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STRESS ON THE SURFACE OF VENUS: ANALYSIS OF DATA PROVIDED BY VENERA-15 AND VENERA-16

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16. Abstract
There are no large-scale sedimentation and erosion processes on Venus, therefore the observed deformation must be formed on the surface or close to it, and in the ellipsoids of stresses one of the main axes must be perpendicular to the surface. According to the deformation visible on the pictures of "Venera-15, 16", the orientations of the ellipsoids of stresses are established in the different sections of the Montes Maxwell and the northern parquet. A geological model is established, according to which the Montes Maxwell is an arched vault and the region to the south a conjugate bend, separated by a shift zone.

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STRESS ON THE SURFACE OF VENUS:
ANALYSIS OF DATA PROVIDED BY VENERA-15 AND VENERA-16

L.B.Ronka

Introduction

In radar images, obtained with the "Venera-15 and 16" stations, no clear indications may be found of the presence of erosion-sedimentary processes on Venus (1). This does not indicate that there are no such processes at all, in as much as their characteristics were detected by previous "Venera" stations (4-6). It is possible that erosion and sedimentary processes on Venus take place only on lower scales than the resolutions of the radar pictures of the "Venera-15 and 16" stations (1-2 km). /54*

The type of tectonic deformations on the surface of Venus is related to these characteristics. Whereas on the earth tectonic deformations are usually observed arising in depth and later uncovered by erosion, the deformations on Venus should be formed on the surface. E.M. Anderson (9) showed that the surface of the planet must be considered as a plane through which no shear region stresses pass (in as much as distances of several hundred of kilometers the curvature of the surface and the unevennesses of the relief may be disregarded). If the material on the surface and close to it is homogeneous enough, the stresses (forces per unit of area) may be represented in the idealized form as ellipsoids of stresses. The ellipsoids of stresses must not be confused with ellipsoids of deformations, which reflect dislocations, and not forces. In as much as the surface of the planet is a plane through which no shear region stresses pass, it may be shown, that one of the axes of the ellipsoid of stresses should be vertical. If this is true, then only definite types of deformations may be observed on the surface of Venus.

*Numbers in the margin indicate pagination in the foreign text.

Usually the radii of the ellipsoid are proportional to the stresses (forces per unit of area) directed towards the center of the ellipsoid (compression forces). But in tectonics, they often talk of forces of extension, which strictly speaking, can not appear on the scale of radar images, but may be assumed starting from the differential decrease of the compression forces, which was described in the publication by D. Griggs and G. Handin (7).

Figure 1 shows sections of ellipsoids of stresses and cracks, which may be expected. It is the convention to assume that σ_1 is the direction of the maximum stress, σ_2 of the intermediate stress and σ_3 minimum. All these are stresses of compression, if we talk of visible stresses of extension, their distribution is inverse: σ_1 is the minimum extension, σ_3 is maximum.

The simplest type of deformations which may be expected on the scale of radar images are ruptures. Theoretically in a homogeneous material ruptures may have only three orientations with regard to the ellipsoid of stresses. The first two are represented by two symmetrical planes perpendicular to the planes with /55. σ_1 and σ_3 and with angles less than 45^0 with regard to σ_1. In this connection usually movements occur, causing relative lateral shift in different directions of the rupture. As a result force, up thrusts and shifts occur according to which direction of the stresses is vertical (σ_1,σ_2,σ_3). If the rupture formation takes place in both planes, the ruptures arising are called conjugate. The third type of ruptures may appear along the plane perpendicular to σ_3. In this connection there are no lateral movements or the small, and the ruptures are called cracks of extension.

Theoretically the deformations may also occur in folds. On the earth with a few exceptions, the folding usually takes place in depth, but it is impossible to establish this for the moment for Venus. If the folds are located on this surface, then it may be assumed that the horizontal traces of their axial planes are perpendicular to σ_1.

Observations and Analysis

The above indicated considerations were used for a region extending east of the Montes Maxwell, where the northern parquet extends (figures 9,11,12 in (2)). Studies are being planned for other regions (4).

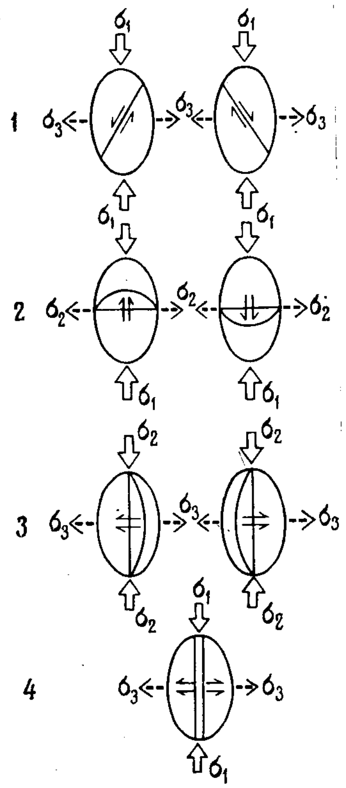

Fig.1. Cross sections of the ellipsoid of tensions and corresponding ruptures. The wide arrows indicate the maximum compression forces, the dotted line ones, additional visible extending stresses (see text) and the double arrows are the direction of shift along the ruptures. The horizontal cross sections are: 1-shifts, 2-up thrusts, 3-poles, 4-cracks.

It is easiest to detect the deformations which are called conjugate ruptures: two networks of ruptures, which do not intersect under direct angles, and of which neither of the networks intersects the other consecutively. Such conjugate ruptures are found in certain sections of linear structures east of the Montes Maxwell and in the northern parquet. As was shown above basic directions of stresses are clearly established in this connection. It is possible to obtain indications on the σ_1/σ_3 ratio, by measuring the angles between the conjugate ruptures, which decrease with the increase of σ_1/σ_3. It is assumed that the orientation of the ruptures corresponds to the orientations of vectors connecting the centers of the ellipsoids with places of interaction of the ellipse with the circle of circumference equal to it (conditions of "hydrostatic stress"). On figures 2 and 3 the black out lines show the orientations and forms of ellipsoids, built up according to the conjugate ruptures.

In certain regions such as the Montes Maxwell, no conjugate ruptures are visible, and deformations are represented by a network in one direction (see fig.2, B-E). If they are ruptured, then according to the above considerations, they are either false (σ_1 is vertical) or upthrusts (σ_3 vertical). The presence in this region of such structures as curved ridges, and the absence of open cracks make it possible to assume the decrease of the area and consequently the presence of up thrusts. If the observed structures are poles, the orientation of the ellipsoids remains the same as the four.

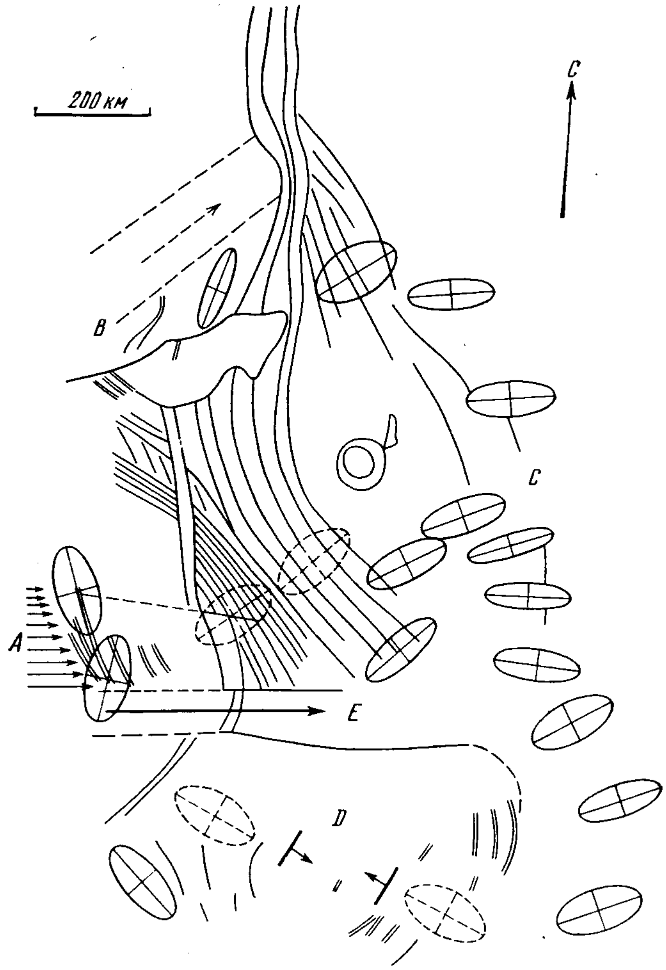

Fig.2. Scheme of the Montes Maxwell. The letters indicate the sections indicated in the text. The ellipses show the distribution of stresses on the representative sections. The ellipses indicated by solid lines, indicate the stresses σ_1 (on the large axis) and σ_3 (on the small axis). The ratio of the axes is approximately proportional to σ_1/σ_3, according to the description in the text. The dotted lines indicate ellipses in the places of proposed up thrusts, with σ_1 on the large axis and σ_2 on the small one. The ratio of the axes is arbitrary. The arrows indicate the shifts and the shear regions (a solid line the relatively reliable ones, the dotted lines, the assumes ones).

If this analysis is correct, then the differences between the Montes Maxwell /56
and the section of the northern parquet (see fig.2,C) are not very large. The diagram illustrating this is shown on fig. 4. In both regions the main direction of the stresses is in latitude, but if on the Montes Maxwell the intermediate stresses are directed horizontally, in the meridional direction, then in the northern parquet the vector of the intermediate stresses is vertical.

A different type of deformation is observed on the planes west of the Montes Maxwell (right of the letter A, see fig.2). It is represented by a system of bent open cracks, expanding towards the south. With steady observation it is apparent that if the cracks are thin, they are interrupted and bridges exist. The edges of the cracks are not smooth, but jagged. The interpretation of these structures, based on the theory of ellipsoidal stresses, is shown in fig.5. These cracks are considered as cracks of extension (perpendicular to σ_3) and shifts (perpendicular to planes with σ_1 and σ_3) whose formation was accompanied by a rotation of the ellipsoid in the southern direction.

A new type of deformation appears further to the east on the northern parquet. Here we see irregular spot of a smooth region (see letters G,F and H on fig.3). /58.
Although reliable characteristics of their origin are not known, they may be related with the cracks of extension (perpendicular to σ_3), filled later with lavas.

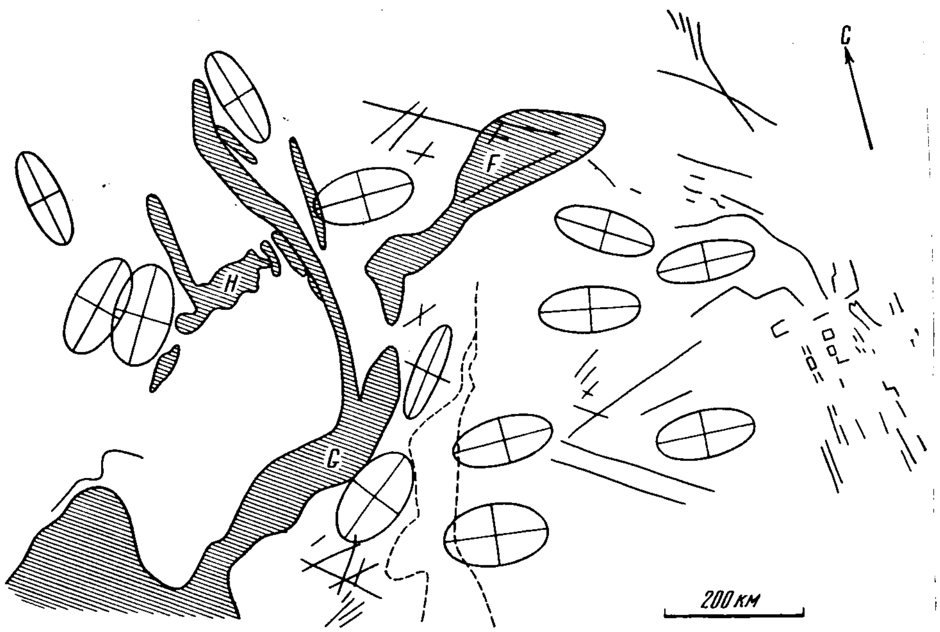

Fig.3. Scheme of the northern parquet. The letters indicate smooth sections, indicated in the text. The ellipses indicate the distribution of stresses in the corresponding sections with σ_1 of the large axis and σ_3 of the small one. The ratio of the axes is approximately proportional to σ_1/σ_3.

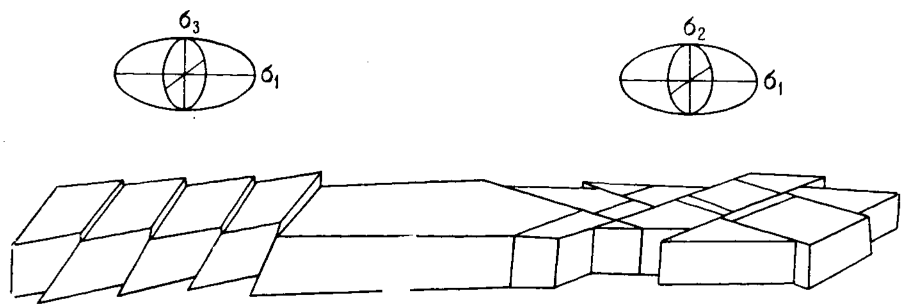

Fig. 4. Block diagram of the deformations in the Montes Maxwell (upthrusts) and on the parquet (falls) and on the parquet (conjugate ruptures) and corresponding orientations of the ellipsoids of stresses.

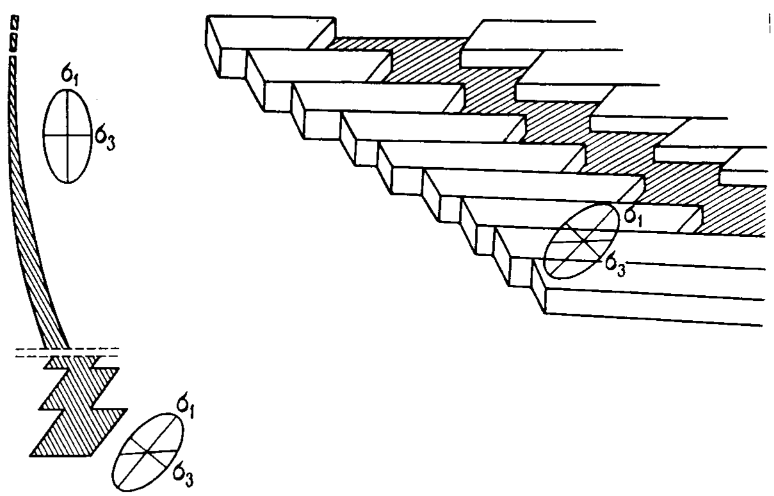

Fig. 5. Model of the shear region southwest of the Montes Maxwell. The limits between the extended blocks are shifts, and the gaps between them are formed by uncovering in the extension. On the left the planimetric scheme of such a split is shown (the southern portion is enlarged). The orientation of the ellipses of stresses is shown.

Interpretation

To understand the stresses responsible for the occurrance of deformations, is only a first step to understanding the entire geological picture. The next step may be the interpretation of the geological structure leading to the understanding of local and overall tectonics. This study proposes a method and its application to one region; the author hopes that this method can be used as a first step.

The overall geological structure of the studied region is for the moment unclear. Nevertheless one of the possible interpretations is given here, for the study of which one must turn to the region south of the Montes Maxwell (see letter D on fig. 2). Judging by the radar altimetry, this region is a deep depression. In the eastern and southeastern sections of this depression open cracks are visible. They may be cracks of extension, created by stresses arising because this region is located as on a hinge on the edge of a buckling region. The depression is filled with some material, probably lavas. The western section of the northern border of the region with the Montes Maxwell has a clear and sharp appearance, as in the case of normal falls. The upthrusts in the Montes Maxwell, the conjugate ruptures on the parquet on the depressions and the falls to the north of this depression may be interpreted as shown on fig. 6.

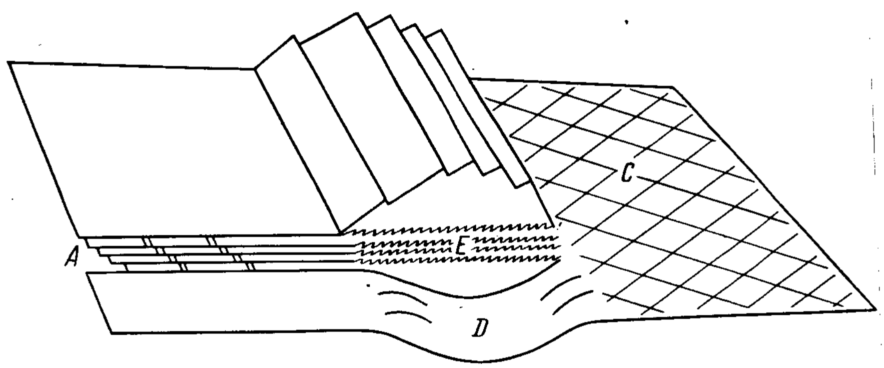

Fig. 6. Simplified diagram of the proposed structure of the Montes Maxwell and depressions to the south of them. It is assumed that latitude stresses cause: 1-the raising of the Montes Maxwell and the upthrusts (these processes are not distinguished on the diagram); 2-the occurrance of zones of shearing; 3-the formation of a depression (for simplicity it is shown in the form of a synclinal, but ruptures are also possible in this connection). The cross structures in the right hand portion indicate conjugate ruptures on the parquet. The letters correspond to sections on fig. 2 indicated in text.

The proposals on the structure of the eastern section of the northern parquet has an even weaker foundation. Figure 3 shows that approximately in the middle of this region a boundary may exist, separating the ellipses with latitude orientations from the meridional ones. This does not necessarily indicate a change in the direction of forces, determining the stresses. These forces may be directed everywhere in latitude, but in the east they appear in the form of compression (along σ_1) and in the west in the form of extension (along σ_3). The conditions of extension for the western portion may be assumed both according to the orientation of the ellipsoid, and according to the presence of the dense sections.

The last step in the construction of the related geological picture must be the determination of the tectonic mechanisms creating the observed structures. Unfortunately this is not possible now. By analogy with the earth we may assume that the determining forces were caused by asthenospheric flows, interacting with /59. the lithosphere. The stresses in the lithosphere may be determined by several variables: 1-the geometry and the philosophy of the asthenospheric flows; 2-the nature of interaction between the asthenosphere and the lithosphere; 3-the thickness, temperature and composition of the lithosphere.

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