SELECTION OF LANDING SITES FOR THE VENERA-D MISSION.
M.A. Ivanov[1], **A.T. Basilevsky**[1],**J.W. Head**[2]**, L.V. Zasova**[3], **and E.N. Guseva**[1], [1]GEOKHI, Kosygin-19 Moscow, Russia[2], Brown Univ., Providence RI, USA, [3]SRI, Profsouznaya-84/32 Moscow, Russia[2],. Contact: mikhail_ivanov@brown.edu

Introduction: The record of time when the Earth took shape and began its geological and geochemical evolution has long since been destroyed. The smaller terrestrial planets (the Moon, Mercury and Mars) retain this record and show that principal processes in these times were impact cratering and volcanism. Missing from these planets is the transition from the stable impacted lithosphere to the mobile recycled lithosphere consisting of continents and ocean basins seen on Earth today

Venus is similar to the Earth in size, bulk density, and position in the Solar System and possesses rich volcanic and tectonic records. The impact craters on Venus suggest that the observable portion of its geologic history extends for about a half-billion years into the geological past. Thus, in contrast to the smaller terrestrial planets, Venus provides an example of the late parts of the spectrum of evolution of terrestrial planets. Nevertheless, conditions on the surface and the global pattern of the volcanic and tectonic landforms indicate that the mode of geological activity on Venus differs radically from that on Earth. The most important difference is the absence of compelling evidence of modern plate tectonics on Venus.

Thus, the two largest terrestrial planets demonstrate different ways of their late geological evolution. The fundamental problem is then: why is the geologic histories of Venus and Earth different and what are the causes of this difference?

Major issues in geology of Venus: The Earth-based studies and interplanetary missions to Venus have resulted in abundant data sets on the surface morphology, global topography and gravity fields, and chemical composition of both the upper portion of the atmosphere and rocks on the surface. These data allowed understanding of the principal details of Venus geology. However, a variety of fundamental problems remain. Here we formulate a dozen of them and sort them by type of missions oriented to address specific problem. (1) Does non-basaltic crust exist on Venus and where can it be found? (2) What is the variety of crustal rocks on Venus? (3) What are the composition and the temperature profiles of the lower 10 km of the atmosphere? (4) What additional (to the high D/H ratio) evidence suggests the presence of free water on the surface of Venus in its geological past? (5) How does the near-surface atmosphere interact with the regolith? (6) What is the lithology of the regolith on Venus? (7) What are the types of the tessera precursor materials? (8) How many craters on Venus are truly volcanically embayed? (9) How did volcanism on Venus evolve and what types of volcanic activity have operated on the planet? (10) How did tectonic activity on Venus evolve? What is the evidence for plate tectonics on Venus? (11) What is the history of the long- and short-wavelength topography on Venus? (12) What is the distribution of mass in the crust/lithosphere of Venus?

Answers to these problems are necessary to address the fundamental questions of Venus geology: How did the planet evolve and is Venus geologically (i.e., volcanically and/or tectonically) active now? These problems that encompass the morphological, geochemical, and geophysical aspects of the geologic history of Venus can be addressed by missions of different types, such as landers and a variety of orbiters.

Selection of the terrain type for the Venera-D mission: The Venera-D mission consists of an orbiter, a balloon and a lander and can potentially help to constrain more than half of the above problems, specifically, from 1 through 7. Because measurements of the atmosphere composition and temperature can be done on the way to the surface, the selection of specific landing point will address the problems 1, 2, 5, 6, and 7. Among these, the problems of the possible non-basaltic crust (1), diversity of the crustal rocks (2), and the nature of the tessera precursor material (3) appear to have higher priority.

Landing on tessera permits collection of data that are required to address all three of these major issues of Venus geology.

Tessera (~8% of the surface of Venus [Ivanov and Head, 2011]) was discovered during the Venera-15/16 mission [e.g., Barsukov et al., 1986; Bindschadler and Head, 1991; Sukhanov, 1992] and represents one of the most tectonically deformed types of terrain on Venus. The materials that form the bulk of tessera are heavily deformed tectonically and the surface of the unit is characterized by several sets of intersecting contractional and extensional structures that largely obscure the nature of the preexisting materials at available resolution. Images taken from the lander during its descent and on the ground will improve this situation drastically. A very important characteristic of tessera is that the boundaries of its massifs provide compelling evidence for embayment by materials of the other units. These relationships indicate that tessera represents one of the stratigraphically oldest units on

Venus. Both the relatively old age and higher elevation of tessera massifs [Ivanov and Head, 1996] are consistent with the hypothesis that tessera may represent outcrops of the non-basaltic crustal material [e.g., Nikolaeva et al., 1992]. This hypothesis seems to agree with analysis of the orbital NIR observations of the Venus surface [e.g., Hashimoto et al., 2008; Gillmore et al., 2011; Basilevsky et al., 2012]. Thus, tessera appears to be the most important "window" into the geological past of the planet and measurements of composition of the tessera materials may significantly extend our understanding of the geochemical history of Venus.

Unfortunately, a diagnostic characteristic of tessera is its high radar backscatter cross section, which is noticeably higher than that of the surroundings [e.g., Bindschadler et al., 1990]. The radar brightness implies that the surface of tessera is rougher at all scales compared to most other units and landing on this type of terrain may cause failure of the mission.

The vast volcanic plains represent the terrain type that appears to be more permissible for the landing from the engineering point of view. The plains are mildly tectonized and, in general, represent flat, slightly undulating surfaces. Three types of the plains are the most abundant on Venus (cover ~60% of the surface): shield plains, regional plains and lobate plains. The stratigraphically older shield plains are characterized by abundant small (< 10 km across) shield-like features that are interpreted as volcanic edifices [Aubele and Slyuta, 1990; Head et al., 1992; Guest et al., 1992]. The great abundance of the constructs implies that their sources were fairly pervasive and nearly globally distributed while the small sizes of the shields suggest that supply of magma in their sources was restricted. Regional plains that occupy the middle stratigraphic position have generally a morphologically smooth surface with a homogeneous and relatively low radar backscatter. These features strongly suggest that regional plains formed by voluminous volcanic eruptions from broadly, near global, widely distributed sources. The stratigraphically youngest lobate plains consist of numerous radar- bright and -dark flow-like features that can reach hundreds of kilometers in length. The interleaving darker and brighter flows suggest that when lobate plains formed the duration of individual voluminous eruptions and the eruption rates have changed from one episode of activity to the other.

Thus, formation of the vast plains on Venus indicates the progressive change of styles and abundance of volcanic activity on Venus [Ivanov and Head, 2013]. These types of plains have been analyzed during the Soviet Venera landers campaign [Surkov, 1983; Surkov et al., 1984, 1986; Abdrakhimov, 2005] and the collected data have been interpreted in different ways in numerous papers [e.g., Nikolaeva, 1990; Nikolaeva and Ariskin, 1999].

Two major shortcomings of the data collected by the Venera landers largely prevent their robust interpretation. First, the set of detected components was rather small: K, U, and Th only for four landers (Venera-8, 9, 10, and Vega-1) and eight major petrogenic oxides (without Na_2O) and S for the Venera-13, 14 and Vega-2 landers. Second, the errors of the measurements are too large (relative errors can reach about 85% e.g., MnO in the data from Vega-2 lander) and introduce great uncertainties in the interpretations.

Conclusions: Tessera and three major types of volcanic plains represent the set of appropriate target terrains for the Venera-D mission. Because of its unique morphologic and topographic characteristic and stratigraphic position, tessera has the highest scientific priority. From the engineering point of view, however, this target is the most difficult to reach and a pre-landing analysis of the tessera potential danger must be done by the images taken from a separate descending probe equipped by a high-resolution camera or by high-resolution images taken by the orbital missions. The major volcanic units appear to be much less dangerous to land on, but varieties of the plains already have been sampled. The quality of the measurements made on the surface of the plains is not high and re-analysis of the plains at modern levels of measurements may provide key information for unraveling of volcanic history of Venus.

References: 1) Ivanov, M.A., and J.W. Head, PSS, 59, 1559-1600 2011; 2) Barsukov, V.L. et al., JGR, 91, D399-D411, 1986; 3) Bindschadler, D.L. and J.W. Head, JGR, 96, 5889-5907, 1991; 4) Sukhanov, A.L., in: Venus GGG, 82-95, 1992; 5) Ivanov, M.A. and J. W. Head, JGR, 101, 14861-14908, 1996; 6) Nikolaeva, O.V., et al., in: Venus GGG, 129-139, 1992; 7) Hashimoto, G.L., et al., JGR, 113, 2008; 8) Gilmore, M.S., et al., LPSC-42, #1498, 2011; 9) Basilevsky, A.T., et al., Icarus, 217, 434-450, 2012; 10) Bindschadler, D.L., et al., GRL, 17, 171-174, 1990; 11) Aubele, J.C. and E.N. Slyuta, EMP, 50/51, 493-532, 1990; 12) Head, J.W., et al., JGR, 97, 13153-13197, 1992; 13) Guest, J.E., et al., JGR, 97, 15949-15966, 1992; 14) Ivanov, M.A., and J.W. Head, PSS, 84, 66-92, 2013; 15) Surkov, Yu.A., in: Venus 1, 154-158, 1983; 16) Surkov, Yu.A., et al., Proc. LPSC 14th, B393-B402, 1984; 17) Surkov, Yu.A., et al., Proc. LPSC 17th, E215-E218, 1986; 18) Abdrakhimov, A.M., PhD thesis, pp. 143, 2005; 19) Nikolaeva, O.V., EMP, 50/51, 329-341, 1990; 20) Nikolaeva, O.V., A.A. Ariskin, JGR, 104, 18889-18898, 1999.