MANTLE DEPOSITS ON VENUS: THE ROLE OF SURFACE STRUCTURE. N. V. Bondarenko[1,2] and J. W. Head[3], [1]LPI, 3600 Bay Area Boulevard, Houston TX 77058-1113, USA; [2]IRE NASU, 12 Ak. Proskury, Kharkov, 61085, Ukraine, nbondar@ucsc.edu; [3]Dept. Geol. Sci., Brown University, Providence RI, USA.

Introduction: The observed properties of any surface are controlled by the structure of this surface and the wavelength of observation λ. Many surfaces on Venus, including lava flows and extended crater-related deposits, exhibit the signature of smooth upper mantle-atmosphere interfaces when observed at λ of 12.6 cm. In particular, Earth-based observations have shown that these features return the radar echo with a significant linearly polarized component, when illuminated by a circularly polarized probing signal [1, 2]. This can occur only when the target surfaces are very smooth and rather transparent to radio waves, so that the waves scattered at internal interfaces or inclusions can reach the observer.

In the present work, smooth and rough mantles on Venus under a state of thermodynamic equilibrium are analyzed using the approach proposed in [3] based on results of Magellan mission (λ = 12.6 cm).

Approach and source data: According to the Kirchhoff law [4], the emissivity of the surface observed from a given direction, $e = 1 - R^*$, where R^* is the hemispheric reflectivity of the surface illuminated from the same direction. The radio thermal emission of the surface covered by a mantle can be defined through the surface reflectivity as stated by the Kirchhoff law [4] as $e = 1 - R_i - R_s$, where R_i is the scattering coefficient at the upper mantle interface, and R_s describes a positive contribution of internal scattering into integral scattered fluxes over all scattering directions. Thus, the emissivity of a surface covered by a rather transparent mantle has to be lower then $(1- R_i)$.

Values of surface emissivity have been obtained during the Magellan radiometry experiment [5]. The spatial resolution of Magellan emissivity data is about 20 km × 30 km at low latitudes and the accuracy is ~0.02. Independent estimates of surface dielectric permittivity, ε, can be made through the so called Hagfors' "Fresnel reflectivity" R_0 obtained by the Magellan radar altimetry experiment with the approximation of received echo sequence by Hagfors law [6]. The spatial resolution for these data is about 15 km × 10 km at low latitudes and the errors of individual measurements can reach ~30% [6].

Thus, surface emissivity can also be calculated using surface ε derived from R_0. In the case of a surface covered by a mantle with a smooth upper interface, the observed emissivity has to be lower then one predicted with the Fresnel equation. The apparent decrease of emissivity depends on the properties of the underlying surface and the mantle. In particular, a thick mantle can cause strong absorption of radiation ($R_s \approx 0$).

A rough upper mantle interface is expected to cause higher observed emissivity values in comparison to those predicted with the Fresnel formula.

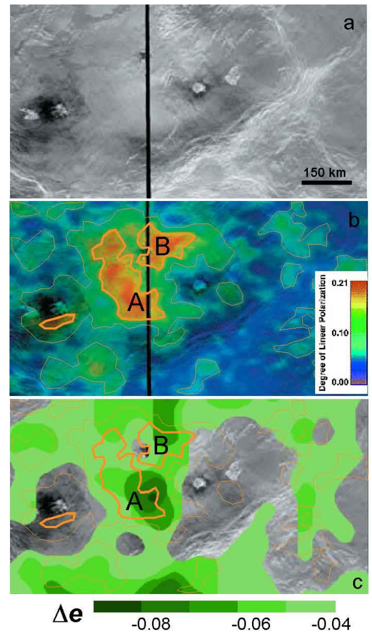

Fig. 1 Crater Anya (39.5°N, 297.8°E).

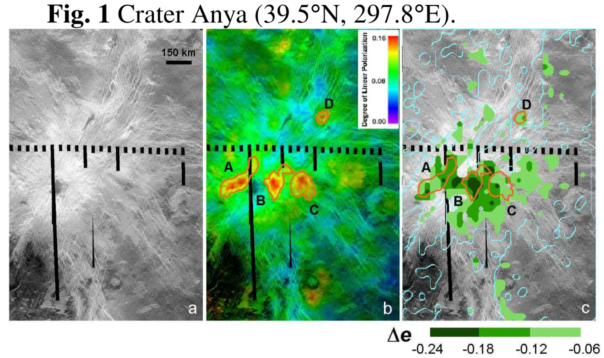

Fig. 2 Theia Mons (22.7°N, 281°E).

Apparent decrease of emissivity and degree of linear polarization: On the basis of the approach discussed above, low resolution (0.25°×0.25°) maps of apparent differences, Δe_D and Δe_C, between observed emissivity (SCVDR data set) and the predicted one for the first Magellan cycle, were compiled. The predicted emissivity was calculated using direct R_0 and one corrected for diffuse scattering (ARCDR data set), corresponded to Δe_D and Δe_C, respectively.

Crater-related deposits. Δe_D and Δe_C were analyzed over areas in the vicinity of ~10 crater diameters from the craters center. Thus, ~85% of the total craters number studied (~700) exhibit negative values of Δe_D and Δe_C. Δe_D < -0.06 is observed near ~ 42% of craters, and Δe_C < -0.06 was found near ~25% of the craters.

All craters that have been reported to exhibit an enhanced degree of linear polarization m_L [1] show negative values of Δe_D and/or Δe_C.The lowest values of Δe_D = -0.37 and Δe_C = -0.20 are observed near the 23 km crater Weil and near the 31 km crater Aurelia, respectively. An example of a spatial distribution of Δe (= Δe_D) in the vicinity of 17.7 km crater Anya (Fig. 1c) shows a strong similarity to the distribution of m_L (Fig. 1b). Average large-scale surface slope ξ (ARCDR data set) in areas A and B is equal to 2.5° and 3.0°, respectively.

The floor of the crater Stuart, showing Δe_D and Δe_C down to -0.18 and to -0.10, respectively, simultaneously exhibits m_L up to 0.26. Deposits of the crater Carson reveal Δe_D down to -0.13, Δe_C down to -0.10, and m_L up to 0.20. Deposits of the crater Aurelia exhibit Δe_D down to -0.15, Δe_C down to -0.20, and m_L up to 0.10.

Lava flow complexes. Lava flow complexes that have been found to show enhanced linear polarization [2] also exhibit an apparent decrease of emissivity. Thus, Δe_D in between -0.08 and -0.05 is observed over a volcanic field in Guinevere Planitia at 17.5°N, 313°E (m_l is up to 0.12, average ξ is ~3.0°) and over lava flows on the western flank of Sif Mons (m_l is up to 0.13, average ξ is ~1.8°).

Highland Volcanoes. Three high-elevation volcanoes were studied during polarimetric observations [2]. Gula Mons shows no linear polarization enhancement and reveals Δe_D = 0.006 (close to a smooth surface). The location of negative values of Δe_D (down to -0.21) in Tepev Mons is correlated with high values of m_L (up to 0.34) observed in a topographic ''saddle'' between two calderas [2].

The spatial distribution of Δe values (= Δe_D) in Theia Mons summit (Fig. 2c) shows a strong similarity to one of m_l (Fig. 2b). The light blue lines in Fig. 3c mark the boundary between negative and positive values of Δe. The average ξ in areas A, B, and C is close to each other and equal to ~5.3°.

Rough surfaces: Positive values of difference between observed and predicted emissivity can be expected for surfaces with rough upper interfaces. Such a case is realized near the craters Guan Daosheng and Eudocia (Fig. 3) and near the crater Stowe, showing Δe_D up to ~0.4 and Δe_C up to 0.31. The spatial pattern of Δe (= Δe_D) (Fig. 3c) correlates with high roughness areas shown in Fig. 3b. The average ξ in areas A, B, and C is equal to 6.9°, 9.1°, and 9.2°, respectively. Radar dark deposits in these sites are known to exhibit anisotropic scattering in the East-West direction that was interpreted as microdune fields [7].

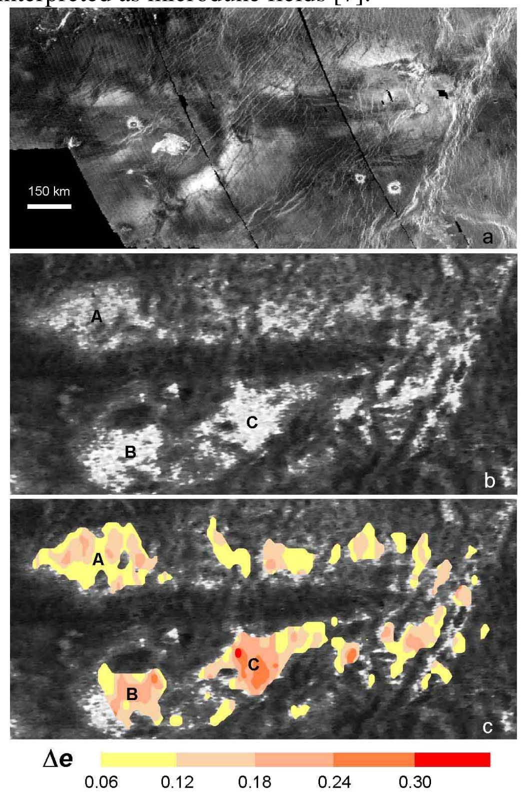

Fig. 3 Crater Guan Daosheng (61.1°S, 181.8°E).

Conclusions: The results obtained in this work show that the strong similarity between calculated Δe and m_l observed near craters, over two lava flow complexes and two highland volcanoes seem to be caused by the same reasons. This means that a smooth mantle-atmosphere interface has to exist at every site and mantle material has to be rather transparent to radio waves. The comparison above also shows that estimates of surface dielectric permittivity derived through Hagfors Fresnel reflectivity produces reasonable results.

A significant apparent emissivity excess was found in microdune fields having a very high large-scale roughness; here the approximation of surface structure by a smooth surface does not work.

References: [1] Carter L. M. et al. (2004) *JGR, 109*, doi: 10.1029/2003JE002227. [2] Carter L. M. et al. (2006) *JGR, 111*, doi: 10.1029/2005JE002519. [3] Bondarenko N. V. et al. (2010) *GRL,* 37, doi: 10.1029/2010GL045233. [4] Ulaby F. T. et al. (1986) *Microwave Remote sensing: Active and Passive*. [5] Pettengill G. H. et al., (1992) *JGR*, *109*, 13091-13102. [6] Ford P. G. and Pettengill G. H. (1992) *JGR, 97*, 13103-13115. [7] Weitz C. M. et al. (1994) *Icarus, 112*, 282 – 295.