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TECTONIC ASYMMETRY OF THE EARTH AND OTHER PLANETS

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16. Abstract

This article discusses the science of symmetry, assemtry, and dissymetry as applied to the study of the tectonic structure of the Earth and the other planets of the Earth group (Mercury, Mars, Venus, the moon).

Comparing tectonics and comparative planetology revealed a very important general law governing the structure of the Earth group — their structural assmetry. This is evident regardless of the dimension, mass, density and distance from the sun.

Further study of asymmetry and non-uniformity of planets in the Earth group will provide important solutions of the structure and evolution of the Earth's lithosphere.

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Techtonic Asymmetry of the Earth and Other Planets

Yu. M. Pushcharovskiy, V. V. Kozlov, & Ye D. Sulidi-Kondrat'yev

In the most diverse branches of natural science the science of symmetry is now being widely used as a method of knowledge of the fundamental laws governing the structure and evolution of material on all levels of its organization--from physical fields and elementary particles to the universe as a whole. The development of the science of symmetry, asymmetry, and dissymmetry (disruption of symmetry) is associated primarily with the names of Ye. S. Fedorov, P. Kyuri, V. I. Vernadskiy, and A. V. Shubnikov. We will be interested in the application of this science to the solution of global tectonic problems. To a certain measure N. S. Shatskiy, N. P. Kheraskov, Yu. M. Pushcharovskiy, and other authors have already been involved in this. /32

In the structure of the upper mantles of earth signs of symmetry and asymmetry have been clearly manifest which require explanation for the substantiation of certain geodynamic models. Therefore one can speak of the tectonic symmetry and asymmetry as important properties of external geospheres subject to tectonic deformations. Characteristic examples of tectonic symmetry--mid ocean ridges (or their fragments), groove structures, and certain geosynclinal zones. But in a global aspect the earth is tectonically asymmetrical. The Pacific Ocean that occupies an enormous area on the planet gives it this asymmetry. Correspondingly, it is justified to divide two segments on the earth: the Pacific Ocean and the Atlantic opposite to it, named thus by N. S. Shatskiy. A natural question arises: what is the reason for the global tectonic asymmetry of the earth, and how is this most important feature in the structure of the globe linked to the extant geotectonic concepts and with the latest data on the structure of other planets of the earth group and

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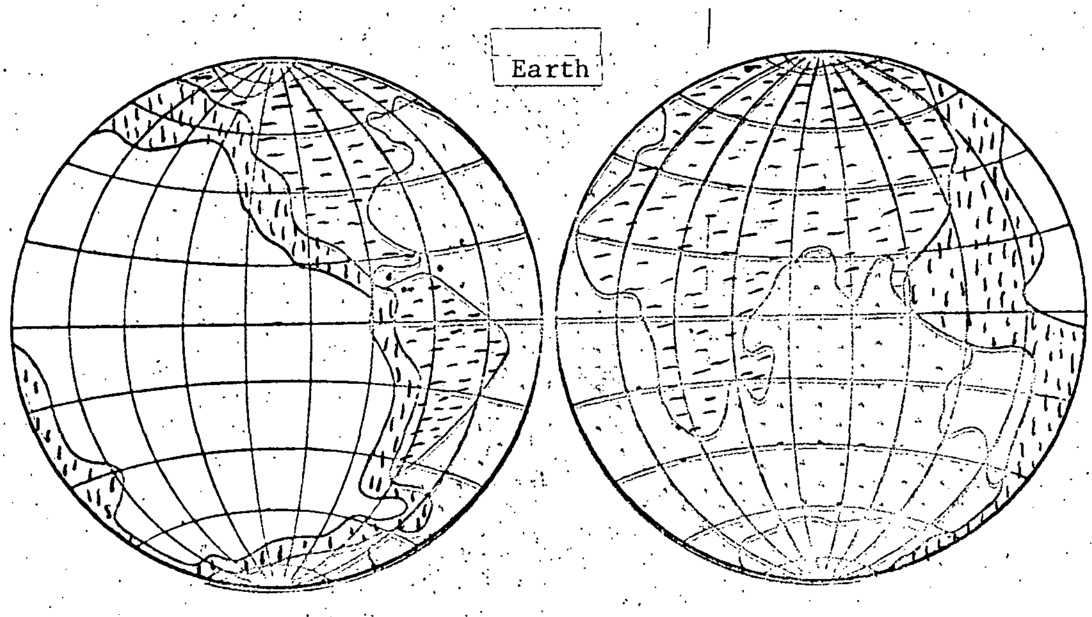
for example in the south Atlantic or in the case of Australia and Antarctica. /33
The eastern and western margins of the Pacific Ocean are constructed differently, which is clearly visible on any globe. Therefore attempts have never been made to converge and unite into one the continents of these margins. In the central parts of the Pacific Ocean there are no microcontinents, and generally no signs of the existence here in the geological



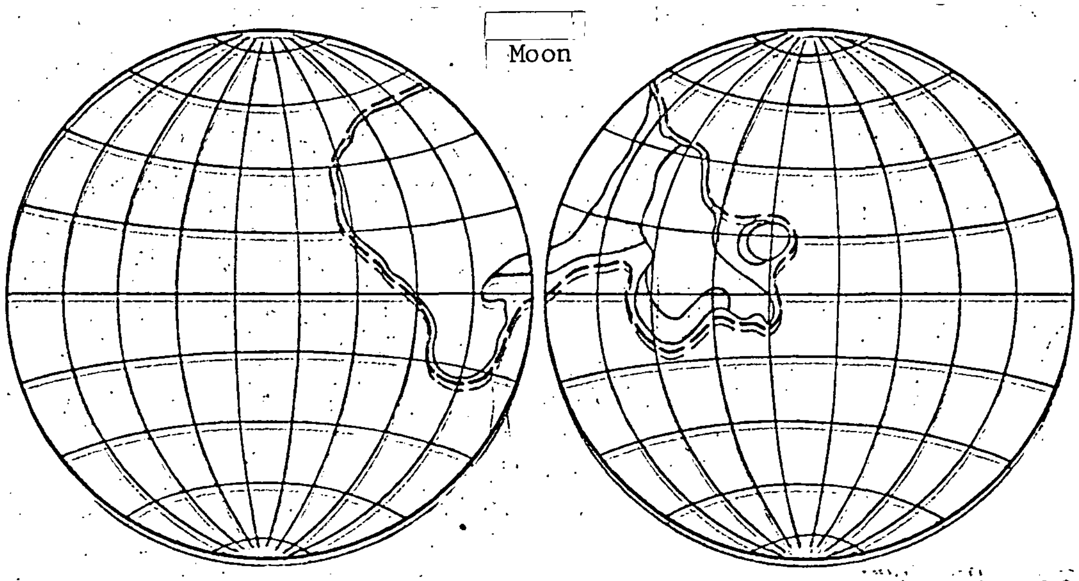
Global Tectonic Elements of Earth. Schemes of Planetary Bodies on Other Figures Compiled in the Same Cartographic Projection.

Continental segments

Oceanic (sea) segments

Secondary oceanic (sea) depressions within the continental segments

Near-oceanic mobile belts



Global Tectonic Elements of the Moon. The Moon's "Sea" Segment is Expressed by a Group of Converged Sea Depressions, While the "Perioceanic" Belt is Manifest in Fragments. These Tectonic Elements are Outlined by a Dotted Line.

past of continental structures. Although it is necessary to note that the earth's crust in these regions is very variable both in the nature and completeness of the section, and in thickness. The latter fluctuates from several kilometers to the first tens of kilometers, and in its values can be compared with the thickness of the earth's crust of the continents. This fact sometimes elicits in geologists a feeling of "confusion," but in light of the latest ideas on the tectonic crowding of the sheets of oceanic crust as a result of their horizontal movements it is not so surprising. The process of the structural development of the crust of an oceanic type is considerably more complicated than it seemed quite recently, and is expressed both in the creation of structural forms and in their destruction. Sections of the oceanic crust can experience compression and stretch, and here different tectonic deformations develop. Altogether all these phenomena comprise the essence of the tectonic self-development of the ocean crust. Since separations and movements in the tectonosphere occur on different levels, then /34 the dimensions of the moving plates and blocks are significantly different.

From here the reader can see the difference in our ideas from the dynamic model of "tectonic plates" that has been developed by the American geophysicists, according to which the giant lithospheric plates, and according to this concept there are only six on earth, are moved along the underlying layer of reduced viscosity called the asthenosphere. Generally the viewpoints developed below do not agree with the mentioned concept.

Now we will say a few words about the framing of the Pacific Ocean depression. This depression has already be understood for a long time as the Pacific Ocean circular tectonic belt. In the American literature it is called Circum-Pacific belt. A characteristic feature of the belt is the natural structural link of its major elements with each other. A tectonic ring is obtained that links Asia and North America on the one hand, and Australia, Antarctica and South America on the other.

It is important that many continental margins of the Pacific Ocean region were near-oceanic zones already at least billions of years ago. This refers to the cordillera of North America, East Australia, and South-east China. Sikhote-Alin' was a well-developed zone of insular arches and marginal seas in the middle Paleozoic era. The geosyncline near-oceanic zone within the limits of the Andes in South America is established as Mesozoic era. Another fact is also curious. It has been proved that in the geosynclinal-folded regions of the Pacific Ocean belt rejuvenation occurs at the time of tectogenesis from its inner sections to the edge of the ocean.

All of this at the same time creates an impression of the stability in time and in space of the Pacific Ocean mobile belt. But the question turns out to be more complicated.

In fact on the periphery of the enormous oceanic depression it is natural to expect a constant manifestation of highly active tectonic, magmatic, seismic and sedimentation processes similar to the modern. They, of course, did occur. But their interpretation of the geological past is not always successful. The main reason--drift of continents. Today there is a lot of data about the drift of Australia and South America a great distance. It is probable that movement of North America towards the Pacific Ocean also occurred. The time of these movements is somewhat different, however mainly they are set within the framework of the Mesozoic era, encompassing possibly, even the early Cenozoic era. Correspondingly, the modern structural plan of the Pacific Ocean circular belt was composed at this time. Nevertheless for the half circle located in the northern hemisphere the paleotectonic reconstructions are possible, perhaps, all the way to the late Precambrian era. Thereby the ancient history is revealed of the half circle and the main tectonic asymmetry of our planet is again stressed. /35

Thus, a global structure nonuniformity is inherent to earth. Within its limits a segment is separated that includes the Pacific Ocean and the Pacific Ocean tectonic belt that outlines it which is characterized by a high degree of mobility and permeability of the tectonosphere. And the other segment--where all the ancient platforms are concentrated, the geosynclinal-folding belts dividing them, and the secondary oceans. It follows from such a contrasting that both of these parts must have been developed by different paths for an extremely long time. A sudden confirmation of this opinion came as a result of studies of the moon.

Before the moon was studied with the help of automatic interplanetary stations (AIS) a hypothesis existed that its far side has an Ocean of Antipodes--an analogy with the Ocean of Storms on the visible side, while on the whole the moon possesses a bilateral symmetry. The first photographs of the far side of the moon showed that the natural satellite of earth is also asymmetrical, and is divided into two segments that differ in structure. The hemisphere that is turned towards earth is characterized by the spread of lunar seas, while on the far side there are practically no seas and there /36 are spread lunar continents whose surface is studded with craters with diameter of tens and hundreds of kilometers, on which in turn, smaller craters are located.

The depressions of the Ocean of Storms and the lunar seas are concentrated in the northern part of the visible hemisphere. They form large depressions that are lowered by 2-4 km relative to the mean level of the continents. The same as on earth they are made of basalts. Along the periphery of the depressions cordillera are developed in the form of mountain structures of block structure. According to gravimetric data based on trajectory measurements of artificial moon satellites over the depressions of the lunar seas there are high positive anomalies of gravity force which is explained by the reduction in the depth of the crust. On the whole an analogy in structure of the depressions of lunar seas and the earth's oceanic depressions is manifest. It is remarkable that the region of depressions on the moon occupies roughly 1/3 of the part of its surface, which is close to the correlation of the Pacific Ocean region and the Atlantic segment of earth. Information on the radiological age of basalts that fill the depressions of the moon indicate that these rocks were formed roughly in the interval of 4-3 billion years ago. They, thus, are younger than the lunar "continental" complex of rocks that were formed about 4.6-4 billion years ago. Consequently on the moon the global tectonic asymmetry developed at the early stages of its evolution.

After obtaining the first photographs of the far side of the moon with the help of the AIS "Luna-3" in 1959 different reasons were advanced for the causes of asymmetry of the visible and the far hemispheres of the earth's natural satellite. The famous Soviet astronomer A. A. Mikhaylov criticized a number of hypotheses explaining the asymmetry of the moon by the action of earth. The essence here is as follows.

In certain cases the earth could affect by its gravity the flow of meteorites, by changing its trajectory and as if focusing such a flow in the direction of the visible hemisphere of the moon. On the other hand the earth had to serve as a type of screen protecting the moon from the meteorite bombardment. In this variant the transformation of the visible side of the moon as a result of impacts of meteorites was even reduced. However calculations indicate that such a focusing or screening effect of earth had to be manifest in very rare variants of meteorite trajectories. Therefore it could not be a determining factor in the creation of the global asymmetry. Moreover these two gravitational effects are opposite in their action on the surface of the moon since in one of them the intensity of the meteorite bombardment increases, and in the other it is somewhat reduced.

The effect of solar eclipses that are manifest on the visible side of the moon, despite the great drops in temperatures, also could not be the cause of the asymmetry. Finally, in the case of the relationship of asymmetry to the development of the system earth-moon it should be expected that the moon has a symmetrical arrangement of the sea segment relative to the center of the lunar hemisphere turned towards earth. In actuality here the so-called Central Isthmus is located with continental structure, while the sea depressions are shifted to the north. Therefore it is necessary to explain the lunar asymmetry in the first place by internal (endogenous) reasons.

On the other hand, the hypothesis of V. Pikkering enjoyed popularity in its time; it explained the origin of the Pacific Ocean depression by the detachment of the moon. The latest calculations indicated the groundlessness of the "Hypothesis of Detachment." As will be stated below global asymmetry is also inherent to other planetary planets of the earth group--Mars and Mercury, that do not have large satellites of the lunar type, which also testifies against the ideas of the possible relationship of asymmetry to the development of the system of the planet and its satellite.

It is necessary to dwell on the tidal action of earth. In the past when earth and the moon could be drawn together the tidal action of earth had to be more significant. Thus calculations made by Dzh. Khartung (1976) indicated that with a distance of the moon from earth comprising 1/3 of the modern, the gravity action on the visible side could be 100 times greater than on the opposite hemisphere of the moon, and with a reduction in distance to 1/10 these differences increased 10,000 times. Thus the gravity action of earth had to promote the creation of a global tectonic asymmetry with the formation of the sea segment precisely on the visible side. It is known that the center of masses of the moon was shifted towards the earth roughly by 2 km relative to the geometric center of /37
the satellite.

Gravity and seismic data indicated the lateral nonuniformity in the structure of the crust and the mantle of the moon. This law is very important since for the moon with the greatest definiteness the antiquity, and as the authors propose, originality of the emergence of the global tectonic asymmetry is established. Within the sea segment on the whole the depth of the crust is reduced to an amount on the order 60 km, while for the far side of the moon with continental structure a thickness of the crust to 100-150 km is assumed. Here the depth of the basalt filler of the lunar seas is estimated as an amount only of several kilometers, which approaches the depth of the layer of the oceanic crust on earth that is made of basalts. Within the sea segments of the moon atypically high velocities of longitudinal seismic waves are noted, which should be explained, in our opinion, by the bulging of the roof of the mantle as occurs on earth under oceanic depressions. Such a model for the moon is not yet strictly proven, but it deserves no less attention than the ideas on the link between anomalies of the gravity force (maskons) of lunar seas with the subsurface disc-like bodies of relatively dense material.

To justify the nonuniformity in the lunar structure with separation of segments or blocks of global scale of importance is the information on the seismicity. Seismometers installed on the surface of the moon recorded a large number of moonquakes produced by different reasons, including tidal with foci in depth primarily 500-700 km, and tectonic, whose foci were located at depths about 300 km.[1] The concentration of epicenters of moonquakes in zones of linking of the continental and sea segments is indicative. Here the continental block in the southeast section of the visible side of the moon is practically aseismic. The marked analogy with the distribution of deep-focus earthquakes on earth which are concentrated in the Pacific Ocean perioceanic belt is completely natural.

Asymmetry in the Structure of Mars and Mercury

Television photographs of Mars obtained with the help of the AIS indicated that in its northern hemisphere a depression of planetary scale is developed, while the southern hemisphere was formed mainly by continental regions. Consequently, also on Mars a global tectonic asymmetry is established with separation of the Boreal and Austral segments (from the names on the maps of Mars of Vastitas Borealis and Tolus Australis). The "sea" regions are distinguished

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[1]Galkin, I. N. "Nature of Moonquakes," Priroda, No 2 (1977).

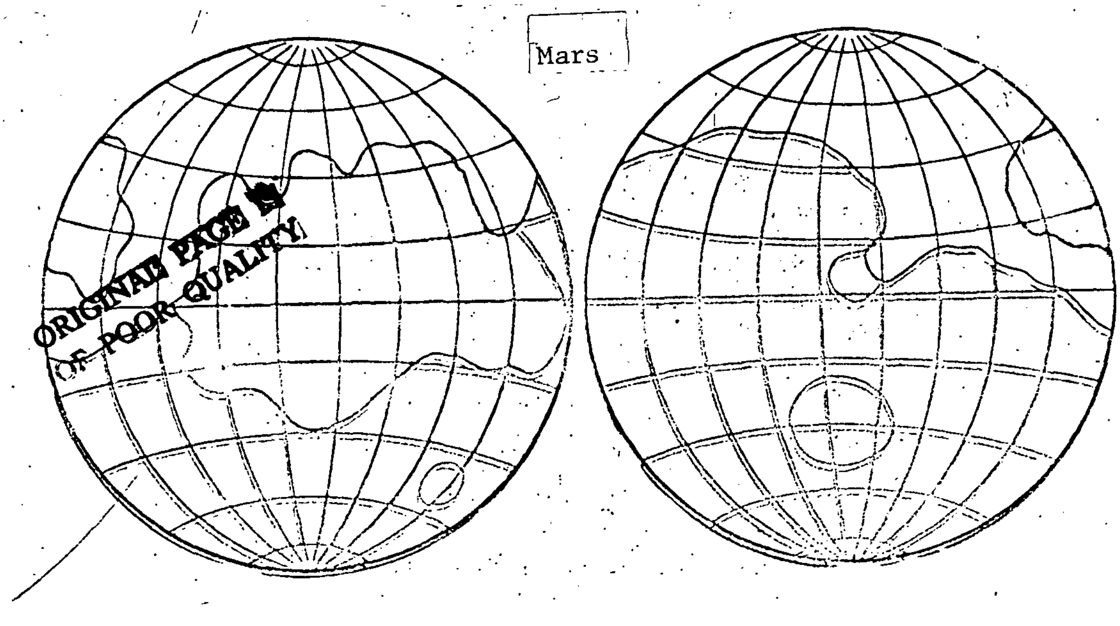
by a leveled surface located mainly 1-2 km below the mean level of Mars, and a small number of well preserved craters of comparatively small dimension, which makes it possible to include them in the younger age generation. In places within the depressions on comparatively large-scale television images winding benches are traced that recall the boundaries of lava coverings on lunar seas. Within the sea regions of Mars positive anomalies of the gravitational field dominate that indicate the reduced depth of the crust. The time of formation of the Martian depressions in their modern form has not been explained. Certain authors estimate it at 2-1 billion years.

Ideas on the age of the oceanic valleys of Mars are based on the degree of reprocessing of their surfaces as a result of meteorite bombardment. Therefore it is necessary to speak only of the age of the relief and the time of formation of the younger volcanic coverings that fill these valleys. The actual depressions that are distinguished from the continental regions in structure of the crust, undoubtedly, were formed much earlier in the ancient stages of crust formation.

Certain researchers doubt the available dating of the age of the Martian surface on the basis of crater distribution. For example in the work of G. N'yukum and D. U. Vis (1976) the age of the Martian volcanoes is defined as 3.8-3.4 billion years and only for the youngest volcano Olympus the age of 2.5 billion years is assumed. With such calculations, which also are far from indisputable, the time of formation of the Martian oceanic depressions is close to the stage of formation of the basalt filler of lunar seas.

As yet one can only hypothesize about the composition of the Martian rocks. /38
On the photographs of the surface obtained from the launchable apparatus of stations "Viking" a rocky desert is visible with individual clumps and sandy

detritus. Certain clumps have a porous structure recalling the earth's volcanic lava. On the whole the surface has a reddish hue. The composition of rocks was determined with the help of X-ray-fluorescent spectrometers. On the basis of the findings mathematical and laboratory simulation was executed. It is assumed that the Martian regolith at the site of landing consists of iron clay that developed during the disruption of the igneous rocks of the basalt type. At the same time the large mass of Mars that occupies the intermediate position between the Moon and Mercury, on the one hand, and earth--on the other hand in combination with the length and complexity of its tectonic-magmatic evolution provide certain bases to assume a higher degree of differentiation of substance for this planet than for the moon, with the formation in the continental regions of igneous rocks of medium composition, if but in small volumes.



Global Tectonic Elements of Mars. Mars has "a Perioceanic" Belt Manifest in the Form of Large Fragments.

A characteristic feature of the Martian tectonics--separation of the equatorial belt that occupies an intermediate position between the Boreal and Austral segments. Within this belt are located the marginal volcanic plateaus, vast anticline elevations with gigantic sheet volcanoes and the groove system Koprat. The marginal plateaus have an irregular shape, smoothed relief, and the quantity of craters on them is smaller than on the continents, and greater than on the oceanic valleys, and on the photographs they usually have a very dark tone. The marginal plateaus are confined to different hypsometric levels, thus forming a type of step on the edge of the "continents". It is assumed that these plateaus were formed from volcanic coverings lying on the "continental" base. In time of formation the marginal plateaus are close to the more ancient sections of the "sea" depressions. The anticline-volcanic elevations of Farsida and Elisium are regions of more pronounced and relatively recent tectonic /39
deformations. Within the anticline Farsida there is a large number of disruptive disorders oriented on the whole radially in relation to this elevation. In the central section of the anticline major sheet volcanoes and bosses are concentrated that are analogous to the basalt volcanic apparatus inherent to volcanoes of the Hawaiian type.

The equatorial groove system Koprat is clearly traced at 2500-2700 km, encompassing about 80° on the arc of the equator. In features of structure and conditions of emergence the equatorial groove system of Mars is usually compared with the continental groove systems of earth. It is located along a slope, the anticline-volcanic elevation of Farsida. On the whole the equatorial belt with manifestations of volcanism and tectonic deformations occupies an intermediate position between "sea" and "continental" segments, which makes it possible to compare it with the Pacific Ocean belt of earth.

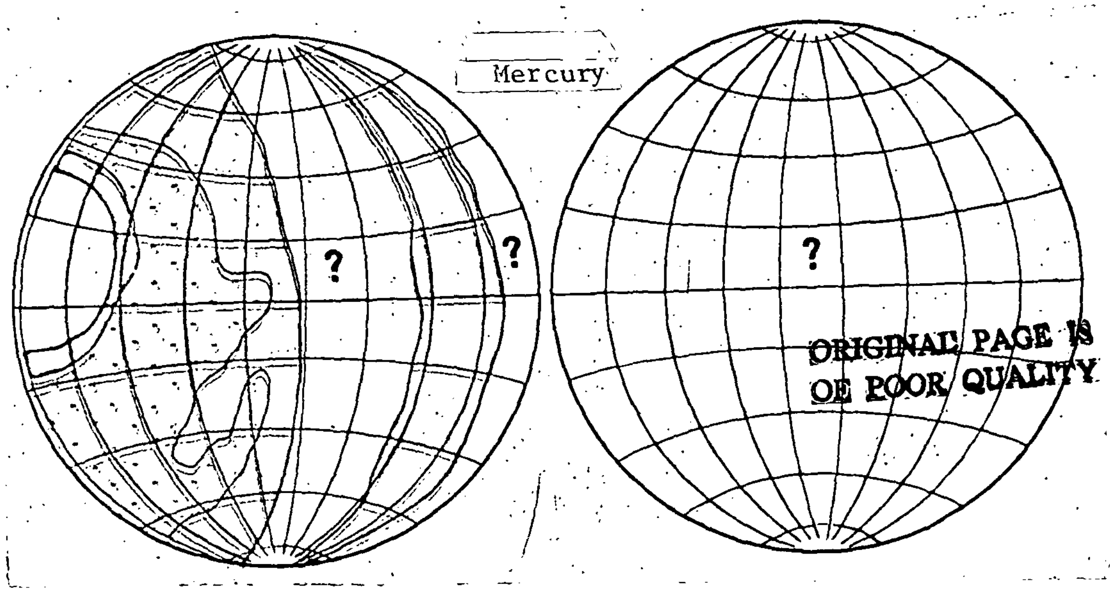
As for Mercury, then currently photographs have been obtained only on 40% of its surface. However on them the main peculiarities of its tectonics are quite definitively revealed. Like the Pacific Ocean depression of earth and the mass depression of the Ocean of Storms on the moon here a depression is also isolated of planetary order--the depression Kaloris (Sea of Heat). Its diameter is 1300 km. It has a radial-cocentric structure, stressed by the arrangement of cracks and crests. The depression Kaloris is formed hypothetically of volcanic rocks. In places here the winding shape of benches are traced that recall the borders of the lava coatings in the lunar seas. In contrast to earth and the moon where the height of the frontal benches usually does not exceed the first dozen meters, on Mercury their height reaches 200-500 m. It is probable that the depression Kaloris was made by weakly differentiated ultrabasic lavas close in composition to the mantle substance of the planet.

On the periphery of the depression Kaloris a series of cocentric elevations are noted which could be compared with the lunar Cordillera and tectonic structures of the Pacific Ocean belt of earth. Smoothed mountain masses in height 1-2 km separated by gently sloping depressions directly adjoin the depression. The depression Kaloris occupies, according to our calculations, 1/3 of Mercury's surface, i.e., the correlation of oceanic and continental zones on Mercury is /40
the same as on other celestial bodies we have mentioned.

Fundamental Law Governing the Structure of Planets in the Earth Group

As could be seen the comparative tectonics and comparitive planetology reveal a very important general law governing the structure of Earth, the moon, Mars and Mercury--their structural asymmetry. It is manifest regardless of the dimensions, mass, density, and distance of the celestial bodies from the sun. In the table given here these properties are indicated (also including Venus)[2].

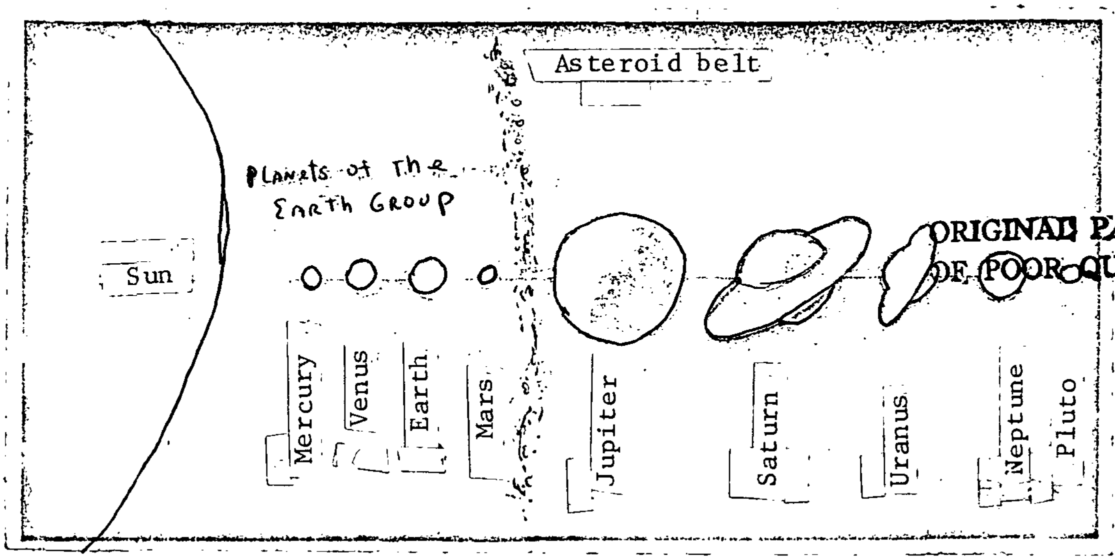
2Head, J., C. Wood, T. Mutch, "Geologic Evolution of the Terrestrial Planets" American Scientist, Vol 55 (Jan-Feb), 1977.



Global Tectonic Elements of Mercury. The Question Mark Notes Territories for Which There are No Television Images of the Surface Obtained With the Help of Automatic Interplanetary Stations.

CHARACTERISTICS OF PLANETS IN THE EARTH GROUP

	Moon	Mercury	Mars	Venus	Earth
Diameter, 1000 km	3.476	4.880	6.787	12.104	12.756
Mass (the mass of earth is taken as 1)	0.01	0.05	0.11	0.81	1
Volume (the volume of earth is taken as 1)	0.02	0.06	0.15	0.88	1
Density, g/cm^3	3.3	5.4	3.9	5.2	5.5
Distance from sun, in million km	150	58	228	108	150



Relative Position of Planets in the Solar System.

It is remarkable that the tectonic asymmetry of the planets is revealed every time that one only succeeds in obtaining about them sufficiently complete morphological and geological data. There are no such data for Venus and a number of other planets in the solar system, but in light of what we now know /41 one can propose a global asymmetry also for them. Apparently this is a fundamental law in relation to the planets of the earth group.

The examined planets and moon are at different stages of evolution. Earth with its widespread granite-metamorphic layer, enormous masses of strictly granites, geosynclines, and secondary oceans from a tectonic viewpoint is at an incomparably higher stage of development than Mars, and more so Mercury and the moon. On earth even now powerful tectonic processes are occurring that result in major structural transformations: the appearance of new mountain crests, deep-water seas, the development of groove zones, and so forth. As for Mars it is not active and deformations and volcanism ended here hundreds of millions, and perhaps, even one billion years ago. The main features of the modern structure of Mercury and the moon were formed about 3 billion years ago. The moon has already been considered by geologists a long time a model of the early stage of evolution of the earth. But under such conditions global tectonic asymmetry also exists. This makes it possible to conclude that asymmetry reflects the primary nonuniformity in the distribution of substance in the upper shells of the planets of the earth group.

Global structural asymmetry--a property stable in time. Thereby we will find an explanation for the deep difference in the development of the Atlantic and the Pacific Ocean segments. The formation of continents, their separation and drift, the development of secondary oceans and depressions with a suboceanic crust--all of this refers only to the Atlantic segment isolated back in the primary differentiation of substance. The ring Pacific Ocean tectonic belt is a surface expression of the zone of demarcation of both segments. In it, as this must be according to the logic of things, very complicated tectonic-magmatic processes occur that are governed by the deep interaction at different levels of diverse regions of the tectonosphere.

And so at the early stages of the formation of the lithosphere of the planets mentioned here enormous depression forms developed that occupy roughly 1/3 of their surface. Such a phenomenon can be linked to a certain deficit of substance that occurred as a consequence of the formation of the protogenic continents. As a consequence this deficit was compensated for by basalt outflows.

The antiquity of the lunar appearance presents researchers with great potentialities to study the processes of the formation of the primary crust, that same "lunar stage" in which the earth could have been about 4 billion years ago. It is assumed that for the formation of the continental crust the anorthosite-gabbroic composition on the moon had to pass differentiation of the primary substance with melting to depths on the order 200-300 km. It can be assumed that this time a lateral nonuniformity occurred in the process of differentiation, which agrees with the reduction in the depth of the crust within the sea segment. It is probable that the primary nonuniformity of the moon and the planetary bodies in the earth group is associated with the participation of the process of accretion of large masses of the planetesimal type.

On the path of further study of the global structure of asymmetry and non-uniformity of planets in the earth group we undoubtedly will encounter important solutions to the main problems of the structure and evolution of the earth's lithosphere.

Recommended Literature

Kozlov, V. V. and Ye. D. Sulidi-Kondrat'yev, Tektonika Luny ["Tectonics of the Moon"], a descriptive note on the tectonic map of the Moon on the scale 1:7,500,000, Moscow, 1969.

Kozlov, V. V. and Ye. D. Sulidi-Kondrat'yev, "Tectonics of Mercury," Priroda, No 5 (1977).

Novoye o marse ["New Facts About Mars"], collection of articles, Mars, 1974.

Pushcharovskiy, Yu. M. "Introduction to the Tectonics of the Pacific Ocean Segment of Earth," Trudy GIN, No 234 (1972), Moscow.

Voprosy Planetarnogo Tektogeneza ["Questions of Planetary Tektogenesis"], 1, Moscow, 1977.