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24

A NEW ROTATION HYPOTHESIS ON THE DEVELOPMENT OF THE TECTONIC SYSTEMS OF THE EARTH'S CRUST

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Introduction

The development of the tectonic structures of the Earth's crust was attributed—by most geologists—to the development of the so-called geosynclines and continental plateaus (Beloúsov 1962, Mikhailov 1970, etc.). These hypotheses have their root in the fact, that there are thick sedimentary parts on the Earth's surface disturbed by intensive foldings and often by orogenic movements. These parts alternate with areas of relatively tranquil tectonism, morphologically characterized by mild structures.

The hypotheses on the development of geosynclines and platforms are not reinforced by a lot of very important regularities. These are: the regularity of the surface distribution of the structures, the straight line of foldings in the geosynclines, the cyclicism of the development of their tectonic system, etc.

Recently, the so-called new global tectonics has become very popular among the specialists (Le Pichon 1968, Morgan 1968, etc.). Its birth is connected with the wide-spread and intensive examination of the oceanic crust resulting in—formerly unknown—geological and geophysical data. Its popularity is partly due to the crisis of the dominant hypotheses on the structure and development of the Earth's crust, being unable to explain the new data.

In this paper a new hypothesis will be outlined on the development of tectonic structures. This hypothesis is based on the regularities recorded on the Ukrainian shield, but—according to the literature—are existing on other areas as well. Some aspects of this hypothesis are not quite new and have already been published by other authors (Katerfeld 1965; Lichkov 1965; Solntzev 1963; Stovas 1963; Tyapkin and Stovas 1968; Hisanashvili 1960; Tsaregradski 1963, etc.).

Herewith, we shall give a short review of the hypothesis.

Initial data

As a result of the complex geological and geophysical investigations carried out on the Ukrainian shield, the following regularities were found in the spatial distribution of the linear tectonic structures—mainly deep fractures:

1. the regional fractures are arranged into definite systems in the shield;
2. each system forms a set of orthogonal fractures with persistent azimuths and the distances between the fractures of similar order are constant;
3. the fractures of different systems, although differ according to their geological properties and age, form similar geometrical networks in certain angles to each other.

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These regularities are thoroughly described in a recently published monograph (Tyapkin 1972). In this article we want to present only the schematic arrangement of the fractures revealed in the first period of the investigations on the Ukrainian shield (Fig. 1). In Fig. 1 two fracture systems can be seen and some minor fractures which do not fit into either of them. Lately, after more intensive investigations four–six systems can be detected in some parts of the shield.

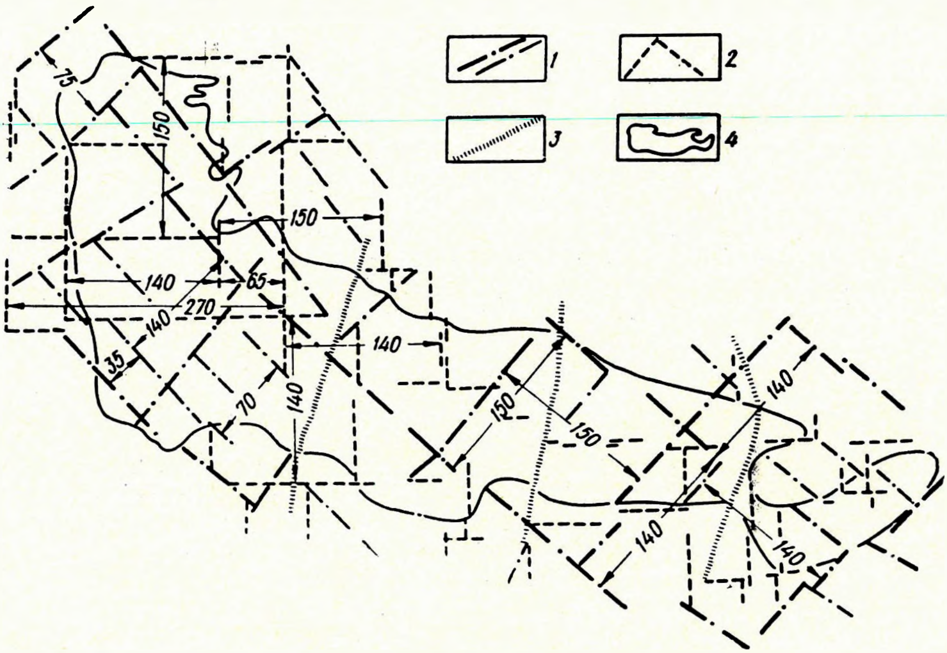

Fig. 1 Deep fracture zones in the Ukrainian shield fractures:
1 — diagonal systems, 2 — orthogonal systems, 3 — submeridional systems, 4 — the supposed boundary of the Ukrainian shield (Distances between the fractures are given in kms)

1. ábra. Mélybeli törések elhelyezkedésének vázlata az Ukrán pajzs területén
1. diagonális rendszerű, 2. ortogonális rendszerű, 3. ÉNy—DK irányú törések, 4. az Ukrán pajzs feltételezett körvonala. A törések közötti távolságok km-ben vannak megadva

Рис. 1. Схема расположения глубинных разломов на Украинском щите
Разломы: 1 — диагональной системы, 2 — ортогональной системы, 3 — субмеридионального направления, 4 — условный контур Украинского щита. Интервалы между разломами даны в км.

Similar geometrical regularities can be observed in other shields, too. In Fig. 2—for instance—we show the schematic arrangement of the fracture systems of the Kola peninsula in the Baltic shield. The sketch was adopted from V. A. Tokaryev's paper (1968). The distance (in kms) between the fractures is illustrated by arrows. It should be noted that neither the author of the article nor the compilers of the map emphasize the above-mentioned regularities. This fact shows that references can hardly be used for demonstrating such regularities, as—according to our knowledge—there are no investigations of this kind under progress. At the same time it confirms the objectivity of the data.

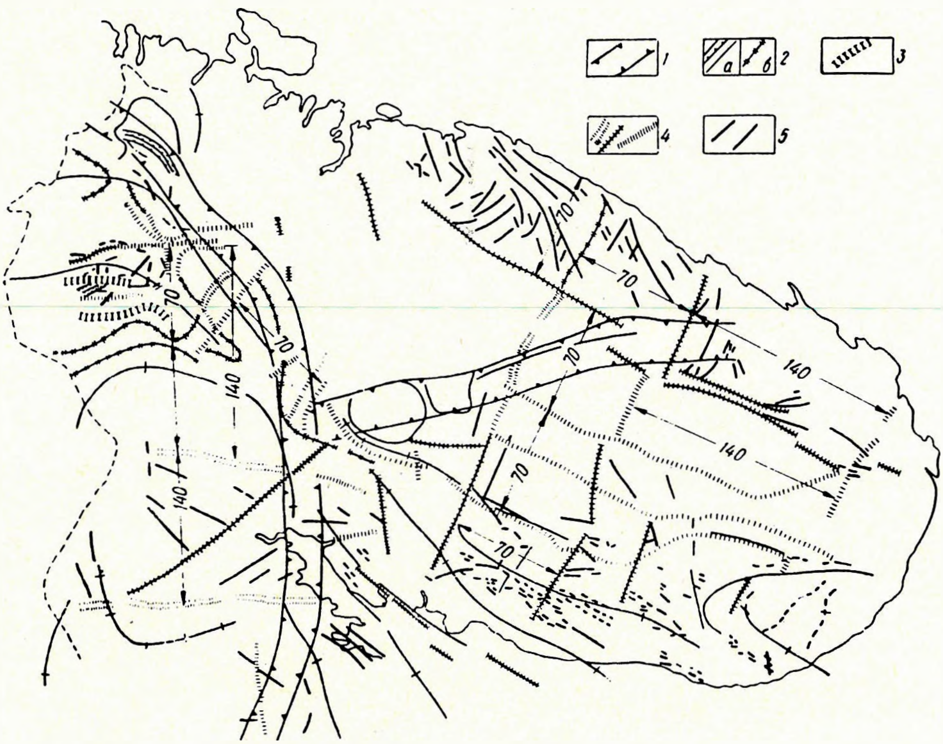

Fig. 2 Deep fracture zones in the Kola peninsula
(compiled by TZIRYULNIKOVA et al.) Deep fractures:
1 — fractures marking the boundaries of crustal blocks
2 — fractures reaching the Moho according to the data of deep seismic sounding (a);
fractures coinciding with the high gradient zones of the gravitational field (b)
3 — fractures reaching the "granulite-basic" layers
4 — fractures in the precambrian basement
5 — shallow fractures (distances in kms)

2. ábra. A mélybeli fő törések elhelyezkedésének vázlata a Kola-félszigeten (CIRJULJNYIKOVA és munkatársai után)
Mélybeli törések, amelyek: 1. nagy földkéregrögök határainak felelnek meg, 2. elérik a Moho diszkontinuitást *a)* kéregkutató szeizmikus mérések adatai szerint, *b)* a nehézségi erőtér nagy gradiensű zónáival egybevetve; 3. elérik a „gránit-bazalt réteget"; 4. a prekambriumi alapkőzetben mutatkoznak meg; 5. kisebb mélységű hasadékok és repedések. A törések közötti távolságok km-ben vannak megadva

Рис. 2. Схема расположения главных разломов на Кольском полуострове (составили Р. Я. Цирульникова, Р. С. Сокол, Э. К. Чечель и Л. Е. Шустова)
Глубинные разломы: 1 — соответствующие границам крупных блоков земной коры, 2 — достигающие поверхности Мохо, по данным ГСЗ (а), совмещенные с зонами больших градиентов поля силы тяжести (б), 3 — достигающие «гранулито-базитового слоя», 4 — проявляющиеся в докембрийском фундаменте; 5 — расколы и трещины небольшой глубины заложения. Интервалы между разломами даны в км.

The above regularities can be identified in other regions as well, see for example the tectonic map of Australia—compiled by E. HILLS (1947). The sketch of the main lineaments is shown in Fig. 3.

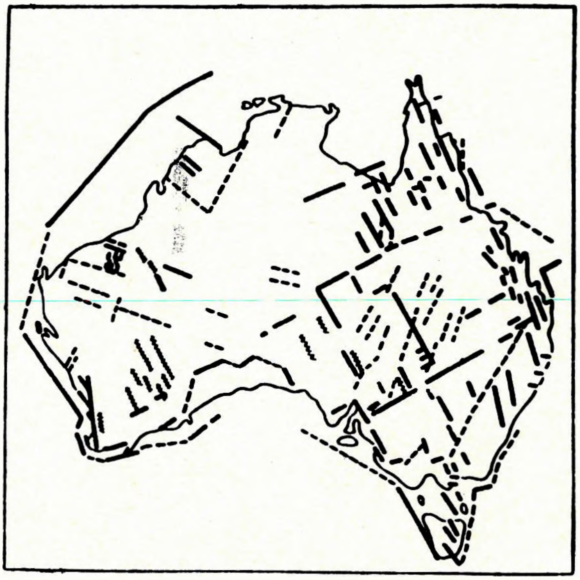

Fig. 3 Fracture system of Australia (after HILLS)
Full and dashed lines mark fractures of different distances, zig-zag lines denote the precambrian structural units

3. ábra. Ausztrália lineamentumainak vázlata [HILLS után]
Folytonos és szaggatott vonalakkal a különböző korú töréseket, hullámvonalakkal pedig a prekambriumi lineáris szerkezeti elemeket szemléltettük

Рис. 3. Схема линеаментов Австралии (По Хиллса).
Сплошными и пунктирными линиями показаны разломы разного возраста, а волнистыми — линейные структурные элементы в докембрии.

The similarity of the above outlined characteristics suggests that they have planetary causes. Moreover it was established that in the Ukrainian shield the directions of the faulted and folded structures harmonize to each other (TYAPKIN 1972). To prove this statement we present a star-diagram in Fig. 4 showing the azimuthal distribution of the strikes in pre-Cambrian rocks in the horizon of the present level of erosion. This diagram represents the strikes of the outcrops, the axes of the linear magnetic anomalies and the strikes of the gravity steps indicating the boundaries of the different erosion level blocks. The close relation between faulted and folded structures proves the common cause of their origin. For instance, the development of linear, nearly vertical, isoclinal folds in the pre-Cambrian rocks can be explained easily by the active drift of the adjacent crustal blocks.

At last, on the Ukrainian shield there are several asymmetric superimposed structures of synclinorium type, built up from the rocks of the Krivoyrog and Konsk-Verkhovtsev series. Undoubtedly, according to the scheme drawn up by J. MOODY and M. HILL (1956), the development of these structures is in connection with the vertical displacement of the blocks. The most important advantage of the scheme that it gives a logical explanation for the development of synclinorium type structures on the rigid base of the crust.

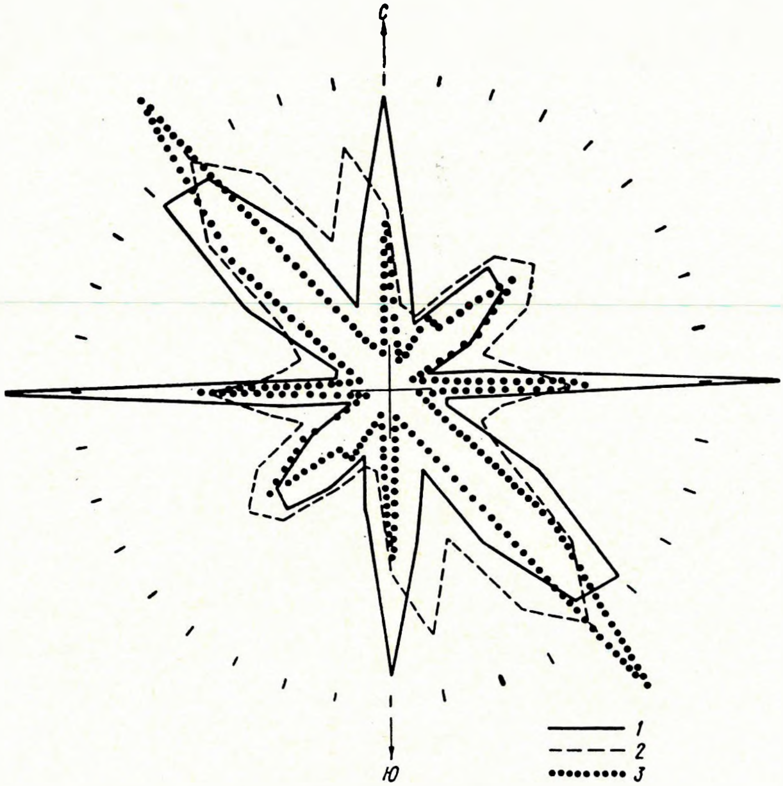

Fig. 4 Polar-diagram of the trends in the Ukrainian shield
1 — axial directions of the magnetic anomalies
2 — strikes of rocks in the outcrops
3 — strikes of the gravitational steps
C = North, Ю = South
(compiled by DASHEVSKAYA and STOVAS)

4. ábra. „Rózsa-diagram" az Ukrán pajzson a következő irányok megoszlásáról: 1. lineáris mágneses anomáliák tengelye; 2. kőzetek csapásiránya kibúvásokban; 3. gravitációs lépcsők csapásiránya; C = Észak, Ю = Dél (készítette: DASEVSZKAJA és SZTOVASZ)

Рис. 4. Розы-диаграммы распределения на Украинском щите направлений: 1 — осей линейных магнитных аномалий; 2 — простираний пород в обнажениях; 3 — простираний гравитационных ступеней. (Составили Е. А. Дашевская и Г. М. Стовас.)

The sketch of the magnetic field of the KMA (Kursk Magnetic-anomaly) in the Voroniezh crystalline rocks (Fig. 5) furnishes a further example for the interrelation between the folded and faulted structures. The intensive magnetic-anomalies corresponding to the iron-bearing quartzite veins are marked by dark colours. The iron-bearing quartzite together with the schistose-amphibolitic sequence form synclinorium-type structures. In Fig. 5 it can be seen that these structures are situated according to a certain system which proves that they developed at the borders of the blocks.

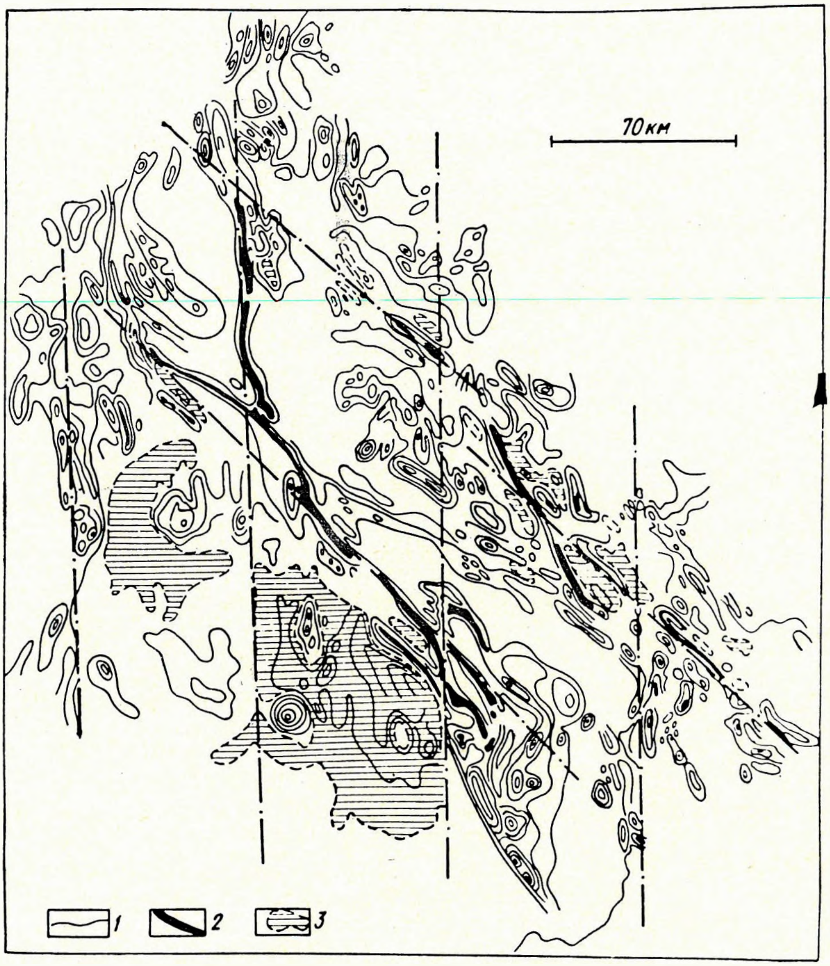

Fig. 5 Sketch of the Kursk magnetic anomaly
1 — isodynam lines; 2 — anomalies greater than 20,000 gamma; 3 — negative anomalies

5. *ábra.* A kurszki mágneses anomália területén a mágneses tér vázlata
1. Izodinamok; 2. 20 000 gammánál nagyobb intenzitású anomáliák; 3. negatív anomáliák

Рис. 5. Схема магнитного поля района КМА.
1 — изодинамы; 2 — аномалии интенсивностью свыше 20 000 гамм; 3 — отрицательные аномалии

The above objective regularities cannot be explained by any of the known hypotheses concerning the development of tectonic structures, therefore the elaboration of a new hypothesis seemed to be necessary. Moreover, this hypothesis should correspond to most of the known geological regularities or at least it should not contradict them.

The essence of the hypothesis

The shape of the Earth (geoid) is produced by the speed of rotation and the mass distribution. It was a general opinion that the Earth and all planets of the solar system are in state of equilibrium (isostasy). At the same time the astronomical (Mikhailov 1970, Pariyski 1954, Stoyko 1972, etc.), paleomagnetic and paleoclimatologic (Strakhov 1960; Hramov and Sholpo 1967; Hramov 1971; Cox and Doel 1960; Spall 1972, etc.) data give evidence of the repeated changes of the Earth's rotating system. During the geological epochs among others the angular speed and the location of the rotational axis changed. The shape of the Earth, consequently, must have been adapted to the new rotational conditions. During these periods, probably, tension was produced in the crust, which determined the regularities of the tectonic structures. This theory is advocated by many specialists, but most of them (Lichkov 1965, Stovas 1963, Tsaregradski 1963, etc.) attribute dominant role to the change of the angular speed, considering the position of the rotation axis constant.

No doubt, these tensions do exist. Their effect on the development of tectonic structures was examined by M. V. Stovas (1963, etc.). Without departing from our subject, we note that—in spite of their obviousness—they cannot give interpretation for several phenomena, first of all, for the asymmetry of the linear tectonic structures, to the present position of the rotational axis.

These regularities can be explained by the hypothesis, which considers the tensions in the crust to be released in the course of polar wandering. Such theories have been published in the literature (Solntzev 1963). Because of the well-known paleomagnetic and astronomical data we do not query the being of such tensions, but the connection between the effects caused by the above-mentioned two factors in the development of tectonic structures can be estimated by analytical calculations only.

For the moment, it can be stated that the regularities in the arrangement of tectonic structures prove the role of the tensions produced by the shift of the rotational axis. Therefore, we focus our attention upon the effect of this factor on the development of the tectonic structures of the Earth's crust.

Our knowledge of pole location is based on the paleomagnetic investigations and—in the last hundred years—on the direct astronomical observations. It is known, that the position of the magnetic and geographic poles have generally coincided in the geologic past (calculated in periods of some 10 thousand years) (Hospers 1955, etc.). So, the mean position of paleomagnetic poles can be identified with that of the geographic (planetary) poles. Here we cannot discuss the causes why the paleomagnetic data do not allow us to mark out the path of pole shifts, but generally their trends are mentioned only. In Fig. 6a the positions of the poles are shown during the Phanerozoic eon from the paleomagnetic data of the Russian Platform (Hramov 1971). Dashed line marks the *trend* of the polar wandering.

To determine the trajectory of polar wandering astronomical data were used. In Fig. 7a the path of the geographic pole for the last few years is given from direct observations. The circular movement of radius $0.1''$ and of almost an annual period is apparent. In Fig. 7b a curve can be seen which shows the annual centres of the poles in a 76 years period 1890–1966. These astronomic data prove that the path of the polar wandering consists of a monotonous regional part with 10 cm/year velocity and cyclic effects of one or more decades' order. The regional component

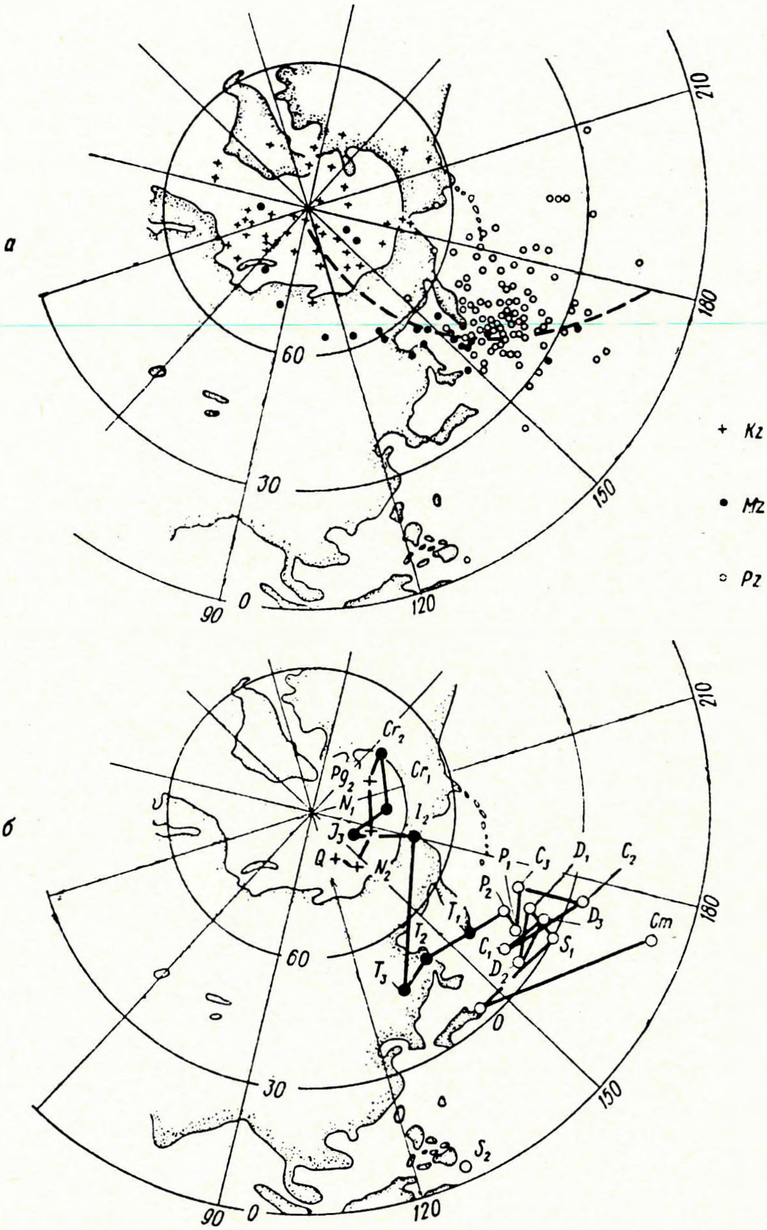

Fig. 6 The positions of poles in the different geologic epochs
a) according to the paleomagnetic data of the Russian platform
(from the catalogue compiled by Hramov et al.)
b) mean positions of the poles in the different geologic epochs according to the data of Fig. a)
+ Cenozoic ● Mesozoic ○ Paleozoic

6. ábra. A pólusok helyzete a különböző földtani korokban:
a) az Orosz táblán végzett paleomágneses meghatározások adatai alapján (Hramov et al. tanulmányából); *b)* a pólusok átlagos helyzete a különböző földtani időszakokban, a fenti adatokból számítva

Рис. 6. Положения полюсов в различные геологические эпохи:
а — по данным палеомагнитных определений на Русской платформе, заимствованных из каталога А. Н. Храмова и др.;
б — средние положения полюсов в различные геологические периоды, вычисленные по указан-

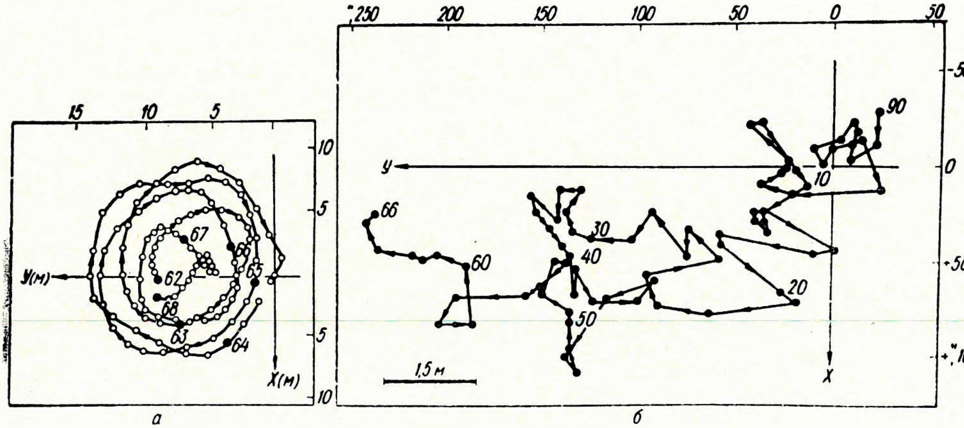

Fig. 7 The trajectory of polar wandering
a) data of A. A. Mikhailov for the years 1962–68
b) the annual centres of poles between 1890–1966 after A. Stoyko

7. ábra. A pólusvándorlás pályája:
a) Mihajlov 1962—1968. közötti adatai alapján; *b)* Sztojko adatai alapján a pólusok évi középpontjai 1890 és 1966 között

Рис. 7. К траектории движения полюса:
а — по данным А. А. Михайлова с 1962 по 1968 г.; б — по данным А. Стойко — годовые центры полюсов с 1890 по 1966 г.

represents part of the some hundred years' period arc. Unfortunately, no data are available for the former positions of the poles.

On the basis of the paleomagnetic data concerning the positions of poles in the Phanerozoic eon (Fig. 6a) it can be stated that in certain periods the poles form "clouds"—by a limited degree of scattering. G. M. Stovas calculated the mean position of the poles in each epoch. The results of this calculations are shown in Fig. 6b. The positions of the pole are linked by straight lines. The result is a polygon of polar wandering which, of course, cannot be considered as its real path. Nevertheless, it proves that the displacement of the pole during the history of the Earth was not monotonous, unidirectional, but is was complicated, loopy, in many features similar to the path determined by recent direct astronomic observations. The regional component shows 1 cm/year mean velocity. Certain loopy formations are superimposed to this, having periods of different order and being characterized by millions of years. These loopy sections of the polygon are composed by the superpositions of the monotonous regional component and the almost circular periodic components of the polar wandering.

H. Spall (1972) established the complicated, loopy character of the Precambrian polar wandering by paleomagnetic measurements carried out in North America and Africa (Fig. 8). The work of A. V. Dolitski and I. A. Kiyko (1963) resulted in a similar trajectory of polar wandering.

Summing up, the path of the geographic polar wandering is similar to an elongated cycloid complicated by high wider loops. This shape makes it possible to find explanation for several known geological regularities. Let us examine the effects of the different components.

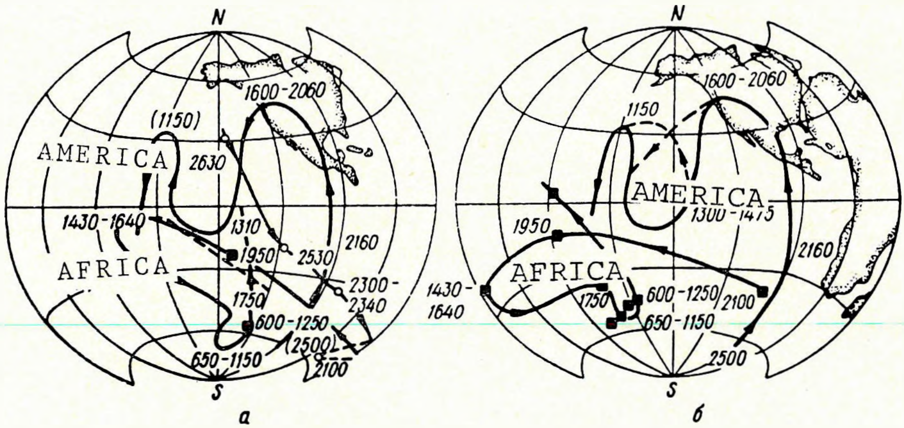

Fig. 8 The trajectory of the precambrian polar wandering (compiled by H. SPALL)
a) after McELHINNY et al. *b*) after BULLARD et al.

8. ábra. A pólusvándorlás pályája; SPALL nyomán
a) McELHINNY et al. adatai alapján; *b)* BULLARD et al. adatai alapján

Рис. 8. Траектория движения полюса в докембрии, построенная Споллом: а — по данным М'Элхини и др.; б — по данным Булларда и др.

The *translative* displacement of the pole, which corresponds to a rearrangement related to the rotational axis of the Earth, demands the restoring of isostatic equilibrium. As a result tensions arise in the crust (Fig. 9). In the two opposite quadrants—in the direction of the polar wandering—compressional zones, in the other two quadrants dilatational zones are produced. With continuous shifting of the poles the tensions are growing until they reach the elastic strength of the crust. At this point the tensions release by means of deep fractures. By the displacement of the great blocks in the crust the isostatic equilibrium of the Earth is more or less restored.

The movement of blocks leads to geosyncline type structures which develop on the rigid base according to the above-mentioned pattern (MOODY and HILL 1956). The rising parts of the blocks are objects of denudation, the sinking parts constitute the areas of accumulation. The fractures in the depth promote active volcanism and the emerging of surplus heat which is one of the most important factors of metamorphism.

Consequently, while the equilibrium of the Earth is restored, the release of tensions produces the most important geologic processes (denudation, accumulation, igneous activity, metamorphism) which cause not only the development of tectonic structures but the formation of different rocks in the crust as well.

The release of tensions is followed by a relatively quiet period when the surface of the Earth gets levelled resulting in the development of platforms while new tensions are accumulating. As soon as these tensions reach the elastic limit, a new epoch of active tectonic rearrangement begins. This epoch will differ from the former one in the position and direction of the compressional and tensional zones, which define the new, strictly determined positions and directions of the new tctonicn structures. The time between the two active tectonic phases depends on the agularf distance and speed of the translational movement o the poeles on the surface.

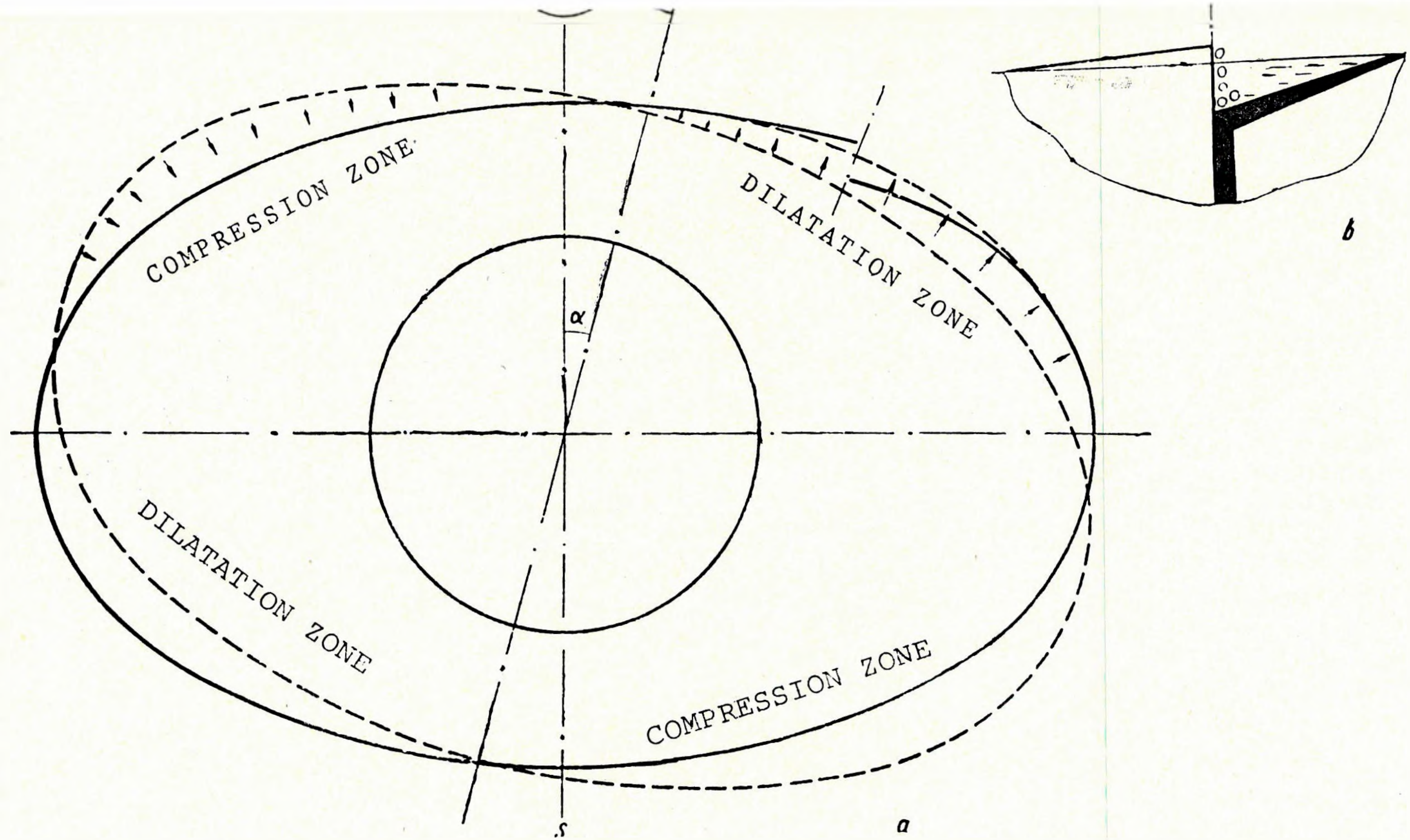

Fig. 9 Tensional zones produced by the shift of the Earth's rotational axis (a) and the sketch of the release of tension in the dilational zone (b)

9. ábra. A Föld forgástengelyének helyváltoztatásakor keletkező feszültségi zónák megoszlásának vázlata (a); valamint a feszültségek feloldódásának vázlata a dilatációs zónában (b)

Рис. 9. Схема распределения напряженных зон, возникающих при изменении положения оси вращения Земли (а), и схема разрядки напряжений в зоне растяжения (б).

The similarity of deep fracture systems of different ages proves that the deformation in the upper zones of the Earth takes place according to uniform laws. This happens, if the regularities of the spatial distribution of the fractures are determined by the elastic properties of a relatively thick, upper zone and not by the sometimes emphasized physical features of the crust.

The *cyclic* components of polar wandering—superimposed to the translational movement—form loops of different order. In the period of the active tectonic rearrangement the principal loop must indicate the inversion of the tectonic structure or some orogenic movements. The different directions along the path correspond to periods of marine transgression and regression. The loops of higher order represent the alteration of sedimentary systems in different epochs and periods.

If the translational movement of the pole explains the *controlled* development of the Earth's crust, the *cyclicity* of geologic processes is the result of cyclic polar wandering of different order.

According to the present hypothesis the close relation between faulted and folded structures becomes evident. The development of both structures are controlled by the release of the same tensions in the upper part of the Earth.

Now, we have outlined only the frame of the hypothesis. The geologic processes are undoubtedly much more complicated than the described scheme. Restoring of isostatic equilibrium could happen not only through mechanical movements of crustal blocks, but through the change of density as a result of intrusive or extrusive activity or some physico-chemical processes in the mantle.

Up to now it was not necessary to mention any other processes taking place in the mantle. Presuming their existence it is supposed, that—together with other geologic processes—they constitute a reaction against certain external forces which swing out the Earth from the state of isostasy.

We do not know about the origin of the forces which produce the displacement of the rotational axis related to the surface. As a matter of fact this question has no importance from the practical point of view, because the position of poles are given by paleomagnetic investigations and astronomical observations. At the same time, however, it is noted that the most probable source of forces producing the displacement of the rotational axis is the heterogeneous magnetic and gravitational field in the outer space.

The Earth—after being swung out from the state of isostasy by these forces—strives for restoring it under the effect of rotational forces. This effort results in the above-mentioned deformations of the Earth's crust and the attending characteristic geologic processes. These latter ones are not discussed here.

Relation of the proposed hypothesis to former ones

First of all, we have to determine the relation between the proposed hypothesis on the development of tectonic structures and the hypothesis of geosynclines. In spite of the modifications of our conventional ideas about the development of geosynclines, one thing has remained unchanged: the efforts of the authors to explain the origin of these structures by the effect of internal forces.

The proposed hypothesis is characterized by tracing back the development of crustal tectonic structures to planetary laws. Moreover, it regards the Earth as a planet which—in certain extent—depends on the space of the surrounding objects.

This means, that the external effects have undoubtedly a dominant role. The only open problem is the relative importance of these external effects in the development of tectonic structures. At the same time, the proposed rotation hypothesis does not contradict the available data related to the geosynclines and platforms. Moreover, it helps to understand the causes of their origin and the properties of their development on a rigid base.

Isostasy constitutes a pillar of the hypothesis at issue. The isostasy of the Earth means the state of equilibrium which corresponds to the effective mass distribution and angular velocity of rotation.

The relation between the proposed hypothesis and the global tectonics can be characterized as follows: in the present stage of investigations it is quite indifferent, whether the plate is moving compared to the axis of rotation, or the axis is moving compared to the plate. Though the displacement of the outer shell compared to the inner parts of the Earth is more imaginable than the displacement of certain plates similarly differentiated, the discussed hypothesis does not contradict the concept of the new global plate tectonics. More exactly, in its present state it can be regarded as a specific expansion of it, applied to the evolution of the inner structure of certain plates derived from their displacement.

Further study of the regularities of the spatial distribution of linear tectonic structures in the different plates will lead us to the possibility of determining their displacement.

Further tasks

To improve the proposed hypothesis the following tasks are to be done:

1. study of linear tectonic structures for extensive areas, in order to find the global structures;

2. determination of the most probable trajectory of the axis of rotation on the Earth's surface;

3. calculation of tensions in the crust in the different geologic epochs by the supposed contemporaneous position of the axis of rotation;

4. comparison of the tensional space with tectonic structures.

Finally it should be noted, that in course of investigations some of the described statements will be corrected and concretized, but the basis of the hypothesis—owing to its obviousness—must remain unchanged.

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ÚJ ROTÁCIÓS ELMÉLET A FÖLD TEKTONIKAI RENDSZEREINEK MAGYARÁZATÁRA

Az Ukrán pajzs törésrendszereinek vizsgálatából kiindulva a földkéregben fellépő ciklikus feszültségfelhalmozódás és -kioldódás folyamatát a Föld forgástengelyének eltolódására vezeti vissza. A forgástengely változásának okát a külső mágneses és gravitációs tér heterogeneitásának tulajdonítja. A forgástengely eltolódása kilendíti a Földet izosztatikus egyensúlyi helyzetéből. Az egyensúlyi állapotba való visszaállás hozza létre a nagytektonikai szerkezeti formákat és ez magyarázza azok szabályos rendszerét az egész Földön.

ТЯПКИН К. Ф.

НОВАЯ РОТАЦИОННАЯ ГИПОТЕЗА ФОРМИРОВАНИЯ ТЕКТОНИЧЕСКИХ СТРУКТУР В ЗЕМНОЙ КОРЕ

Исходя из изучения систем разломов Украинского щита, автор связывает циклический процесс накопления и развязывания напряжений в земной коре с перемещением оси вращения Земли. Причина этого изменения положения оси вращения объясняется неоднородностями внешнего магнитного поля и поля силы тяжести. Перемещение оси вращения Земли приводит к нарушению изостатического равновесия Земли. Процесс восстановления равновесия обусловливает макротектонические структурные формы и тем самым объясняется и регулярная система последних по всей Земле.