ARACHNOIDS ON VENUS: STRUCTURAL ANALYSIS, CLASSIFICATION AND MODELS OF FORMATION.

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Introduction. Arachnoids are features *"characterized by concentric or circular pattern of fractures or ridges and radial fracture patterns or ridges extending outward for several radii"* [1].*"Catalog of Volcanic structures of Venus"* includes 265 arachnoids [2]. They are most common between 50 and 175 km diameter [1] and are represented by depressions [3,4]. They are interpreted to have formed by evolution of rather small mantle diapirs with rather deep position [1,3,4]. Formation of radial extensional structures was described as due to traces of radial dike emplacement [5]. Previously we suggested tectonophysical models of arachnoid formation [6,7]. **Goals of the study: 1)** To study the topography and geology of sample of arachnoids and their local surroundings. We studied 53 arachnoids (20% of population, each 5<u>th</u> structure from the catalog [2]). **2)** To classify arachnoids by sets of tectonic patterns. **3)** To assess models of arachnoid formation and evolution on the basis of our observations, models of arachnoids [6,7] and related structures formation (coronae [8,9], novae [9,10] and calderas [11,12]), and use processes of radial dike swarm emplacement [13,14] and mantle diapirism [15,16]. **Methods.** We used "*Magellan*" C1 and F-MIDR and GTDR data for geological analysis, which included: **1)** Study of topography. **2)** Study of distribution and kinematics of their deformation structures. **3)** Detail geological mapping of typical examples.

Geology and topography of arachnoids. The average diameter ($\bar{d}$) of 53 arachnoids studied is 110 km, standard deviation (S) is 48 km. Initially diameters were measured by [2], in our processing (*Table 1*) larger diameter was used if structure is asymmetric. We subdivided arachnoids into 6 types, for each of them a unique set of deformation structures is common, extensional structures are represented by fractures and graben, compressional by ridges. In all arachnoids concentric extensional fractures are located on the depression slope. Five structures are located in gaps of altimeter data. Statistics are shown in *Table 1*. Depth of depression was measured as a difference between average elevation of two randomly chosen points at its borders above the deepest point inside the depression. Study showed that part of arachnoids mapped started to form before regional plains with wrinkle ridges formation and finished after that. The following types of arachnoids were subdivided: ***I. Arachnoids with concentric extensional structures.*** Fourteen are depressions, in 3 parts of rim very low are observed, 5 are irregular flat, 2 in topo data gaps. ***II. Arachnoids with concentric extensional, radial compressional structures running outside of depression and concentric compressional structures inside depressions.*** All arachnoids are depressions, in 1 it is surrounded by very low rim. ***III. Arachnoids with concentric extensional and radial compressional structures running outside of depressions.*** Five are depressions, 1 is irregular flat, 1 - in topo data gap. ***IV. Arachnoids with concentric and radial extensional structures.*** Four are depressions, 1 is irregular flat, 1 is dome-like. ***V. Arachnoids with concentric extensional structures and chaotic and/or concentric compressional structures inside depressions.*** Four are depressions, 1 in topo data gap. ***VI. Arachnoids with radial and concentric compressional structures.*** Three are depressions, 1 is irregular flat, 1 in topo data gap. Two arachnoids do not satisfy suggested structural criteria of types subdivided.

Type	Number (n)	% of studied population	Diameter ($\bar{d}$), *km*		Diameters comparison, *km*		Depth of bottom, *km*	
			Average	Standard deviation (S)	$\bar{d}\pm 2S$	$\bar{d}\pm x$, $x=\frac{T\bullet S}{\sqrt{n}}$	Average	Standard deviation (S_l)
1	19	36	122	50	122±100	122±23.3	1	0.5
2	9	17	101	39	101±78	101±26	1.2	0.7
3	7	13	84	17	84±34	84±13.1	1	0.5
4	6	11	116	82	116±164	116±68.3	1.6* 1.1**	0.5* 1.1**
5	5	9.5	105	27	105±54	105±24.5	1.4	0.7
6	5	9.5	92	33	92±66	92±27.5	1	0.7

Table 1. Statistics of arachnoid classes. Two arachnoids (4% of population) because of unusual geological and topo characteristics are not shown. T - Student T-test, T=2; n - numbers of arachnoids of this class. * - including dome-like arachnoid, **- without it.

Models of arachnoid formation. Arachnoid classes are not distinguished by diameter (*Table 1*), therefore they could be formed by diapirs with similar diameters, because the outline of the diapir on surface is close to its diameter [15]. As was suggested [1,3,4] arachnoids are formed by relatively deep neutral buoyancy level (n_0^d) of diapirs, apparently because of that no related massive volcanism was observed. Below we suggest four models of formation of arachnoid types (*Fig. 1*). We will use terms relative shallow and deep position of n_0^d for variations of depth of n_0^d. ***<u>First model</u>:*** **1)** Mantle diapir trying to reach n_0^d influences the upper brittle part of the lithosphere penetrating lower ductile lithosphere and essential thinning it, n_0^d is shallow (h_1). Partial melting in diapir head occurs due to adiabatic decompression [16], magmatic reservoir forms and produces radial dike swarms, which create radial fracturing and occur along the neutral buoyancy level of the reservoir (n_0^r) [13,14]. **2)** Lateral spreading of the diapir and lower ductile part of the lithosphere takes place [8,9,15]. Depression forms by complete relaxation relative to lithospheric isostatic equilibrium (n_0^l) because of lithosphere thinning by updoming, extensional structures occur on depression slope due to radial stress (σ^r). This model describes ***Type IV*** arachnoids formation, which is the same as negative novae [10] and in relaxation stage mechanically the same as calderas [11,12]. ***<u>Second model</u>:*** **1)** Diapir trying to reach n_0^d influences the upper brittle part of the lithosphere, penetrating lower ductile lithosphere and essential thinning it, n_0^d is deeper (h_2). Hereafter we do not see evidence of magmatic reservoir formation and dike emplacement, probably due to deeper n_0^d. **2)** Lateral spreading of the diapir and lower visco-plastic part of the lithosphere takes place [8,9,13]. Depression is formed by complete relaxation relative to n_0^l because of lithosphere thinning by updoming, extensional structures occur on depression slope due to σ^r. This model describes ***Type I*** arachnoids formation.

In thinner upper brittle part of the lithosphere (b_1) compressional ridges inside depression are forming. It leads to ***Type V*** arachnoids formation, which in relaxation stage is mechanically the same as calderas [11,12]. ***Third model:*** **1)** Diapir trying to reach n_0^d influences the lower ductile lithosphere penetrating part of it and thinning it, n_0^d is deeper (h_3). **2)** Lateral spreading of the diapir and lower ductile part of the lithosphere takes place [8,9,13]. Depression forms by complete relaxation relative to n_0^l because of lithosphere thinning by updoming; extensional structures occur on depression slope due to σ^r. Due to tangential stress (σ^{tg}) radial compressional ridges form [6,7]. It leads to ***Type III*** arachnoids formation. Thinner upper brittle part of the lithosphere (b_3) due to both σ^{tg}, σ^r radial and concentric compressional ridges inside depression form [6,7], which leads to ***Type II*** arachnoid formation. ***Fourth model:*** ***Type VI*** arachnoids form approximately by the same processes described for *Types I-III, IV,* but in their formation regional compressional stress influences (σ^{reg}) and approximately predominates over local stress.

Summary. 1) We have studied 20% of the arachnoid population [2]. **2)** Most arachnoids are represented by depressions. **3)** We classified them (6 classes) on the basis of tectonic sets characteristic of each class. Part of arachnoids (*Type I*) (36%) have the same set with calderas [11,12] and should be described as calderas. Part of arachnoids (*Type IV*) (11%) have the same set with novae [8,9,10] and should be described as novae. **4)** All arachnoids could be formed by diapirs with similar diameters. **5)** Formation of radial extensional patterns could be explained by radial dike propagation [6,13,14]. **6)** Results of stratigraphical analysis are in agreement with model of global and regional stratigraphy [17]. **7)** Must of arachnoids mapped started to form before regional plains with wrinkle ridges and finished after that. **8)** We suggest models of their evolution (*Fig. 1*), key factors of them are: **a)** Depth of neutral buoyancy of arachnoid producing mantle diapir; **b)** Thickness of the upper brittle part of the lithosphere; **c)** Rheological conditions of the part of lithosphere, in which mantle diapir interacts - lower ductile or upper brittle. These factors are analogous to key factors of novae formation [10], arachnoids form by smaller diapirs with relatively deeper neutral buoyancy level of mantle diapirs.

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Figure 1. - extensional structures, - compressional structures, σ^r - radial stress, σ^{tg} - tangential stress, σ^{reg} - regional stress, n_0^d - neutral buoyancy level of the mantle diapir, n_0^r - neutral buoyancy level of the magmatic reservoir, n_0^l - level of lithospheric isostatic equilibrium, h - depth of n_0^d ($h_1<h_2<h_3$), b - thickness of the upper brittle part of the lithosphere ($b_1<b_2$, $b_3<b_4$).