GEOLOGIC MAPPING OF "VENERA" AND "VEGA" LANDING SITE AREAS ON VENUS

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Geologic maps of the seven areas on Venus have been compiled to produce a background for the analysis of the results of the surface soil/rocks chemical composition measurements at the landing points of seven space stations of "Venera" and "Vega" series. The aim of this mapping was to determine the stratigraphic position of the material that most probably has been analyzed by these landers. The radar images, obtained by the side-looking radar of "Magellan" orbiter, were used for the mapping. These images have resolution of 225 and 75 meter per pixel (images of C1-MIDRP, F-MIDRP, and FMAP formats). The interpretation of the geologic units of the surface of Venus was based on the global stratigraphic scheme proposed for the planet by Basilevsky and Head (1995, 1998, 2000). Nine material complexes were distinguished as a result of the photogeologic analysis of seven areas of "Venera" and "Vega" landing sites. The size of each mapped area is ~ 650 x 850 km. The relative age of these units was determined on the basis of the relations between material complexes – the material of younger units is superimposed on older units or embays them, whereas younger structures cut more ancient ones.

All seven maps have unified legend, which includes 9 geologic material units and 4 morphological structural features. The following material complexes were identified in a sequence of units from older to younger ones.

Tessera (Tt) material forms a strongly dislocated terrain, which consists from intersected ridges and grooves of clearly tectonic origin. The typical spacing between ridge crests is about 5 to 20 km. Tessera material have a high brightness on radar images. Tessera areas, as a rule, are topographically higher then the surrounding geologic units. They are usually seen as large blocks or groups of islands, tens to hundreds of kilometers across, which are embayed and partly superimposed by the material of surrounding plains. Tessera material is, by the structural relationships, the oldest stratigraphic unit within the seven areas of our maps. Direct evidence for the chemical composition of tessera material is absent.

Densely fractured plains (Pdf) material. The surface of densely fractured plains is scarred by radar-bright, subparallel, linear and radial or concentric grooves with a typical spacing between them about 1 km or less. Usually, areas of densely fractured plains slightly rise above the surrounding plains. The zones, where the fractures gradually change their direction, are not uncommon.

Ridged and fractured plains (Pfr) material is characterized by the presence of belts of broad (3-5 km) banklike ridges extending for tens of kilometers. The space between such ridges is often superposed by a younger lava material, which "embays" separate ridges. The surface of the Pfr material is fairly smooth and shows moderate radar brightness.

Fracture belts (FB) material consists of subparallel and branching fractures. Bunches of fractures in such belts often resemble the fractures that are typical for the densely fractured plains Pdf. Such zones of tectonic fragmentation basically include the units that are older than the regional plains Pwr (see below). In the belts, one can distinguish several fracture generations. Boundaries between fracture belts and regional plains are usually gradual.

Shield plains (Psh) material forms areas with tens to hundreds of relatively small volcanic edifices (less than 15 km in diameter) are concentrated. Such areas frequently look mottled on radar images, consisting from clusters of dark and bright spots. Volcanic shields in the areas of Psh material have very gentle slopes; it provides ground to consider such edifices as formed by liquid, obviously basaltic, lavas. Where the separate shield volcanoes are superposed on the regional plains, we mapped them as a component of the Pwr material.

Plains with wrinkle ridges (Pwr) material. The surface of this unit is covered with network of wrinkle ridges. The ridges are of 1-2 km wide and several tens of kilometers in length. On the radar images, this material looks alternately either monotonously gray, or radar-bright, or mottled. Such plains occupy 50-60% of the entire surface of Venus and are, therefore, often called "regional" plains. Pwr material occupies a mean position in the stratigraphic column: it covers older units (Tt, Pdf, Pfr) and is superposed by the younger plains and tectonic structures (see below). The surface morphology indicates that this material is probably basaltic.

Lobate plains (Pl) material forms elongated fields with "lobate" contours in plane; these fields are characterized by the absence of wrinkle ridges. Fields of lobate plains have contrast changes of brightness on radar images. The Pl material forms vast (up to several hundreds of kilometers) fields that are confined to zones of young rifts and large volcanic centers. The lobate-shaped contours and the association of Pl material with volcanic edifices and fractures indicate the lava origin of this material.

Rift zones (RT) material. Such material forms narrow, elongated areas with dense jointing of linear fractures, which have length of hundreds to thousands kilometers. Fractures and graben of the rifts form subparallel and branching swarms and clusters, which cut any geologic units, but some patches of lobate plains. Rifts are characterized by large-scale linear topographic depressions. In some areas, the rift fractures are very closely spaced and have almost identical widths, resembling fracture swarms typical for the densely fractured plains (Pdf). Rift fractures are, however, much wider and they have more distinct shapes, which are seen as a very sharp contrast in brightness between their "illuminated" and "shaded" sides.

Impact craters (Cu) material. This unit includes a complex of materials, which is associated with the formation of impact craters: the materials of crater depression, ejecta blanket, and outflows from craters. Craters and their ejecta are characterized by high radar brightness. Within the mapped areas, there are 12 impact craters 7 to 40 km in diameter, with the width of the ejecta zone ranging 40 to 100 km around the craters.

In addition to the material complexes (geologic units) four types of individual morphologic features of tectonic and volcanic origin have been mapped.

Grooves appear on radar images as elongated bright lineaments, which probably represent large grooves and faults. Grooves, associated with rifts, form subparallel and branching swarms and clusters.

Grabenlike structures are elongated tectonic depressions with well-defined walls. As a rule, they form associations with fracture belts and rift zones.

Coronae are large ring structures, up to several hundreds of kilometers across. They are typically distinguished by the central depression bounded by an annular rim. The Pdf and Pfr units (forming the rims), as well as the Psh, Pwr, and Pl units (making up the coronae-connected areas of volcanism), are frequently associated with such structures.

Large volcanoes. Two varieties of relatively large volcanic edifices were identified in the mapped areas – steep-sided volcanic domes and large volcanic shields. The steep-sided domes are lump-shaped edifices with distinct steep, convex slopes. Their diameter in the investigated areas is 15 to 50 km. The unusual appearance of them is supposed to be due to high viscosity of lavas forming the edifices. The large shield volcanoes have gentle slopes and are 100 to 200 km in diameter. They resemble terrestrial shield volcanoes, which formed as a result of effusions of a low viscous melt of tholeiite basalts. Large volcanic edifices in the mapped areas are confined to rifts.

The geologic maps were used to estimate the areas, occupied by the different geologic units (Table 1). The values have been measured for the restricted areas within each map – so named landing spot. The shape and size of such spot are defined with the uncertainty of the ballistic trajectory of the spacecraft. For "Venera" and "Vega" landers the landing spots are considered as a circle with diameter of 315 km. So, the area of the landing spot is 78×10^3 km^2.

It could be seen (Table 1) that the material, analyzed at "Venera 8" landing site, appears to be most probably the material of shield plains (Psh), as this unit is prevailing within the landing spot – it occupies 75% of the landing spot area. Areas of "Venera 9, 10, 13" and "Vega 1, 2" sites contains mainly the material of plains with wrinkle ridges (Pwr). So, the highest probability for these areas is that the analyzed material was of that geologic unit, which is most common on Venus. And at "Venera 14" site it is most probable that the analyzed material was that of lobate plains (Pl).

Table 1

Geologic unit areas within the landing spots of "Venera" and "Vega" landers (%)

Geologic unit	*"Venera"*					*"Vega"*	
	8	*9*	*10*	*13*	*14*	*1*	*2*
Cu	-	-	-	-	0.5	-	-
RT	-	-	-	-	14	-	-
Pl	8	-	21	3	**52**	-	0.8
Pwr	16	**60**	**59**	**91**	27	**98**	**99**
Psh	**75**	4	0.7	3	5	0.6	-
FB	0.5	-	-	-	1	-	-
Pfr	-	21	1	1	-	-	0.1
Pdf	0.4	-	3	1	0.5	1	-
Tt	-	15	15	0.3	-	-	-
Total	99.9	100	99.7	99.3	100	99.7	99.9

The data on the chemical composition measurements of the planetary surface material at the landing points (Surkov, 1990) provide a possibility to make links between the chemical composition and the geologic units. A geochemically advanced material, measured at "Venera 8" site, could be considered as shield plains material (Psh). Tholeiitic basalt compositions, obtained by "Venera 9, 10" and "Vega 1, 2", looks to represent the material of plains with wrinkle ridges (Pwr). But the similar, tholeiitic basalt, composition at "Venera 14" site is likely to be material of relatively younger lobate plains (Pl).

Considering the geologic history of all seven landing site areas after their geologic maps and in situ measurements of chemical composition of the soil, we can suggest the following scenario of the geologic evolution for these areas. The earliest reliably known event was the formation of a tessera material Tt of still unknown composition, which was completed by its intensive deformation. The next event marked in the morphology of different regions is the formation of the Pdf material (apparently of basic composition) and the subsequent deformation of it by a system of closely spaced parallel fractures. The next phase was the eruption of the Pfr material (also apparently basic) and it's crumpling into broad ridges, evidently in the compression environment. Thereupon, a local formation of fracture belts FB occurred, obviously in the tension environment, and the geochemically advanced material of shield plains (Psh, "Venera 8") formed in some areas due to the heating of the Venusian crust. Later, the character of volcanism changed, and vast eruptions of substantially tholeiite basalt lavas ("Venera 9, 10", "Vega 1, 2") formed Pwr plains, which were subsequently distorted by the network of wrinkle ridges (in the compression environment). During the final phase of the reconstructed geologic history of Venus, lavas of lobate plains, Pl, also of tholeiite composition ("Venera 14"), were formed, and the formation of rift zones RT took place under the tension environment.

Such scenario is similar with the ones known for many other regions of Venus and therefore reflects the main features of the geologic evolution of the planet as a whole.

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