THARSIS LOW SHIELDS: MORPHOMETRY, STRUCTURAL CONTROL AND STATISTICAL ANALYSIS.
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Introduction: The objective of this study is to assess the distribution and control – structural and volcanic – of volcanic vents in areas of plains volcanism in eastern Tharsis (Fig. 1). Fields of small shields have been recognized here, as well as in Tempe, south of Ceraunius Fossae, Syria Planum, in the caldera of the Tharsis Montes shields, and on the aprons of those shields [1].

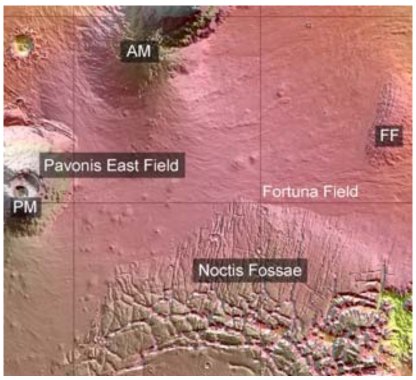

Figure 1. MOLA shaded relief showing the study areas: the Fortuna Field and the Pavonis East Field. PM: Pavonis Mon; AM Ascraeus Mons; FF: Fortuna Fossae.

Small, low relief shields and associated vent- and fissure-fed flows on Mars are similar to that of the Snake River Plains and represent a style of volcanism termed "plains volcanism" by [2]. Recent analyses of such fields in Tharsis suggest that at least some represent the final eruptive activity and that vents are randomly distributed. Those conclusions are inconsistent with observations for vents in the two study areas: the Fortuna Field and the Pavonis East Field which occur between the flank of Pavonis Mons and Fortuna Fossae and Noctis Fossae (Fig. 1).

Methodology: Morphologic and statistical parameters were determined using a combination of Viking, MOC, and THEMIS images and MOLA altimetry. The vents occur in two clusters: Fortuna Field (west of Fortuna Fossae (FF) and east of 258°E) and the Pavonis East field between Pavonis Mons and Noctis Fossae (NF). Vents on the southern aprons of Pavonis (PM) and Ascraeus Mons (AM) were not included.

Results: Almost all of the constructs in both fields have the form of a low relief shield volcano with flank slopes of <<1° and relief of <200 m. Only a few have a morphology suggestive of pyroclastic materials. Fig. 2 illustrates typical morphology.

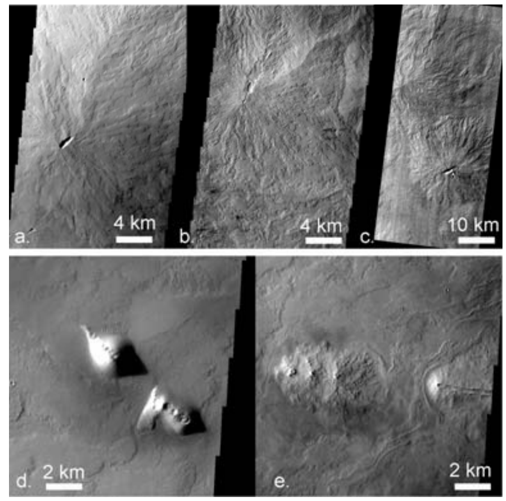

Figure 2. Vent morphologies: a, b, and c show typical low shields with radial lava flows; d and e show possible spatter or pyroclastic features (a: V13198001; b V19051001; c: I03711008; d: V20385007; e: V19076002).

Fortuna Field: A total of 15 vents were identified which exhibit a range of exposed area and relief. Almost all have some degree of elongation of both exposed flank and summit vent. The elongation of the shield is due both to the regional topography (flows moving downslope building an asymmetric edifice) and elongate vents along which asymmetric eruptions occur. Elongation of the vents is considered to be the result of structural control of the eruption location(s). Relief is typically <50 m; only one vent reaches 225 m. There is no correlation between shield relief and summit altitude or location. The long axis of the vent (assumed to represent underlying structural control if present) is typically northeast - an orientation radial to the southern apron of AM rather than along the trends of NF, which presumably underlie the volcanic plains.

Pavonis East Field: A total of 59 vents are included in the analysis having typical relief of 100 m, although heights >100 m to 250 m are not uncommon. The exposed area of the shields and the vents themselves have a typical NE trend parallel to a set of young pit chains and rilles that cut the plains and some of the shield flanks. This parallelism suggests that it is the stress system responsible for these young rilles that controls the orientation, and possibly the location, of the vents rather than the faults from NF that presumably underlie the volcanic plains. Only those vents near the boundary with NF appear to be influenced by those faults; vents on the west side of the field are controlled by the southern apron to PM.

Statistical Analysis: An analysis of the spatial distribution of the two groups of vents was performed ; the statistics are listed in Table I. The approach is to evaluate the distribution of nearest neighbors (NN) and test whether it is consistent with Poisson spatial randomness. Poisson spatial randomness suggests that the formation of one feature has no influence on the location of other features. When other non-Poisson forms of spatial randomness are present, the nature of the distribution of nearest neighbors can lead to inferences about the underlying physical processes and controls on feature formation [3,4].

Table I. Descriptive Statistics

Statistic	Fortuna	Pavonis E
Average Spacing (km)	79.1	23.5
Median Spacing (km)	67.3	17.6
Std. Dev. (km)	32.3	21.5
Range (km)	82.3	94.9
Std. Skewness	1.319	4.740
Std. Kurtosis	0.144	4.108

The NN distribution for the Pavonis East field is shown in Fig. 3. Although the distribution qualitatively resembles the Poisson NN distribution, the standardized skewness and kurtosis clearly preclude spatial randomness. These values reside well beyond acceptable limits (as illustrated in figure 8a of [99]). The population is clearly clustered. The statistical result indicates that the tendency for shield clustering greatly exceeds what would be expected by chance. The Fortuna Field has a distribution with skewness and kurtosis values within the limits of acceptability for Poisson spatial randomness. However, due to the small sample size other types of distributions cannot be rigorously precluded.

Discussion: [5] conducted a statistical analysis of the low shields on the southern apron of Pavonis Mons. With 88 vents, they calculated a mean spacing of 14.1±2 km. Because the distribution was well-described by the Poisson NN statistic they concluded it was consistent with a random distribution - vents likely to occur anywhere in the area and that one vent does not influence the location of any other vent.

Statistical analyses such as these can only be taken so far before inappropriate geologic conclusions are drawn. While the statistics of a volcanic area may suggest the location of vents is "random," it clearly can not always be interpreted to indicate that a low shield or vent may (or does) occur anywhere. Vents and low shields in the Tharsis area are localized on the aprons of the Tharsis Montes shields and on restricted plains areas that experienced tensional stresses because the magma sources and pathways to the surface are localized.

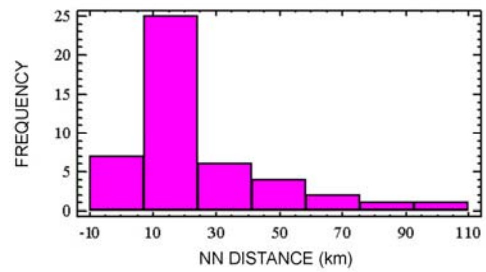

Fig. 3. Nearest Neighbor distances for vents in the Pavonis East field.

[6] identified a number of constructional volcanic vents on the southern aprons of Pavonis and Ascraeus Mons. They suggest that these shields represented the most recent effusive event in the area. That relation clearly does not hold for the low shields of the Pavonis East and Fortuna Fields. This region has been largely covered by lava flows extending from the aprons of PM and AM. The margins of all of the vents are embayed by younger flows. These flows, up to 60 m thick, extend eastward past Fortuna Fossae into southern Kasei Valles, a distance of ~1500 km.

Conclusions: The Fortuna and Pavonis East fields are typical of plains volcanism; the vents are almost exclusively low shields built by eruption of lavas from a central vent. Their location, distribution, and orientation are controlled by tectonic features and proximity to the magma sources that fed the southern aprons of Pavonis and Ascraeus Mons. Statistical analysis indicates that the Pavonis East vents are not randomly distributed, consistent with a model of tectonic control, while the analysis for the Fortuna vents is equivocal.

References: [1] Hodges C. and Moore H. (1994) USGS Prof. Paper 1534; Plescia J. (1981) Icarus, 45, 587-601; Sakimoto S. et al. (2002) LPS XXXIII, Abstract 1717; Schupack B. and Sakimoto S. (2006) LPS XXXVIII, Abstract 1157; Mouginis-Mark P. and Christensen P. (2005) *JGR, 110,* doi:10.1029 / 2005JE002421. [2] Greeley R. (1982), *JGR, 87*, 2705-2712. [3] Baloga S. M. et al. (2007), *JGR 112*, E03002, doi:10.1029 / 2005JE002652. [4] Bruno B. C. et al. (2006) *JGR, 111,* doi:10.1029/2005JE002510. [5] Glaze L. et al. (2007) *GSA Abstracts with Programs, 39*, 124. [6] Bleacher J. et al. (2007) *JGR, 112*, E09005, doi:10.1029/2006JE002873.