**ANALYSIS OF FLANK VENTS AT LARGE VENUSIAN VOLCANOES.** E.R. Stofan[1] and L.S. Glaze[2], [1]Proxemy Research, PO Box 338, Rectortown VA 20140, ellen@proxemy.com, [2]NASA Goddard Space Flight Center, Greenbelt MD 20771.

**Introduction:** Flank eruptions on large volcanoes provide a window into the volcano's interior plumbing system. Small cones and vents are common on the flanks of terrestrial volcanoes and form in many cases over dikes connected to the central conduit (e.g. Mount Etna [1]; Kilauea, Hawaii [2]). Flank vents provide evidence for the drainage and repetitive intrusion and extrusion of magma from the central conduit [3]. At terrestrial volcanoes, satellite or flank vents are often related to the influence of faults that allow magma to migrate laterally from the main magma chamber or sometimes vertically from a magma system, and the products of these flank vents generally have a broader range in composition than main vent eruptions (e.g., 3-6).

Small edifices (<5 km diameter) on large venusian volcanoes indicate that flank eruptions are an integral part of their formation, occurring throughout their evolution [7, 8]. They are located both at the summit and on the flanks of large volcanoes, with many located at the edifice break in slope and the lower portions of the flanks, suggesting that these regions are areas of lowest stress where magma might propagate through the volcano more easily (Brian et al., in prep.). Large numbers of small edifices are also located around many volcanoes' summit regions (e.g. 7, 9). Some of these are steep-sided domes, which may indicate differing late stage eruption conditions and/or more evolved lava compositions. Individual flows from sources on the flanks of venusian volcanoes are difficult to detect, even at the highest resolution of the data, possibly due to similar radar backscatter to the flow apron they are emplaced upon and probable small size. However, some flank flows can be seen (e.g., 7), and their approximate source area identified. Several recent studies of terrestrial and planetary volcanic features have shown that analyses of their spatial distributions can, in some cases, be used to help constrain physical processes that influence formation [10-16].

**Method:** Spatial relationships are assessed for the small vents on the flanks of Sif Mons, Kunapipi Mons, Hathor Mons and Maat Mons on Venus to determine something about the style of volcanism at each center, the degree of randomness in the locations of these small vents, and using any systematic behavior to provide insight into formation mechanisms. We compare information on spatial distributions of small vents to ascertain whether significant similarities or differences exist. These differences may be due to changes in eruptive style from one volcanic center to the next, or possibly a reflection of differences in the plumbing (and lava distribution) systems of the volcanic centers. We also compare results for volcanoes on Venus with similar work currently being conducted for small vent fields near the Tharsis volcanoes on Mars [16, 17].

**Preliminary Results:** We have done an initial analysis of two of our large volcanoes, Sif Mons and Kunapipi (KP) Mons. Sif Mons is located on a topographic rise (Western Eistla Regio) and has a summit caldera; KP Mons is located on a rift zone and has a complex summit region consisting of several episodes of dike intrusion, caldera formation, and caldera infill [7]. We describe the nature of the flank eruption site, note its position on the volcano, its relative stratigraphy and its elevation. Given the resolution of the Magellan data, we are likely to be under-representing the number of flank eruption sites, and potentially misidentifying some features. Magellan SAR image data (80 m/pixel) were used to identify small volcanic vents on the flanks of the edifice. As this was a proof of concept, we used fairly loose criteria for a vent, including points of flow initiation, small edifices and pits. Using these criteria, 295 such vents were identified at Sif Mons (Fig. 1), and 495 at KP.

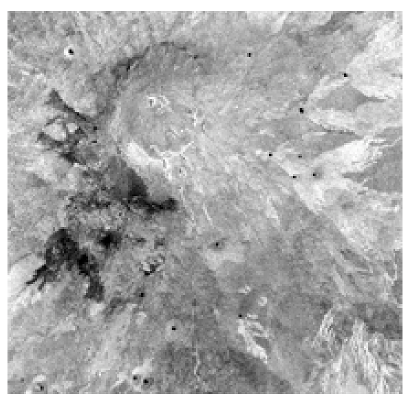

*Figure 1. 180 km across Magellan SAR image of Sif Mons summit region. Black dots indicate locations of flank vents.*

The Nearest Neighbor (NN) technique [15, 18 19], where the distance from each point to its nearest neighbor is calculated, was used to analyze the spatial distributions of small vents. Analysis of the distribution of NN distances is commonly used to determine the degree of randomness in a spatial population. Baloga et al. [15] has developed several useful statistical methodologies for distinguishing between classic randomness caused by a Poisson process, and other possible random distributions. These other random process include a renormalized Poisson NN distribution that accounts for a finite lower limit on distances (e.g., remote sensing resolution limitations), and scavenging processes that may deplete resources (e.g., lava) available to form subsequent features. Figure 2 shows the distribution of NN distances for the KP small vents. Despite the fact that KP has almost twice as many small vents as Sif, the distribution of NN distances for small vents appears quite similar at both volcanoes. Also shown are the Poisson and renormalized Poisson NN distributions. The distribution of NN distances is not well described by either random distribution, or by the scavenging distributions. Thus, we preliminarily conclude that there is a systematic control on the locations of the vents at both KP and Sif. As the lack of fit with the Poisson distribution occurs at shorter distances, we infer that the small vents on the flanks of these volcanoes naturally occur in clusters.

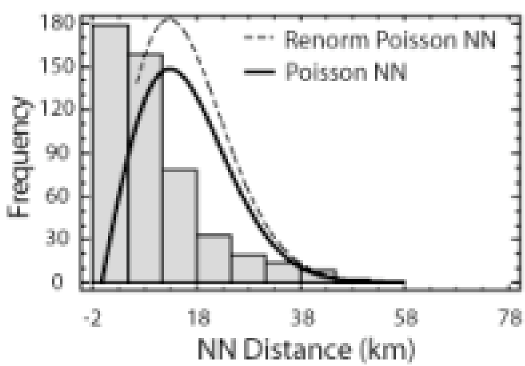


*Fig. 2. Distribution of NN distances for KP vents.*

**Preliminary Conclusions:** The clusters of vents mapped at Sif and KP Montes may be associated with dike systems or rift zones within the volcanic constructs. This is substantially different from what has been found in a study of the small vent field on the southern flanks of Pavonis Mons [16], where the NN distances are well fit by the Poisson NN distribution, and vent locations are more strongly controlled by regional stresses and fractures than internal plumbing. Given the very different settings of the two venusian volcanoes (topographic rise vs. rift zone) our conclusion is somewhat surprising. However, KP is superposed on the rift, with only minor fracturing of its flows [20]. Our study of vents may indicate that regional stresses associated with rift formation had largely subsided by the time of KP growth.

**References:** [1] Chester D.K., A.M. Duncan, J.E. Guest J.E. and C.R.J. Kilburn (1985) *Mount Etna. The anatomy of a volcano*. Chapman and Hall London: 1-404 pp. [2] Klein, F.W. (1982) *J.Volc.Geotherm Res*., 12, 1-35. [3] Guest, J.E. and A.M. Duncan (1981) *Nature* 290, 584-586. [4] Dieterich, J. H., and R. W. Decker (1975) *J. Geophys. Res*., 80, 4094-4102. [5] Rogers, P.G. and M.T. Zuber (1998) *J. Geophys. Res*. 103, 16,841-16,854. [6] Davidson, J and S. De Silva (2000), in *Encycl. Volcanoes,* H. Sigurdsson (ed.), Academic Press, San Diego, 63-681. [7] Stofan, E.R., J.E. Guest and D.L. Copp (2001) *Icarus*, 152, 75-95. [8] Brian, A.W., S.E. Smrekar, E.R. Stofan, J.E. Guest (2004) *Lunar Planet. Sci XXX.*. [9] Keddie S.T., and J.W. Head, (1994) *Planet. Space Sci.*, 42, 455-462. [10] Connor, C.B. and M.F. Conway (2000) in *Encycl. Volcanoes*, H. Sigurdsson (ed.), pp. 331 - 343, Academic Press, San Diego. [11] Glaze, L.S., E.R. Stofan, S.E. Smrekar and S.M. Baloga (2002) *J. Geophys. Res*., 107, 5135. [12] Bruno, B.C., S.A. Fagents, T. Thordarson, S.M. Baloga, and E. Pilger (2004) *J. Geophys. Res.*, *109* doi:10.1029/2004JE002273. [13] Bruno, B.C., S.A. Fagents, C.W. Hamilton, D.M. Burr, and S.M. Baloga (2006) *J. Geophys. Res.* 111, doi:10.1029/2005JE002510. [14] Glaze, L.S., S.W. Anderson, E.R. Stofan, S.M. Baloga, and S.E. Smrekar, (2005) *J. Geophys. Res*., *110*, doi:10.1029/2004JB003564. [15] Baloga, S.M., L.S. Glaze, and B.C. Bruno(2007) *J. Geophys. Res. 112*, doi:10.1029/2005JE002652. [16] Bleacher, J.E., L.S. Glaze, R. Greeley, E. Hauber, S.M. Baloga, S.E.H. Sakimoto, D.A. Williams, and T.D. Glotch (2009) doi:10.1016/j.volgeores.2009.04.008. [17] Glaze, L.S., J. Bleacher, R Greeley, T.D. Glotch, and S.M. Baloga (2007) *Proc. GSA, Paper #46-13*. [18] Hertz, P., (1909) *Math. Ann.*, *67*, 387 - 398. [19] Clark, P.J., and F.C. Evans (1954) *Ecology*, *35*, 445-453. [20] Stofan, E.R. and J.E. Guest (2003) *USGS Geol. Inv. Series Map I-2779.*