ROUGHNESS ASYMMETRY AS A CLUE TO THE EVOLUTION OF CRATER-ASSOCIATED DARK DIFFUSE FEATURES ON VENUS. ***N. V. Bondarenko***[1,2] and ***J. W. Head***[2], [1]Institute of Radiophysics and Electronics, National Academy of Science of the Ukraine, Kharkov, 61085, Ukraine, natasha@mare.geo.brown.edu; [2]Dept. Geol. Sci., Brown University, Providence RI, USA

Introduction. About 65% of large (>30 km) craters on Venus have associated radar-dark diffuse features (DDFs) [1], including well-expressed radar-dark parabolas [2]. DDFs were interpreted as surficial deposits of loose material lifted during crater formation [2, 3]. Craters with parabolas are thought to be the youngest [2]. The morphological sequence of the DDFs from parabolas to halos to faint radar-dark patches has been used as a degradation sequence of DDFs [1].

Here we study possible mechanisms of parabola degradation, which is as yet not well understood. We consider two end-members: (1) removal of the loose material by wind and (2) induration and subsequent roughening by eolian erosion, which diminishes the radar signature of the deposits. We analyze DDFs using several Magellan data sets in order to understand the relative role of these mechanisms.

North-South roughness asymmetry - Doppler centroid maps. Radar echo Doppler centroid derived from the Magellan radar altimeter data is a measure of surface scattering asymmetry in the north-south (N-S) direction [4]. The Doppler centroid measurements are a part of GVDR and SCVDR data sets from PDS. To a first order, the Doppler centroid represents the deflection of the strongest surface echo from the nadir. The effective spatial resolution of Doppler centroid is rather poor: ~ 50 km in the 20°S – 40°N latitude zone (where we used these data) and allows the study of large DDFs only.

In general, observations have shown that the strongest surface echo systematically deflects from the nadir in many areas [4]. In the plains, the Doppler centroid is a measure of the N-S asymmetry of surface roughness at scales from centimeters to hundreds of meters [5].

We studied about 45 large craters (>30 km) with associated DDFs localized in 20°S – 40°N latitude zone. We also picked up several smaller DDF craters clearly recognized in the Doppler centroid map. We found that radar-dark parabolas and well-expressed halos are usually associated with areas of zero Doppler centroid (N-S symmetric roughness). As examples, dark parabola crater Bassi (19°S 64.7°E, 35 km) and dark halo crater Elena (18.4°S, 73.4°E, 17 km) are shown in **Fig. 1**. Crater-related DDFs here have zero Doppler centroid, while the volcanic plains over which they are superposed have a pronounced N-S slope asymmetry.

Decameter-scale surface roughness derived from Magellan radar altimeter measurements (both ARCDR [6] and SCVDR [4] data sets) is usually lower for the parabolas and halos than for the surroundings. These observations support the interpretation of the DDFs as surficial deposits with a flat upper surface [2, 3].

It has been noted that DDF-associated microwave emissivity features, especially emissivity parabolas, are larger than the DDFs seen in the radar images [3]. The DDF-associated areas of zero Doppler centroid are often larger than the radar-dark features too. This provides additional evidence that the crater-related loose material deposits have a wider extent than the DDFs in the radar images.

We also found bands of a distinctively high degree of N-S roughness asymmetry along the boundaries of the DDF-associated areas of zero Doppler centroid for parabola craters Boleyn (24.4°S 220.1°E, 69.8 km) and du Chatele (21.5°S 165.0°E, 19 km). The radar image of crater Boleyn and its appearance in the Doppler centroid map are shown in **Fig. 2**. The bright band (marked with "2") is not associated with any specific features in the radar image. The most plausible cause for the observed roughness asymmetry is the presence of eolian features (microdunes, ripples, etc.) on the surface [7, 5]. The observed bands of increased asymmetry at the periphery of the crater-related deposit indicate wind reworking of the deposit material in the areas where the deposit is thin.

East-West roughness asymmetry - SAR images. Surface roughness asymmetry in the east-west (E-W) direction has been studied [8, 7] by comparison of left- and right-looking radar images. Three areas of very strong E-W asymmetry (difference is up to 8 dB) interpreted as microdune fields [8] are localized in the western parts of parabolas. This again is a sign of wind reworking of the DDF material.

We revisited right- and left-looking radar observations paying attention to craters with DDFs and DDFs themselves. In general, about 50 craters of different sizes were studied using 1st and 2nd cycle images in the 40°S – 60°S latitude zone. 7 craters located in 7°N – 22°N latitude zone were studied using 2nd and 3rd cycle Magellan images.

Additionally to [8], we found DDF areas with scattering asymmetry (difference is ~1 – 4 dB) westward from several small craters including Adaiah (52.2°S, 111.2°E, 18 km) and Abigail (27.3°S, 253.4°E, 19 km). Also, a dark diffuse area in 2nd cycle data nearby flow crater Chiyojo (47.8°S, 95.7°E, 38.8 km) shows an increase of 1.5 – 2 dB during the 1st cycle of observation. This surficial deposit is rather large and overlies several boundaries between lava flows.

The dark parabola of the crater Stowe (43.2°S, 233.0°E, 80 km) exhibits scattering asymmetry in the inner and west parts. The outer eastward parabola part shows no clearly visible asymmetry. This also is consistent with a suggestion about removing of parabola material by winds (westward in this case).

The majority of DDFs associated with other craters studied are characterized by symmetric scattering in the E-W direction. In particular, the parabola structure of the crater Adivar (8.9°N, 76.2°E, 29 km) has similar appearances in 2nd and 3rd cycle SAR images.

Induration and roughening by eolian erosion. We studied the surroundings of 31 large (>30 km) "old" craters without any radar-dark features nearby and also 23 large craters having a faint dark halo.

With the radar images, we were looking for any features that could be interpreted as "altered", "brightened" parabolas. For example, we were looking for diffuse disappearance of boundaries of volcanic units in the places where the parabola edge would be expected.

We did not find any clear evidence of this kind. We observed only several examples of weak changes in radar contrasts of lava flows boundaries. For example, small lava flows located at the west from crater Nijinskaya (25.8°N, 122.5°E) are brighter then the surrounding surface by 1.0 db while radar contrasts for other flows looked very similar in the same area, varying from 1.4 dB to 2.2 dB.

We found many examples of radar dark deposits in wind shadows at small topographic features westward from old craters. For example, a bright lava flow to the southwest of the crater Agrippina (33.3°S, 65.7°E) shows small dark wind streaks along ridges, and the flow clearly is seen in the microwave emissivity map. The wind streaks mean the presence of loose surficial deposits; the emissivity signature means that this material does not cover the flow entirely.

Conclusions. We found evidence for reworking of the loose material of DDFs by winds. This process is very slow, and thick DDF deposits remain flat for a long time. However, movement of loose material by winds can be the process responsible for degradation and removal of DDFs. Widespread roughness anisotropy outside the DDFs [7, 5] indicates the presence of eolian features and hence, some amount of loose material virtually everywhere.

This material could have formed during old impact events and moved by winds from former DDFs. In our data we do not see evidence for degradation of DDFs through induration and roughening of the deposits [9], though we cannot completely rule out this process.

References: [1] Basilevsky, A. T., and J. W. Head (2002) *JGR 107*, doi:10.1029/2001JE001584; Basilevsky A. T. et al. (2003) *GRL, 30*, doi:10.1029/2003GL017504. [2] Campbell, D. et al. (1992) *JGR* **97**, 16249 – 16277. [3] Bondarenko, N. V. and J. W. Head (2004) *JGR 109*, E09004. [4] Tyler, G. L. et al. (1992) *JGR* **97**, 13115 – 13139. [5] Bondarenko, N. V. et al. (2005) *LPSC. XXXVI*, abstract # 1236. [6] Ford, P. G. and G. H. Pettengill (1992) *JGR 97*, 13103-13114. [7] Kreslavsky, M. A. and Vdovichenko, R. V. (1999) *Solar System Res. 33*, 110. [8] Weitz, C. M. et al. (1994) *Icarus 112*, 282 – 295. [9] Basilevsky A. T. et al. (2003) *JGR, 109*, E12003.

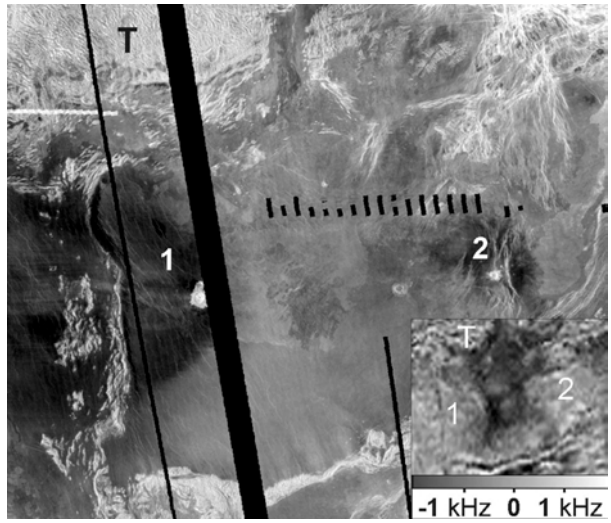

Fig. 1. Magellan SAR mosaic of craters Bassi (19°S 64.7°E, diameter - 35 km, marked with "1") and Elena (18.4°S, 73.4°E, diameter - 17 km, marked with "2"). Inset shows the Doppler centroid map of the same area, gray shades denote zero Doppler centroid, dark and bright shades mean deflection of the Doppler centroid from nadir. T - Ovda Tessera.

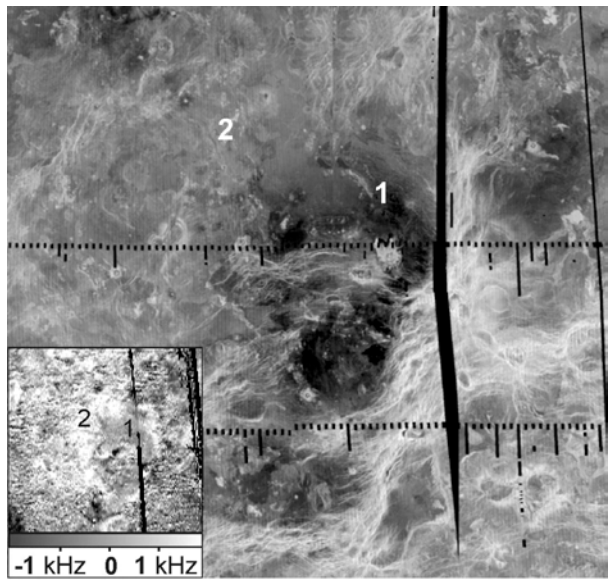

Fig. 2. Magellan SAR mosaic of crater Boleyn (24.4°S 220.1°E, diameter - 69.8 km). Inset shows the Doppler centroid map of the same area (see description in Fig. 1). "1" marks DDF-associated area of zero Doppler centroid; "2" marks band of distinctively high degree of N-S roughness asymmetry (1.4 kHz – 2.3 kHz).