VENUS' SURFACE LAYER: A NEGLECTED CLASS OF VENUS EXPLORATION TARGETS.
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We propose a large number of surface targets for high-resolution radar imaging for understanding the nature of the surface layer, aeolian transport and other aspects of "Quaternary geology" of Venus.

Session: Observations from orbit.

Target: A large set of surface targets including hundreds of randomly chosen samples that span the whole range of latitudes, elevations and terrain types, as well as a set (tens) of known sites of interest; for examples dunes fields, microdunes, wind streaks, etc.

Science Goal(s): Geomorphological study of surficial deposits on Venus is a key for advances in understanding of surface – atmosphere interaction on Venus and hence it contributes to VEXAG Goal/Objective III.B. However, the very existence of the surface layer and related geological processes is neglected in the current version of VEXAG Goals, Objectives and Investigations document.

Discussion: At first glance, the surface of Venus, as it is seen in Magellan radar images, is dominated by lightly or heavily tectonized volcanic plains [1]. However, many lines of evidence indicate that almost everywhere the original volcanics are covered by veneers of another material, which we refer as surficial deposits. This material is often not apparent in the Magellan images. The evidence for the presence of such material is Venera-9,-10,-13, -14 and Vega-1 ands -2 in situ observarions [e.g., 11 – 13] and remote sensing observations including: (1) the presence of crater-related radar-dark parabolic and irregular haloes (so-called dark diffuse features, DDF) [2, 3] interpreted as deposits of granular material ejected by impacts and redistributed by the atmosphere; (2) microwave emissivity signatures of crater-related deposits of larger extent [4] outside the DDFs; (3) ubiquitous weak anisotropy of the microwave backscattering function interpreted as the result of asymmetric meter-scale aeolian bedforms [5, 6]; (4) the presence and non-uniform distribution of "splotches" [7]; (5) the presence of abundance wind streaks [8]; (6) reduction of radar contrasts and decrease of dielectric permittivity with stratigraphic age interpreted as accumulation of altered material [9, 10], etc. Formation of the surface layer proceeds through mechanical and chemical weathering of the surface and aeolian transport of the particulate material; however, details of these processes are very poorly known.

Analogs of Venus surface layer on other planets are: regolith on the Moon and other atmosphereless bodies, terrestrial vegetation and Quaternary deposits, a variety of icy mantles, aeolian deposits, duricrust, dust veneers on Mars.

Meter and decameter-scale morphology of the surface layer and its formation processes are very interesting themselves, since they comprise an essential part of surface – atmosphere interaction (VEXAG's III.B). Aeolian bedforms might record wind regimes in the past; their studies potentially can reveal the evolution of the wind regime on Venus and thus contribute to understanding of atmospheric dynamics (VEXAG's I.B) and climate change (I.A). In particular, the record could contain information about the presence of atmospheric superrotation in the past (I.B, I.A). Only the youngest impact craters possess radar-dark parabolas; older craters have irregular radar-dark halo. It has been suggested that the haloes are results of parabola degradation [9], however, there is also a viable suggestion that haloes were formed before the onset of atmospheric superrotation. There is a good chance that morphological observations of aeolian deposits will allow distinguishing between these alternatives.

Another interesting question with a good chance to be solved is the relative role of regular circulation-induced winds [14] and the catastrophic transient impact-induced winds [15] in transport of the surface layer material.

A question of exceptional importance is the degree of mixture of the surficial material. Is there global aeolian transport of sand-size particles and thus all materials at the surface are well mixed? Or are bedform materials derived from local or regional sources? The answer to this question is critical for interpretation of all material investigations by landers (VEXAG's investigations II.A.5, II.B.1, II.B.2, II.B.5, III.A.3, III.B.1, III.B.2, III.B.4).

Finally, study of the surficial deposits on Venus is extremely interesting from a comparative planetology view point, because it allows studies of naturally forming aeolian bedforms in an environment strongly contrasting with the other planets. This would add significant information for understanding the physics of saltation of sand-size particle and formation of aeolian bedforms.

Exploration means. The surface layer can be observed with the whole range of techniques: in-situ observations from landers and rovers and remote sensing observations from low-flying balloons or from orbit. For the comprehensive study of the surface layer, a combination of both remote sensing and in-situ observations is absolutely essential. However, given the current state of knowledge and limited prospects for new missions, remote sensing from orbit with advanced microwave radar imaging techniques is the only affordable means able to provide a breakthrough in understanding of the Venus surface layer through analysis of small-scale surface morphology. Below we consider scientific requirements specifically for *orbital microwave imaging radar* as a necessary first step in studies of the surface layer.

Instrument requirements for orbital microwave imaging radar. The most essential requirement is high radar image resolution, at least ~10m, an order of magnitude better than Magellan. Even higher resolution is highly desirable. For specific surface layer morphology studies, higher resolution is more important than global coverage. However, sampling of the whole range of latitudes, elevations, and terrain types is essential. In addition to random or non-specific sampling, several known objects of interest should be targeted. They include samples of known dune fields, microdune fields, wind streaks of different kinds, etc.

Radar images have inherently low signal-to-noise ratio. The ratio of 10 is the limit below which geomorphological interpretation is inhibited.

The individual high-resolution image mosaics should be large enough to be properly placed in Magellan image context; the minimum mosaic size is ~80 km × 80 km (which is ~ 1 Mpix at Magellan resolution, >100 Mpix at ~10m resolution, and >5 Gpix at ~2 m resolution). A desirable alternative that avoids too large a data volume is the use of nested images of different resolution. A smart imaging strategy with nested images is to take a lower resolution context image first, and then use it to fine-target one or several high-resolution images.

The choice of looking (incidence) angle for imaging radar is not trivial when resolution is high. Terrain is likely to have short very steep slopes; to avoid radar layover in these cases, grazing incidence angles (~45º) are desirable. On the other hand, at grazing incidence angles, subtle topography variations are indistinguishable. This problem may require taking two images with different look angles for the same target.

The use of stereo pairs would help in geological interpretation of images, giving additional topographic information. The use of an interferometric synthetic aperture radar technique, which gives higher-quality digital terrain models (topography), would be very helpful; however, it is not an essential requirement for achieving a breakthrough in understanding of the surface layer. The same is true for a multipolarization capability for the imaging radar (in a sense, for geomorphological analysis, polarization information in radar images is somewhat analogous to color information for optical images).

Concluding remarks. High-resolution microwave radar imaging from orbit, that we consider as a necessary first step in understanding surficial deposits and aeolian transport on Venus, is also extremely useful for many other lines of scientific exploration of Venus. Such a mission is also essential for support of any mission including a lander. Geological context of the landing site is extremely valuable for analysis of lander data, and the nested high-resolution images are the only way to place the optical descent images into global (Magellan) context.

References:

[1] Ivanov M. A. and Head J. W. (2011) P*lanet. Space Sci*., *59*, 1559-1600. [2] Schaller C. J. and Melosh H. J. (1998) *Icarus*, *131*, 123–137. [3] Basilevsky A. T. et al. (2004) *JGR*, *109*, doi:10.1029/2004JE002307. [4] Bondarenko N. V. and Head J. W. (2004) *JGR*, *111*, doi: 10.1029/2005JE002599. [5] Kreslavsky M. A. and Vdovichenko R. V. (1999) *Solar System Res.*, *33*, 110-119. [6] Bondarenko N. V. et al. (2006) *JGR*, *111*, doi: 10.1029/2005JE002599. [7] Schaber G. G. et al. (1992) *JGR*, *97*, 13257-13301. [8] Greeley R. et al. (1995) *Icarus*, *115*, 399-420. [9] Izenberg N. R. et al. (1994) *Geophys. Res. Lett.*, *21*, 289–292. [10] Bondarenko N. V. and Head J. W. (2009) *JGR*, *114*, doi:10.1029/2008JE003163. [11] Florensky K. P. et al. (1983) *Science*, *221*, 57-59. [12] Basilevsky et al. (1985) *JSA Bull.*, *96*, 137 – 144. [13] Basilevsky et al. (2004) *JGR 109*, E12003. [14]. Greeley, R. et al. (1997) in *Venus II*, 547 – 589. [15] Schultz, P. H. (1992) *JGR 97*, 16183.