

RADIOPHYSICAL BEHAVIORS OF VENUS' PLATEAUS AND VOLCANIC RISES: UPDATED ASSESSMENT. J. F. Brossier^{1*}, M. S. Gilmore¹, K. Toner¹. ¹Wesleyan University, Planetary Science Group, Middletown CT, 06459 USA (jbrossier@wesleyan.edu)

Introduction. In the early 90s, NASA's Magellan radar images revealed a venusian surface with an average crater age of ~ 500 Ma [1] that can be broadly divided into three major types of terrain involving three chronological eras of Venus' history based on their stratigraphic position. First, the heavily deformed plateaus named tesserae [2] are considered as the oldest materials on Venus. Then, the volcanic plains buried $\sim 80\%$ of the planet. Finally, the large volcanoes forming clusters are the most recent of Venus's history [3]. While the composition of the volcanic plains is inferred to be basaltic [4], the composition and timing of the tesserae and the large volcanoes are open questions.

Several studies [5,6] have recognized that many of the summits of Venus display anomalous decreases in radar emissivity. This behavior is thought to be the result of atmosphere-surface interactions at lower highland temperatures [e.g., 7-9]. These reactions are a function of rock composition, atmospheric composition, and degree of weathering. The detailed variations in radar emissivity may yield insight into these characteristics. Here we investigate the radiophysical behaviors of tesserae, mountain belts and large volcanoes at different locations and elevations on the planet, and place them in geologic and geographic context in order to retrieve, or at least constrain, their composition and age.

Methods. Regions of interest are selected using radar datasets returned by the Magellan mission ($f = 2.385$ GHz, $\lambda = 12$ cm). Tesserae are mapped by [10] and large volcanoes by [11] using Synthetic Aperture Radar (SAR) images at 75 m per pixel. Elevation and emissivity data are extracted to produce scatterplots of the variation of emissivity with altitude. Elevations given throughout this abstract may differ from those found in the past literature as we use values measured from a mean planetary radius of 6051.8 km [12]. Spatial resolution of the emissivity data is relatively poor, about 20-30 km at low latitudes.

Results. As found in previous works [5,9], the emissivity of many regions decreases from a global mean value of ~ 0.8 from low to higher elevations. We define the elevation at which an emissivity low occurs as an emissivity excursion. In this study, nearly half the tesserae and almost all the large volcanoes show such excursions. The elevations and magnitudes of excursions are variable from a region to another. We observe different trends of excursions, as illustrated in Fig. 1 and 2: (i) a strong decrease where emissivity declines to low values ranging from 0.7 to 0.3, (ii) subtle decrease where emissivity reaches slightly lower

values and remains above 0.7, or (iii) no changes and emissivity is nearly constant with elevation.

Tesserae –The few tesserae with excursions are those at high elevations in the major crustal plateaus of Ishtar and Aphrodite Terrae, as well as tesserae located near major volcanic rises such as Beta, Phoebe and Eistla Regiones. Interestingly, the tesserae found nearby large volcanoes exhibit emissivity excursions at relatively low elevations in comparison to tesserae from Ishtar and Aphrodite Terrae, such as Fortuna (6055.9 km) and Ovda (6054.6 km). For instance, Salus and Gbadu from Southeast Eistla Regio both display excursions at ~ 6052 km [13].

Mountain belts – The mountains confined to Ishtar Terra also show excursions. However, their emissivity remains constant with elevation until ~ 6054 km and then decreases to their summits, except for Maxwell Montes. Indeed, above 6056 km, emissivity slowly increases to slightly greater values as reported in [5,9].

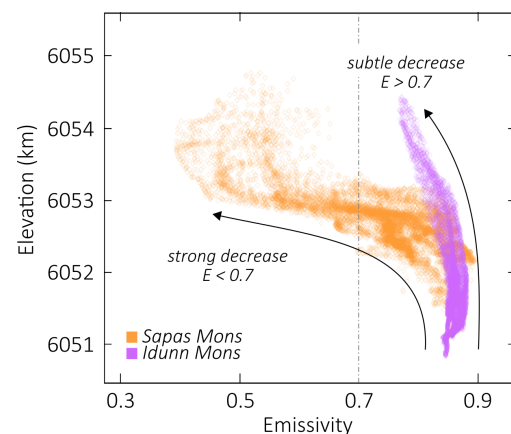


Figure 1 – Scatterplot of relationships between elevation and emissivity for Sapas and Idunn Montes showing the difference between strong and subtle decreases.

Large volcanoes – The relationship between emissivity and elevation allows us to group the volcanoes sharing similar patterns (Fig. 2). The tallest volcanoes reaching 6056 km and above, namely Maat, Ongwuti, Ozza, Theia and Tepev Montes, have very distinctive patterns [6,9]. Their emissivity decreases smoothly with elevation to a maximum of ~ 6055 km, and then increases abruptly to their highest elevations. High emissivity summits correspond to SAR-dark calderas, domes, flows of lava or debris [14]. The five tallest volcanoes on Venus form Group 1. Although Tepev Mons shares same behaviors at its highest elevations like the volcanoes from Group 1, unlike the others, its

emissivity decreases gradually with elevation from a very marked elevation of ~ 6052 km. This pattern is seen for a few volcanoes forming Group 2. The volcanoes from Group 3, including Sapas Mons (Fig. 1), also show a drop of emissivity starting at ~ 6052 km like in Group 2. However, this decline is precipitous with elevation, unlike the gradual decrease observed in the Groups 1 and 2. Group 4 includes volcanoes that show slight drops in emissivity with elevation, remaining above 0.7 (e.g. Idunn Mons in Fig. 1). Finally, Group 5 contains all volcanoes that show no changes with elevation above 6054 km. Some volcanoes selected in our study show unique patterns and are therefore unclassified.

Discussion. The Group 1 volcanoes. These tallest volcanoes, reaching over 6056 km, have emissivity patterns compatible with the presence of ferroelectric minerals in the rocks as they show a decreasing emissivity with elevation and an abrupt transition to high emissivity on their summits [7,8], also seen in Ovda Regio [9]. The similar altitude of these excursions suggests a ferroelectric mineral common to volcanoes and tesserae.

The Sapas Group 2 and Tepev Group 3 volcanoes have low emissivity excursions and rates of emissivity decrease that indicate a different set of high permittivity minerals are controlling the emissivity of these groups relative to Group 1 and each other.

The volcanoes of Lakshmi Planum are very different than all others, with an emissivity pattern that is similar to the tessera and mountains in the region. This is a strong argument that the production of high permittivity minerals in this region is unique and distinctive from the rest of the planet. This may be the result of different

rocks and/or different atmosphere as suggested by [9]. However, the fact that Colette and Sacajawea volcanoes have the same pattern suggests that either the volcanoes (presumably basaltic) and the mountains/tesserae are similar composition, or that they lie beneath an atmosphere that prevents the production of the requisite mineralogy either due to atmospheric composition and/or temperature.

The magnitude and elevation of the emissivity excursions may provide new clues about the composition and evolution of the magmas associated with these volcanoes. It is possible that the general geographic clustering of the Group 1 and the Group 3 volcanoes may be related to common magma pipelines (plumes).

The gentle decrease of emissivity of Idunn relative to other volcanoes of the same elevation is consistent with it having a relatively young surface, as hypothesized by [15] where the minerals have not had time to react with the atmosphere to produce high permittivity products.

References: [1] Strom et al. (1994) *JGR* 99, 10899. McKinnon et al. (1997) *Venus II*, 969. [2] Ivanov and Head (1996) *JGR* 101, 14861. [3] Price and Suppe (1994) *Nature* 372, 756; Price and Suppe (1995) *EMP* 71, 99. [4] Weitz and Basilevsky (1993) *JGR* 98, 17069. [5] Klose et al. (1992) *JGR* 97, 16353. [6] Pettengill et al. (1992) *JGR* 97, 13091. [7] Arvidson et al. (1994) *Icarus* 112, 171. [8] Shepard et al. (1994) *GRL* 21, 469. [9] Treiman et al. (2016) *Icarus* 280, 172. [10] Ivanov and Head (2011) *PSS* 59, 1559. [11] Toner et al., *this conference*. [12] Ford and Pettengill (1992) *JGR* 97, 13103. [13] Gilmore et al., *this conference*. [14] Robinson and Wood (1993) *Icarus* 102, 26. [15] Smrekar S. E. et al. (2010) *Science* 328, 605.

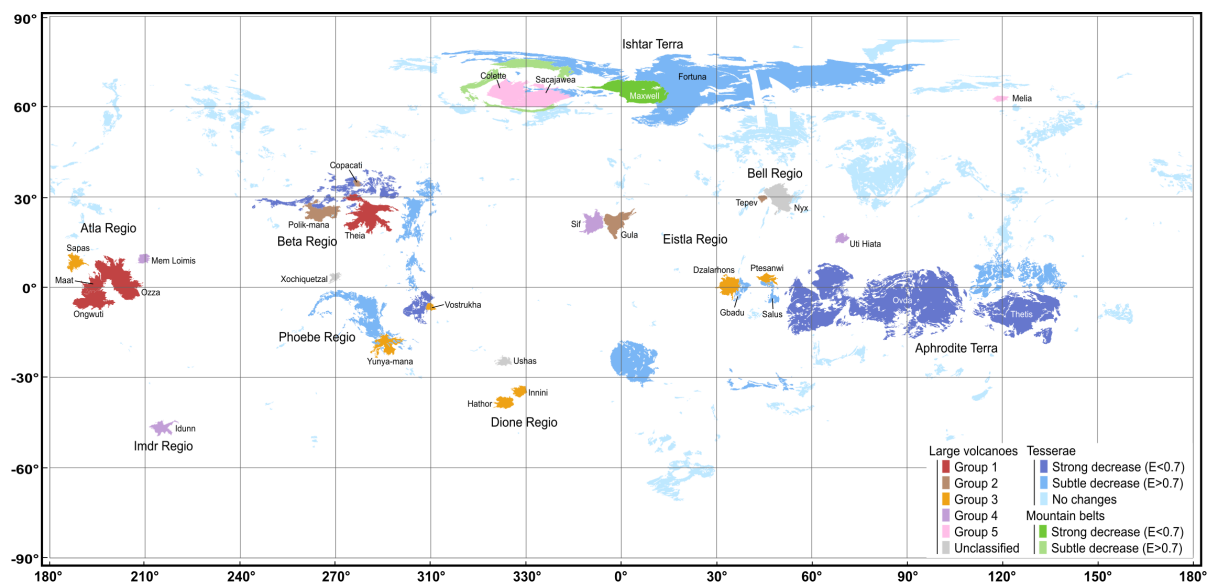


Figure 2 – Map of venusian tesserae, mountain belts and large volcanoes selected in our study. Each terrain type is color-coded considering how varies emissivity with elevation: tesserae in blue, mountain belts in green and the large volcanoes with 6 different colors as they have a more specific classification (see text for details).