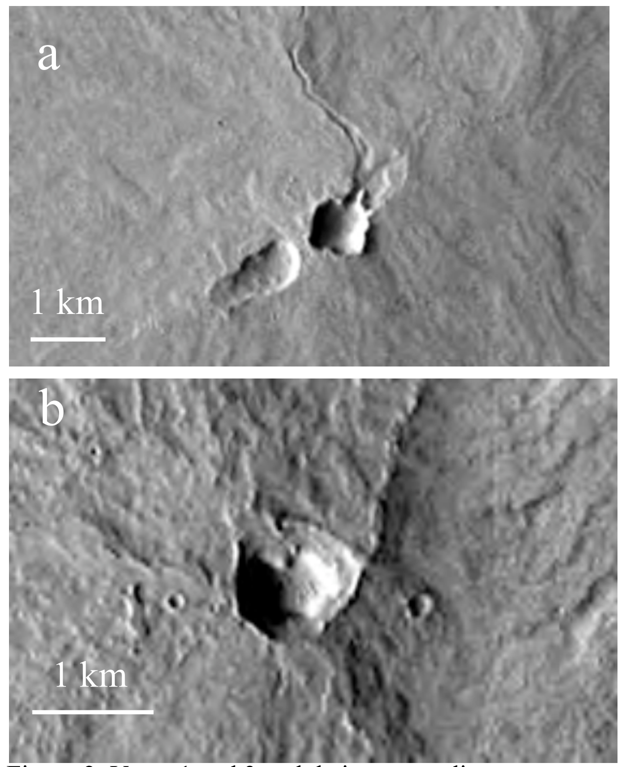

Figure 2. Vents 1 and 3 and their surroundings.

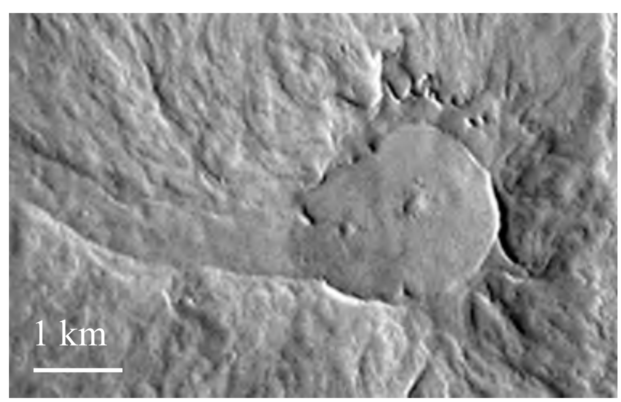

Figure 3. Vent 2. Perched lava lake with multiple overflows and circular collapse features where lava has been drained from beneath the cooled crust.

The lake shown in Fig. 3 bears a marked morphological resemblance to the Kupaianaha lava pond on Kilauea Volcano, Hawai'i (Fig. 4) and probably represents a similar evolutionary history. Counting of craters >500 m in diameter after [3] suggests an age of <100 Ma for all parts of the flow field.

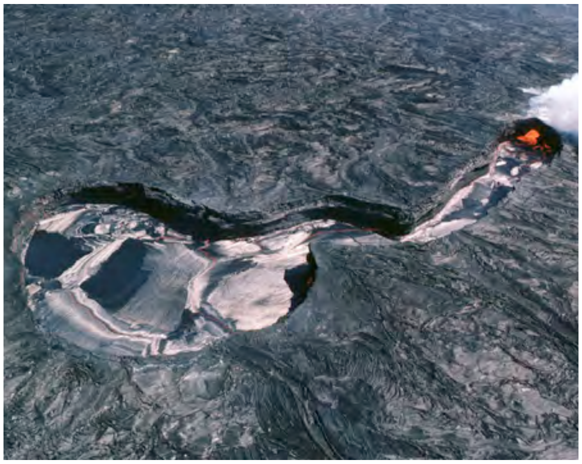

Figure 4. Kupaianaha lava pond on Kilauea volcano. Maximum diameter 300 m. USGS photo., J.D. Griggs.

Analysis: THEMIS visible images were used with ImageJ software and photoclinometric techniques to extract the lengths, mean widths and mean thicknesses of 12 lava flows. These were used to find the volume flux (F) (i.e. volume effusion rate) for each flow using the Gratz number equation [4] rearranged as:

$$F = (G_z \kappa \, L \, W) \, / \, (n^2 \, d) \qquad \text{(eqn. 1)}$$

where G_z is the dimensionless Gratz number at the critical value of 300 at which point a cooling-limited lava flow becomes stationary, κ is the thermal diffusivity of the lava (~7×10^{-7} m^2 s^{-1}), L is the length of the flow (m), W is mean width of the flow (m), d is thickness (m) and n can be found using:

$$n = d_e \, / \, d \qquad \text{(eqn. 2)}$$

where $d_e = 2 \, W \, d \, / \, (W + d)$ is the equivalent hydraulic diameter of the flow [4]; for most flows n = ~2 [5]. Also, strictly, the width needed in the above analysis is the width of the flow's central channel; however, it was not possible to distinguish central channels in almost all of the flows examined here and so the total flow width was used instead. The individual eruption durations (τ) for each flow were calculated by dividing total lava volume (V) by the volume flux (F) (Table 1).

Table 1. Variables are flow number (#), flow length (L, km), flow width (W, km), flow thickness (d, m), flow volume (V, km^3), volume flux (F, m^3/s) and eruption duration (τ, days).

#	*L*	*W*	*d*	*V*	*F*	τ
1	2.43	0.71	17.8	0.031	5	70
2	4.95	0.37	8.7	0.016	11	17
3	4.68	0.37	6.1	0.011	15	8
4	4.93	0.5	7.5	0.019	17	12
5	22.36	1.31	27.0	0.792	57	161
6	30.33	2.33	20.6	1.458	180	94
7	14.07	0.97	20.6	0.281	35	94
8	15.43	2.28	28.2	0.992	66	175
9	18.43	1.6	31.6	0.933	49	221
10	3.2	0.23	19.0	0.014	2	79
11	4.8	1.88	8.6	0.078	55	16
12	6.3	0.73	10.7	0.049	23	25

Discussion: Morphological observations and quantitative measurements enable constraints to be placed on the volcanic processes forming this 3-vent system. Key morphological features, such as preserved welded spatter, suggest that eruptive episodes from the three vents may have been predominantly hawaiian in style. This implies the magmas were sufficiently rich in volatiles to enable fragmentation during ascent [5]. Magma was transported to the surface via an en echelon dike system, with eruptive activity propagating eastward with time, forming 3 progressively younger vents and flow field complexes. It is inferred that these Martian flow fields were emplaced in a similar manner to those from the Pu'u 'Ō'ō eruption at Kilauea volcano in Hawai'i. Lava flows originated from central vents either by overflowing the vent or as rootless flows produced from fountaining episodes. Many episodes apparently lasted long enough for lava tube systems to form; tubes can be identified on many flow units as discontinuous, sinuous ridges. By comparison with the previously analyzed fissure vent system to the west [2], flows here were similar in length and width but somewhat thicker, and had similar effusion rates. The exceptional preservation of these flows provides an important record of geologically recent (<100 Ma), small scale volcanic processes on Mars.

References: [1] Mouginis-Mark, P.J. & Christensen, P.R. (2005) JGR 110(E8), doi: 10.1029/2005JE 002421. [2] Mackown, J., Wilson, L. & Mouginis-Mark. P.J. (2007) LPS 38, #1546. [3] Hartmann, W.K. & Neukum, G. (2001) Space Sci. Rev. 96, 165. [4] Pinkerton, H. & Wilson, L. (1994) Bull. Volcanol. 56, 108. [5] Wilson, L. & Head, J.W. (1994) Rev. Geophys. 32 (3), 221.