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Rifting and Its Role in Tectonic Structure and Meso-Cenozoic Geodynamics of the Earth*

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I

This communication gives a brief summary of concepts on some most important tectonic features of the Earth's lithosphere in Late Mesozoic and Cenozoic and on the part the rift structures played in it. Global kinematics of tectonic movements and possible deep processes defining them are also described. Some of the below developed concepts were elaborated by the author and A. M. NIKISHIN and presented in a recently published article [8].

The world system of intra-oceanic rift ridges and inter- and intra- continental rift zones representing their blind terminations or lateral ramifications are known to play an exceptionally important role in the newest global architecture of the lithosphere. As seen from Fig. 1 and 2 the main elements of this system are sublatitudinal rift belts of the Southern ocean surrounding the Antarctic continent by nearly a continuous ring as well as four submeridional intra-oceanic rift belts which leave this ring in the northern direction.

Three of these belts— Mid-Atlantic, West-Indo-oceanic and East Pacific— are well known ; the fourth— West-Pacific was first distinguished by us in the mentioned work as a united tectonic element. It is remarkable that all four main submeridional rift belts are spaced approximately by 90° from each other by the longitude and all of them are subjected to sharp displacement westward by nearly 30° in the equatorial zone after which they continue to move northward and gradually degenerate and die out at different latitudes of the northern hemisphere ; the West-Indo-oceanic belt earlier than the others, then West and East Pacific, and finally, the longest Mid-Atlantic belt near the North Pole of the Earth. These striking geometric regularities of the modern world rift system can not be accidental. Therefore it is difficult to assume the main rift belts in Paleogene or Late Cretaceous to be located on the Earth's surface in a chaotic way. With regard to the Mid-Atlantic, West-Indo-oceanic and, evidently, West Pacific belt we may confirm that their mutual dislocation on the Earth's face did not change, at least since Late Cretaceous epoch. Therefore we may assume that the fourth — East Pacific rift belt — during this time also preserved its more or less stable position with regard to other main rift belts of oceans and did not "wander" in the Pacific space similar to

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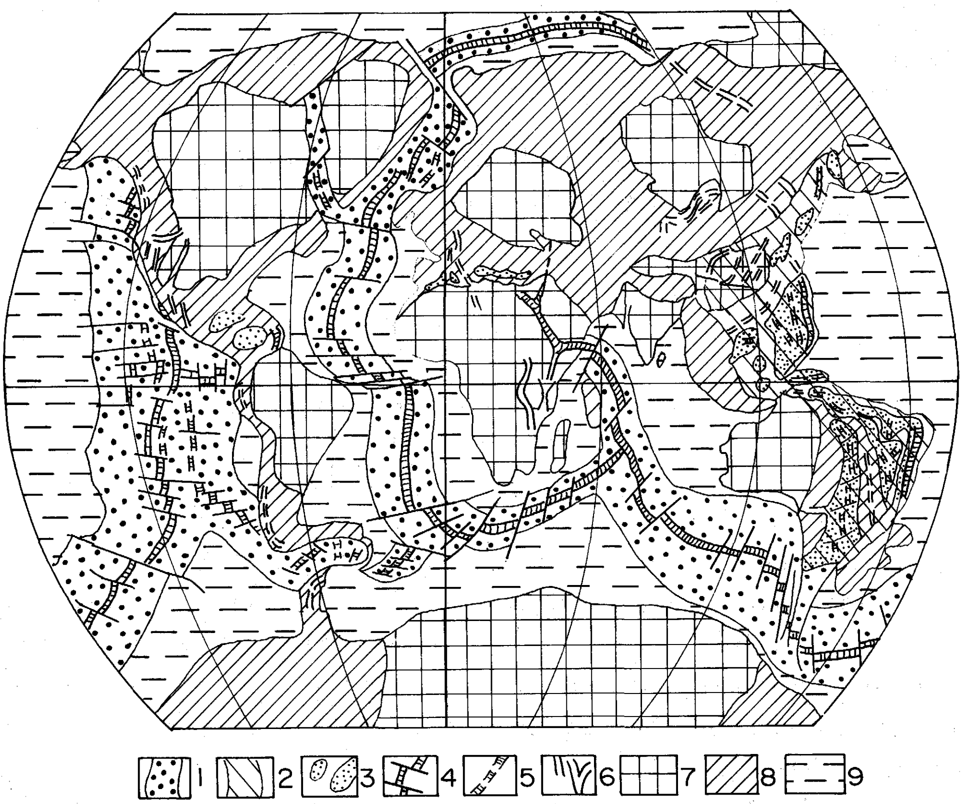

Fig 1. The world system of rift belts of the Earth. 1. Cenozoic intraoceanic rift belts; 2. West-Pacific continental-oceanic rift belt, developed from the late Cretaceous up to present; 3. marginal sea basins with late Mesozoic or Cenozoic crust of oceanic or suboceanic crust or with destructed continental crust inside the West-Pacific rift belt and some other regions; 4. active spreading axes in intraoceanic and intercontinental rift zones; 5. the same, extinct ones; 6. Cenozoic continental rifts; 7. ancient platforms; 8. mobile belts and metaplatform regions without dividing; 9. oceanic areas with basaltic basement of Mesozoic (here and there early Cenozoic age, sometimes with relicts of continental crust).

a number of other spreading zones as was given by geodynamic models constructed in accordance with the conception of plate tectonics [4, 11].

The newest data of seismo-tomography show the main rift belts of the Earth to be of a very deep setting [1, 23, 24]. As seen from Fig. 3 most of the main links of the world system of intra-oceanic rift belts at the depth of about 150 km correspond to the zones of relative lower velocities of seismic waves and, evidently, of relative heating and lower density of the mantle material. These anomalies in elastic, thermal and density features of matter are preserved mainly within nearly the whole upper mantle down to the depths of 350～500 km; below, mainly at the depths of 500～700 km essential changes of seismic, thermal and density anomalies of the mantle substance take place (Fig. 6, 7). We may assume that in the southern hemisphere of the Earth a process of fragmentation and general widening of the lithosphere started in Mesozoic which finally led to the breakdown of the Gondwana supercontinent into a number of blocks separated from one another. Rifting and later spreading zones occurred among the latter. Finally they were transformed as into wide areas with the crust of oceanic type. In the southernmost part of the Earth close to the Antarctics the process of lithosphere blocks spreading was not compensated by the events of their collision and therefore it may be explained only from the positions of assumption of some general expansion of the whole Earth, or, at least, its southern hemisphere in Mesozoic and Cenozoic and recognition of gradual displacement of sublatitudinal rift ridge axes surrounding the Antarctic during

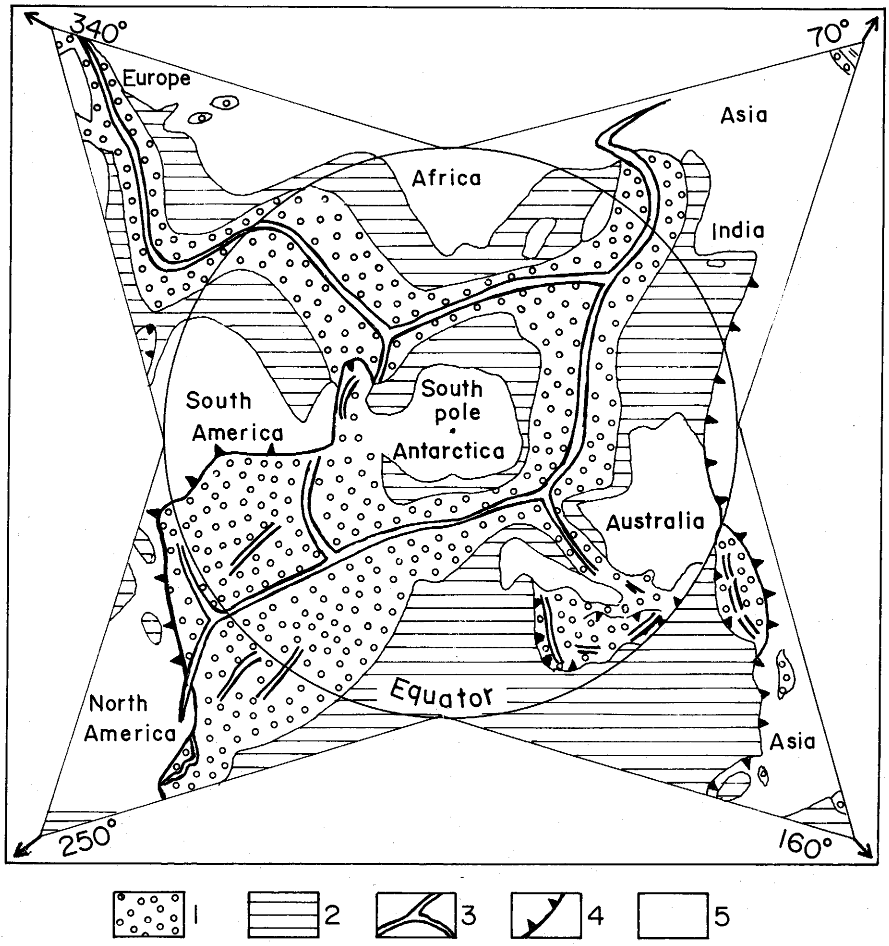

Fig 2. World rift system shown in the projection with the South Pole in the centre (by MILANOVSKY and NIKISHIN, 1988).
1. oceanic rift belts with Cenozoic basaltic basement; 2. oceanic areas with the Mesozoic basaltic basement; 3. active and partly extinct Cenozoic axes of spreading; 4. some zones of plate convergence (deep sea trenches and seismofocal zones); 5. dominantly continental crust.

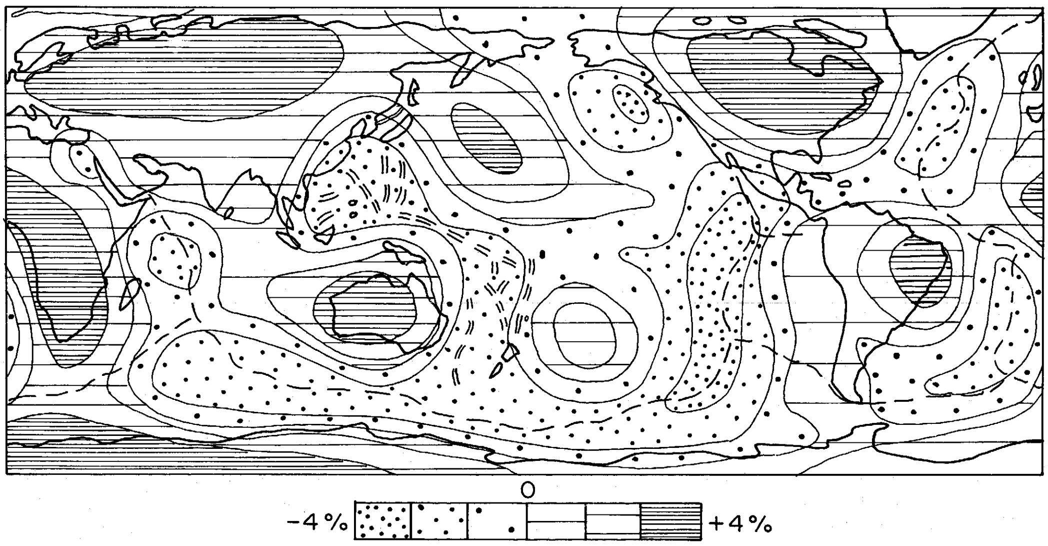

Fig 3. Variations in the seismic shear waves velocity and density in the upper mantle on the depth of about 150 km according to the seismotomographic data (by T. WOODHOUSE and A. DZIEWONSKI). Below is shown a scale of anomalies of shear velocities on the depth 150 km in %. Interrupted thick lines on the map show the axes of intraoceanic rift belts; double lines- the spreading axes (active and extinct) in West Pacific rift belt.

spreading northward.

Similar relative extension gradually decreasing northward should be experienced by the submeridional rift belts axes going off of Circum-Antarctic rift belt northward (though angular distances between them evidently did not change essentially). Thus during spreading the axes of the southern part of the Mid-Atlantic, West-Indo-oceanic and southern part of the West-Pacific rift belts divided respectively by ancient continental blocks of Africa and Australia had to move from each other.

Rifting and spreading processes later involved also the northern himisphere. However here they did not reach such a scale as in the southern. Nevertheless in the northern hemisphere we observe not only the features of progradation of the main submeridional rift belts in the northern direction (as in the zones of the Aden Bay and the Red Sea in the Indo-oceanic belt and in the north Atlantic and Arctic ocean in the Atlantic belt), but the appearance of intra-continental rift systems in North America, Europe and Asia (the Cordillera rift system, the Rhine, Baikal, Moma rift zones, North Chinese rift system) as well, some parts of which so far are not connected with the world rift system.

Though the main rift belts of oceans form a united geometrically regular global system, they essentially differ in their structure and kinematics of movements within them. These differences to a great extent are caused by differences in tectonic character of those regions which were overlapped by extensional deformations. Among the areas subjected to rifting and spreading in Mesozoic and Cenozoic we may distinguish roughly the ancient continental areas (first of all it is the Gondwana supercontinent and Laurasia to a less extent), oceanic areas (ancient, Pre-Mesozoic (?) bottom of the Pacific ocean) and mobile (or geosynclinal) belts characterized by a combination of zones with the crust of continental, oceanic and transitional type (to them first of all belongs the western part of the Circum-Pacific mobile belt striking along the eastern margins of Asia and Australia).

In the areas where Meso-Cenozoic rifting and later spreading led to fragmentation and later to complete separation of ancient continetal blocks, these processes were of concentrated nature and as a result a united spreading zone realatively stable in area occurred in each of them. It gradually expands and grows (progrades) in its striking northward. To this "concentrated" type refer rift belts of the Atlantic, western part of the Indian and to a less extent — Arctic ocean.

In the eastern part of the Pacific where not continental but oceanic lithosphere was subjected to rifting in Late Mesozoic and Cenozoic, (since almost all the researchers assume the ancient age of the Pacific bottom) spreading was of a less concentrated more diffuse nature (Fig. 4). This was expressed in larger width of zone covered by process of extension during the period of one more or less continuous epoch in simultaneous or nearly simultaneous existence within its limits of several more or less parallel axes of spreading and their periodic "jumping" from one place to another one. Such a diffuse and wandering nature of spreading evidently is connected with the presence of thin oceanic type crust and lithosphere and high position of the roof of hot asthenosphere in the wide zone of the ocean.

Finally, in the West-Pacific rift belt where processes of horizontal extension and new formation of the oceanic crust in Late Cretaceous and Cenozoic overlapped the

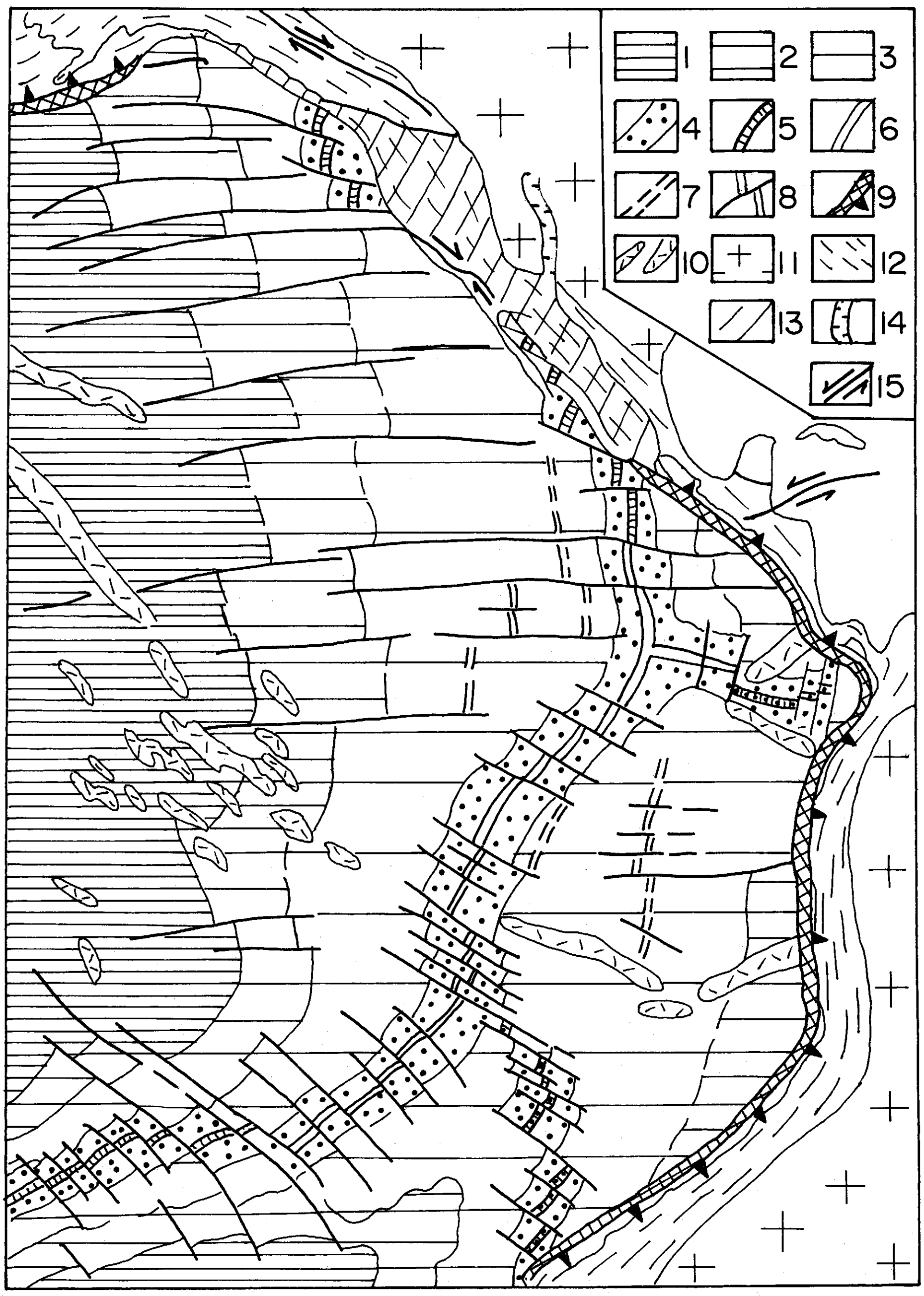

Fig 4. Tectonic scheme of the East Pacific rift belt (compiled by the author). 1~10 Pacific ocean area. 1. parts of Pacific ocean floor with the second layer of oceanic crust of Cretaceous age (older than 65 m. y.) ; 2. flanks of East Pacific rift belt with the second layer of oceanic crust of Paleocene-Eocene age (65~25 m. y.) ; 3. the same, of Oligocene-Miocene age (25~5 m.y.) ; 4. inner parts of spreading ridges with the second layer of oceanic crust of Pliocene-Quaternary age (5~0 m.y.) ; 5. axial zones of active intraoceanic spreading ridges with a rift valley ; 6. the same, without rift valley ; 7. axial zones of extinct intraoceanic rift belts ; 8. large transform faults in the oceanic crust ; 9. deep sea trenches with the connected with them upper parts of seismofocal zones dipping under continents ; 10. aseismic volcanic ridges of Cenozoic age on the oceanic floor. 11~15 Continents. 11. ancient platforms of North and South America ; 12. epigeosynclinal folded regions and recent geosynclinal regions in the eastern part of Circum-Pacific mobile belt (Cordilleran and Andean) ; 13. Cordilleran region of Oligocene-Quaternary continental epirogenic rifting, superposed on the Mesozoic folded regions of the same name ; 14. late Cenozoic continental rift zone Rio Grande, superposed on the western marginal part of North American platform ; 15. great late Cenozoic wrench fault zones.

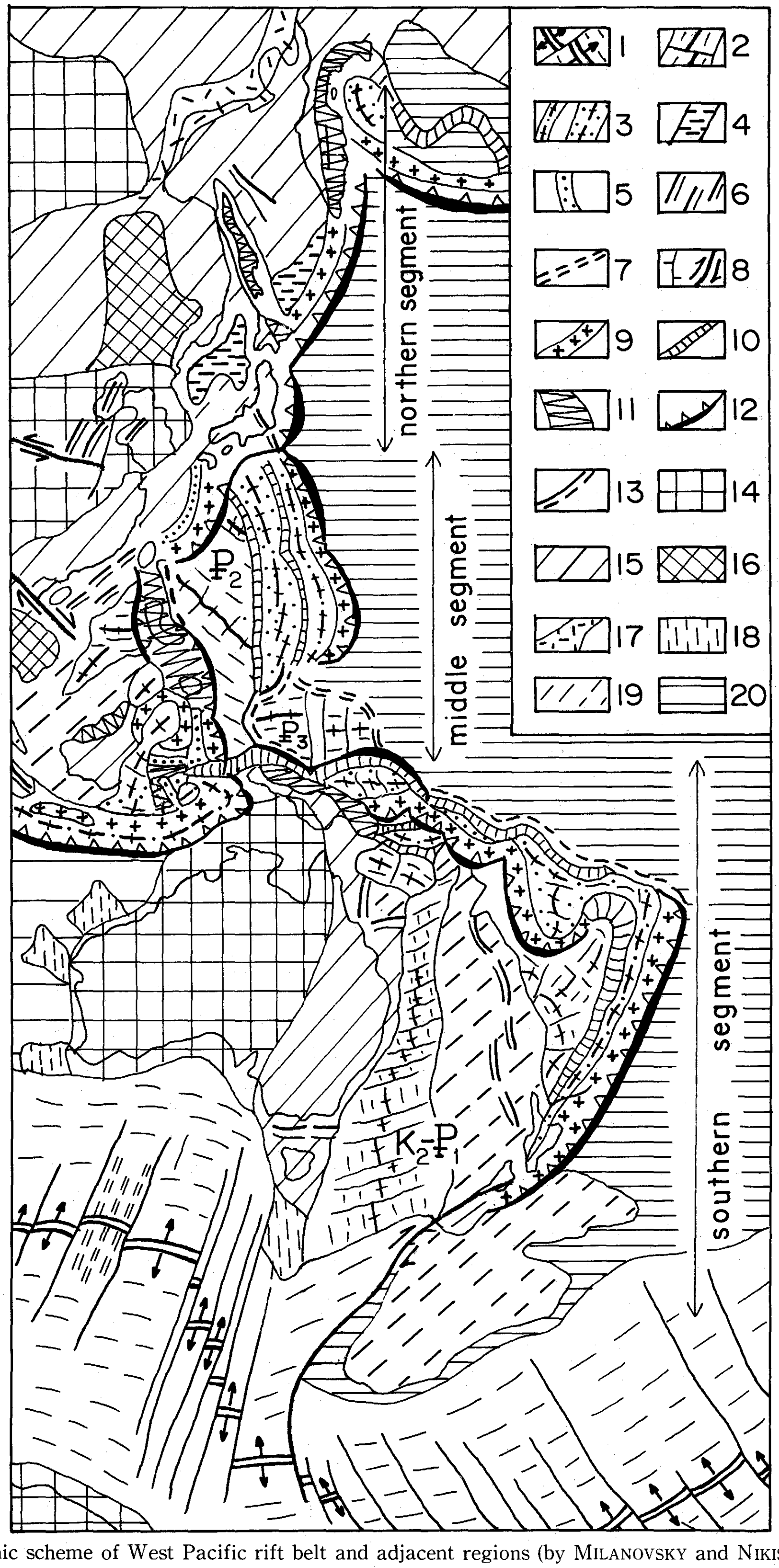

Fig 5. Tectonic scheme of West Pacific rift belt and adjacent regions (by MILANOVSKY and NIKISHIN, 1988).
1. intraoceanic rift belts with active axial zones ; 2. extinct zones of autonomous spreading with the oceanic crust and their age ; 3. zones of back-arc and inter-arc spreading with the oceanic crust ; 4. zones of back-arc dispersed spreading with the suboceanic crust ; 5. zones of back-arc rifting with strongly thinned and stretched continental crust ; 6. Cenozoic continental rift zones ; 7. crevasse-like grabens on the oceanic crust ; 8. transform faults and wrench faults ; 9. active magmatic island arcs ; 10. extinct magmatic island arcs ; 11. Cenozoic folded zones ; 12. active developing deep sea trenches connected with seismofocal zones and their dipping ; 13. the same, lost their activity ; 14. ancient platforms ; 15. Paleozoic and Mesozoic folded regions and zones within the mobile belts ; 16. greatest median massifs in them ; 17. some Mesozoic volcanic belts ; 18. microcontinents-fragments of ancient platforms ; 19. the same, fragments of Phanerozoic folded zones ; 20. bottom of oceans and separated from them marginal seas with the oceanic type crust formed or renovated in Mesozoic.

western part of the Circum-Pacific mobile belt at a considerable part of its area whose geosynclinal development has not completed and whose crust was chracterized by a wide range of transition from oceanic type to continental, we observe a complicated mosaic combination of parts displaying diffuse or concentrated spreading (mainly in the southern and middle part of the rift belt) or rifting (prevailing in the northern, less "mature" part of the belt) and also the presence within the limits of this belt of compression zones not typical for the most part of other rift belts. However the general scope of compression manifestation in such zones in Cenozoic gave way to the general scale of expansion in respective segments of this rift belt for the same time (Fig. 5).

In addition to the West-Pacific rift belt within the Pacific geosynclinal ring in Late Mesozoic and Cenozoic, there were two other rift areas of the similar type — the Carribean and South Antilles, where the scale of manifestations of horizontal extension of the oceanic type crust generation essentially overpassed the scale of compression manifestation.

II

Geological-geophysical data accumulated during the recent years are in favor of large-scale relative displacements of vast lithosphere blocks with which deformations in the upper crust horizons are associated. At the same time they allow to doubt some dogmatic statements of the lithosphere plate tectonics theory, which having arisen more than 20 years before remains a leading tectonic conception at least among American and west European scientists(*1).

To the number of fundamental statements of the "classical" model of plate tectonics causing some doubts and worth mentioning because of their importance for the subject of this paper refer in particular as follows:

1) The idea on sliding of relatively thin (several tens km under the oceans, about 100 km beneath the continents) lithosphere plates along the asthenosphere layer of continuous global distribution. The data of seismic (including seismo-tomographic), geothermal and other studies show the asthenosphere under a considerable part of continents, in particular, under ancient platforms and especially under their shields to be absent at the depths assumed by the plate tectonics model, while the lithosphere propagates in any case till the depths of over 200～300 and even 500～700 km. According the seismo-tomographic data [15, 23] on the lower depths (400 up to 700 km under the different continents) the relatively higher seismic velocities characteristic for the continental lithosphere rather sharply change by relatively lower ones which may be connected with relatively higher (for corresponding depths) temperatures and plasticity of the matter. Consequently, if continents participated in relative horizontal movements, then only as very thick (up to several hundred kilometers) blocks. All enormous experience of studying geology of continents and, in particular, ancient shields as vast (up to one or several thousand kilometers in diameter) areas of continuous upbulging during 1.5～2 billion years indicates this as well. If continents including ancient platforms slided as

(*1) But nowadays, as it was shown by V. E. Khain [17], initially strict postulates of this conception are getting more and more flexible and complicated, including the elements of other earlier hypotheses, in particular, those of pulsation, contraction and rotation.

thin (of the order of 100 km) lithospheric plates along the asthenosphere layer (as is assumed by the "classical" model of global tectonics) we should seek the reason causing the steady upbulging of the shield during exceptionally continuous time within the limits of this incommenturately thin compared with the shield diameter "plate" which seems to be unlikely. It is much more natural to assume that the "engine" causing continuous shield upbulging is at the depth of several hundred kilometers, or even deeper.

The newest data of seismotomography obtained for the North American continent [16] show the North-American platform and especially the Canadian shield to be chracterized on the whole by anomalously increased velocities of longitudinal waves propagation (and respectively higher density and decreased heat flow) down to the depths of about 300～400 km, while under some parts of the Canadian shield even to 500 ～600 km. As was mentioned the same deep "roots" but on the contrary "hot" with relatively decreased velocities of seismic waves and matter density have main rift belts of the Earth within the limits of the oceans.

2) The idea of constant equality (on a global scale) of the total value of increase of the Earth's crust area in the zones of extension (mainly as a result of neogenesis of the crust of oceanic type in spreading zones) and of its shortening in collision zones (mainly, and in the first models of the plate-tectonics conception, almost completely) as a result of consumption of old crust in subduction zones. Such an equality theoretically is possible only at invariability of the total area of the Earth, therefore one of the starting points of plate tectonics conception is a postulate on the Earth's invariable dimensions during the geological history [3]. However this initial assumption can not be considered as proved and on the contrary more and more data are accumulated allowing to assume some changes of the Earth's dimensions (i. e., its mean radius, surface and volume) and, possibly, its form (geoid), in the process of its development either of unidirectional (hypothesis of the Earth's expansion and compression), or more complicated changeable in time character (hypotheses of periodic pulsations of the Earth, including those occurring on the background of certain general expansion or compression). In particular, periodic pulsational variations of the Earth's volume and respectively the cyclic nature of its endogenous activity are assumed by V. E. KHAIN— one of the leading supporters of the plate-tectonics conception in the USSR [17]. However it is evident that assumption of changes of the Earth's surface in time unavoidably breaks the global equality of effects of expansional and collisional processes simultaneously taking place which forms the basis of an elegant geometrical picture of lithosphere block displacements on the sphere. Empirically stated irregularity in time in manifestations of both extension (spreading, rifting) and contraction of the crust (various forms of its blocks convergence and collision) did not receive by itself a natural explanation within the framework of conception of plate tectonics. It could at least not to have contradicted the conception only if the phases of collisional and expansional processes on the Earth coincided in time. In fact, however, analysis of real data shows the phases of intensification of collisional processes (folding phases) and those of spreading and rifting activization on a global scale not to coincide but alternate with each other [6, 7, 21], which is one of the important arguments in favour of pulsational conception.

3) The idea on reality of subduction phenomenon and its enormous significance as a process completely or mainly compensating the spreading and rifting effect in rift

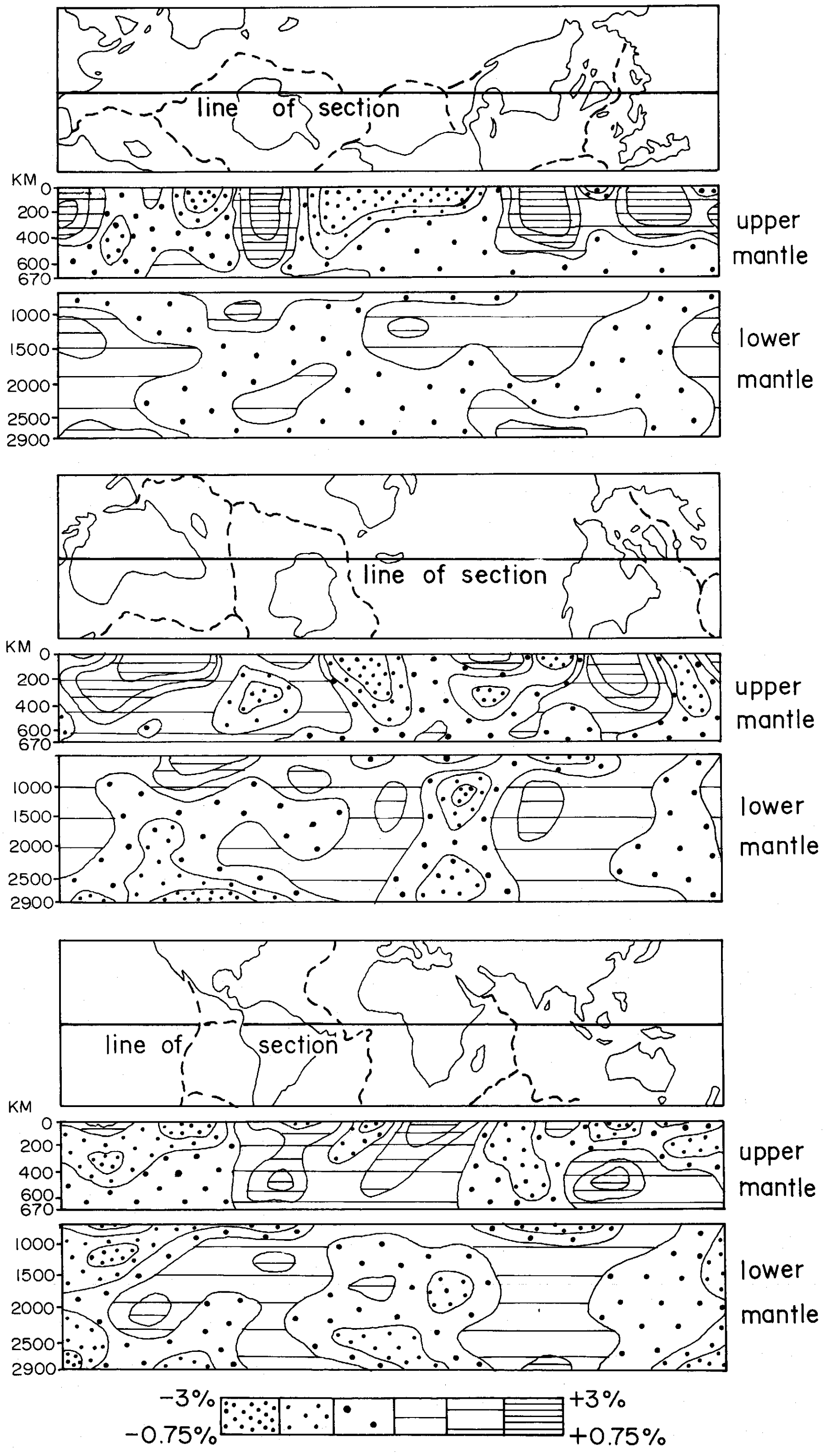

Fig 6. Seismotomographic sections of the upper and lower mantle of the Earth (by WOODHOUSE and DZIEWONSKI). Above each section are given the maps showing position of the lines of sections. Interrupted lines show the axes of intraoceanic rift belts. Under the sections is the scale of anomalies of velocities of shear (above) and compressional seismic waves (below) in % on the corresponding depth of the upper mantle. In the lower mantle the values of anomalies decrease in comparison with the upper mantle.

zones of the Earth.

As known this assumption originated not on the grounds of an analysis of geological facts but rather as a witty theoretical construction allowing to connect the ideas on spreading and horizontal displacements of lithosphere blocks and the postulate on invariability of the Earth dimensions in geological past into a single attractive in its simplicity and logic conception of plate tectonics. Let us note however, that not everywhere on the Earth we may observe the hypothetical subduction zones which could compensate manifestations of horizontal expansion and neogenesis of the oceanic crust in undoubtful spreading zones conjugate with them. An example may be even the actively expanding rift belt surrouding the Antarctics from all the sides; southward of it subduction zones are completely absent while northward of it they may be assumed only on separate plots. Another example is the Mid-Atlantic rift belt. Eastward of it (between it and West-Indo-oceanic rift belt) subduction zones are also absent and westward of it though they are assumed to exist (along the western margin of South and Central America), but the origin and development of these zones according to the plate tectonics conception is connected with spreading not in the Mid-Atlantic but in the East-Pacific rift belt. At present even most of those supporting the plate tectonics conception reject absolutization of the hypothetical mechanism of subduction as a process, compensating the spreading and rifting effect on a global scale and recognize that this compensation on the Earth of an invariable radius alongside the subduction zones was realized in the zones of folded- and nappe compressional deformations (and cosequently clustering and thickenning of the crust) in mobile belts on the active margins of continental lithosphere plates and in the zones of similar but less intensive intra-plate deformations.

Supporters of the Earth's expansion conception either deny completely the reality of subduction process calling it a myth as for instance S. W. CAREY [14] , or assume its possibility, but think the subduction together with other more reliable processes of horizontal Earth's crust deformations only partially compensated spreading in these zones and respectively general crust expansion during Mesozoic and Cenozoic, for instance, H. G. OWEN [19] *et al.*

Inspite of numerous seismic experiments, deep-drilling and other studies specially made for the proof of the existence of subduction phenomenon, the concept on it as a real process occurring in seismofocal zones did not receive so far non-ambiguous reliable confirmation. It must be noted that in contrast to modern supporters of the plate tectonics hypothesis one of the founders of the theory on seismo-focal zones ("Zavaritsky-Benioff zones")— A. N. ZAVARITSKY [2] considered them to be not certainly the zones of underthrust of oceanic lithosphere under that of the continental margin but rather, on the contrary as zones of overthrust of the latter on the Pacific plate, i. e. as the zones of obduction in the wide sense(*2). The other one— H. BENIOFF — assumed some dextral wrench character of displacements in these zones [13].

The reality of large-scale phenomena of obduction for lithosphere blocks of the oceanic type was stated in a number of regions, in particular, in the zones of a wide development of ophiolite complexes such as Oman, New Guinea and others. As for the

(* 2) The outstanding geologists H. STILLE [12] and P. N. KROPOTKIN [5] in the 50-ies also considered these seismo-focal zones as zones of deep overthrust (or obduction in the wide sense).

situation in seismofocal zones where in a lying (underthrust) wing of oceanic crust is present and in the hanging (overthrust) wing there is a block with the crust of continental or transitional type, the structural analysis allows to state only the kinematic character of relative lithosphere blocks displacements in such regions but not their reason, i. e., it does not give a possibility to find out whether the overthrust or underthrust of lithosphere plate which played the main role of active moving factor at their interaction in this seismofocal zone. The latter may be stated only with the account of general geodynamic situation in a respective region of the Earth. Therefore we can not ignore the possibility of obduction on the oceanic lithosphere by the lithosphere blocks moving upon it with the crust of continental or transitional type where many modern seismofocal zones located in particular along the periphery of the Pacific. At the western periphery of the Pacific the obduction process may be connected with the existence of active mantle diapirs in the West-Pacific rift belt, ascent of their deep material and asymmetric expansion of their upper parts towards the Pacific bottom with the overthrust onto its lithosphere. It is remarkable that dipping of some studied siesmofocal zones of this region, for instance of the Kurile-Kamchatka zone, beginning with the depths of about 300 km increase [9]. At the eastern periphery of the Pacific on its boundary with the South American continent we may assume the overthrust of the latter as a lithosphere plate 500～600 km thick along the seismofocal zone on the oceanic lithosphere. In this connection let us emphasize that seismofocal zones dipping under the western margin of the South American continental block are submerged practically down to these depths. In contrast to western periphery of the Pacific ocean they have a trend not to become steeper but on the contrary to be smoothed out with depth (Fig. 7).

4) The idea on the presence of morphologically expressed rift valley in the axial part of the intra-oceanic rift belt as an indicator of a relatively low rate of spreading, and on the contrary on the absence as a proof of a high rate of this process (see, e. g. [10]).

In accordance with this assumption the supporters of the plate tectonics hypothesis believe that the highest rates (up to 8～10 and 15 cm/year) and highest total scale of spreading in Cenozoic characterize the East Pacific rift belt [11, 20], where the rift valley is not expressed but on the contrary the axial uplift is traced morphologically and the general width of the area where Late Cenozoic rifting was manifested is very big in comparison with other rift belts of oceans. But the rift valley is also absent (and also "replaced" by the axial linear uplift) in the northernmost part of the Atlantic rift belt in the submarine Reykjanes ridge where spreading rate is considered by all the researchers to be insignificant in comparison with southern segments of this belt. This must be admitted unwillingly though by the supporters of the plate tectonics conception thinking this fact to be an "exception".

I believe the presence or absence of the rift valley in intra-oceanic rift belts must indicate not a relative spreading rate as such, but rather the intensity of magma emission in a respective segment of the rift belt (greater in the regions of absence of the rift valley), or various correlations between the magma emission and spreading rate(*3).

(＊3) On high intensity of the volcanic process in the zone of the Reykjanes ridge we may judge by its direct connection with Iceland where this intensity is extraordinarily high and apparently reaches the maximum value on the scale of the whole Earth.

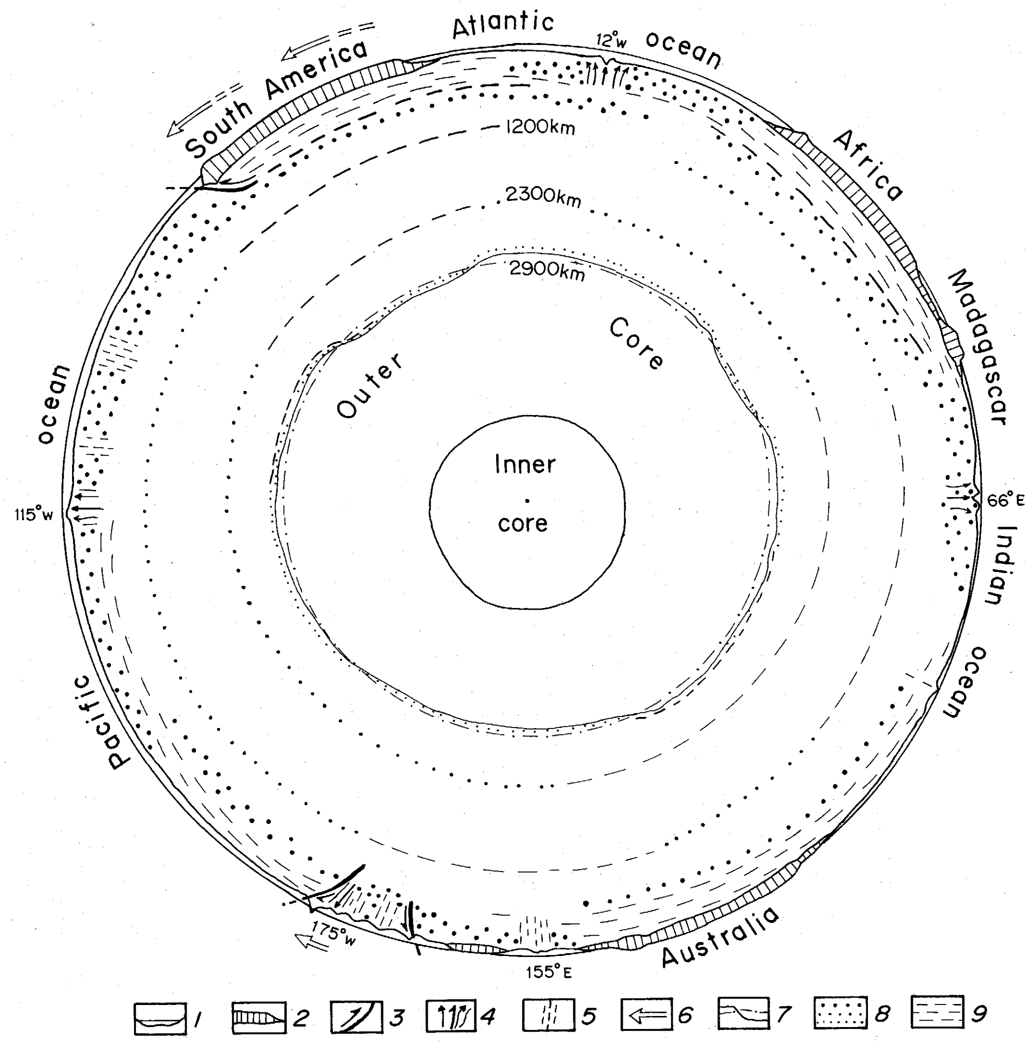

Fig 7. Schematic section of the Earth's interior along the 20° South latitude. (complied by author using the seismo-tomographic data of MORELLI, DZIEWONSKI and WOODHOUSE).

1. Oceanic basins (the depths are exaggerated in comparison with the scale of section) ; 2. continental crust ; 3. seismofocal zones in the upper mantle and supposed directions of the active displacements along them ; 4. axes of intraoceanic rift belts (active axes of spreading and ascent of heated mantle material) ; 5. the same, extinct ; 6. proposed directions of relative horizontal displacements of the large blocks of the crust and upper mantle ("lithospheric plates") ; 7. core-mantle boundary established by seismotomographic data (continuous lines) and the average global level of this boundary (interrupted lines), values of their differences are exaggerated in comparison with the scale of section ; 8. areas of anomalously lowered (for corresponing depths) velocities of seismic waves in the upper mantle, in the uppermost part of the lower mantle, on the depths 1200 km, 2300 km and 2900 km (on the base of lower mantle) ; 9. the same, of anomalously increased velocities.

In other words, in the rift belts of oceans there may be zones with relatively high spreading rate and relatively low intensity of basalt extrusions and vice versa.

The great width of the East Pacific rift belt according to the author may be connected not with the high rate and the great total result of Cenozoic spreading in it but with its diffuse nature, i. e. with the presence within this belt of several (up to three almost in its any section) spreading zones mutually parallel and partly diagonal and almost transversal to each other spreading zones "working" alternatively and sometimes nearly simultaneously, which as if "wandered" by the wide surface of this belt (Fig. 4).

Identification of linear magnetic anomalies within this belt causes serious difficulties and therefore the ideas on the age of the basalt fundament (the roof of the 2nd layer) for many of its parts are unreliable. Against the assumed large scale of the horizontal expansion of the lithosphere in the East Pacific rift belt is the fact that in its northern part where it is almost completely concealed under the North-American lithosphere plate, and subducted under it, according to the plate tectonics conception, the general amplitude of horizontal expansion of the crust for Neogene-Anthropogen judging by the analysis of the structure of the Cordilleras rift system does not exceed the first hundred km and the mean rate of expansion does not reach 1 cm per year, i. e. yields to such in the Mid-Atlantic rift belt.

Assumptions on enormous scales and spreading rates in the East-Pacific rift belt are contradicted also by the fact that this belt rather quickly degenerates in striking northward and attenuates already between 50° and 60° N whereas the Mid-Atlantic rift belt continues still for several thousand km further northward penetrating to the limits of the Arctic ocean and crossing it.

The said above allows to make an assumption that the Mid-Atlantic rift belt differing from the East-Pacific in large extension and concentrated character of spreading whose axis during a continuous time retained its median position relative to the flanks of the rift belt not only yielded in rate and scale to the East-Pacific rift belt but on the contrary overpassed it.

5) One of the particular but quite important for the subject of this article statement of plate tectonics conception is an idea on Cenozoic underthrust or subduction of the lithosphere of Pacific ocean beneath the continental lithosphere plates of the North and partially South America. First the Farallon plate was subducted which is the eastern flank of the East-Pacific rift belt and later the northern part of the axial zone of this rift belt was also subducted under the North American lithosphere plate (see, e. g. [4]). This assumption seems to me quite doubtful. It is not clear how the intra-oceanic rift belt cosidered to be the most rapidly expanding and energetically the most powerful, able to push to the west and north-west the immense Pacific lithosphere plate moving with the rate of up to 8~10 cm/year away by many thousand kilometers, how can it at the same time move itself and "dive" with its axial spreading zone and even with the part of its western flank beneath the margin of the North American continental block extended under an acute angle toward its striking? According to the plate tectonics conception subduction is caused by spreading in the axial rift belt and compensates the lithosphere expansion in it. What makes the spreading zone itself in the northern part of the East Pacific rift belt first approach the western margin of North-American lithosphere plate and then to hide under its western flank, i. e. under Mesozoic structures of the Cordilleras? From the standpoint of structural analysis and common sense it is more natural to assume that not the northern termination of the East Pacific rift belt was subducted under the North-American lithosphere block but on the contrary this block itself was obliquely overthrust (obducted) on the northern part of the rift belt[*4]. If it is the case then what could serve the reason of obduction of powerful lithosphere blocks of the North and South America on the Pacific ocean bottom, including the

(*4) The San-Andreas diagonal wench displacement zone going along the front of this deep overthrust originated later, but though it is very long, it evidently does not reach the lower horizons of the crust.

northern part of the East Pacific rift belt ?

We may assume these processes were caused by almost continuous since the middle of Mesozoic up to the present spreading in the Mid-Atlantic rift belt which overpassed in intensity the spreading in the northern part of the East-Pacific rift belt and damped the expansion effect in the latter. Such an assumption seems to contradict a widely developed opinion on much greater rate and total scale of spreading in the East-Pacific rift belt in comparison with the Atlantic. However we have mentioned the insufficient grounds of this opinion and most likely the things are just the opposite. We assume that in connection with intensive and continuous spreading in the Mid-Atlantic belt its western flank together with the zone of passive margin in the western part of the Atlantics and also with joining it from the West very thick continental lithosphere blocks of North and South America moved westward and the western margins of these continental blocks in their turn gradually overthrust different zones of the eastern part of the Pacific ocean bottom.

Though the structure of the Mid-Atlantic rift belt seems to be quasi-symmetrical, the expansion in this belt and especially in its northern part probably took place mainly in the western direction. Similar to the Antarctic the great lithosphere block of Africa almost from all the sides except the northern was surrounded by spreading belts. The most actively expanding belts among them are framing the African block from west and east.

Within the African lithosphere block there are continental Mesozoic and Cenozoic rift zones and sub-isometric "hot spots" — mantle diapirs continuously preserving their position (Ahaggar, Tibesti, Kamerun and others). On the contrary any compression zones which could at least partially compensate expansion in the oceanic rift belts framing the African block are almost absent within it (similar to the Antarctic lithosphere block). Such situation allows to assume that the African lithosphere block was less mobile during Late Mesozoic and Cenozoic and, evidently, was subjected only to certain displacement northward or east-northward towards the Mediterranean mobile belt while axial zones of the adjacent intra-oceanic rift belts gradually moved away from the African block : the axial zone of the West-Indo-oceanic belt was displaced generally in North-North-Eastern direction while the axial zone of the Mid-Atlantic belt was displaced westward even more intensively.

Since thick lithosphere blocks of the South and North America join with the bottom of the Atlantic ocean through the zones of passive margins these blocks in the process of the "opening" of Atlantics were to move from Africa westeward at a distance approximately equal to the total amplitude of Meso-Cenozoic rifting and spreading in respective transversal segments or latitudinal cross-sections of the Atlantic rift belt.

If we do not follow the extreme views of CAREY [14] and some other supporters of the hypothesis on very significant increase of surface and volume of our planet according them, the spreading of the bed of all the oceans in Meso-Cenozoic is approximately equal to the total increase of the Earth's surface due to its expansion, and on the contrary if we believe that it should have been partly compensated by different phenomena of collision of lithosphere blocks, in particular, compression of some zones and their overthrust on each other we will have to assume that the widening of the Atlantic ocean in the process of Meso-Cenozoic rifting and spreading and motion of the lithosphere blocks of South and North America was accompanied by general compression and "clustering" of the lithosphere in the western zones of these continents— in the Andean -Cordilleran mobile belt — and by overthrust (or obduction) of these blocks on the eastern part of the Pacific bottom. As we said above the overthrust of these thick lithosphere blocks according to the author's assumption occurred and in the western edge of South and Central America continue to occur along the seismofocal zones which go under the continent of South America gradually being smoothed out with the depth of down to 500～650 km (Fig. 4).

The fact that the expansion of the Atlantic bottom occurs mainly in the western direction where are also displaced the axis of the Mid-Atlantic rift ridge and lithosphere blocks of the South and North America (with the rate twice higher than the former) may be caused by the Earth's rotation and sliding of the American lithosphere plates (up to 500～600 km thick) possessing a little smaller angular velocity of rotation in comparison with their substratum and as if drifting in relation to the latter westward. Changes in location of seismic and thermal anomalies in the mantle under the continents at the depths of 500～700 km agree with this assumption. At the same time such gigantic inhomogeneity of the Earth as the Pacific area (with the exception of its western marginal part) according to the newest seismological data continue through the whole upper and lower mantle up the core surface judging by relatively decreased velocities of seismic waves propagation. In the relief of a core surface a vast elevation up to 6 km in relation to the mean level and up to 10～12 km relative to the largest depressions of this surface corresponds to it. It is interesting to note that in the topography of the core suface the very clear elevations correspond also to other oceanic depressions — Atlantic and Indo-oceanic (Fig. 8). The main depressions of the core surface correspond to the most part of the continents (with the exception of small Australia) and to the West

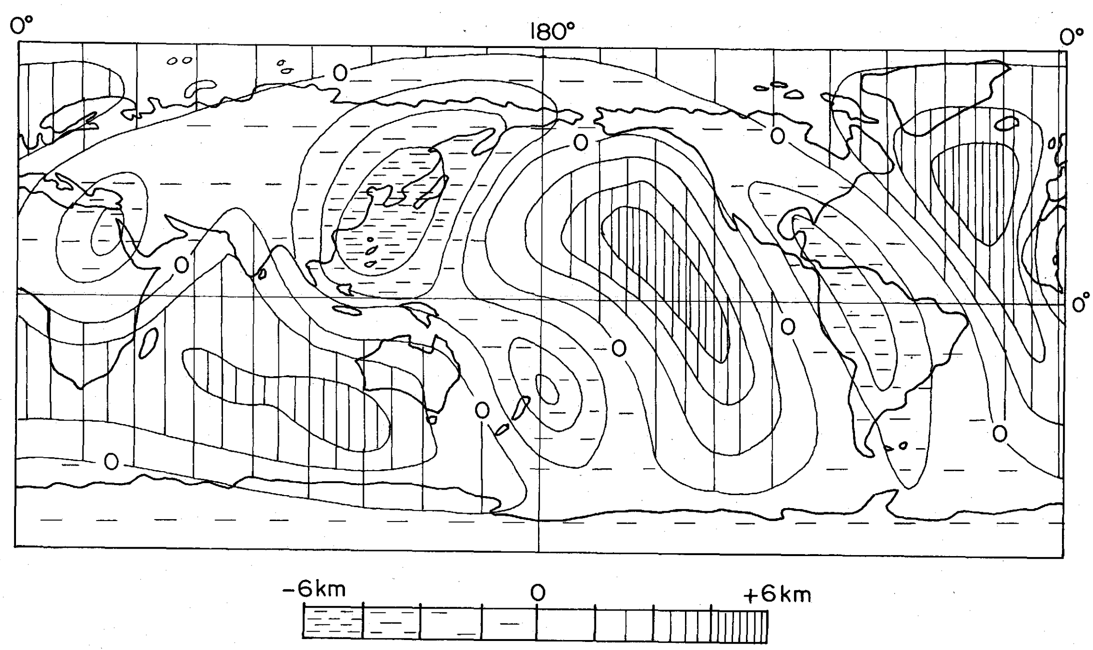

Fig 8. Topography of the core-mantle boundary according to seismo-tomographic data (by MORELLI and DZIEWONSKI). Below is shown a scale of the deviations of real position of this boundary (its elevations and depressions) from its average level.

Pacific mobile belt(*5). Thus, the relief of the core surface similar to the Moho surface roughly reflects the relief of the Earth's surface like in mirror. These striking correlations between the surface and super-deep structures of the globe which can not be simply combined with the orthodox plate tectonics conception will wait for their interpretation. However the global interconnection of the largest structures at different levels of the lithosphere, mantle and even the Earth's core and deep processes forming them is getting evident even now.

III

Let us try in a preliminary form to put forward our assumptions on possible deep mechanism of the largest tectonic movements of the lithosphere of the Earth in Mesozoic and Cenozoic which proceed from the above stated ideas and considerations on the leading role of rifting caused by processes in the very deep planet interior. The proposed conception is a mobilistic (moderately mobilistic) but in contrast to the orthodox conception of plate tectonics it is not connected with dogmas on invariability of the Earth dimensions during its geological history and on necessary complete or almost complete compensation of spreading and rifting in rift belts and zones by simultaneous subduction in convergence zones of lithosphere plates on a global scale. We assume the diversity of forms of manifestation of collision of lithosphere blocks (obduction, general clustering and may be subduction at more local areas and on a limited scale) and recognizes a possibility of horizontal displacements of continental blocks as much thicker plates (up to 500～600 km thick) than the thin lithosphere plates operating in plate tectonics model(*6).

According to the proposed hypothesis the leading deep tectonic process on the Earth in Meso-Cenozoic is rifting and in particular its most mature and large-scale form—spreading— realized in the zones of uprise and propagation of the deep mantle material under conditions of some general Earth expansion that began (or renewed) in Mesozoic and continued till nowadays. This expansion is evidently connected with several powerful pulses of heat emission from the Earth interior irregularly manifesting itself on its surface; it started earlier and reached the highest scale in the southern (Gondwana) hemisphere of the Earth, but later propagated to its northern hemisphere and led as a result to neogenesis of the Indian, Atlantic and later Arctic oceans with their intra-oceanic rift belts and to renewal and tectono-magmatic reworking of the bottom of older Pacific ocean and also to formation of inter-continental and numerous intra-continental rift zones and their systems. The main intra-oceanic rift belts of the Earth gradually formed in the zones of the most intensive expansion and spreading

(*5) First an assumption on the existence of such irregularities in the surface relief of the outer core was proposed by A. Vogel [22] about 30 years ago by the results of studies of seismic wave reflections from this surface.

(*6) This does not exclude a possibility of horizontal displacements of much thinner lithosphere plates in the zones of wide development of typical well pronounced asthenosphere with the roof at the depths of several tens～one hundred kilometers, in particular, within the oceans and certain thermally active parts of continents. With the assumption of the existence of two "floors" of convection in the Earth's mantle we could believe that if convection took place in both "floors", i.e. in the upper and lower mantle, in thermally active Earth areas such as oceans, then within colder continental areas with thick (up to several hundred kilometers) lithosphere convection occurred only at the lower of these "floors" and respectively thick blocks or plates of the crust and upper mantle are subjected to the main horizontal displacements as the whole relative to the roof of the lower mantle.

within the supercontinent of Gondwana, and also within the North-Atlantic folded belt, West-Pacific mobile belt and eastern and south-eastern part of the Pacific ocean inspite of some structural reorganizations mainly preserved during the late Mesozoic and Cenozoic their regular dislocation relative to the Earth axis of rotation, relative to Earth southern pole (as an "epicenter" of the area of the highest expansion of the lithosphere) relative to the equator near which the westward displacement of all longitudinal rift belts takes place in the northern hemisphere in comparison with their position in the southern hemisphere, and also relative to each other though the linear distances between them gradually somewhat increased in connection with the Earth's expansion, especially in the southern hemisphere where it was more significant.

Continental lithosphere blocks bordering the depressions of the Atlantic and Indian ocean along the zones of "passive" margins as very thick plates including the crust and the whole upper mantle (or its significant part) moved away from the axes of expanding rift belts and some of these blocks (in particular, South and North American) overthrust along the inclined seismo-focal zones on the margins of the Pacific ocean or sometimes somewhere underthrust under them or under the Mediterranean mobile belt, as for instance, Indian plate underthrust under Himalayan zone. In the southern hemisphere where the Earth's expansion was the largest these continental blocks as a rule separated from each other whereas in the northern hemisphere where the scale of general expansion decreased and it gradually stopped in a number of regions in particular in the Mediterranean-Himalayan mobile belt as a result of displacements northward of continental blocks of Africa, Arabia, India and others, their collision with the Eurasian continental lithospheric block took place. Here occurred complicated and diverse compressional deformations in the lithosphere of the mobile belt sometimes propagating far beyond its boundary (Tien-Shan and others). In the north-eastern part of the Pacific ocean till the middle of Cenozoic overthrust of the North American continental block westward on the northern termination of the East-Pacific rift belt took place caused by the fact that the Mid-Atlantic rift belt located eastward of the North American block was subjected to more intensive expansion (mainly westward) than the East-Pacific one. The scale of Meso-Cenozoic expansion in secondary oceans was much smaller than the one assumed in plate tectonics models since spreading took place only in their inner zones whereas in wide marginal zones and in the parts of narrowing of secondary oceans, in particular, in the marginal zones and in the northern part of the Atlantic and Western part of the Indian ocean mainly fragmentation, extension and irregular thinning out of the continental crust which was subjected to destruction and reworking took place and its numerous slightly reworked blocks ("microcontinents") were preserved. Respectively considerable smaller, than assumed in plate tectonic models, were the amplitudes of horizontal displacements of thick lithosphere blocks of continents framing the secondary oceans and amplitudes of their overthrust (and partly underthrust) on (or under) the active margins of oceans and the margin of the Mediterranean mobile belt.

A specific role in the Mesozoic-Cenozoic tectonics of the Earth is played by the West-Pacific rift belt superimposed on the ancient mobile belt of the same name; its tectonic development in Late Cretaceous and Cenozoic was a peculiar combination of geosynclinal and rift processes with the leading role of the latter. In this belt there occurred continental crust rifting and also spreading and neogenesis of the crust of oceanic and suboceanic type though on a smaller scale than in the other main rift belts. In contrast to the latter horizontal expansion in this rift belt was sharply asymmetrical one on the whole, take place in the eastern direction leading to the consecutive formation of new rift and spreading zones in its eastern part (for instance, in the Philippine Sea) and to obduction of its eastern flank on the Pacific plate along a number of seismofocal zones.

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