POSSIBLE FELSIC SUMMIT OF TUULIKKI MONS, VENUS: EVIDENCE FROM 1-MICRON SURFACE EMISSIVITY AND MAGELLAN-VIEWED MORPHOLOGY.

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Introduction: In the analysis of the data taken by the Venus Monitoring Camera (VMC) on board Venus Express for the area SW of Beta Regio, it was found that the summit of Tuulikki Mons volcano shows the 1-µm emissivity that is lower than that of the main body of the volcano (whose morphology is typical of a basaltic volcano [e.g.,1]). This suggests that the volcano summit material may be close to felsic; this suggestion is supported by the observation of a feature resembling a steep-sided dome on the volcano summit [2].

VMC observations and analysis: VMC takes images in four spectral channels; one of which, centered at 1.01 µ, registers the night-side thermal emission from the planetary surface [3,4]. The radiation flux from the surface depends on the surface temperature and the emissivity of the surface material. which is a function of a number of parameters including surface texture and mineralogical composition. The latter permits a search for geological features whose chemical / mineralogical composition may be different from that of basalts, which dominate the surface of Venus. Details of the VMC data description and analysis for derivation of the 1-µm emissivity of different geologic units of the study area can be found in [2]. Figure 1 shows the general morphology of the study area and the map of calculated 1-µm emissivity.

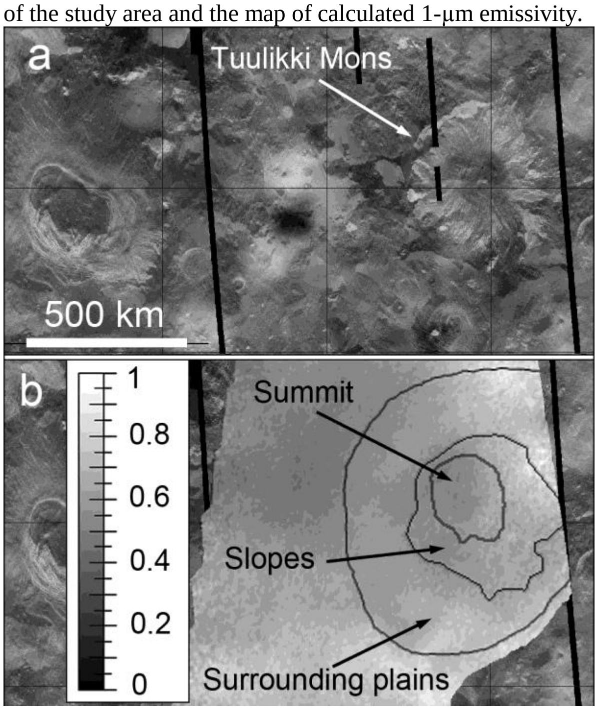

Figure 1. a) Magellan SAR image of the study area; b) the map of 1-micron emissivity of the Tuulikki summit, slopes and the surrounding plains with the legend bar of 1-µm emissivity.

Tuulikki volcano (10.3°N, 274.7°E) is located within Hinemoa Planitia ~1200 km SW of Beta Regio. Its diameter is 520 km and its summit stands above the surrounding plains by 0.5-1 km. The latter represent a complicated mosaic of the shield plains, wrinkle-ridged plains and lobate plains [5,6] (Figures 1, 2). The volcano slopes are very gentle and formed of radially arranged lobate lava flows that are typical of the majority of relatively young Venus volcanoes of this size [7]; these are considered to be basaltic lavas [8].

The results of calculation of the mean values of the 1-µm emissivity (e) for the Tuulikki volcano slopes, its summit and the surrounding plains are given in Table 1. Calculations were done for two models: lr8-e08 - atmosphere temperature lapse rate (lr) is -8K/km and reference emissivity (e_0) is 0.8, and lr8-e058 - lr is -8K/km and e_0 is 0.58 [2]. To assess the significance of the observed differences in the mean e we applied Welch's test [9].

Table 1

Unit A / Unit B	e ± st. dev		Diff. at 0.05 level
	Unit A	Unit B	
Model lr8-e08			
Slopes / Summit	0.63 ± 0.07	0.55 ± 0.04	Yes
Slopes / Plains	0.63 ± 0.07	0.53 ± 0.45	Yes
Summit / Plains	0.55 ± 0.04	0.53 ± 0.45	No
Model lr8-e058			
Slopes / Summit	0.48 ± 0.04	0.43 ± 0.02	Yes
Slopes / Plains	0.48 ± 0.04	0.38 ± 0.4	Yes
Summit / Plains	0.43 ± 0.02	0.38 ± 0.4	No

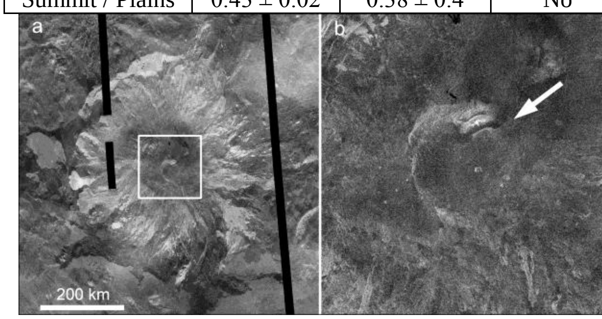

Figure 2. a) Morphology of Tuulikki Mons volcano as seen on Magellan SAR image; b) Magellan image of the summit area (white box in Figure 2a); arrow shows the feature resembling a steep-sided dome.

It is seen from Table 1 that the emissivity of the Tuulikki Mons summit is lower than that of the volcano slopes and this difference is statistically significant for both lr8-e058 and lr8-e08 models suggesting that the difference is probably real. The lower emissivity of the summit material is unlikely to be explained by either the differences in the degree of weathering (on the volcano summit and slopes it should be approximately the same or somewhat younger) or by the coarser grain size of the summit surface material due to its higher altitude/higher wind velocities (it should work in the opposite direction). The reason may be different (more felsic) composition of the summit part of the volcano. This suggestion is supported by the presence of a feature resembling a steep-sided dome on the volcano top (Figure 2b). Steep-sided domes are considered to be formed by eruptions of viscous lavas geochemically more evolved than basalts [10] although other suggestions on their nature have also been published [10,11,12].

More felsic composition of the Tuulikki summit material could be explained by differentiation within the magma chamber resulting in more evolved composition of the late portions of the lavas. On Earth an intrachamber differentiation from basaltic to more felsic compositions is typical for subduction zones [e.g., 13, 14] and also occurs on ocean islands related to hot-spot magmatism (Iceland, Azores, Hawaii etc). In the latter case felsic volcanics are usually more alkaline and shifted toward trachytic compositions [15].

Compared to the volumes of basaltic lavas, the percentage of intermediate and acid deposits is relatively small. For example, in products of Quaternary volcanism of Kamchatka the percentage of intermediate / acid lavas varies from 30 to less than 10 % of total volume of volcanics [16]. Similar amounts of felsic rocks (20 %) are estimated for Iceland [17]. We could not estimate the percentage of supposed felsic lavas in the total volume of the Tuulikki volcanics, but it seems to be similar to this range. The terrestrial small-sized analogy for Tuulikki could be Hualalai shield volcano, composed of tholeitic and alkaline basalts with post-shield stage trachitic extrusion [18] (Figure 3).

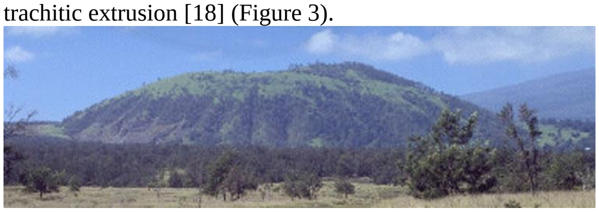

Figure 3. Trachyte dome Puu Waawaa on Hualalai volcano, Big Island, Hawaii http://www.soest.hawaii.edu/GG/HCVhualalai.html.

Iceland (which is close to Tuulikki volcano in area) could also be considered as a potential candidate; in this case, the felsic magmas on Venus would be lavas instead of pyroclastics due to suppressed explosivity because of the very high atmospheric pressure on Venus. Tuulikki analogies could also be found in subduction zones, for example on Kamchatka Sredinny range, where some basaltic shield volcanoes have the subordinant intermediate and acid lavas concentrated at the volcano summits (Figure 4).

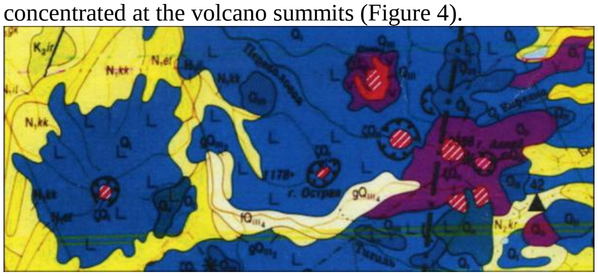

Figure 4. Fragment of the geologic map of the part of Sredinnyi Range volcanic province, Intermediate / acid lavas (reds) are at the summits of essentially basaltic constructs (blues). Yellow colors designate alluvium [19].

A critical aspect for direct analogy of Tuulikki with terrestrial subduction zone volcanoes is the analysis of global and regional tectonics of Venus which shows that in the morphologically observable part of history of this planet (when Tuulikki volcano formed), its global tectonic style does not resemble plate tectonics of Earth [20,21]. So the presence of felsic lavas at the late stage of formation of Tuulikki volcano can not find a straightforward analogy with volcanism of terrestrial subduction zones. However in the early history of Venus, this planet could have plate tectonics and be rich in water [e.g., 22,23]. Tessera terrain, whose relatively low NIR surface emissivity is interpreted in a number of recent works as an indication of felsic composition [e.g., 24-27] may be a material remnant of that period of Venus history. Partial melting and assimilation of tesserae material by mafic magma enhanced by longer residence time in a chamber could also be an additional way of generation of felsic magmas forming the steep-sided dome on the Tuuliki summit [10]. Remelting of the basaltic crust to produce more evolved magmas may be one more explanation the generation of the steep-sided domes [28].

Conclusions: Analysis of the data taken by the Venus Monitoring Camera on board Venus Express for the area SW of Beta Regio shows that the summit of Tuulikki Mons volcano has a lower 1-µm emissivity than that of the main body of the volcano, whose morphology is typical of a basaltic volcano. This suggests that the volcano summit material may be close to felsic in composition and this suggestion is supported by an observation of a feature resembling a steep-sided dome on the volcano summit. Formation of felsic material observed on the volcano summit may be due to differentiation within the magma chamber resulting in a more evolved composition of the late-stage portions of the lavas. Other possibilities may be partial melting and assimilation of tesserae material by the dominant basaltic magma or remelting of the basaltic crust to produce more evolved magmas.

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