DISTRIBUTION OF INTERMEDIATE VOLCANOES ON VENUS AS A FUNCTION OF ALTITUDE. Shannon Ristau (Geology Dept., Smith College, Northampton, MA 01063), James Sammons III (Geology Dept., Washington and Lee University, Lexington, VA 24450), Eric Grosfils and, Linda Reinen (Geology Dept., Pomona College, Claremont, CA 91711), Martha Gilmore and Samuel Kozak (Geology Dept., Washington and Lee University, Lexington, VA 24450).

Overview: Analysis of the distribution of intermediate volcanoes on Venus as a function of elevation, in agreement with model predictions [1], suggests that their emplacement was controlled by neutral buoyancy. The intermediate volcanoes as a single population show a preference for forming at intermediate elevations, 6051-6053 km. The steep-sided domes occur at intermediate elevations. Ticks also form at intermediate elevations, although their range is slightly higher than the steep-sided domes. The anemones form at higher altitudes than the other two classes of intermediate volcanoes, with over half the population occurring at altitudes greater than 6053 km. These results, when combined with those from previous studies [2,3], suggest that neutral buoyancy has played an important role in the observed behavior of reservoir-derived volcanism on Venus.

Introduction: The population of 274 intermediate volcanoes on Venus, which range from 20-100 kilometers in diameter [4], is divided into four separate classes on the basis of morphology: 145 steep-sided domes [5], 50 ticks, 25 anemones, and 54 volcanoes of various morophologies that are found in other size divisions. The steep-sided domes are flat-topped, circular features with steep sides that often have central depressions [5]. Ticks are characterized by a raised, circular plateau that may be flat or have a topographically depressed central area, with radiating ridges extending from the raised rim. The similarity of the ticks and the steep-sided domes has raised a hypothesis that ticks form from steep-sided domes [6]. The anemones typically have petal-like, radar-bright, flows that radiate from a source that is crater-like or fissure-like [4].

Construction of intermediate volcanic edifices implies the presence of an underlying magma reservoir from which magma erupts. Existing theoretical models [1] suggest that magma reservoir formation on Venus may be dependent upon altitude, as the physical behavior of the erupted materials will be sensitive to the magnitude of the atmospheric pressure at the eruption site. Specifically, this model predicts that given the normal range of basaltic magma volatile concentrations one expects no reservoirs below 6051 km, that reservoir depth will increase with altitude, that reservoir size will increase with altitude, and thus that there is a progression from smaller edifices at lower elevations to larger volcanoes and then intrusives at higher altitudes. This theory is supported by the results found in studies on large volcanoes [2] and radiating dike swarms [3]. Here we continue testing the neutral buoyancy model predictions by examining the distribution of steep-sided domes, ticks, and anemones as a function of elevation across the surface of Venus, and assess the implications for intermediate volcano formation.

Methods: We use the data from the Magellan Global Topography Data Record to determine the basal altitude of the volcanoes. For each edifice we obtain the average altitude of four points adjacent to the base. To assess the data we utilize chi square tests to compare the distribution of the intermediate volcanoes with the randomly distributed population. A random distribution of volcanoes would be the expected number of volcanoes at a given elevations in direct proportion to the amount of Venusian surface that occurs there.

Results: The intermediate volcano population exists mainly at intermediate elevations, although a small number do occur at slightly higher elevations in relation to the predicted randomly distributed population (Figure 1). The mean altitude for the intermediate volcanoes is 6051.6 km. A chi square test reveals that the observed population and the expected population are different populations with >85% confidence level. An examination of intermediate volcano elevations by class reveals that the steep-sided domes have a mean elevation of 6051.8 km; this places the steep-sided domes, on average, at or slightly below the mean planetary radius (Figure 2). A chi square calculation indicates with 99% certainty that the steep-sided domes are statistically different from a random distribution [5]. Ticks occur slightly above the steep-sided dome population with a mean altitude of 6051.7 km (Figure 3). The ticks and a randomly distributed population are different with a 99% confidence. The anemones fall at higher altitudes than ticks or steep-sided domes; the mean altitude of the anemones is 6052.6 km (Figure 4). There is a 99% confidence that the anemones are different from a randomly distributed population. These data indicate the population of intermediate volcanoes is not randomly distributed as a function of altitude.

Discussion: Neutral buoyancy predicts a paucity of volcanic edifices below 6051 km, however, our study indicates more than 30 percent of intermediate volcanoes form at or below this altitude. This could indicate that the predicted depth of magma reservoir formation is deeper than the actual depth. If we compare the mean elevations of the intermediate volcano, large volcano, and radiating dike swarm populations, however, the observed trends follow the predictions of the neutral buoyancy theory. The transition between volcano size and intrusive-dominated features with elevation does increase with elevation as predicted.

While the distribution of steep-sided domes and ticks follow the predictions of the neutral buoyancy theory, the anemones do not. Anemones occur at a much higher altitude than a shallow magma chamber volcano should, they even form at higher elevations than the large volcanoes and radiating dike swarms. One potential problem is that the anemone population is small, and thus those few features observed at unusually high elevations may skew the data. Alternatively, the observed distribution may indicate that the anemones represent an unusual style of volcanism on Venus. While further work is required to constrain the anemones' time of formation and physical volcanic style, it is clear that these features are an enigmatic population.

Our data indicate that ticks occur at a mean altitude of 6051.7 km, while steep-sided domes have a mean elevation of 6051.5 km. Our data thus indicate that, if ticks are forming through collapse of steep-sided domes, this process is elevation dependent, suggesting that the potential for collapse and landslide formation is altitude dependent. In any event, models which attempt to explain tick formation in this manner need to take the observed elevation difference into consideration. These results, along with those of previous studies [2,3,5], indicate that volcanic processes on Venus are altitude dependent, and that neutral buoyancy has played an important role in the observed behavior of reservoir-derived volcanism on Venus.

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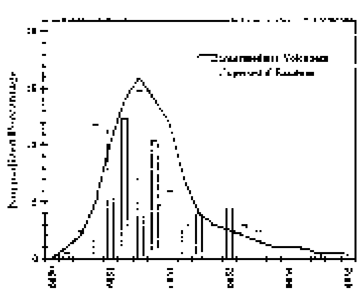

Fig. 1. Graph of observed distribution of intermediate volcanoes as a function of altitude.

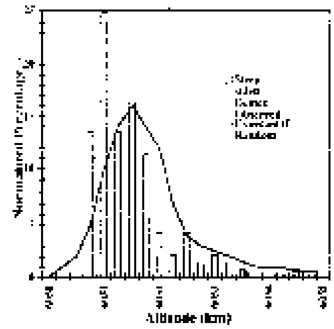

Fig. 2. Graph of observed distribution of steep-sided domes as a function of altitude.

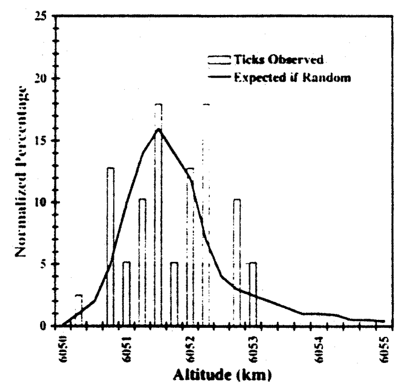

Fig. 3. Graph of observed distribution of ticks as a function of altitude.

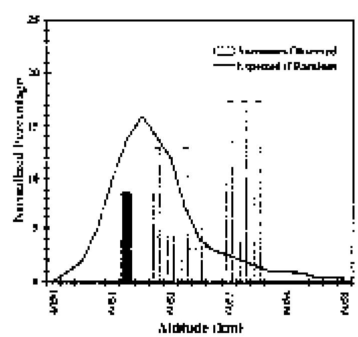

Fig. 4. Graph of observed distribution of anemones as a function of altitude.