COMPLEX RADAR EMISSIVITY VARIATIONS AT SOME LARGE VENUSIAN VOLCANOES. K. Toner, M. S. Gilmore and J. F. Brossier, Dept. of Earth and Environmental Sciences, Planetary Science Group, Wesleyan University, 265 Church St., Middletown CT, (mgilmore@wesleyan.edu).

Introduction: Several authors [1-3] observe reductions in radar emissivity at high altitudes (>2.5 km above MPR of 6051.8 km) on volcanoes that are best explained by changes in mineral compositions at these locations. The presence of ferroelectric or semiconductor materials are possible explanations for the low emissivity. The elevation and temperature of these transitions can constrain the possible minerals present on these volcanoes. This study attempts to characterize the variability of the magnitude and elevation of the low emissivity changes found on 21 large volcanoes on Venus.

Methods: In ArcMap, 21 volcanic features were mapped using Magellan SAR FMAP global mosaic, with a resolution of ~75 km/pixel. These features include 19 large volcanoes that are > 2.5 km tall, with the exception of Nyx Mons which was included due to its proximity to two other volcanoes that do meet the requirement. The other two features mapped are Mahuea Tholus and Ovda Fluctus. Elevation and radar emissivity were derived for each volcano from global maps created by [4]. The data were subdivided by whether or not the surface is beneath a crater parabola to investigate whether these crater materials effect emissivity signatures.

Low emissivity excursions are defined as the region on an emissivity – elevation plot (Fig. 1) where emissivity values drop rapidly and become distinct from the emissivity values seen at lower (and sometimes higher) elevations which tend to cluster at the global plains average of ~0.8-0.9. Temperatures for each elevation are calculated using data from [5] assuming that the temperature follows a standard adiabatic lapse rate in the near-surface atmosphere.

Results and Discussion: *General trends.* The emissivity of 19 volcanoes declines steadily with elevatios above ~6052 km. Two volcanoes, Colette and Mahuea, do not change emissivity with elevation. This general trend can be seen on Ozza Mons (Fig. 1) where emissivity values of ~0.8-0.9 at the lowest elevations begin to steadily decrease near MPR reaching a minimum < 0.4 at ~ 4 km elevation before sharply increasing in emissivity at higher elevation. The magnitude and the elevation of these emissivity minima, or excursions, varies on different volcanoes and can be used to group volcanoes with common trends [6].

In addition to the general trend, 8 volcanoes have additional low emissivity excursions, such as that seen on Ozza at ~ -0.5 km (Figs. 1-3). A single volcano may have multiple excursions of different magnitudes at different heights, but they are typically sharp, with a near-horizontal slope in the emissivity-elevation plot.
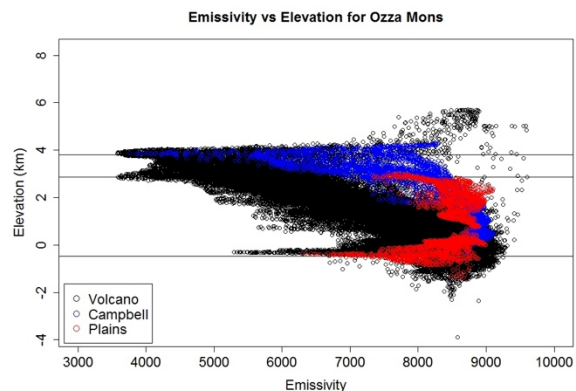

Figure 1: Emissivity (x1000) versus elevation (relative to 6051.8 km) of Ozza Mons. Blue values correspond to pixels covered by visible parabolas reported in [7], red are pixels modeled crater parabolas from plains craters [4], black are pixels that are not covered by crater parabolas. Lines correspond to major emissivity excursions.

The Summits. The emissivity of several volcanoes appears to be controlled by elevation, a proxy for temperature. By examining the relationship between the SAR data and the emissivity, we see that the general trend of lower emissivity with elevation corresponds to volcano summits as has been seen in previous studies [1,2]. The behavior of the emissivity at Ozza Mons (gradual decrease in emissivity to a low value, then a sharp increase in emissivity with elevation) is consistent with the presence of a ferroelectric mineral that reaches a maximum at the Curie temperature [1-3].

Localized Emissivity Excursions. The sharp excursions seen on the various volcanoes correspond to geographically localized deposits. In Ozza Mons, the -0.5 km emissivity excursion corresponds to two lobes at the end of a lava flow on the northern flank (Fig. 2). On Maat Mons, three low emissivity excursions occur within a radar-bright lava field lying on the southern flank of the volcano (elevations from 1.1 to 3.4 km, emissivity values of 0.50-0.58), and at the end of a lava flow to the northwest of Maat (elevation -0.1 km, emissivity ~0.68). In Ongwuti Mons, two low emissivity excursions take place on a lava complex on the south (elevation 0.2-1.1 km, emissivity of 0.62-0.63 and another lies near the summit at 3.7 km, emissivity ≥0.65).

Effect of Crater Parabolas and Time Constraint. Parts of most of the volcanoes are covered by crater ejecta parabolas. These include the radar-dark parabolas observed across the planet by [7] ("Campbell" parabolas) which are formed from ejecta lofted from (in this region) plains craters and transported westward by high altitude winds. We can also assume that all craters would have initially had a parabola that has been removed by erosion over time [8]. These "modeled" parabolas can be derived from craters from on plains or tesserae. All parabolas have the potential to change the emissivity of underlying surfaces, either due to adding materials of a different composition and/or by adding materials that are young and have not had time to weather to low emissivity materials. The 49 visible parabolas represent 10% of the total population of Venus craters, yielding a crater age of approximately 50 Ma, while we expect modeled parabolas should have a mean age of the surface of ~500 Ma [9].
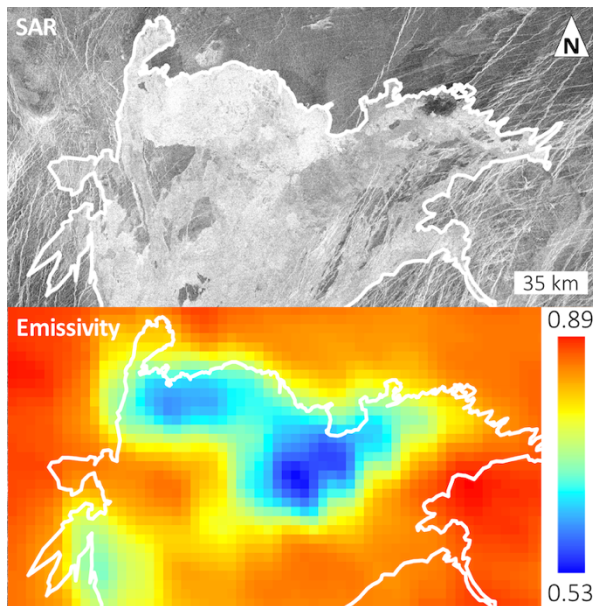

Figure 2: SAR-bright lava flow field to the north of Ozza Mons where low emissivity excursion at -0.5 km is detected. This area is centered at 9.2˚N, 203˚E.

For Ozza, both visible and modeled parabolas show some degree of emissivity decrease with altitude, where the location of the excursions of overlaps the values for the uncovered (no parabolas), and therefore older, volcano surfaces. This implies that the relevant ferroelectric mineral is present in all three materials. The Campbell parabola values reach values as low as the lowest values on the uncovered surfaces. This suggests that the deposits from this crater have had enough time to weather to produce the emissivity anomaly; or, it takes 50 Ma or less for the weathering reaction to occur in these (plains) sediments at this location.

Variety of Emissivity Excursions. The volcanoes display multiple emissivity excursions over an elevation range of 5 km or 40K! This includes localized excursions below MPR. The elevation of the primary, summit excursions is similar for the large volcanoes: Maat, Ongwuti, Ozza,Theia and Tepev Montes (~4 km), however differs for Sapas, Polik-Mana and Gula (~MPR) [1, 3, 6]. This requires that these groups of volcanoes have high dielectric minerals of different composition. The localized flows can occur at any elevation, although they may cluster at some common elevations (indicated by lines in Fig. 3). At Ozza, the wide range of elevations suggests that there are multiple ferroelectric minerals with different critical temperatures present on this single volcano. This may be due different rock compositions of individual flows, or different atmospheric compositions, say from volcanic vapors associated with a specific eruption [e.g., 10].

The magnitude of the emissivity excursions, even at multiple elevations, does seem to correlate with an individual volcano. That is, each of Ozza's three excursions are lower than those of Theia which are in turn lower than Ongwuti (Fig. 3). The size of the excursions is a function of the volume of ferroelectric minerals, or age/degree of reactivity, which would the ferroelectrics to react more completely than other volcanoes.
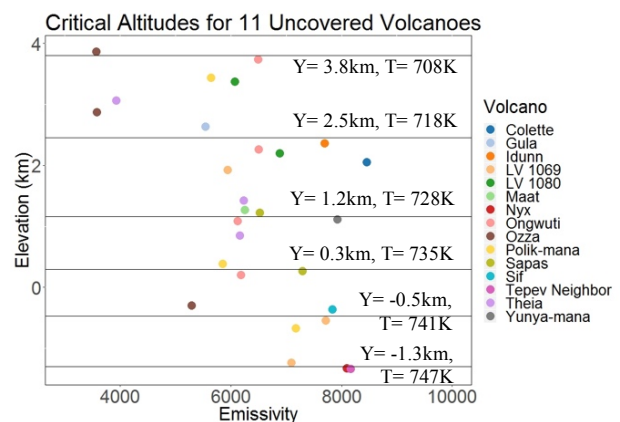

Figure 3: The lowest emissivity points of each volcano's emissivity excursion on ejecta-free surfaces. Horizontal bars mark the average elevation of a cluster of critical altitudes with the corresponding elevation and temperature values [5] for reference.

References: [1] Klose et al. (1992) *JGR, 97,* 16353. [2] Shepard et al. (1994) *GRL, 21,* 469. [3] Treiman et al. (2016) *Icarus, 280*, 172. [4] Stein and Gilmore (2017) *48th LPSC*, 1183. [5] Seiff et al. (1985) *Adv. Space Res., 5,* 3. [6] Brossier et al., this conference. [7] Campbell et al. (1992) *JGR, 97,* 16249. [8] Basilevsky A. T., et al. (2004) JGR 109, E12003. [9] Strom et al. (1994) JGR 99, 10899; McKinnon et al. (1997) Venus II, 969. [10] Brackett R. A. et al. (1995) JGR 100, 1553.