LANDING ON VENUS: PAST AND FUTURE. M. Aittola[1], J. Raitala[1], A. T. Basilevsky [2], M. A. Ivanov [2], and J. W. Head [3], [1]Astronomy, Department of Physics, University of Oulu, Finland; [2]Vernadsky Institute, RAN, Moscow, Russia; [3]Department of Geoloogical Sciences, Brown University, Providence, R.I. USA.

Introduction: Venus is a planet very similar to Earth in its mass, size and thus bulk density, but very different in surface environment and recent general geodynamic style. To understand better what is the cause of these differences more data about Venus geology, geochemistry and geophysics are needed. A crucial part of these data can be obtained only by *in-situ* measurements on the planet surface. This paper briefly reviews what was done in previous landings by the Venera/Vega spacecraft, discusses a new approach for selection of the landing sites, and considers a few candidate sites for future landings.

Previous landings on Venus: There were ten successful landings on Venus: *Venera 7*, 1970, partial success: only data of surface temperature and pressure were transmitted back to Earth; *Venera 8*, 1972, contents of K, U and Th in the surface material were measured by gamma-ray spectrometer (GRS); *Venera 9 and 10*, 1975, TV panoramas, contents of K, U and Th by GRS; *Venera 11 and 12*, 1978, compositions of atmosphere (down to the surface) and clouds; *Venera 13 and 14*, 1981, TV panoramas, composition of the surface material by X-ray-fluorescence spectroscopy (XRFS); *Vega 1 and 2*, 1984, GRS and XRFS (only Vega 2) analyses of the surface material. The geochemical analyses have been interpreted as evidence that the surface materials analyzed are generally mafic and compositionally close to tholeiitic basalts (Venera 9, 10, 14, Vega 1, 2) and alkaline basalts (Venera 8 and 13) [e.g., 1]. TV panoramas showed the presence of dark soil and finely bedded rocks (Figure 1) [e.g., 2, 3].

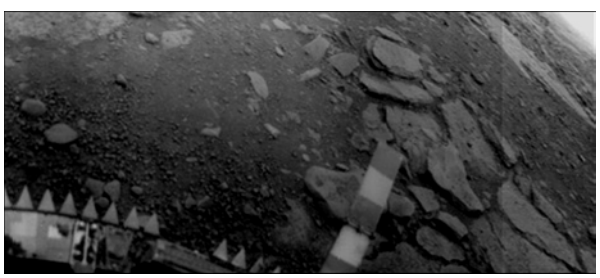

Figure 1. Fragment of the Venera 13 panorama B. Darker soil and brighter finely bedded rocks are seen. The tips of "teeth" of the lander supporting ring are 5 cm apart.

The photogeologic mapping of Magellan images on the Venera Vega landing sites [4] showed that within the landing ellipses (actually circles) of the Venera 9, 10, 13, 14 and Vega 1, 2, the most widespread are extensive plains whose morphology suggests formation by the high-yield eruptions of non-viscous lavas. In the regional and global stratigraphy model [5] these are mostly plains with wrinkle ridges (pwr) often called as regional plains and locally lobate plains (pl). Within the Venera 8 landing ellipse the most widespread are plains whose morphology suggests the low-yield eruptions of non-viscous lavas forming small gentle-sloping shields (shield plains, psh [5]).

It was recently suggested, however, that the finely bedded rocks seen on the Venera TV panoramas (Figure 1) could be partly indurated airfall sediment consisting of the fine fraction of ejecta of the upwind (located east of the given site) impact craters [6]. This hypothesis is supported by the very low mechanical strength of these rocks [2, 3] and implies that the source of the sampled material at the Venera sites could be rocks from the kilometers-deep subsurface (including tessera material tt) excavated by those craters. This possibility was explored and the alternative interpretation of what material could be analyzed by the landers in this case were suggested [6]. So now there are alternative interpretations on which units have been analyzed by the Venera/Vega landers (Table 1).

Table 1. Options of material units analyzed by the Venera-Vega

Lander	Analyzed material	
	Seen in Magellan	Airfall ejecta supply
Venera 8	psh	tt, pwr
Venera 9	pwr	tt
Venera 10	pwr	psh
Venera 13	pwr	pwr
Venera 14	pl	pwr
Vega 1	pwr	pwr
Vega 2	pwr	Minor presence of different units

What units to sample in future missions: It is seen from Table 1 that Venera/Vega landers almost certainly analyzed regional plains with wrinkle ridges (pwr) but the situation with sampling and analysis of other important units is ambiguous. Meanwhile one these units – *tessera terrain material (tt)*, - underlies other units and may be the most abundant component of the upper crust of Venus [7]. Tessera material is the oldest in the local and maybe in global time sequences [5], could be formed in different geodynamic environment (plate tectonics?) [8] and may have nonbasaltic composition [9]. So we suggest that it should be the first candidate to be analyzed by future missions.

Two other candidates are *shield plains (psh)*, which could be a result of partial remelting of the upper crust of Venus, and *lobate plains (pl)* whose typically young age and specific morphology may reflect different (from pwr and psh) petrogenic environment (young hot spots) and thus some compositional differences.

If in some future a sample return mission is considered, most important in that case is to bring samples of the most widespread on the surface *regional plains with wrinkle ridges (pwr) and also tessera material (tt)*. Besides, the geochemical and petrochemical consideration, sample return of pwr material is important as ground truth for estimates of absolute ages of the Venusian surface based on the statistics of impact craters.

How to select landing sites for new missions: Although the suggestion that fine-bedded mechanically weak rocks observed on panopramas of Venera 9, 10, 13 and 14 are air-fall deposits of ejecta from upwind craters [6] is still a hypothesis, it should be seriously considered in the selection of future landing sites. So it is necessary to search for places where the unit desired for analysis is present and has no upwind impact craters relatively near whose ejecta could overlay the unit we wish to analyze. To avoid potential contamination by the ejecta from the upwind craters we suggest to use the "model parabolas" approach, as was done in [6].

A modification of this approach for sampling the tessera material is suggested: Parabolas of the upwind craters should not cover the potential site but the site itself should be within the dark halo associated with a crater sitting on tessera terrain. The 1-3 km range of altitudes observed within large blocks of tessera terrain [7] suggests that the thickness of this material is not less that a few kilometers. So craters with diameters not larger than a few tens of kilometers should excavate the tessera material [10]. The latter approach can not be used however for other units of interest whose estimated thickness is probably smaller than 1 to 3 km.

Potential landing sites and their tests by the model parabola approach: We assumed that their size should be not larger than the Venera/Vega error circles (D = 200 km).

Tessera terrain. A preliminary search [11] led to selection of four sites: T1 - vicinity of crater Carter, 5.3N, 67.3E, 17 km, Ovda Tessera; T2 - vicinity of crater de Beausoleil, 5S, 102.8E, 28.2 km, Ovda Tessera; T3 - vicinity of crater Whiting, 6.1S, 128.0E, 35.7 km, Thetis Tessera; T4 - vicinity of crater Magnani, 58.6N, 337.2E, 26.4 km, Clotho Tessera. At the present stage of the study, all of them were however found to be potentionally covered by ejecta from the upwind craters. Fortunatelly, all these craters are sitting on tessera and, thus, are not the source of contamination by non-tessera material. Nevertheless, one more site has been selected: T5 - vicinity of crater Quimby, 5.7S, 76.7E, 23.2 km, Ovda Tessera (Figure 2).

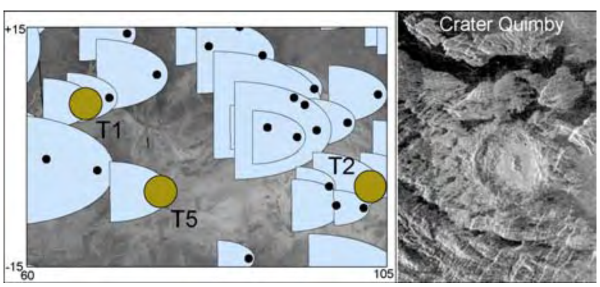

Figure 2. Candidate landing sites to sample tessera terrain material and model parabolas of the craters D >11 km.

Shield plains. The preliminary search [11] led to selection of two sites: Psh1 - eastern edge of Vellamo Planitia (43N, 131E), a reference site of the psh unit decribed by [12]; Psh2 - western part of Sedna Planitia (43.5N, 333.5E), large field of small shields with clear stratigraphy. At the present stage of the study it was found that Psh1 may be partly contaminated by ejecta from the upwind craters while Psh2 in this respect looks free of them (Figure 3).

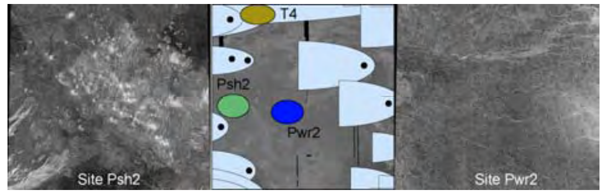

Figure 3. Candidate sites Psh2, Pwr2 and T4. Magellan images for Psh2 and Pwr2 are 200 x 200 km.

Lobate plains. The preliminary search [11] led to selection of three sites: Pl1 - northern flank of Sekmet Mons (47N, 242.5E), where lobate lava flows are clearly superposed on the regional plains (pwr); Pl2 - western slope of Sapas Mons (8N, 187E), where lobate lava flows clearly postdates the regional plains; Pl3 - Mylitta Fluctus (55S, 353.5E), a huge complex of lava flows superposed on the regional plains. It is not related to any large volcano that could indicate that the Mylitta flows were emplaced during a relatively short time ("catastrophic" eruption). At this stage of the study, Pl1 was found not contaminated by the ejecta of the upwind craters, Pl2 was found to be potentionally contaminated, and Pl3, to be partly contaminated (southern part of the site). Shift of the Pl3 site to the north by ~100 km avoids contamination.

Plains with wrinkle ridges. The preliminary search led to selection of two sites: Pwr1 - vast plains between Matlalcue and Helmud Valles in Zhibek Planitia, (33S, 170E); Pwr2 - vast plains in Sedna Planitia (42.5N, 342.5E). The first one was found to be partially contaminated by ejecta from the upwind crater Pena (the contamination can be avoided by moving the site by 50-100 km south) while the second one looks as being not contaminated (Figure 3).

Conclusion: This work does not pretend to be the final suggestion of the sites for future landings on Venus. For that more studies are needed and they should be closely coordinated with proposed mission characteristics. However, we think it is time for the planetary science community to discuss the major types of materials to be analyzed and the approaches how to select the landing sites to provide the highest likelihood of collecting and analyzing the material of interest.

References: [1] Barsukov V. L. (1992) in *Venus Geology, Geochemistry Geophysics,* Ariz. U. Press, 165-176. [2] Florensky C. P. et al. (1983) *Science, 221*, N 4605, 57-59. [3] Basilevsky A. T. et al. (1985) *Geol. Soc. Amer. Bull., 96*, 137-144. [4] Abdrakhimov A. M. *LPS XXXII,* Abstracts 1590, 1601, 1632, 1653, 1670, 1700, 1719. [5] Basilevsky A. T. & Head J. W. (2000) *Planet. Space Sci., 48*. 75-111. [6] Basilevsky A. T. et al. (2004) *JGR, 109*. E12003. [7] Ivanov M. A. & Head J. W. (1996) *JGR, 106*. 17,515-17,566. [8] Turcotte D. L. *JGR, 100*. 16931-16940. [9] Nikolaeva O. V. et al. (1988) *LPSC XIX,* 864–865. [10] Melosh, H. J. (1989), *Impact Cratering: A Geologic Process,* 245 pp., Oxford Univ. Press, New York. [11] Aittila M. et al. (2006) VEP Initiative 1st Landing Sites Workshop, Nov. 14-16, Vienna, Austria. [12] Aubele J. (1995) *LPSC XXVI,* 59–60.