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THE CONTINENTAL REJUVENATED MOUNTAIN BELTS

ABSTRACT: Ufimtsev G.F., *The continental rejuvenated mountain belts*. (IT ISSN 0391-9838, 1994).

Continental rejuvenated mountains are represented by three types of mountain belts: the Mongolia-Siberian, Ural-Appalachian and margin-continental or East-Asian types. Orogenic belts of the Mongolia-Siberian type are when tectonic relief has clear paragenesis with deep structure. Mountain belts of the Ural-Appalachian type form in the zones of rapprochement of continental platform. Mountain belts of the East-Asian type are formed along the margins of intensive subsidences in the basins of the Pacific ocean marginal seas.

The Central-Asian belt of rejuvenated mountains and the East-African rift system have no analogy in the continents. The former appears in a zone of intercontinental collision of lithospheric plates, but the latter is the only recently rejuvenated orogenic belt in the southern continents.

The reasons and conditions for the formation of rejuvenated orogenic belts are diverse. Of great importance in their formation are the protrusions of asthenoliths (anomalous mantle) and inclined bedding of the asthenospheric roof, above which there is the development of zones of linear warping or narrow structural block uplifts.

KEY WORDS: Continental rejuvenated mountain belts, Cenozoic geodynamics, Neotectonics.

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Le catene continentali ringiovanite sono rappresentate da tre tipi di fasce montuose: il Mongolo-Siberiano, l'Uralo-Appalachiano e il continentale marginale o tipo dell'Asia Orientale. Le fasce orogeniche del tipo Mongolo-Siberiano si manifestano quando il rilievo ha chiare interdipendenze con la struttura profonda; le fasce del tipo Uralo-Appalachiano appaiono nelle zone di accorciamento della piattaforma continentale; le fasce montuose del tipo dell'Asia Orientale si sono formate lungo i bordi fortemente subsidenti dei bacini oceanici marginali dell'Oceano Pacifico. Oltre a questi dobbiamo menzionare le fasce di catene ringiovanite dell'Asia Centrale (Altai, Tien Shan, ecc.), che si sviluppano in zone di collisione intracontinentale di placche litosferiche, e quelle del sistema del *rift* dell'Africa Orientale, che sono le sole dell'Emisfero Meridionale.

Le cause e le condizioni per la formazione di catene continentali ringiovanite sono diverse. Di grande importanza nella loro genesi sono le protrusioni di astenoliti (mantello anomalo) e corpi inclinati di materiale astenosferico, sopra il quale c'è lo sviluppo di aree di inarcamento lineare o l'innalzamento di stretti blocchi strutturali.

TERMINI CHIAVE: Catene continentali ringiovanite, Geodinamica Cenozoica, Neotettonica.

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INTRODUCTION

Epiplatformal (or rejuvenated) orogenic belts occur in the areas of cyclic denudation of plains during the renewal of tectonic activity. Commonly rejuvenated mountain belts are found within Paleozoic and older folded and metamorphic complexes. There is often the complicated problem concerning the mountain belts or epigeosynclinal mountains within Mesozoic folded regions. So the concept of «renewed mountains» (HAIN, 1965) was proposed as an intermediate link between epiplatform mountains and epigeosynclinal structures. Analysis of the tectonic relief of intercontinental mountain regions shows that renewed structures are a variety of rejuvenated mountains (FLORENSOV & UFIMTSEV, 1984).

In this paper we propose typical characteristics of rejuvenated mountain belts of continents. Mountain belts are large forms of the Earth's relief. As a rule, their length exceeds their width more than two-fold. Their constituent neotectonic forms are grouped in linear chains. The main feature of mountain belt structure is a regulation in distribution of forms. Often the order of orogenic belt structure may be well described in terms of symmetry doctrine.

The size of mountain belts range from a length of 1600-3000 km to a width of usually 600-1200 km. There are very narrow mountain belts, the width of which is not greater than 250 km (the Urals, for example). Mountain belt area varies from 1.0 to 3.3 mln km^2, but rejuvenated mountain belt areas are never more than 2.2 mln km^2. The rejuvenated continental mountains can be grouped into the following types of mountain belts: the Mongolia-Siberian, Ural-Appalachian and East-Asian types. There are also the central Asian orogenic belt and the East-African rift belt which have no analogy.

MONGOLIA-SIBERIAN OROGENIC BELT TYPES

The mountain belts of the Mongolia-Siberian type consist of large domal uplifts, rift zones and zones of linear

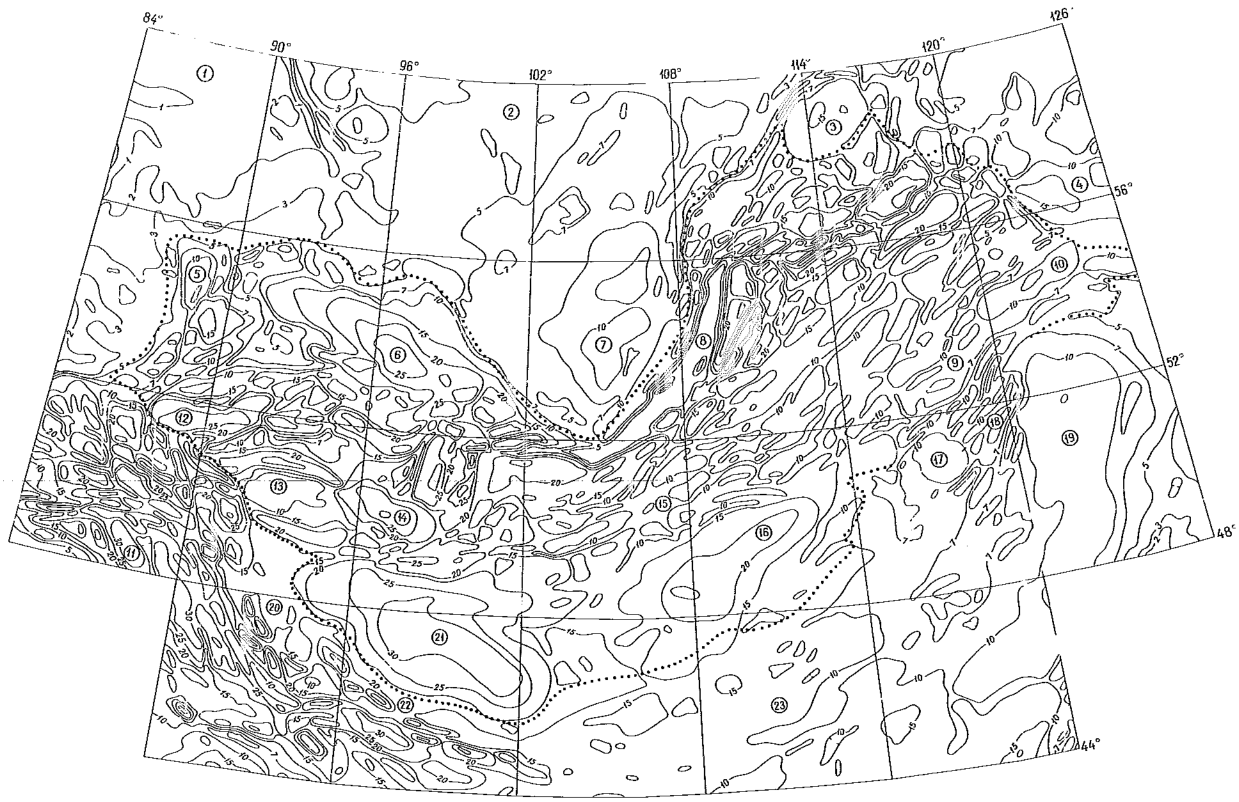

FIG. 1 - Tectonic relief of the northeastern part of Inner Asia (the Mongolia-Siberian mountain belt and its framing). Isolines of tectonic relief are drawn 100, 200, 300, 500, 700, 1000, 1500, 2000, 3000 and 4000 m (in 100 m). A dotted line shows the boundary of the Mongolia-Siberian mountain belt. Numbers in circles show: West-Siberian accumulative plain (1), Middle-Siberian plateau (2), Patomskoje upland (3), Stanovoy Ridge (4), Kuznetsovsky Alatau (5), East Sayan (6), Upper-Lenian plateau (7), Lake Baikal (8), near-Shilka low mountains (9), Olekmian Stanovik (10), Altai (11), West Sayan (12), Uvs Nuur basin (13), Sangulen ridge (14), Selenga middle mountains (15), Khentey (16), mountains of Unda-Borzian interamnian area (East-Transbaikalian dome) (17), ridges and basins of Shilka-Argun interamnian area (18), Large Hingan (19), Depression of Large Lakes (20), Khangay (21), Valley of Lakes (22), East-Gobian plains (23).

warping which are a combination of small domes with arcogenic thrusts on their flanks and intermontane basins. Mountain belts of this type are subdivided into two varieties. The first variety consists of the Mongolia-Siberian and Verkhoyan-Kolymsky (NE Asia) mountain belts. Structure-forming elements of these mountain belts are characterized by: (1) rift zones, (2) zones of linear warping, (3) chain of large domal uplifts (figs. 1, 2). These neotectonic forms are located on common socle uplift which is distributed throughout the area of the mountain belt (UFIMTSEV, 1988) (fig. 3). Morphology of the common socle uplift of the Mongolia-Siberian mountain belt has a link with the main features of deep structure. This socle uplift is of an isostatic nature and is located above the anomalous mantle lens (asthenolith). The Baikal rift zone is a geomorphological result of subvertical protrusion of anomalous mantle above the NW edge of the asthenolith. Longitudinal systems of basins and block uplift are located in the central part of the rift zone. Its NW flank consists of inclined horsts, but its SE flank is a group of domes (fig. 4). Zones of linear warping in the central part of the Mongolia-Siberian mountain belt are a result of horizontal compression of the Earth's crust. They consist of small domes with marginal thrust (figs. 5, 6) and basins. They compensate the tension of the lithosphere in the Baikal rift zone. Large domes are isostatic uplifts within a lithospheric block which is built of low density rocks (fig. 7). These uplifts are stable in geological time. Large domes are well regulated systems of stepped block uplifts in the axial parts (figs. 8, 9) and inclined block uplifts and inclined horsts on the flanks (fig. 10). The Verkhoyan-Kolymsky mountain belt in North-Eastern Siberia is an analogy of the Mongolia-Siberian mountain belt (fig. 11).

For other varieties of mountain belts of this type there is a tendency for longitudinal alteration of structure-forming elements. This is the situation in the East China mountain belt, in the mountains of North America, including the Rio Grande rift, Rocky Mountains and Mackenzie Mountains. These rejuvenated mountain belts also have socle uplifts, which are connected with higher socle uplifts of contiguous epigeosynclinal mountain belts. The socle uplift of the East China rejuvenated mountains joins in the southwest with the high (3000 m and higher) socle uplift of the Tibet-Himalayan epigeosynclinal mountain belt. The rejuvenated mountains of North America have a common socle uplift with an epigeosynclinal orogenic belt. Here there is also the close paragenesis between the rejuvenated mountain structure and main features of deep structure. The uplift of mountain socle takes place above an asthenolith, but the Rio Grande rift connects with the

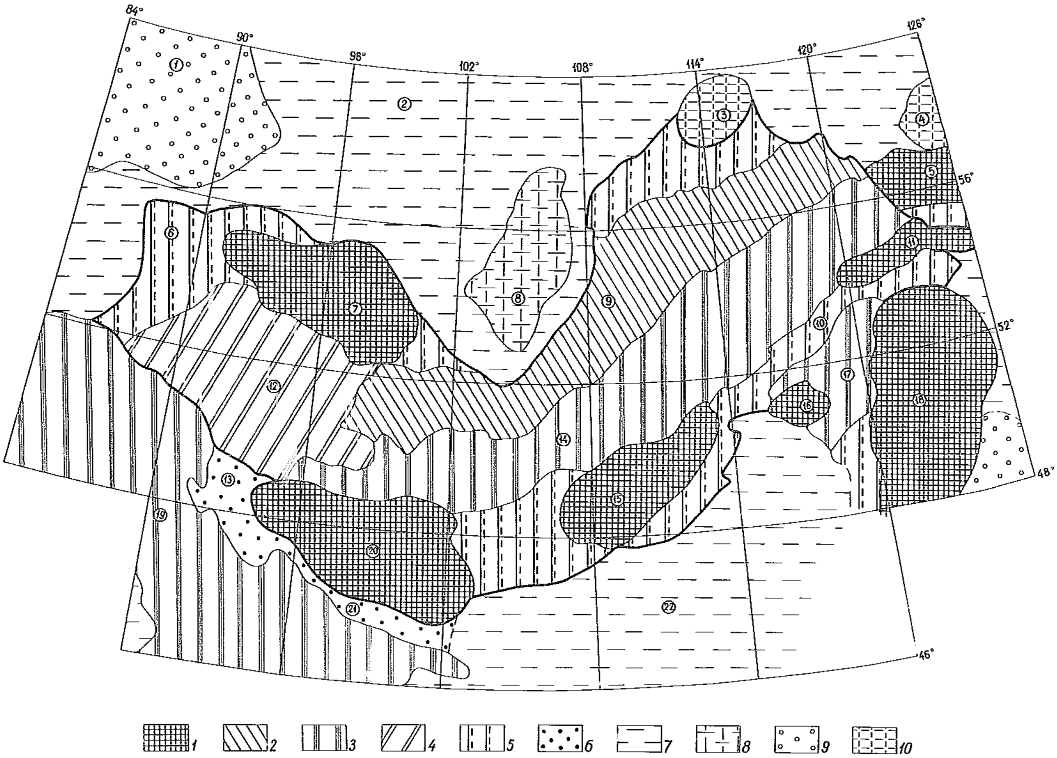

FIG. 2 - Structure of the Mongolia-Siberian orogenic belt and surrounding territories. 1-6 - areas of orogenesis: large domal uplifts (1), rift zones (2), zones of linear warping (3), zones of linear warping with large uplifts and basins (4), block fields (5) and large intermontane basins (6); 7-10 - plain-platformal areas: common uplifts (7), high steps (8), young accumulative plains (9), shield-like uplifts in marginal parts (10). A thick solid line marks the boundary of the Mongolia-Siberian mountain belt. Neotectonic forms (West-Siberian young plate (1), Siberian platform (2) with Upper-Lenian high step (8), Patomskoye (13) and Central-Aldanian (4) uplifts; large domes: Stanovoy (5), East-Sayanian (7), Olekmian Stanovik (11), Khentey (15), East-Transbaikalian (16), Large Hingan (18) and Khangay (20); block fields: near-Shilka (10), Kuznetsky Alatau (6), Baikal rift zone (9); zones of linear warping: Tuvinian (12), Selenga-Vitimian (14), Shilka-Argunian (17) and Altai side of the Central-Asian mountain belt (19); basins: Depression of Large Lakes (13) and Valley of Lakes (21); East-Mongolian plain-platformal area (22).

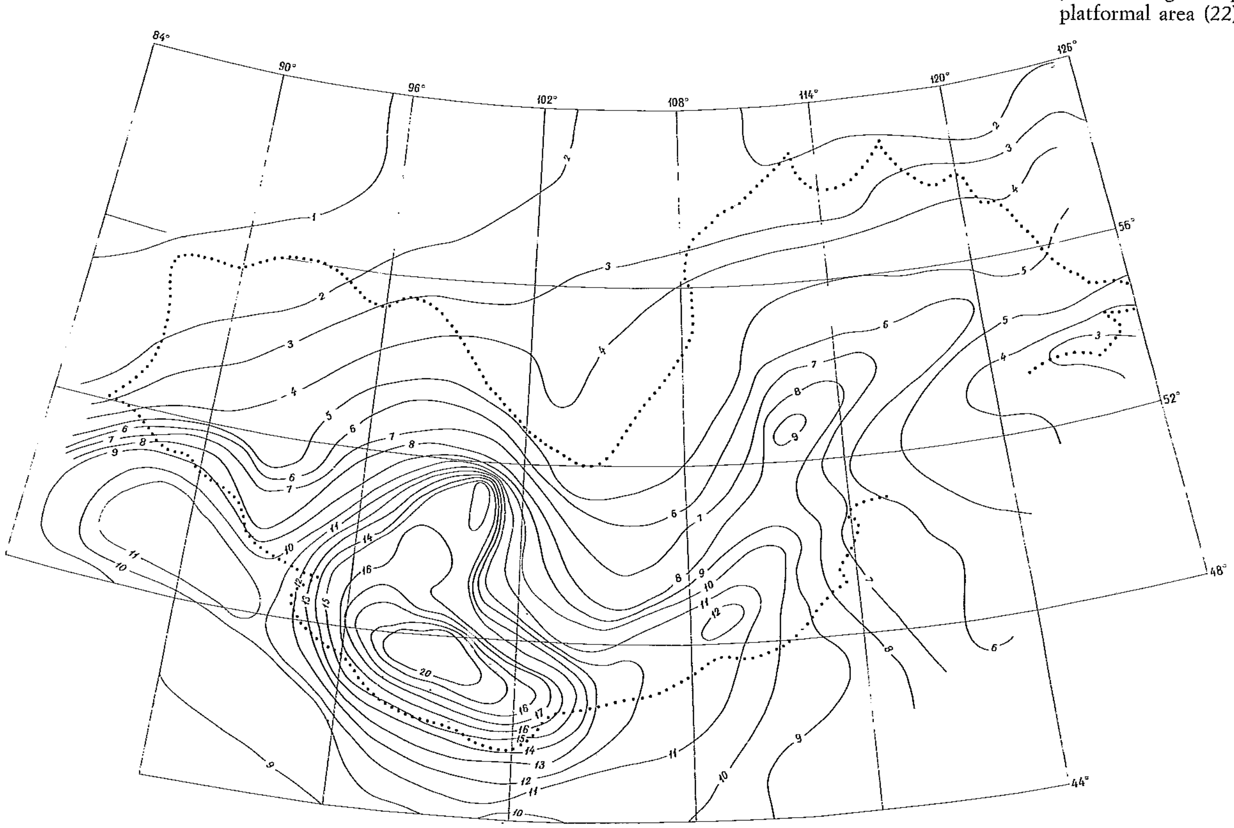

FIG. 3 - Main basic surface of the northeastern part of Inner Asia (socle surface of relief on mountain belt level). Contour lines are drawn in 100 m. A dotted line shows the boundary of Mongolia-Siberian mountain belt.

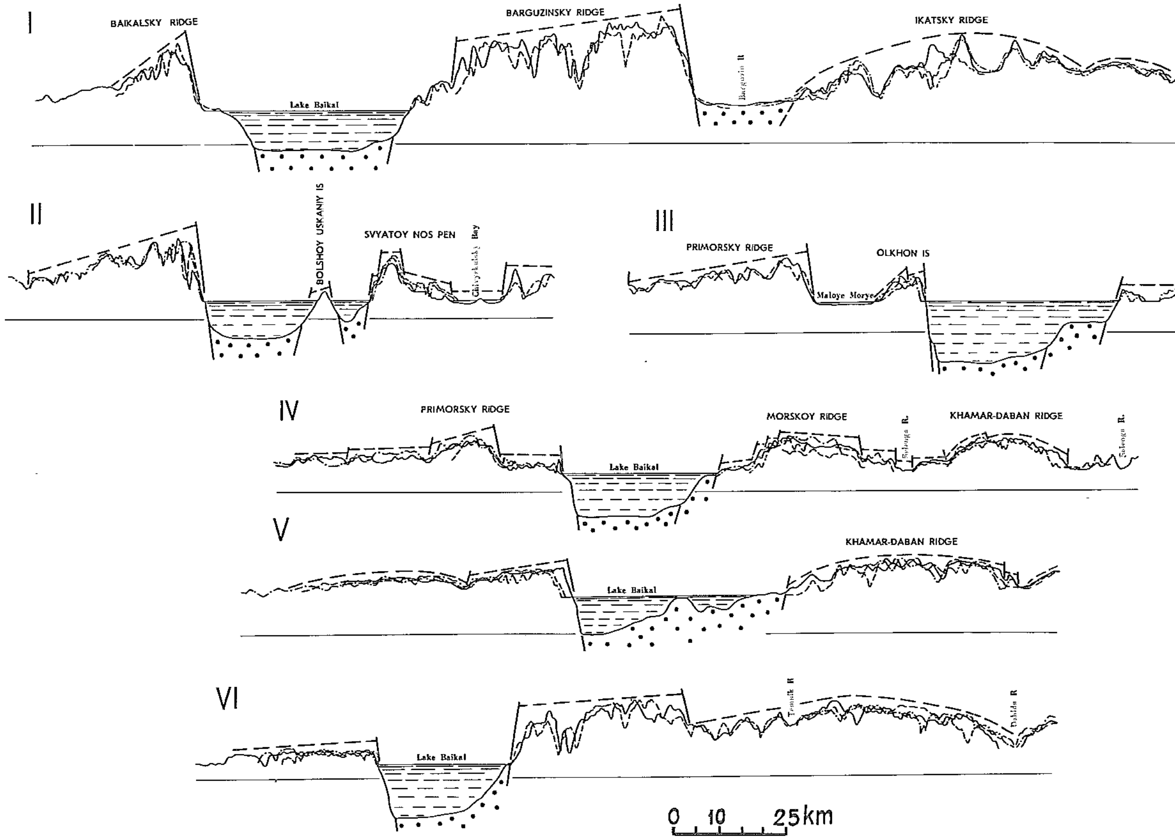

FIG. 4 - Transversal profiles of summit surface of the Baikal rift zone and their structural interpretations on subzone level. Marks show rift valleys (circles) and fields of cenozoic basalts (angles). Vertical scale exceeds horizontal by ten times.

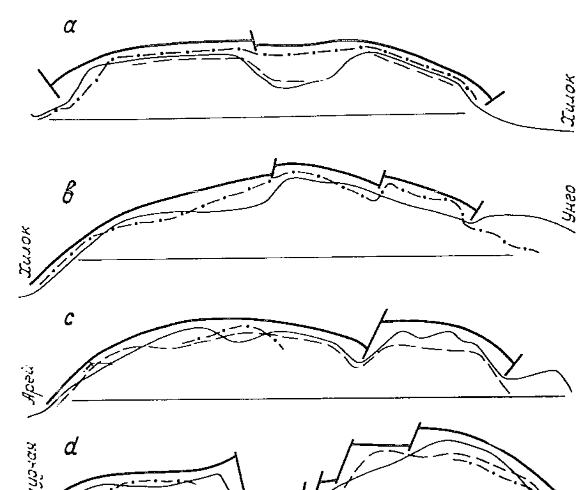

FIG. 5 - Combined transversal profiles of Zaganian (a), Bezymyanian (b) and Malkhanian (c, d) small domes in Selenga-Vitimian zone of linear warping and their structural interpretation (thick lines). Vertical scale exceeds horizontal by ten times.

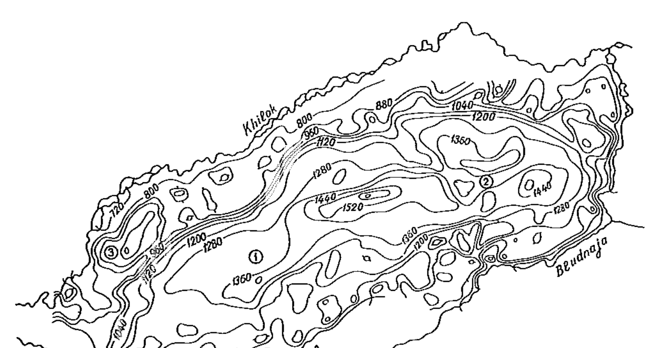

FIG. 6 - Tectonic relief of Bezymyany ridge in Central Transbaikalje: small domal uplift (1) and axial compensative graben (2) in it; separated horsts (3) in intermontane subsidence.

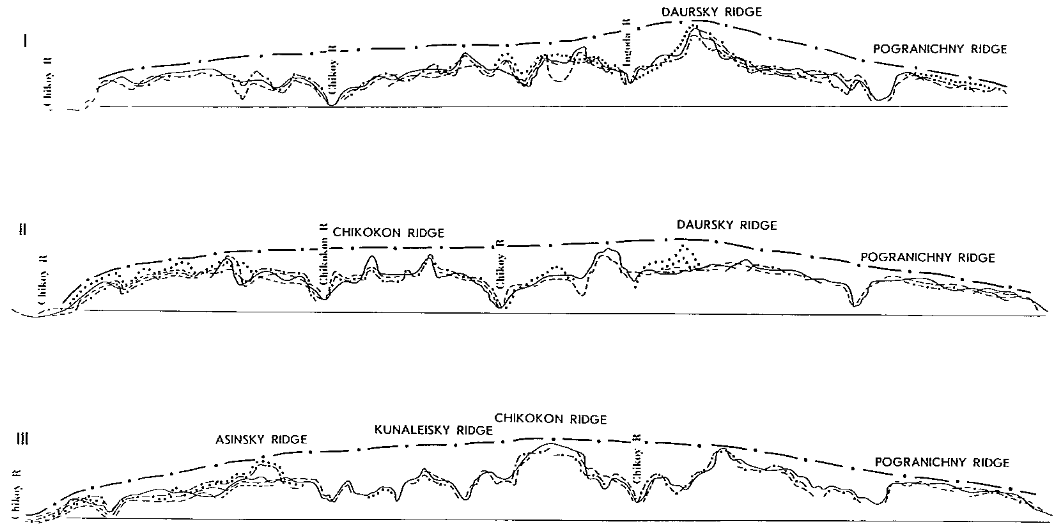

FIG. 7 - Transversal profiles of Khentey mountains and their structural interpretations on neotectonic zone level. Vertical scale exceeds horizontal by ten times.

FIG. 8 - Stepped block uplilt of Chikokon ridge in central part of Khentey-Daurian dome. (Northwestern view).

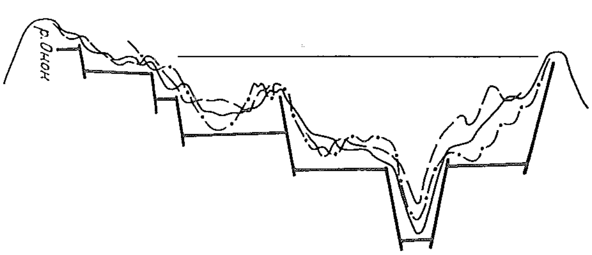

FIG. 9 - Gungurtuy stepped block uplift in central part of Khentey-Daurian dome. Vertical scale exceeds horizontal by ten times.

FIG. 10 - Alkhanian uplift on the south-eastern side of Khentey-Daurian dome. Vertical scale exceeds horizontal by ten times.

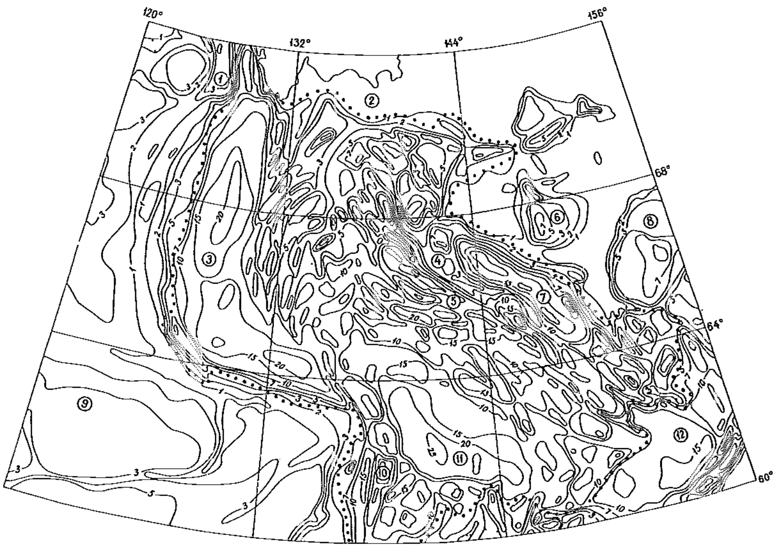

FIG. 11 - Tectonic relief of Verkhoyano-Kolymian mountain belt and cojugative territories. Dotted line: boundary of Verkhoyan-Kolymian mountain belt; circled numbers: neotectonic forms (1 - Chekanovsky range, 2 - Yano-Indigirian lowland, 3 - Verkhoyanian ridge, 4 - Moma-Selennyakhian basin, 5 - Chersky highland, 6 - Alazeyan upland, 7 Momian ridge, 8 - Yukagirian upland, 9 - near-Lena plateau, 10 - Sette-Daban, 11 - Suntar-Chayat highland, 12 - Kolymian highland).

protrusion of anomalous mantle (BALDRIGE (ed.), 1984; MILANOVSKY, 1982).

Well expressed paragenesis of recent structure of orogenic belts of the Mongolia-Siberian type with the elements of structure shows that they have their own sources of development, first of all large asthenoliths. Saturated elements of deep structure ensure: (1) common domal-like uplifts of these mountain belt socles, rifting and compensating the rifting horizontal compression and linear warping of upper parts of the lithosphere. Rapid isostatic uplift of large domes also connects with influence of the asthenolith. Horizontal displacements of contiguous lithospheric plates are the additional factor of structural formation for mountain belts of the Mongolia-Siberian type.

Mountain belts of the Mongolia-Siberian type are located in the inner parts of the continents of Eurasia and North America. They are found along the boundaries of ancient platforms.

CENTRAL ASIAN OROGENIC BELT

The Central Asian orogenic belt is the complex of the zones of linear warping (Altai, Tien Shan, Dzhungar Alatau and others, fig. 12) which frame the central Dzhungarian intermontane plains (UFIMTSEV, 1989). Zones of linear warping have a lens-cellular pattern of faults and consist of the domes (figs. 12, 13, 14) and intermontane basins. Thrusts are widespread on the flanks of the domes. Mountain ridges are linked by intermontane basins in the process of orogenesis (fig. 15). These features of orogenic belt structure illustrate its formation under conditions of horizontal compression and crushing of the lithosphere with longitudinal displacement in the region of the intracontinental collision of lithospheric geoblocks. The Central Asian mountain belt is part of a zone of intercontinental collision of lithospheric plates.

Bilateral symmetry is peculiar to the structure of the Central Asian orogenic belt. This symmetry depends on a homological likeness of the Altai and Tien Shan mountains (fig. 12). It is well expressed in the morphology of the socle surface of the mountain belt (fig. 16). Altai and Tien Shan are located in inclined surfaces of socle with small uplifts in the Russian Altai and West Tien Shan. Inclined surfaces of socle frame a central subsidence located in the Dzhungarian intermontane region (UFIMTSEV, 1989).

Comparison of recent structure with data regarding deep structure lead us to suppose that the Altai and Tien Shan flank systems of zones of linear warping are located above the places of inclined occurrence of the asthenospheric roof. These places are the expression of the inclined socle surfaces of the mountain belt. It can be supposed that inclined parts of the asthenospheric roof are favorable for the crushing of lithosphere, linear warping of its upper layers and longitudinal displacement of blocks under conditions of intracontinental collision. Here the formation of very contrasting mountain relief takes place. Contrary to the Mongolia-Siberian type of mountain belts, firstly convergence and collision of lithospheric plates accompanied by external structure forming geodynamic influence are the main deep structure elements of the Central Asian orogenic belt.

The central Asian mountain belt has no analogy among orogenic belts on continents. Zones of linear warping are widespread in other mountain belts, especially the Mongolia-Siberian type. But here the degree of differentiation of tectonic relief not so great as in the Central Asian mountain belt. Some zones of linear warping separate the north continents. In the Southern hemisphere a system of ridges and basins is located only in the roof of the Andean eastern slope near Cordoba (Argentina). The zones of linear warping are grouped in a large mountain belt with contrasting mountain relief, which includes the depressional Dzhungarian «median mass».

EAST AFRICAN RIFT BELT

Another recent unique orogenic system is the East-African rift belt. Information on morphotectonics from previous papers (ALMOND, 1986; KAZMIN, 1987; LOGATCHEV, 1977; MCCONNEL, 1972; MILANOVSKY, 1969a, 1969b, 1976

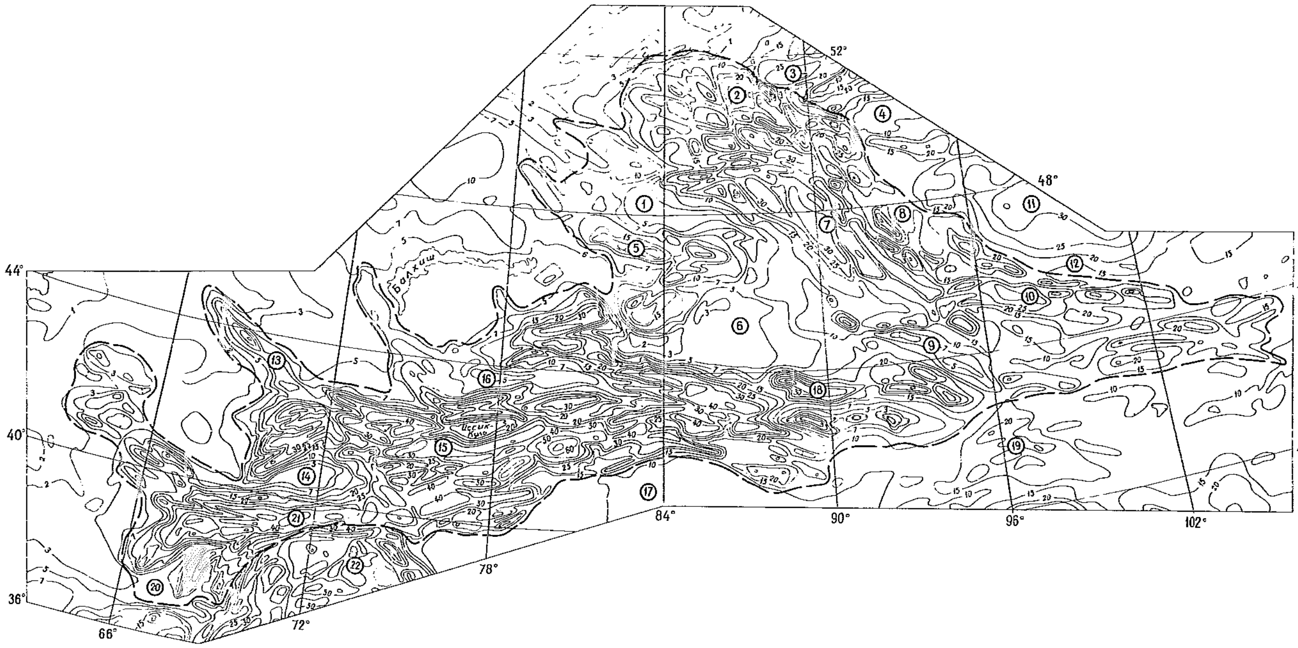

FIG. 12 - Summit surface (tectonic relief) of Central Asia (Altai, Dzhungaria, Tien-Shan and conjugative territories). Dashed line: boundary of Central-Asian mountain belt; Circled number: neotectonic forms (Zajsanian basin (1), Russian Altai (2), Western Sayan (3), Ubsunurian basin (4), Tarbagatay (5), Dzhugaria (6), Mongolian Altai (7), Depression of Large Lakes (8), Dzhungarian Gobi (9), Gobian Altai (10), Khangay (11), Valley of Lakes (12), Karatau (13), Ferganian basin (14), Northern Tien Shan (15), Ilian basin (16), Tarim (17), Eastern Tien Shan (18), Beysnan (19), South-Tajik basin (20), Southern Tien Shan (21), the Pamirs (22).

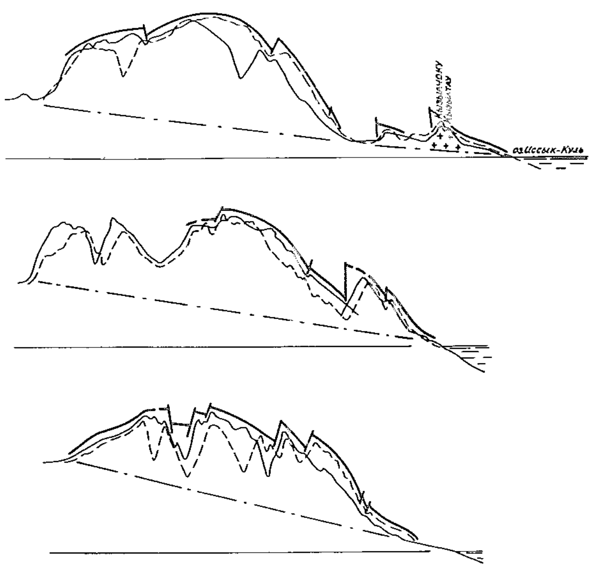

FIG. 13 - Combined transversal faults of Terskey-Alatau ridge and their structural interpretations (thick solid line). Dotted-dashed line: basic ridge surface; 2 - position of Kyzylchoku granitic massif. Vertical scale exceeds horizontal by 5 times.

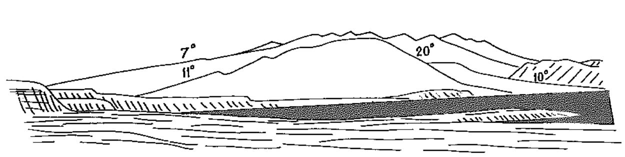

FIG. 14 - Profiles of the eastern part of Kirghiz ridge. (Eastern view).

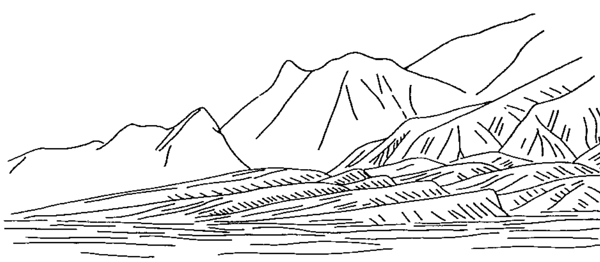

FIG. 15 - Incline uplifted marginal part of Issyk Kul basin (foreground) in front of Terskey-Alatau near vil. Tona. (View from the West).

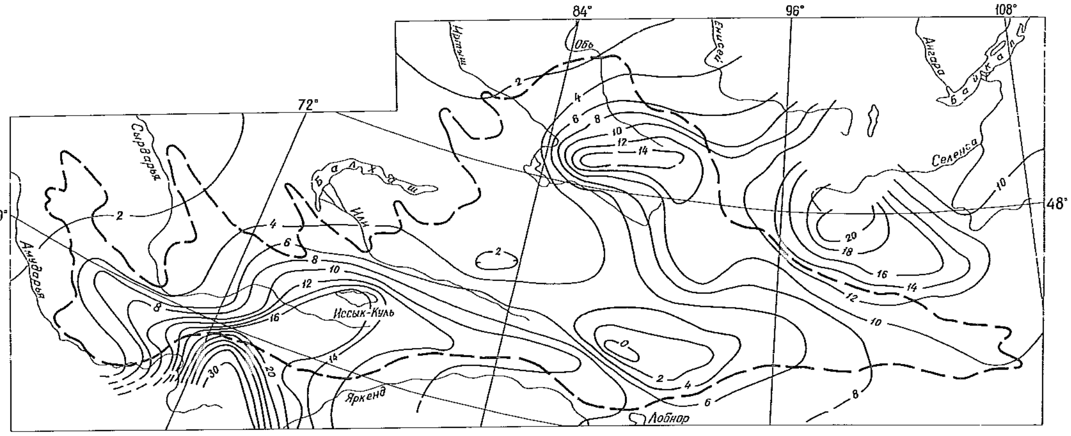

FIG. 16 - Main basic surface of Central Asia (socle surface of relief on level of mountain belts). Contour lines are drawn in 200 m. Dashed line shows boundary of Central-Asian mountain belt.

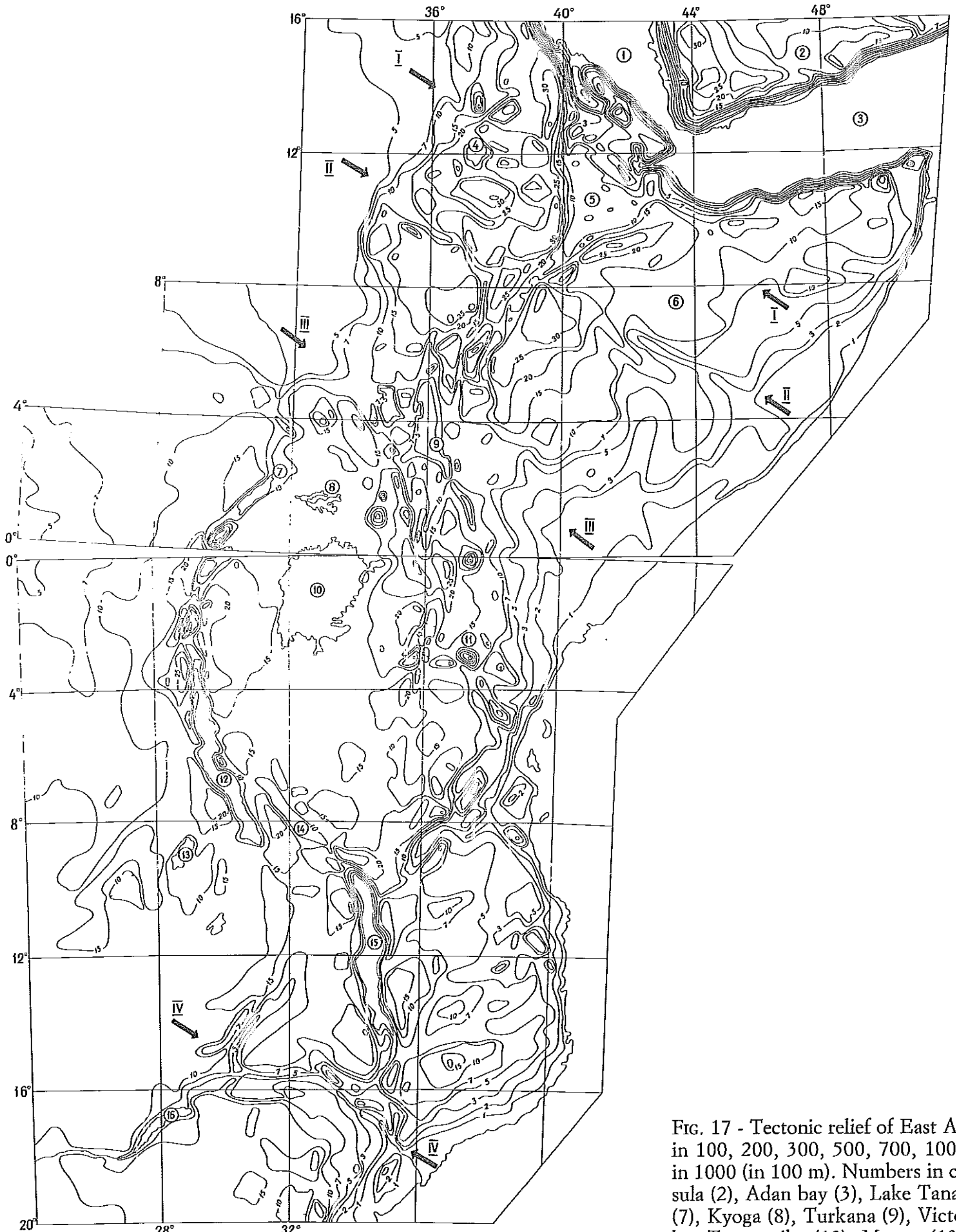

FIG. 17 - Tectonic relief of East Africa. Isolines of tectonic relief are drawn in 100, 200, 300, 500, 700, 1000, 1500, 2000, 2500, 3000 m and over in 1000 (in 100 m). Numbers in circles show: Red Sea (1), Arabian peninsula (2), Adan bay (3), Lake Tana (4), Afar (5), Ogaden (6), Lakes Albert (7), Kyoga (8), Turkana (9), Victoria (10), mountain Kilimanjaro (11), lakes Tanganyika (12), Mweru (13), Rukwa (14), Malawi (15) and Kabira reservoir (16). Arrows show largest systems of transversal faults.

are represented in fig. 17, scheme of the East-African tectonic relief, allow a generalized characterization of this orogenic belt. Let us consider the sharp difference between morphology of tectonic relief of the Red Sea, Aden Gulf and Ethiopia regions on the one hand, and areas on the Lake Turkana latitude on the other. In the Red Sea region we can see a classic form of the rift system: the central Red Sea rift cuts an extensive domal uplift along one axis, at the terminations of this rift, two rift valleys branch off it, so complicating the periclines of the dome. The genetic sequence of rift valleys, the rift valleys of Central Ethiopia, Afar, Akaba and the Suez rifts, the Red Sea and Aden bay rifts represent all the stages of rift genesis with the break of continents and divergence of continental massifs and the creation of the mid-oceanic ridge. On the continent and on sea areas there are widespread transversal transform faults, which are very visible in Ethiopia and Somalia in accordance with the generalized model of tectonic relief (fig. 17).

In the Ethiopian-Red Sea region we see a well-conserved group of morphotectonic elements, gigantic domal uplift with rifts, which is the result of continental break-up and the initial stages of formation of the oceanic rift system.

We have another situation south of Lake Turkana though the main structure-forming elements of the recent tectonics of this region are also rift valleys. We can consider the similarities between the East-African rift system and the southwest part of the Ethiopian-Red Sea rift belt.The boundaries between them are defined by a large transversal depression with a north-western strike, called the Turkana depression (ALMOND, 1986). This transversal depression is similar to the transform faults of the Ethiopian-Red Sea intercontinental rift system (fig. 17). The Turkana depression borders this rift system in the southwest. It is well expressed in the tectonic relief (fig. 17) and the deformation of separate denudational surfaces (KING, 1983). Located here rift valleys (the Turkana rift and oth.) are deprived of shoulder-counter uplifts which are inclined horsts, accompanying other rifts of East Africa.

There is another transversal linear system located along the Zambesi valley (fig. 17) and limited to a region of rift valleys in the south. They form the East African rift belt. It has a complicated structure. There are two rift systems (Eastern and Western) framing the median high plain («interrift») massif of the lake Victoria region. The East-African rift valley system has a Y-like configuration.

The western and eastern rift systems of the East-African belt are attributed by Milanovsky (1969) to different types. The significance of large accumulative massifs (Kilimanjaro, Mt. Kenya) is important for the morphotectonics of the eastern part of the rift belt. Thus, tectonic features are better expressed in the western rift system and the Malawi (Niassa) rift zone.

The marginally inclined horsts and the central rift valleys define a bilateral symmetry of the East-African rift zone. Such a structure is commonly intepreted as domal uplift with complication by rifts along the axial surface. But the question regarding the primary nature of rift valleys or, indeed the domal uplift in general, is very complex. On one hand we see the mature rift valleys and morphologically young inclined horsts on their border and rejuvenation of drainage systems after the uplift of this horst. This is the situation on the eastern low shoulder of the Albert rift (OLLIER, 1984). The another situation is between the Rukva and Malawi rifts where domal uplift is out by a narrow rift valley.

Transcurrent faults are less important in the morphotectonics of the East African rift belt than in the Ethiopian-Red Sea rift system (fig. 17), and emphasizes structural differences between the East African and Ethiopian-Red Sea rift systems. The former is a part of continental morphotectonics, and the latter is part of an intercontinental formation. Structural isolation of these forms is expressed in the relief of the socle surface (fig. 18). The East African rift belt has a common domal-like uplift of the socle surface where in the central part of the median plain «interrift» massif of the Victoria lake region is located. Rift valleys are situated in the upper and median parts of marginal slopes of this socle uplift.

Bilateral symmetry is peculiar to the structure of the East African rift belt: a Y-like combination of rift zones frames the median high-uplifted plain massif. This structure of rift belts may be defined by the following combination of deep structure elements: (1) common uplift of the asthenosphere roof and (2) its local subvertical protrusions with steeply dipping borders which are located under marginal subsidences of (1). The last aspect has some similarity with some features of bilateral symmetry of the East African rift zones, in contrast to the Baikal rift zone (figs. 1, 4, 17).

The East African rift belt is unique in two respects: (1) it is the only rift belt on the continents of Earth which oc-

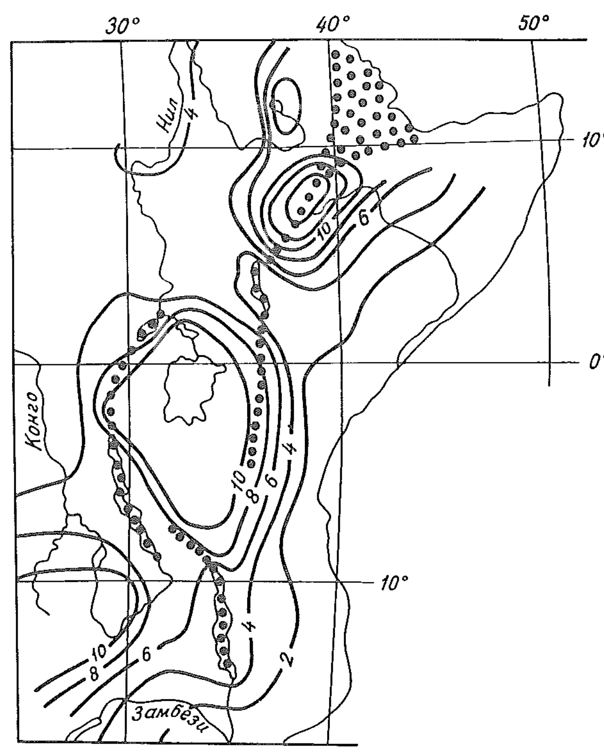

FIG. 18 - Main basic (socle) surface of relief of East Africa and largest rift valleys located there (shown by circles). Isolines of tectonic relief are drawn in 200 m.

cupied an area of nearly 2.2 mln km²; (2) it is also the only recent intracontinental rejuvenated orogenic belt in the southern continents, fragments of Gondwanaland. Within Gondwanaland there are no other rejuvenated orogenic belts.

URAL-APPALACHIAN OROGENIC BELT TYPE

The morphological likeness of the Ural and Appalachian Mountains and their identical position in the relief of the continents has been well documented in the literature (HAIN & MILANOVSKY, 1956; FLORENSOV & UFIMTSEV, 1984).

These mountain structures are located between platforms of different ages and have considerable extension with narrow width. The Urals together with the structures of Novaya Zemlya island extend for more than 3000 km, and its width is more than 250 km. In the Ural mountains the width of the northern part is no more than 100 km (fig. 19). The linear form of this mountain belt and its location along the boundary of platforms of different ages indicate its structural origin. The same can be said for the Appalachian mountains.

The Ural morphology of the tectonic relief shows the prevalence in it of block neatectonic forms. In the Northern Urals, the Polar Urals, where the mountain belt has a narrow width, prevale block uplifts dividing along the strike of the transversal and obliquely cross-cutting faults which are expressed by narrow dissected depressions of tectonic relief (fig. 19). These faults exceed rare bounds the mountain belt what points out a presence of extensive marginal faults. On the eastern slope of the North Urals they form high tectonic escarpments which have no basal facets. This explains why marginal faults dip under the mountain belt. There are also well-known thrusts and upthrow faults by which the rocks of the basement overthrust onto Mesozoic-Cenozoic deposits of the marginal part of the young West Siberian platform. In the axial part of the mountain belt extruded ultrabasite rock massifs often form high horsts. This shows that formation of the Urals recent structure is the result of horizontal lithospheric compression (TRIFONOV & *alii*, 1970).

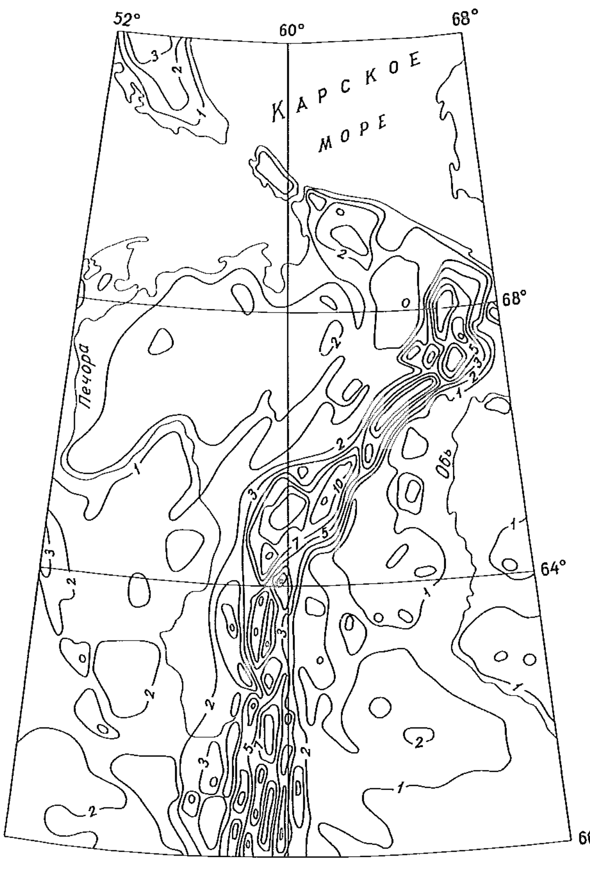

FIG. 19 - Tectonic relief of North and Polar Urals and adjacent terrains. For explanation see figure 1.

In the South Urals the recent structure is characterized by the presence of a series of subparallel narrow horsts located on a commonly uplifted socle. The recent structure of this part of the mountain belt has an analogy with the block uplift of the Sette-Daban Ridge located near the southwestern margin of the Siberian platform. The North and Polar Urals are similar to the Tukuringra-Dzhagdinsky uplift in the near-Amur region in terms of structure (UFIMTSEV, 1984). All these neotectonic forms refer a sutural type. All of the features of the Ural mountain belt, such as its linear form and location on the boundary of platforms of different ages isolated from other mountain structures testify that the Ural mountain belt is also a gigantic neotectonic form of the sutural type occurring due to a rapprochement of two large geoblocks (lithospheric plates) and «hummocking» of the lithosphere on their boundary. The peculiarities of tectonic relief of the mountain belt primarily indicate a displacement of the Russian platform to the east.

Proceeding from the computations of geothermal anomalies (CHERMAK, 1982) the Ural mountain belt is a geomorphic expression of two neighbouring geoblocks with different lithospheric thicknesses. This mountain structure is located above the line of inclined occurrence of the lithospheric foot. Here we have a situation where a gradient zone in the relief of the asthenospheric roof promotes crushing and hummocking of the lithosphere under the influence of a horizontal compression.

EAST-ASIAN OROGENIC BELT TYPE

In the eastern margin of Eurasia where rejuvenated and renewed mountains are located near the marginal sea basins of the Pacific Ocean, there are mountain belts of another type. Asymmetric block uplifts (the Kolymsky, Dzhudzhur, Sikhote-Alin and other ridges) are the main elements of these mountain belts (fig. 20). The margin-continental mountain belts of the «East-Asian type» include some other forms: zones of basins and uplifts, large basins and original marginal continental rift zones (fig. 21).

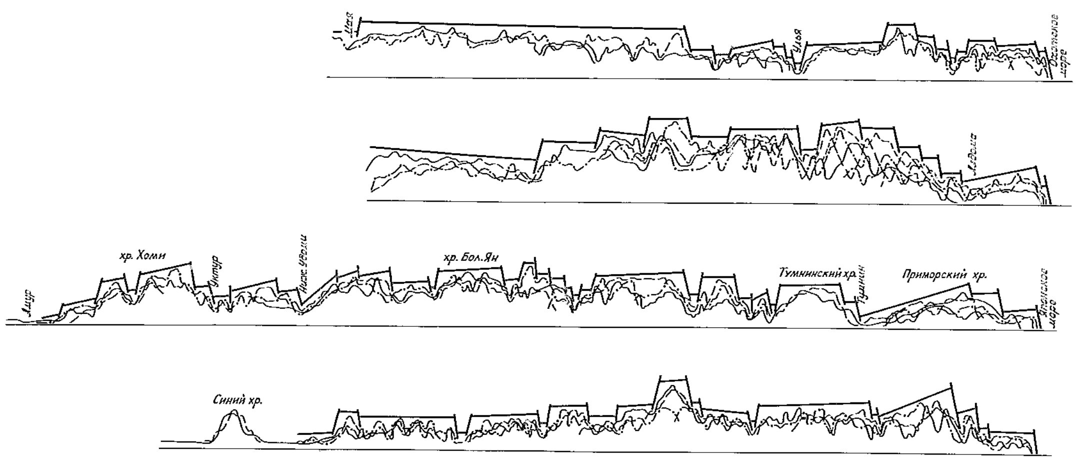

FIG. 20 - Transversal profiles of Dzhugdzhurian (above) and Sichote-Alin (below) block uplifts and their structural interpretation (thick solid lines). Vertical scale exceeds horizontal by ten times.

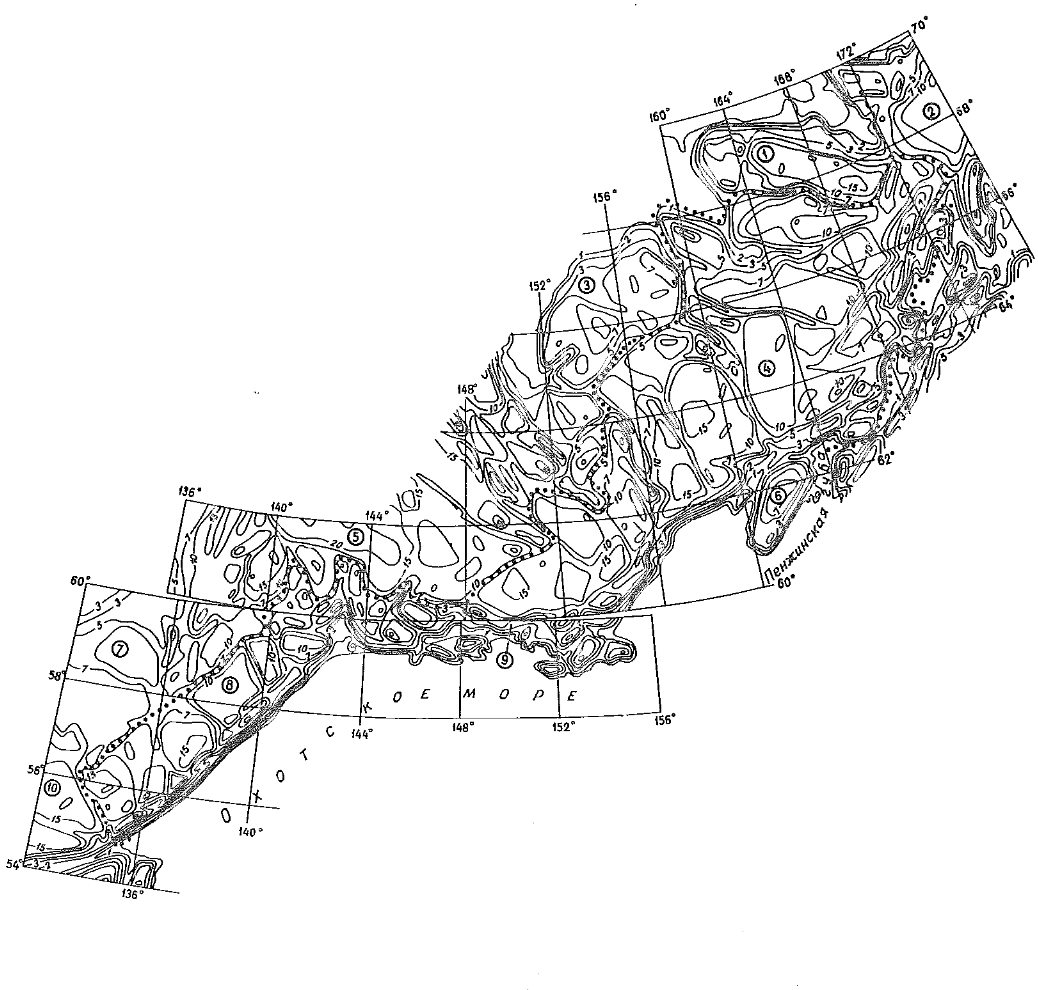

FIG. 21 - Tectonic relief of Okhotsk-Chukotsk mountain belt (dotted line shows boundaries). The isolines are drawn at 100, 200, 300, 500, 700, 1000, 1500, 2000 (in 100 m). Numbers in circles show: Rauchuanian uplift (1) and West-Chukotsk dome (2), Yukagirsk uplift (3), Kolymian block uplift (4), Suntar-Hajata dome (5), Taygonossian stepped block uplift (6), southeastern margin of Siberian platform (7), Dzhugdzhurian block uplift (8), near-Okhotsk margin-continental rift zone (9) and Stanovoy dome (10).

In the eastern margin of Eurasia there are two mountain belts of this type. The Okhotst-Tshukotian orogenic belt includes the Kolymian and Dzhugdzhur asymmetric block uplifts. The rift zone near Okhotsk in the Magadan region and combinations of block forms (zones of horsts, block uplifts and faul-block valleys). The second mountain belt includes the Sikhote-Alin and Korean asymmetric block uplifts, zone of uplifts and basins of North-East China, complexes of block forms of the near-Amur region. Southward, perhaps, there is another mountain belt of the East-Asian type including block uplifts of South-East China and Vietnam.

The structure of mountain belts of the East-Asian type has some peculiarities. Between large block uplifts there are great ruptures in the form of dissected depressions of tectonic relief or zones of horsts and graben valleys, for example, the rupture between the Sikhote-Alin and Korean uplifts. The Okhotsk-Chukotian orogenic belt is typical. Large asymmetric block uplifts which have the paragenetic links with the Mesozoic margin-continental volcanic belt are the basis of the East-Asian type of orogenic belt (figs. 20, 21). These uplifts have wide northwestern flanks with gentle slopes to the intracontinental areas. There are prevailing transversal faults having a northwestern strike. The flanks of asymmetric uplifts, located opposite, have high tectonic scarps with small basins and block uplifts along the foot of the scarps (figs. 22, 23). They are geomorphic expression of deep faults of the Mesozoic volcanic belt. Here longitudinal faults prevale. High scarps face the marginal sea basins (UFIMTSEV, 1984).

Southward of the Kolymian uplift there is a particular margin-continental rift zone. It is a system of large grabens and block uplifts (fig. 24) extending in a narrow stretch of the Earth's crust thinning out along the boundary of the Okhotsk margin sea basin. At the margin of the latter occur more ancient analogical rift zones have ceased active development and are overlain by sea sediments. On the northern coast of the Okhotsk sea we can see an early stage of the Earth's crust extension and outhinning of the continental margin. This process stipulates and expansion of margin sea basins.

On the opposite (continental) flank of the Okhotsk-Chukotian mountain belt large block uplifts are often accompanied by systems of horsts and fault-block valleys. The differentiation of tectonic relief here is stipulated by active autonomous uplifts of geological bodies, mainly of young granitoid massifs composed of low density rocks. This stipulates an isostatic uprising of granitoid massifs and complication of tectonic relief.

Analysing the formation of mountain belts of the East-Asian type is important to favour the following conditions. These mountain belts attend by extensive regions of subsidence of shelves and deep-sea basins of the marginal seas and zones of tension and outhinning of the earth's crust along their boundaries.

Thus, these mountain belts interact with the regions with a prevalence of rift or rift-like geodynamic conditions. Structure-forming elements of the East-Asian type of mountain belts are asymmetric block uplifts falling to the side of marginal seas with high and longitudinal

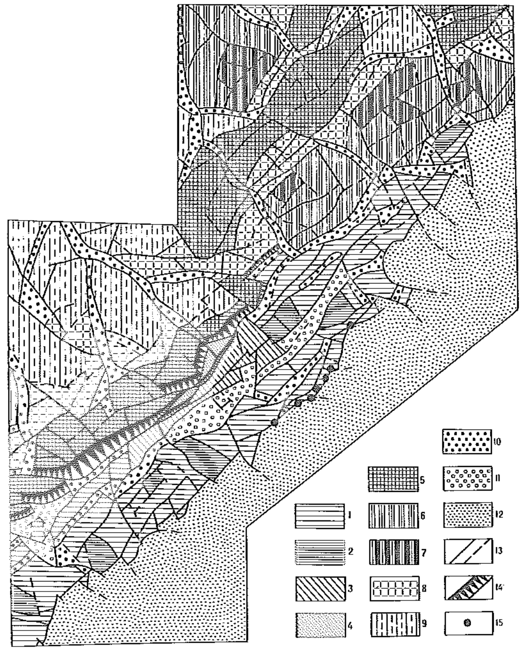

FIG. 22 - Scheme of morphotectonics of Dzhugdzhur ridge in the Ayan region. Coastal subzone: 1-2 - linear or elongated block up-lifts and their high steps (2); 3-4 - piedmont inclined step and its uplifted blocks (4). Main step of Dghugdzhur uplift: 5 - Linear horsts of axial part of uplift; 6-7 - isometric uplifts and their upper steps (7); 8 - block fields; 9 - weakly elongated transversal uplifts of «structural capes» type; 10 - fault-block valleys; 11 - intramontane basins; 12 - shelf plain-platform region; 13-14 - recent faults and high frontal scarps of Maior step (14); 15 - fault-collapses of seismogenic origin.

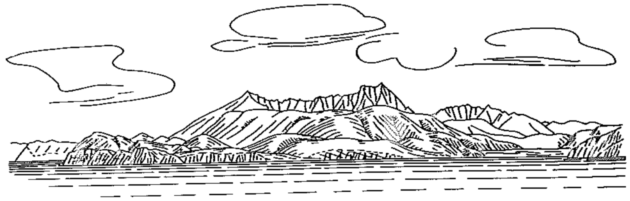

FIG. 23 - Myadali stepped block uplift on the north-western coast of Okhotsk Sea near port Ayan. (Northeastern view).

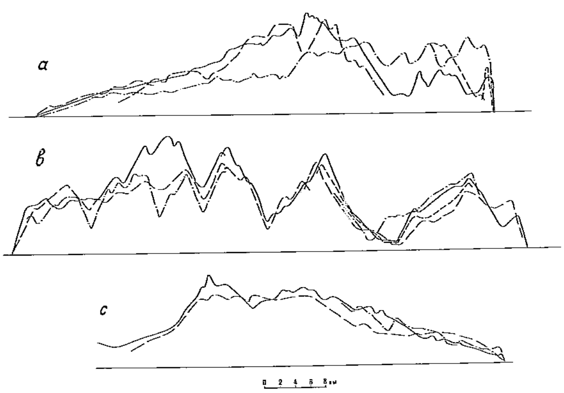

FIG. 24 - Mountain uplifts on the northern coast of the Okhotsk Sea, on Koni peninsul (A, B) and Pyagin peninsula (C). Vertical scale exceeds horizontal by 5 times.

tectonic scarps. These uplifts have an analogy with the raised edges of the Gondwana land continents and subcontinents, with the inclined horst of the western edge of the Arabian peninsula, for example with West Ghatts of peninsular India and Great Divide Ridge in the east of Australia (OLLIER, 1984), which can be due either to intercontinental rifts or regions of tension, or intensive subsidence of the oceanic earth's crust. This leads us to suppose that the symmetry of block uplifts is a morphological response to tension of the earth's crust and intensive subsidence within marginal sea basins. Formation of the marginal continental mountain belts of the East-Asian type can be considered as a reaction of «steady» continental edges to intensive subsidences in marginal sea regions of the Pacific ocean.

This is not the only reason for the formation of the Dzhughzhur, Sikhote-Alin and Kolymian asymmetric large block uplifts. There are other geodynamic factors. The presence of numerous intrusions and volcanic-tectonic structures composed of rocks of low density, was the reason for atonomous uplifts of geological bodies (UFIMTSEV, 1984). It ensures a considerable differentiation of tectonic relief at the margins of block uplifts forming the base of the marginal continental mountain belts of East Asia. These block uplifts differ from uplifted edges of Gondwanaland continents by a high degree of complication of tectonic relief.

GEODYNAMICS OF REJUVENATED OROGENIC BELTS

The rejuvenated mountain belts of continents vary greatly in structure and geodynamics. There are basic and additional elements and element-inclusions in the structure of every mountain belt. Plain-platformal intermountain inclusions in the Central Asian mountain belt and in the East African rift belt are of this kind. Basic elements define the structural peculiarities of mountain belts of one or another type without these mountain belts losing their qualitative features. Additional elements of recent mountain belt structures increase their sizes without bringing to them the important qualities.

Mountain belts of the Mongolia-Siberian type, rift zones, zones of linear warping and large domal uplifts, have the most numerous range of basic structural elements. Rejuvenated mountain belts of other types have, as a rule, only one structure-forming element: rift zones in the East African belt; linear sutural block uplifts of the Ural-Appalachian type; large asymmetric block uplifts of mountain belts of the East-Asian type. The recent structure of the Central Asian mountain belt is defined by zones of linear warping and in the western part of this mountain belt large intermontane basins have a structure-formation meaning, for example the Fergana basin.

Reasons for the formation of rejuvenated mountain belts are numerous and cannot be reduced to the simple scheme: (1) horizontal displacement of geoblocks (lithospheric plates) or (2) uplifts of the asthenospheric roof or to forming of asthenoliths.

Environmental factors define an origin of the Central Asian mountain belts, Ural and Appalachian uplifts (collision of lithospheric plates) and mountain belts of the East-Asian type (the Earth's crust tension and the forming of margin sea basins). The dominating influence of energy saturation of deep structural elements on recent orogenesis is peculiar to the mountain belts of the Mongolia-Siberian type and the East-African rift belt. Large uplifts of the anomalous mantle roof define common domal-like uplifts of a mountain belt socle, and dike-like protrusions of anomalous mantle reaching the Moho surface, stipulate development of the rift zones.

The importance for recent orogenesis of elements of deep structure such as stretches of inclined occurrence of the asthenospheric roof. Certainly, these discourses have probable character because of fragmentary data on deep structure. In regions of primary horizontal lithospheric shortening (intracontinental collision of lithospheric plates) just above gradiental zones of asthenospheric roof there is the formation of zones of linear warping with great variations in the elevation of tectonic relief and contrasting combinations of mountain uplifts and basins. These are zones of crushing and clustering of the lithosphere. In other cases, with no great changes in the depth of the asthenospheric roof, no high block mountain belts of a sutural type form, for example the Urals.

Another situation is in mountain belts which are not testing an essential environment geodynamic influence. Here, on the slope of the asthenospheric roof protrusion of anomalous mantle form and they define an occurrence of the rift zones. If protrusion of anomalous mantle lift from the upper part of the asthenospheric roof and a rift zone with bilateral symmetry is formed (East-African rift belt and Khubsugulian link of the Baikal rift zone). If the protrusion of anomalous mantle lifts from the foot of the slope of the asthenospheric roof, as in the Baikal rift zone, so we fix another symmetric peculiarities of recent structure of rift zones (longitudinal axis of antisymmetry of second order).

Geodynamic conditions for the formation of rejuvenated orogenic belts of different types are shown in figure 25.

MOUNTAIN BUILDING AND BASIN FORMING

We can consider the most important problem of epiplatform orogenesis, the problem of basin forming and mountain building. In rift zones, the Baikal rift zone for example, this problem has quite a simple solution. The formation of rift valleys defines a development of mountain uplifts located near them (rift shoulders). This is an essence of residual-horst or Baikal orogenesis (FLORENSOV, 1965), in which the basin forming is the main geodynamic peculiarity.

Another situation must be taken into consideration when studying zones of linear warping. Their recent structure, especially in the Central Asian mountain belt, is the result of dome-block or Gobian orogenesis (FLORENSOV, 1965), in which mountain build in height and lateral due to contiguous intermontane basins which created in domal uplifts.

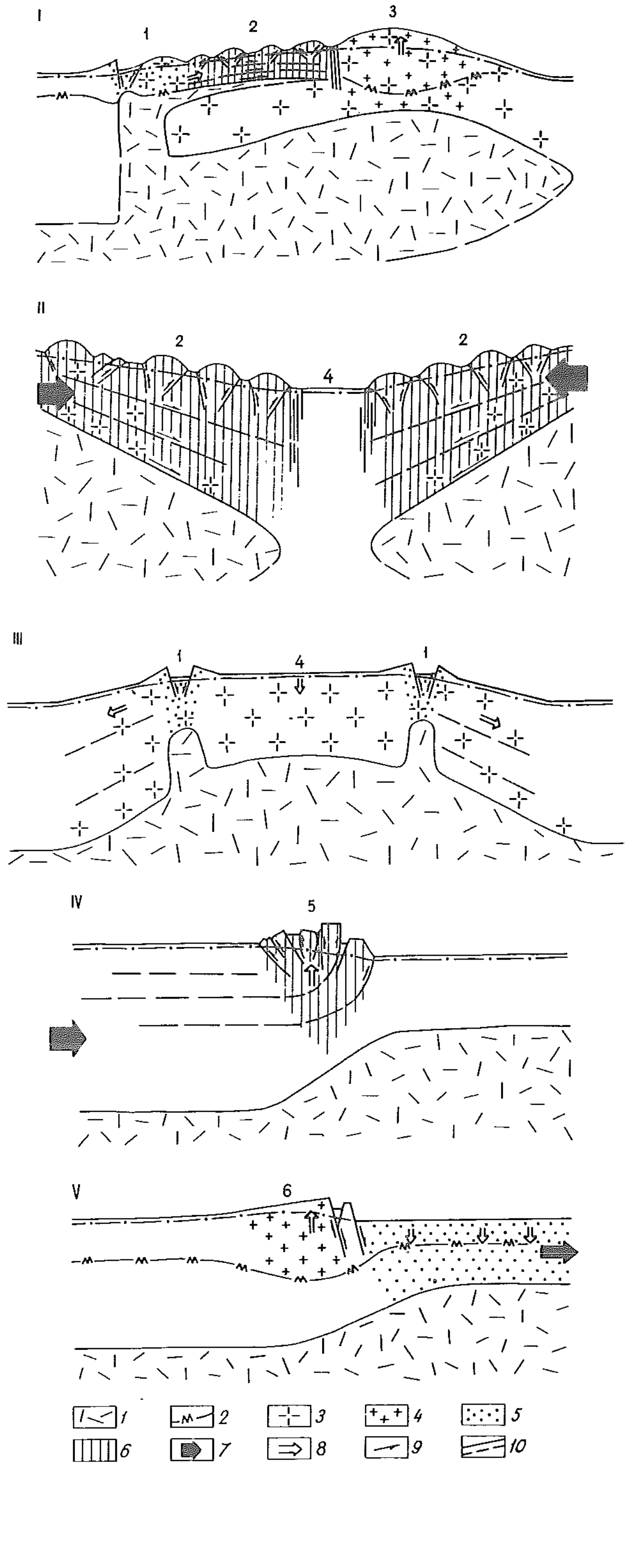

FIG. 25 - Models of formation of recent rejuvenated orogenic belt of the Mongolia-Siberian type (I), Central-Asian mountain belt (II), East-African rift belt (III), mountain belts of ural-appalachian (IV) and east-asian (V) types. 1 - asthenosphere, 2 - Moho surface; 3-6 - lithosphere, also its more warmed parts above asthenoliths (3), parts formed by rocks of low density (4); parts are experienced horizontal tension (5) or compression (6); 7 - directions of displacement of lithospheric plates; 8 - directions of displacement of geoblocks in lithosphere; 9 - directions of displacement of active flanks of faults; 10 - major fractures.

Geomorphological data characterize a geodynamics of zones of linear warping for the time of post-active basin formation. Basins are filled with sediments which are the analogy of geological formations of the Cenozoic rift zones. Thus, we think that the geodynamics of zones of linear warping are an interchange of rifting and domal block uplift stages.

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