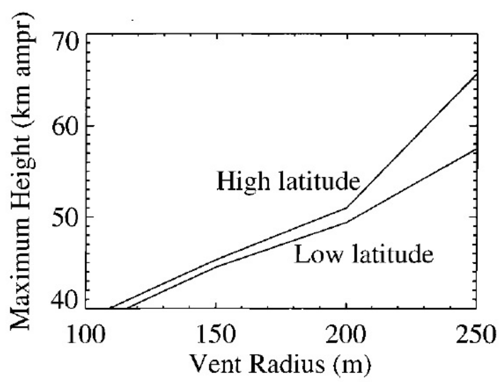
CHARACTERIZING VOLCANIC ERUPTIONS ON VENUS: SOME REALISTIC (?) SCENARIOS. E.R. Stofan[1], L.S. Glaze[2] and D.H. Grinspoon[3]. [1]Proxemy Research, PO Box 338, Rectortown VA 20140, ellen@proxemy.com, [2]NASA-Goddard Space Flight Center, Greenbelt, MD 20771, [3]Denver Museum of Nature and Science, Denver, CO 80229.

Introduction: When Pioneer Venus arrived at Venus in 1978, it detected anomalously high concentrations of SO_2 at the top of the troposphere, which subsequently declined over the next five years [1]. This decline in SO_2 was linked to some sort of dynamic process, possibly a volcanic eruption [1]. Observations of SO_2 variability have persisted since Pioneer Venus [2-6]. More recently, scientists from the Venus Express mission announced that the SPICAV (Spectroscopy for Investigation of Characteristics of the Atmosphere of Venus) instrument had measured varying amounts of SO_2 in the upper atmosphere; VIRTIS (Visible and Infrared Thermal Imaging Spectrometer) measured no similar variations in the lower atmosphere (ESA, 4 April, 2008). In addition, Fegley and Prinn [7] stated that venusian volcanoes must replenish SO_2 to the atmosphere, or it would react with calcite and disappear within 1.9 my. Fegley and Tremain [8] suggested an eruption rate on the order of ~1 km^3/year to maintain atmospheric SO_2; Bullock and Grinspoon [9] posit that volcanism must have occurred within the last 20-50 my to maintain the sulfuric acid/water clouds on Venus. The abundance of volcanic deposits on Venus and the likely thermal history of the planet suggest that it is still geologically active, although at rates lower than Earth. Current estimates of resurfacing rates range from ~0.01 km^3/yr [10] to ~2 km^3/yr [11, 12]. Demonstrating definitively that Venus is still volcanically active, and at what rate, would help to constrain models of evolution of the surface and interior, and help to focus future exploration of Venus.

Sources of Volcanism: We attempt to constrain the atmospheric contributions of explosive volcanic eruptions on Venus, advancing beyond previous studies by linking improved data on the distribution and nature of volcanic features on the surface to plume modeling and our latest understanding of atmospheric dynamics. In order to constrain volcanic eruptions on Venus, we need to consider the major likely contributors to a significant volcanic eruption, their likely eruption style, vent elevation and vent size. The likely major sources of volcanism on Venus are likely to be large and intermediate volcanoes, coronae and large lava flow fields (e.g., 13). We have a catalogue of 135 large volcanoes on Venus, [14], coronae (e.g., 15, 16), and intermediate volcanoes [17]. In addition, a catalogue of 200 major flow fields on Venus has been published [18]. We can further constrain volcanic eruptions on Venus by linking these feature types to known terrestrial eruption rates and styles, for example, large flow fields. Mylitta Fluctus lies at a relatively low elevation at high southern latitudes [19]. The flow volume at Mylitta Fluctus is somewhat smaller than terrestrial flood basalts due to its lower estimated thickness. However, estimates of SO_2 release for Deccan Traps eruptions are on the order of 3.5 teragrams of SO_2 for every cubic kilometer of lava erupted [20]; Mylitta Fluctus has an estimated minimum volume of 2 x 10^4 km^3 [19], corresponding to a potential contribution of 7 x 10^4 teragrams of SO_2 over the duration of the erup-



tion.

Glaze [21] investigated the possibility of an explosive volcanic eruption plume causing the Pioneer Venus SO_2 anomaly, improving upon previous models of eruption plume evolution (e.g., 22, 23) by using a continuous solution for the transition of the plume from the jet region to the buoyancy-driven region. This solution is strongly dependent on initial temperature and volatile species, and shows that the plume becomes buoyancy-driven almost immediately above the vent. Glaze [21] also looked at the effect of latitude and elevation, finding that the stability of the upper atmosphere at high latitudes and the sharp gradient in atmospheric pressure with latitude results in higher plumes over northern highlands than in the equatorial lowlands (graph above). At Maat Mons, she found that plumes could reach heights detectable by Pioneer Venus from large vent/large mass flux eruptions, using an initial magma water content of 5 weight %. Glaze et al.[24] investigated the shape of vents on atmospheric plume rise, and concluded that although boundary conditions required to sustain a buoyant plume above a linear vent are more restrictive than a circular vent, linear vent plumes are capable of rising much higher on Venus than analogous plumes (i.e., mass eruption rates) from circular vents.

The sulfuric acid clouds of Venus are created by photochemical reactions of SO_2 into SO_3, which subsequently reacts with H_2O to form H_2SO_4. As SO_2 is lost over time to surface-atmosphere reactions (primarily $SO_2 + CaCO_3 \leftrightarrow CaSO_4 + CO$), a volcanic source is required to maintain the clouds over time. Large episodes of volcanic activity can thus potentially change the overall thickness and radiative properties of the clouds, causing climate feedbacks [9]. We combine the plume models and atmospheric dynamics with constraints from surface geology to determine what ranges of eruption and atmospheric conditions are capable of producing the observed variations in the atmosphere described above.

Progress to Date: We have identified an initial set of possible candidates for current eruptions (Table 1), with different vent morphologies (calderas, fissures) at a variety of latitudes and elevations. For each plausible eruption site (latitude and elevation) identified, we are determining the range of boundary conditions (vent size, eruption velocity, volatile fraction) required to establish a buoyant plume. These results are combined to explore the cumulative volatile contributions resulting from a range of plausible scenarios. Thus, we explore the relative contributions of a number of scenarios, including: 1) a single large eruption, 2) three large and five intermediate simultaneous eruptions, and 3) five large and 15 intermediate simultaneous eruptions. These results are combined with atmospheric models, to determine the fate, and likely detectability of these eruption plumes.

As an example, at Idunn Mons, a possible site of recent volcanism [25], we estimate that an explosive eruption sustained for 24 hours would be capable of rising to a height of ~63 km ampr and of injecting 60,000 Mt (6×10^{13} kg) of water vapor over the 24 hour period (equivalent to 0.12% of the total water vapor in the Venus atmosphere).

References: [1] Esposito, L. (1984) *Science, 223,* 1072; [2] Esposito, L. et al. (1988) *JGR, 93,* 5267; [3] Na, C.Y. et al. (1990) *JGR, 95,* 7485; [4] Na, C.Y. et al. (1991) *Bull. Amer. Astr. Soc., 23*, 1196; [5] Na, C.Y. et al. (1993) *LPS XXIV*, 1043; [6] Barker, E.S. et al. (1992) *Bull. Amer. Astr. Soc., 24*, 996; [7] Fegley, B. and R.G. Prinn (1989) *Nature, 337,* 55; [8] Fegley, B. and A. Tremain (1992) In *Venus and Mars: Atmospheres, Ionospheres and Solar Wind Interactions*, J.G. Luhmann et al. eds., 7, AGU, Wash. D.C.; [9] Bullock, M.A. and D.H. Grinspoon (2001) *Icarus, 150*, 19037; [10] Basilevsky, A.T and J.W. Head (2002) *Geology, 30*, 1015; [11] Phillips, R.J. et al (1992) *JGR, 97*, 15923; [12] Bullock et al (1993) *GRL, 20* , 2147; [13] Stofan, E.R. and S.E. Smrekar (2005) *GSA Spec. Paper 388*, 841; [14] Brian, A.W. et al. (2004) *LPS XXXV*; 1179; [15] Stofan, E.R. et al. (1992) *JGR, 97*, 13378; [16] Stofan, E.R. et al. (2001) *GRL, 28*, 4267; [17] White, O.L. et al. (2008) *LPS XXXIX*, 1248; [18] Magee, K.P. and J.W. Head (2001) *GSA Spec. Paper 352*, 81; [19] Roberts, K.M. et al. (1992) *JGR, 97*, 15991; [20] Self, S. et al. (2008) *Science, 319*, 1654; [21] Glaze, L.S. (1999) *JGR, 104*, 18899; [22] Thornhill, G.D. (1993) *JGR, 98*, 9107; [23] Robinson, C.A. et al. (1995) *JGR, 100*, 11755; [24] Glaze, L.S. et al. (2010) *LPS XXXIX*, 1326; [25] Smrekar, S.E. et al. (2010) *Science, 328*, 605.

Feature	Length	Width	Altitude	Lat	Lon
Fracture at Colette volcano	72	2.4	6055.5	66N	324
Tepev Mons, Bell Regio		11, 31	6056.5	29.6N	44.5
fracture, Nyx Mons, Bell	41	0.8	6053	30N	50
Idunn Mons Imdr Regio		5.6	6054.5	46.6S	214.5
Mielikki Mons fracture	10	0.4	6052.8	28.1S	281.2
plains fracture	12	1	6053	4.1S	202
plains fracture	32	1	6053.5	0.9N	206.3

Table 1. Initial set of analyzed volcanic features on Venus. All were chosen as they are stratigraphically young, and some correspond to high emissivity VIRTIS signatures (i.e., [25]).