

SPATIAL AND ALIGNMENT ANALYSES FOR A FIELD OF SMALL VOLCANIC VENTS SOUTH OF PAVONIS MONS, MARS. J.E. Bleacher¹, L.S. Glaze¹, R. Greeley², E. Hauber³, S.M. Baloga⁴, S.E.H. Sakimoto⁵, D.A. Williams², T.D. Glotch⁶. ¹Planetary Geodynamics Laboratory, Code 698, NASA Goddard Space Flight Center, Greenbelt, MD, 20771, Jacob.Bleacher-1@nasa.gov, ²School of Earth and Space Exploration, Arizona State University, Tempe, AZ, 85287, ³DLR Deutsches Zentrum für Luft- und Raumfahrt, Berlin, Germany. ⁴Proxemy Research, Farcroft Lane, Laytonville, MD, 20715. ⁵Dept. of Civil Engineering & Geological Sciences, University of Notre Dame, Notre Dame, IN 46556. ⁶Dept. of Geosciences, Stony Brook University, Stony Brook, NY, 11794.

Introduction: The Tharsis province of Mars displays a variety of small volcanic vent (10s km in diameter) morphologies. These features were identified in *Mariner* and *Viking* images [1-4], and Mars Orbiter Laser Altimeter (MOLA) data show them to be more abundant than originally observed [5,6]. Recent studies are classifying their diverse morphologies [7-9]. Building on this work, we are mapping the location of small volcanic vents (small-vents) in the Tharsis province using MOLA, Thermal Emission Imaging System, and High Resolution Stereo Camera data [10]. Here we report on a preliminary study of the spatial and alignment relationships between small-vents south of Pavonis Mons, as determined by nearest neighbor and two-point azimuth statistical analyses.

Terrestrial monogenetic volcanic fields display four fundamental characteristics: 1) recurrence rates of eruptions, 2) vent abundance, 3) vent distribution, and 4) tectonic relationships [11]. While understanding recurrence rates typically requires field measurements, insight into vent abundance, distribution, and tectonic relationships can be established by mapping of remotely sensed data, and subsequent application of spatial statistical studies [11,12], the goal of which is to link the distribution of vents to causal processes.

Approach: Our study region (Figure 1) covers a ~ 480 by 270 km area, including the low shield field (LSF) south of Pavonis Mons [8]. This area includes the mapped extent of the Pavonis Mons southwest LSF, a distal portion of the Arsia Mons NE rift apron, and a portion of the Tharsis plains east of Arsia. Each small-vent's location in space and time was reduced to a two dimensional point. To these data we applied a Nearest Neighbor (NN) analysis to determine the degree of spatial randomness, and a two-point azimuth analysis to identify vent alignments.

The NN approach is a method for evaluating the degree of randomness in a spatial distribution [13,14]. The basic approach is to measure the distance from every point to its nearest neighbor. Most applications of the NN approach compare the resulting distribution of nearest neighbor distances to that expected from the Poisson probability distribution, which is indicative of a random process.

We also applied a two-point azimuth technique [15 and references therein] as a measure of the statistical

significance of alignments between vents. The azimuth of line segments connecting each of the vents was measured from west to east across the study area. We produced histograms of azimuth values (0°=north, 90°=east, 180°=south) in 10° bins. Peaks in the azimuth histogram are suggested to result from preferred alignments of points in response to structural controls [12,15]. We compared alignments that we identified in this study with the published tectonic trends identified in the Tharsis province [16,17 and references therein].

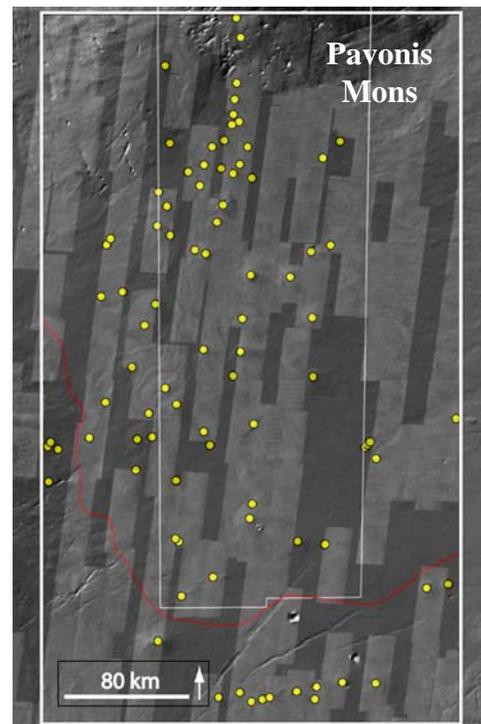


Figure 1. The study area is outlined by the large white box. The small box outlines the extent of HRSC data, and THEMIS images are superposed. The LSF extent is shown in red and the small-vent locations are shown in yellow.

Results: We identified 88 vents in this study. The Pavonis Mons LSF includes 71 small-vents. We identified 4 small-vents within the distal portion of the Arsia Mons rift apron, and 13 east of Arsia Mons. Because these vents are near the margin of our study area they might be members of a different population of small-vents.

The distribution of NN distances within the study region is very well fit by the classic Poisson Nearest

Neighbor distribution, with a mean value of $14.1 \text{ km} \pm 2 \text{ km}$. Because the spatial distribution is so well described by the Poisson distribution, we infer the spatial distribution of these small-vents to be consistent with a randomly distributed Poisson process. We suggest that the effect of such a process was that small vents were equally likely to occur at any location within the sample area, and the existence of any vent did not influence the location of any other vent. Analyses of skewness and kurtosis of the NN distribution also fall well within the acceptable ranges for a Poisson spatial process, further supporting the basic inference that the vents in the study area are spatially random in a Poisson sense.

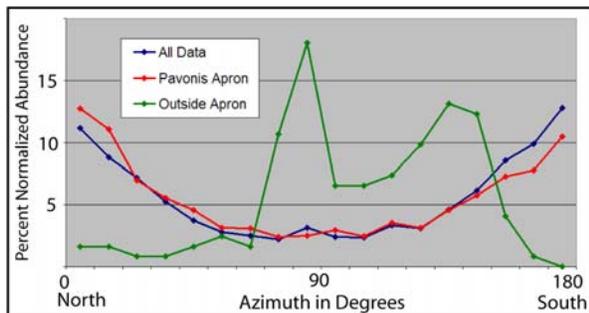


Figure 2. A histogram of azimuth measurements between small-vents in the study area. All vents are shown in blue, only vents within the LSF are shown in red, and only vents outside the LSF are shown in green.

Vent alignments within the study region show concentrations at 0° - 10° and 170° - 180° (Figure 2), which is comparable with the previously measured trend of the LSF's axis [6,8]. Exclusion of vents outside of the LSF results in a slightly stronger N/NE alignment relationship than is shown for all vents within the study area. Both data sets display weak E/W relationships.

Analysis of small-vent alignments outside of the LSF results in a bimodal distribution with weak N/S relationships (Figure 2). A peak centered at 85° represents the alignments within the group of small-vents located in the Tharsis plains east of Arsia. The smaller peak centered at 135° represents the alignments between the vents located at the distal extent of Arsia's rift apron and the vents east of the volcano.

Discussion: NN analyses of the small-vents that comprise the LSF indicate that these features are randomly distributed. The inference that the formation of one vent did not influence the formation of younger vents is consistent with the hypothesis that the development of each vent was driven by independent shallow magma chambers opposed to a single, centralized plumbing system [18,8].

The Pavonis Mons SW rift apron displays a NE

trend [6,8] that is nearly parallel to the trend of the Tharsis Montes chain, suggesting a relationship to that structural pattern. The LSF displays a N/S trend [6,8] as do the small-vent alignments within the field. This trend is offset by several 10s of degrees from the trend of the Tharsis Montes, suggesting a different structural control. Tectonic mapping [16] suggests that a Noachian event produced north trending fractures in this area, and that a later Noachian to Hesperian tectonic event produced west trending fractures in this area, parallel to Valles Marineris. The small-vents inside the LSF display alignment relationships that are nearly parallel to the older, north trending tectonic pattern than to the trend of the Tharsis Montes. Small-vents south of the LSF that display strong E/W alignments might be related to the Noachian-Hesperian tectonic pattern. We do not suggest that these vents developed synchronously with, or as a result of, the tectonic events, but that the pre-existing tectonic patterns acted as a structural control on the locations of vent formation as each independent magma body ascended to the surface.

Conclusions: Statistical analyses of a group of 71 small-vents located in the Pavonis Mons LSF suggest that these features formed independently of each other and that their location was structurally controlled by a pre-existing N/S tectonic pattern. Results for a much smaller sample of vents outside the LSF also imply independent formation and possible structural control by an E/W tectonic pattern. While this sample is small and we are less confident of its statistical significance, our results suggest that the combination of mapping and statistical analyses can be used to identify groups of small-vents with unique spatial and alignment relationships. As we continue to map the entire province, these unique signatures will be used to place the development of possibly unique small-vent fields within the context of Tharsis province evolution.

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