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GENNADI F. UFIMTSEV (*)

MORPHOTECTONICS OF THE BAIKAL RIFT ZONE (U.S.S.R.)

Abstract: UFIMTSEV G. F., *Morphotectonics of the Baikal rift zone (U.S.S.R.)* (IT ISSN 00391-9838, 1990).

The Baikal rift zone is the northern wing of the Mongolo-Siberian rejuvenated orogenic belt. Longitudinal faults and transverse transformal faults usually being dextral displacements are of great importance in its recent structure. The Baikal rift zone and that located south-eastward the Selenga-Vitim zone of linear warping have the common systems of transverse faults.

The rift zone consists in subzones: (1) rift valleys, uplifted inter-basins and large tectonic steps, (2) systems of inclined horsts - rift shoulders, (3) inner block uplifts and (4) arch curve of the south-eastern wing. The rift zone structure has high symmetry and paragenetic link with the deep-seated structure.

Cenozoic geodynamics of the south of East Siberia is characterized by: (1) tension of lithosphere in the Baikal rift zone above the anomalous mantle protrusion; (2) displacement of lithospheric blocks to the south-east above subhorizontal layer of anomalous mantle; (3) compression of lithosphere, linear warping of its undersurface parts and formation of thrusts in the Selenga-Vitim zone.

KEY WORDS: Morphotectonics, Baikal rift zone, East Siberia.

Riassunto: UFIMTSEV G. F., *Morfotettonica del rift del Baikal (U.R.S.S.)* (IT ISSN 0084-8948, 1990).

La zona del *rift* del Baikal è l'ala settentrionale della catena orogenica ringiovanita mongolo-siberiana. Una grande importanza nella sua strutturazione recente va attribuita alle faglie longitudinali e a quelle trasversali trascorrenti che normalmente provocano movimenti destri. Infatti la zona a *rift* del Baikal e quella situata a Sud-Est del tratto Selenga-Vitim di una fascia a inarcamento lineare hanno in comune sistemi di faglie trasversali.

Il *rift* si compone di alcune parti: (1) fosse, bacini interni dislocati e grandi gradini di origine tettonica, (2) sistemi di pilastri inclinati (3) blocchi interni sollevati, (4) porzione dell'arco della catena Sud-Orientale. La zona del *rift* ha una elevata simmetria e una relazione paragenetica con la struttura profonda.

La dinamica terziaria della porzione sud-orientale della Siberia è caratterizzata da: (1) tensioni nella litosfera della zona del *rift* del Baikal al di sopra di anomale protrusioni del mantello; (2) dislocazioni di blocchi litosferici verso Sud-Est sopra scorrimenti suborizzontali di mantello anomalo; (3) compressione di litosfera, inarcamento delle sue parti sottocutanee e formazione di *thrusts* nella zona Selenga-Vitim.

TERMINI CHIAVE: Morfotettonica, Area di frattura (*rift*) del Baikal, Siberia Orientale.

(*) *Institute of the Earth's Crust, 664033 Irkutsk, USSR.*

INTRODUCTION

The Baikal rift zone is located in the northern segment of the Mongolo-Siberian orogenic belt. The north-western wing of the rift borders the Siberian platform or the neotectonic forms which are transitional from the area of mountain building to the platform. To the South-East is the Selenga-Vitim zone, which is a combination of arches and intermontane basins (FLORENSOV, 1960; UFIMTSEV, 1984). The latter are filled with Upper Jurassic - Lower Cretaceous carboniferous molassa in formational respect similar to Cenozoic sediments of rift zone basins. This indicates that the Selenga-Vitim zone rifting was (BOGOLEPOV, 1979) followed by sub-horizontal compression. The latter is substantiated by arcogenic thrusts at the wings of small arches (UFIMTSEV, 1984).

The complex model of rift zone morphotectonics and zone surroundings includes the common geographical scheme with mapped rift zone boundaries (fig. 1), map of tectonic relief (relief without the erosional forms) (fig. 2), scheme of the morphotectonic elements of the south of East Siberia and North Mongolia (fig. 3), map of the socle surface of relief, which is built upon the position of basin bottoms and talwegs of large valleys (fig. 4) and transverse profiles across the rift zone (fig. 5). The model of Cenozoic geodynamics will be represented in the final part of the article.

The south-western termination of the rift zone, i.e. its Khubsugul segment, is located in the interior part of the Mongolo-Siberian orogenic belt (fig. 2, 3). The segment is characterized by peculiarities of morphotectonics and seismic regime (fig. 5-VI) (MISHARINA & SOLONENKO, 1981). In the seismic focus the sub-horizontal compression is marked.

Longitudinal and transverse faults are prominent in the structure of the Baikal rift zone. The longitudinal faults are usually longliving. In the Late Cenozoic they were faults with a shift component. The transverse faults are also of great importance in the structure of the rift zone (UFIMTSEV, 1984). These are systems of echelon-like faults with the NW strike or united long faults of the Main Sayan fault type. Most transverse faults are dextral shift. The Baikal rift zone and the Selenga-Vitim zone of linear warping have common systems of transverse faults well-expressed in the tectonic relief (fig. 2, 3, 6). The main ones in the structure are the Olekma-Amur belt of transverse faults controlling the NE termination of the rift zone (1), the system of faults between the North Baikal and the Upper Angara basins (2), the Main Sayan fault and its SE continuation (3), the system of faults at the SW termination of the rift (4). The transverse faults divide the rift into sections and in its structure they are transform faults.

The recent structure of the Baikal rift zone consists in few types of neotectonic forms. Combinations of these structural elements form the following subzones (fig. 3): systems of intermontane basins and interbasin links and large steps (1), complexes of inclined horsts and asymmetric block uplifts at the NW wing (shoulders of the rifts) (2), the marginal arch of the SE wing (3), inner block uplifts (4). In the Tunka rift valley the main elements of rift zone structure are clearly seen (fig. 7).

SYSTEMS OF INTERMONTANE BASINS

The subzones of intermontane basins and interbasin uplifts and large tectonic steps are the basin of the rift zone recent structure. They are linear chains in which these structural elements alternate along their strike. Additional elements are intermediate steps at the slopes of the basins. The largest basins are 50 km wide and over. Their length may exceed 200 km. They are filled with Oligocene-Quaternary sediments up to 6000 m thick according to the geophysical data (South Baikal basin) (ZORIN, 1971). In the Cenozoic section of the Tunka rift valley basalt covers and tufogenic formations play a significant role (FLORENSOV, 1960; LOGATCHEV, 1968). The basins are deep asymmetric downwarps with steep NW and N slopes formed by faults. Synclines with gently sloping wings alternate with relative uplifts along the strike of the rift valleys (fig. 8). Some basins are the alternation of blocks with different deepths of basement bedding, divided by transverse faults. The example of this situation is the Upper Angara basin where the transverse faults divide the area of intensive young subsidences from inversional uplifted steps (fig. 9).

There are large and small basins (FLORENSOV, 1960). The latter are exemplified by the Mondy and Bystraya basins. They are filled with sediments similar to those from the large basins (LOGATCHEV, 1968) and are closely connected with the interbasin uplifts, which they are part of it.

In the recent structure of the large basins there are active inner uplifts. They can be connected with uprising basement blocks, but there are rootless forms. The Badary uplift in the Tunka rift is the example of such also

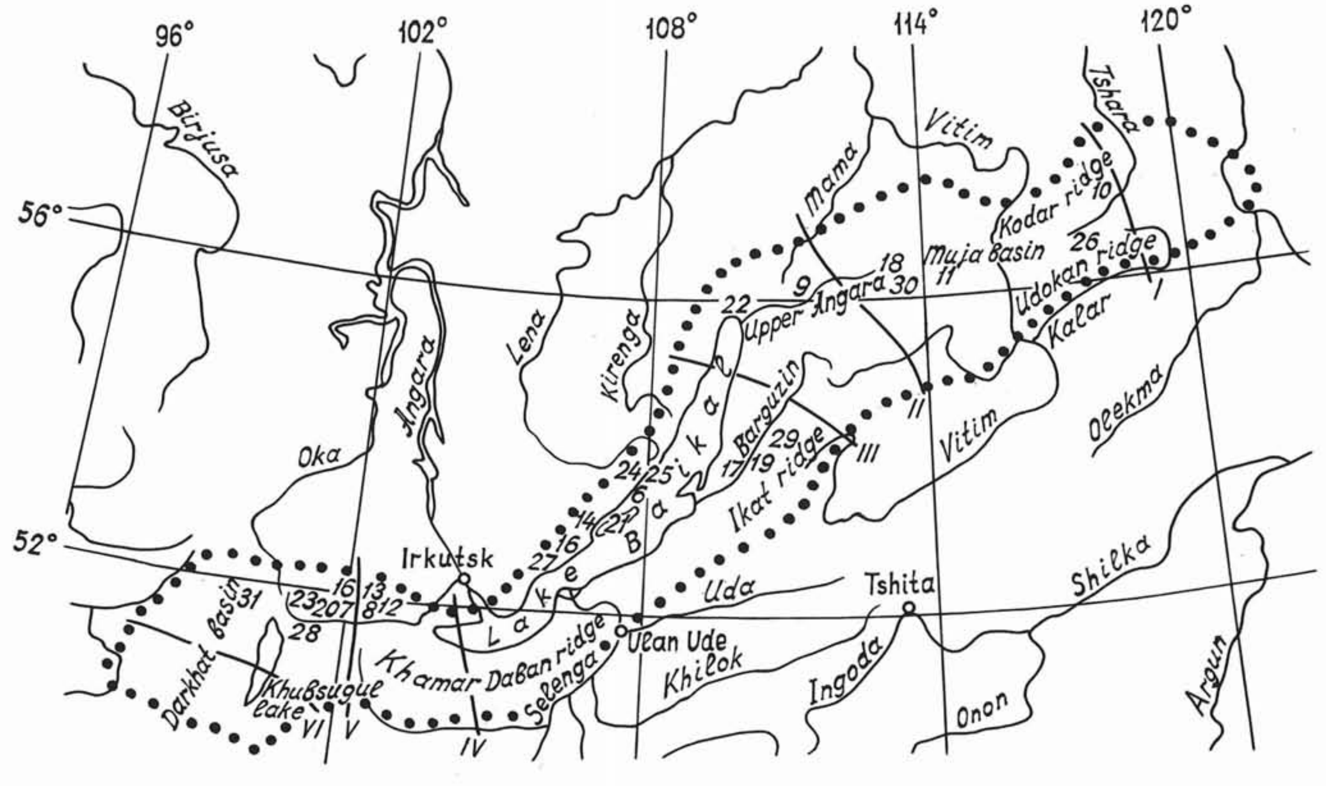

FIG. 1 - Reviewed scheme of South-East Siberia and North Mongolia. The Baikal rift zone boundary is shown by circles in ink. Numbers in the scheme show the numbers of corresponding illustrations, lines show the transverse profiles appearing in the fig. 5.

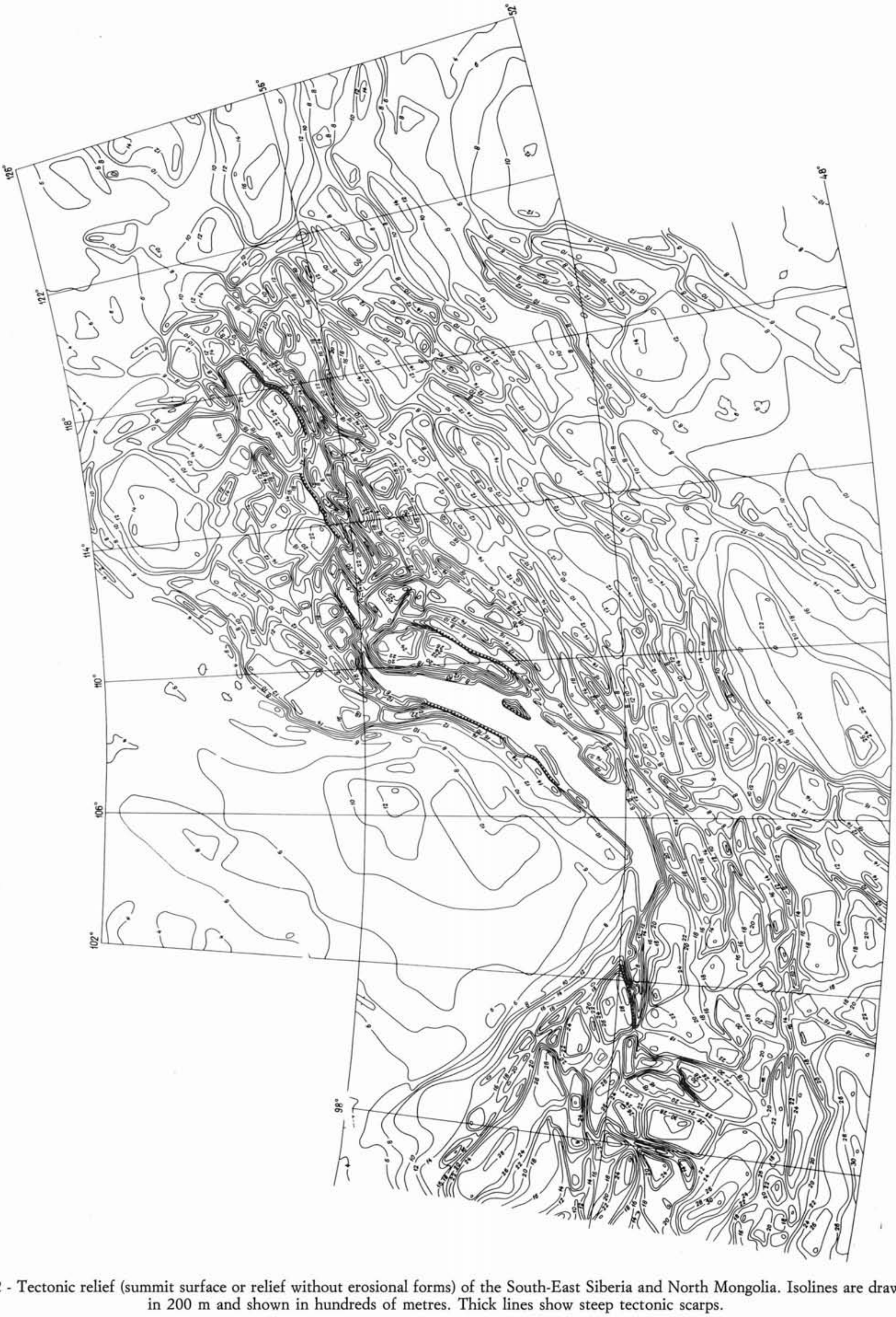

FIG. 2 - Tectonic relief (summit surface or relief without erosional forms) of the South-East Siberia and North Mongolia. Isolines are drawn in 200 m and shown in hundreds of metres. Thick lines show steep tectonic scarps.

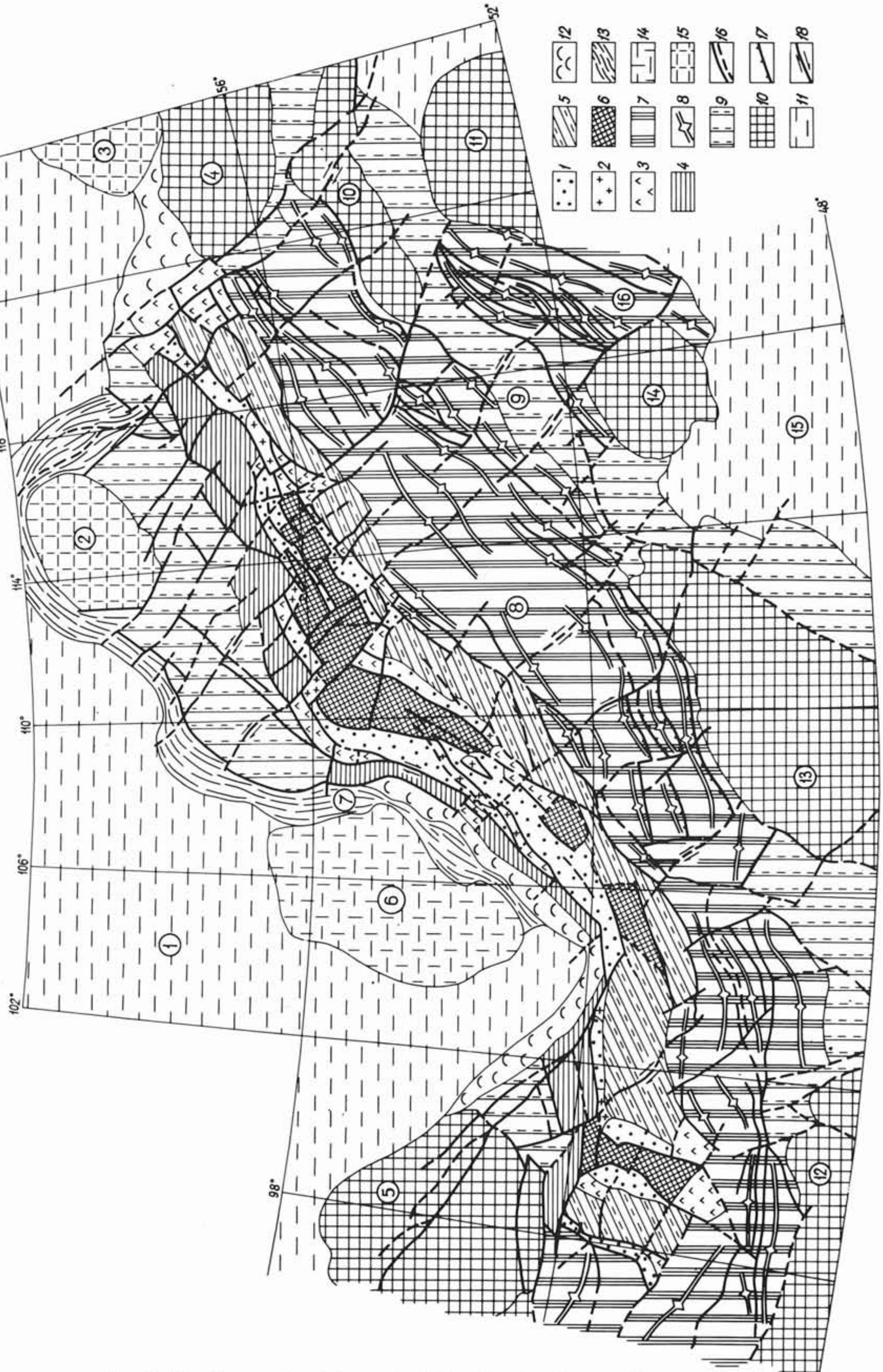

FIG. 3 - Morphotectonics of the south of East Siberia and surrounding areas.
Orogenic region: 1-6 - The Baikal rift zone including rift valleys (1), interbasin uplifts (2), large steps (3), inclined horsts of rift shoulders (4), marginal domal curve (5) and stepped block uplifts (6); 7-8 - zones of linear warping including separate domes (8); 9 - block fields; 10 - large domal uplifts. Platform regions: 11 - common uplifted zones; 12 - piedmont pedestals; 13 - zones of piedmont folds; 14 - uplifted large steps; 15 - marginal shield-like uplifts. 16-18 - young and rejuvenated ruptures including thrusts (17) and faults (18). Figures in circles designate: the Siberian platform (1), Patomskoye (2) and Central-Aldan (3) uplifts, Stanovoye (4) and East-Sayan (5) large domal uplifts, the Upper-Lena step (6), Predbaikal piedmont fold zone (7), the Selenga-Vitim zone of linear warping (8), the Upper-Amur block field (9), Olekmian Stanovik (10), Large Khingan (11), Khangay (12), Khentey (13) and East-Transbaikalian (14) large domal uplifts; the East-Mongolian platform region (15); the Shilka-Argun zone of linear warping (16).

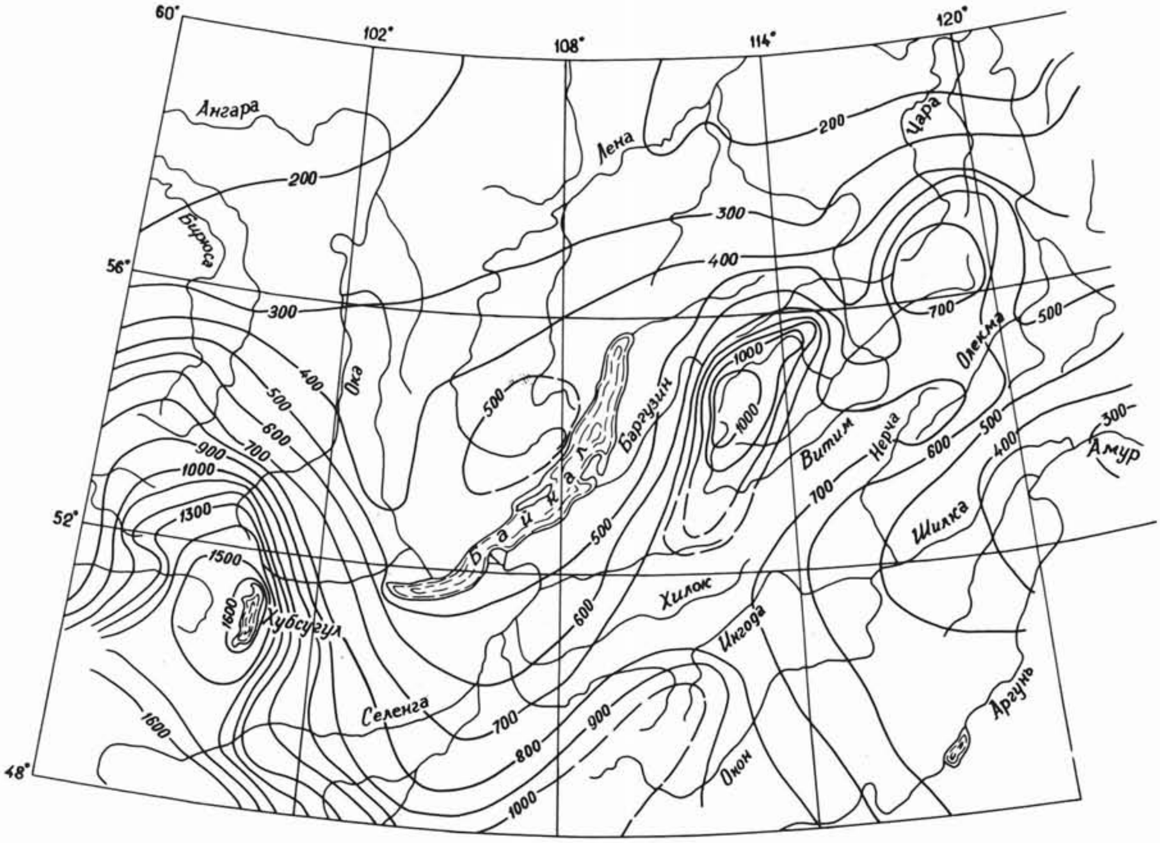

FIG. 4 - Socle surface of the rift zone and its surroundings built over talweg heights of the river valleys, which are located in Mesozoic and Cenozoic basins. Isolines are drawn in 200 m.

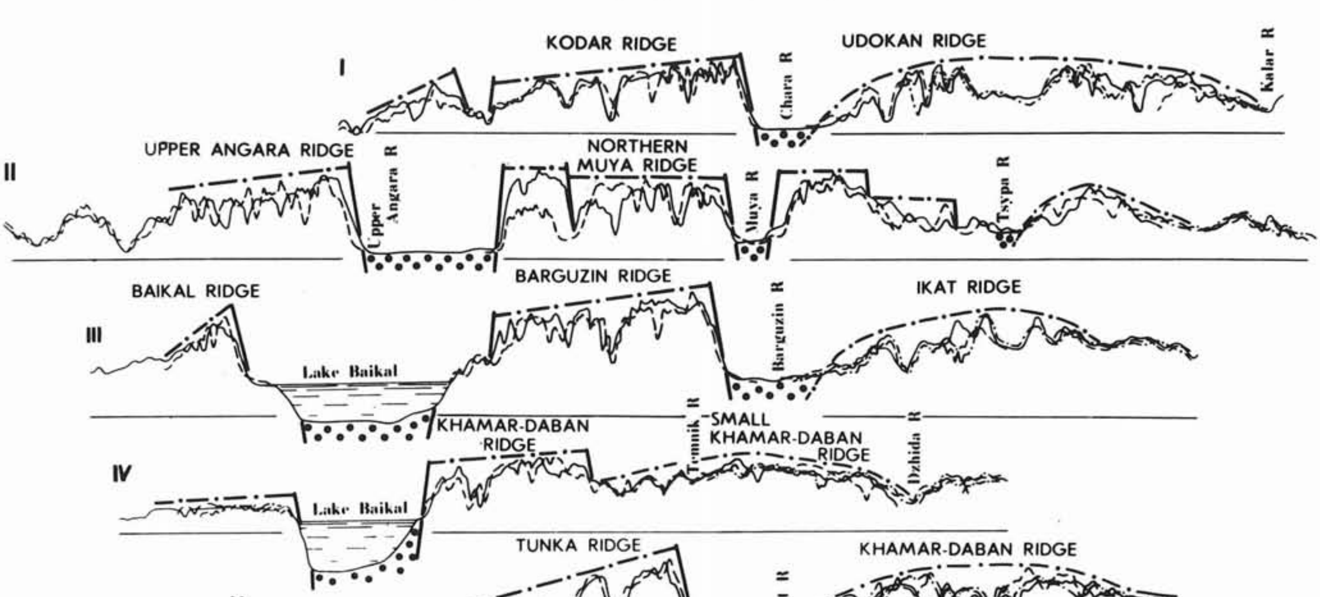

FIG. 5 - Transverse profiles of the Baikal rift zone and their tectonic interpretation (thick lines). Basins are shown by circles in ink. Location of profiles is shown in fig. 1. Vertical scale is 10 times the horizontal.

FIG. 6 - Change in heights of intermediate step (a) and the Primorsky ridge uplift (b) in the Zunduk transverse fault expressed by system of conjugated valleys and water-divided saddlebacks.

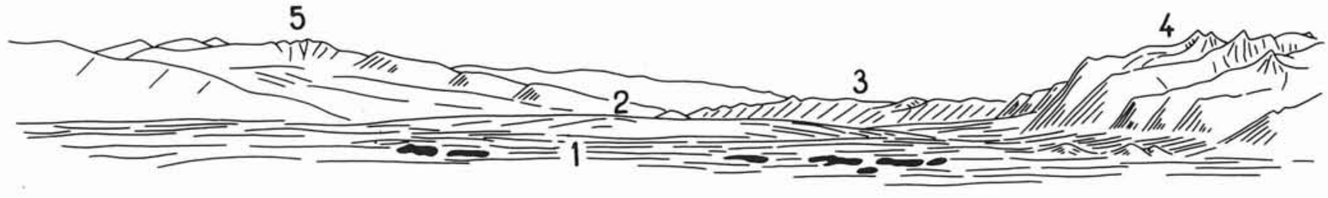

FIG. 7 - Rift zone structure in the Tunka basin area: 1-2 - the Tunka basin bottom including Badar inversional uplift (2); 3 - the Nilovsky spur (interbasin uplift); 4 - the Tunka ridge uplift; 5 - Khamar-Daban dome. View from the Elovsky spur westward.

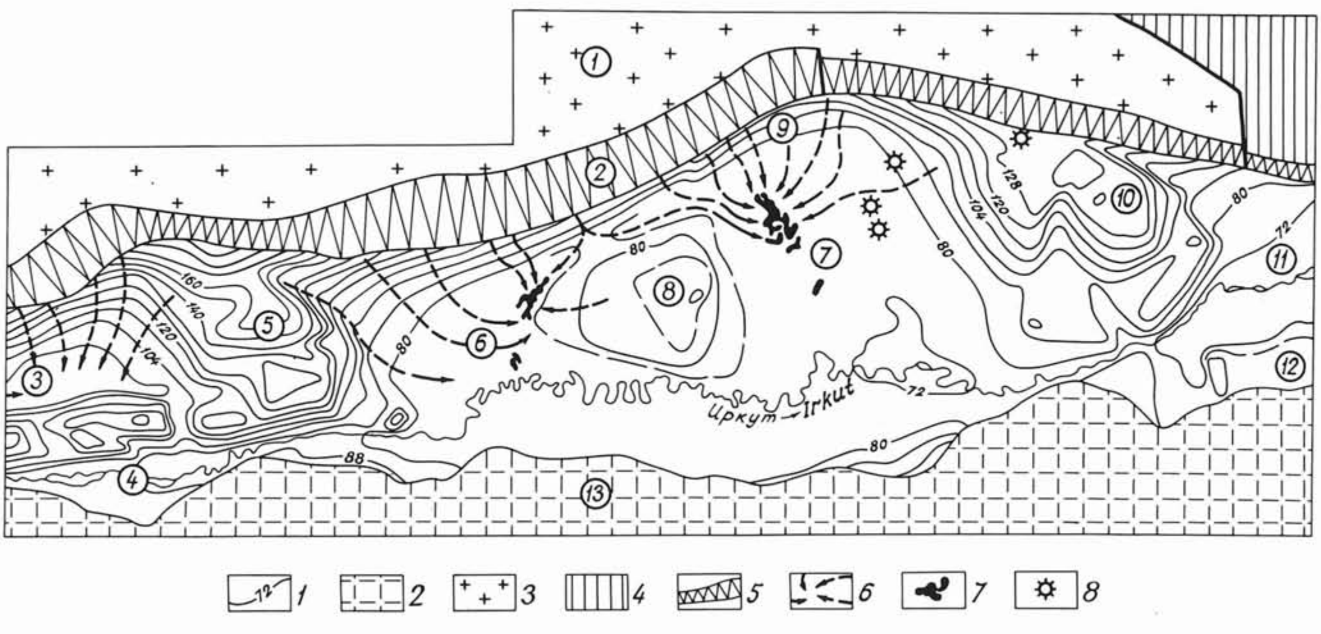

FIG. 8 - Morphotectonics of the Tunka rift valley.
1 - rift valley bottom with tectonic relief isolines (figure indicates the height in tens of metres); 2 - domal uplift; 3 - inclined horst; 4 - system of tectonic blocks of different hights; 5 - fault scarps; 6 - centripetal river patterns; 7 - lake-like expansion of river; 8 - volcanic cones. Figures in circles mean: 1 - the Tunka ridge uplift; 2 - scarp of the Tunka fault; 3 - the Khoytogol basin; 4 - the Turana basin; 5 - interbasin uplift of the Nilovsky spur; 6-9 - the Tunka basin including zones of young subsidences in the Engarga (6) and Tunka (7) river basins, Badar inversional uplift (8) and piedmont (9); 10 - interbasin uplift of the Elovsky spur; 11 - the Tory basin; 12 - the Zun-Murin inversional «sandy» step; 13 - Khamar-Daban dome.

forms (fig. 8). There are different explanations of the formation of the rootless uplifts in the sedimentary cover of the basins. The most probable is that these forms have resulted from gravitational tectogenesis, at the expense of sliding of the sedimentary layers all over the basement surface from the wings to the central segments of the basins (ZAMARAYEV, 1975). The shapes of the basins, the morphology of the geological boundaries in the sedimentary cover and peculiarities of supply of fragmental products into the accumulative zones influence the shapes and sizes of such inversional rootless uplifts.

The north and north-western slopes of the rift valleys have a complex composition. Their central parts are occupied by high tectonic scarps created by recent faults in zones of longliving ruptures (fig. 10, 11). The amplitude of the recent movement amounts to 2 km and over. In the morphology of the displacement surfaces there are traces of vertical and horizontal movements. In the zones of tectonic scarps vertical movements prevail.

Tectonic scarps on the slopes of rift valleys have a complex composition which is stipulated by the existence of some active surfaces of displacement. Usually there are some rows of tectonic facets of relief (fig. 12). There are basal facets, summit facets and antifacets limiting the upper reaches of valleys of their parts. These tectonic relief facets point out the strong breaking of the undersurface parts of earth's crust at the rift valley slopes. In basements of basal facets are commonly observed low scarps and trenches, usually cutting the alluvial sediments (fig. 13). They are the results of Holocene tectonic movements.

Main surfaces of displacement in the zones of young faults have a 60-75° angle of fall to the basin side. Between them are located numerous fractures with the angles of fall at 40-50°, along which the plate-like blocks are sliding. Thus, their tectonic scarps often have numerous narrow steps (fig. 14).

Gently sloping to the basins the surfaces connected with the zones of longliving faults are located above the tec-

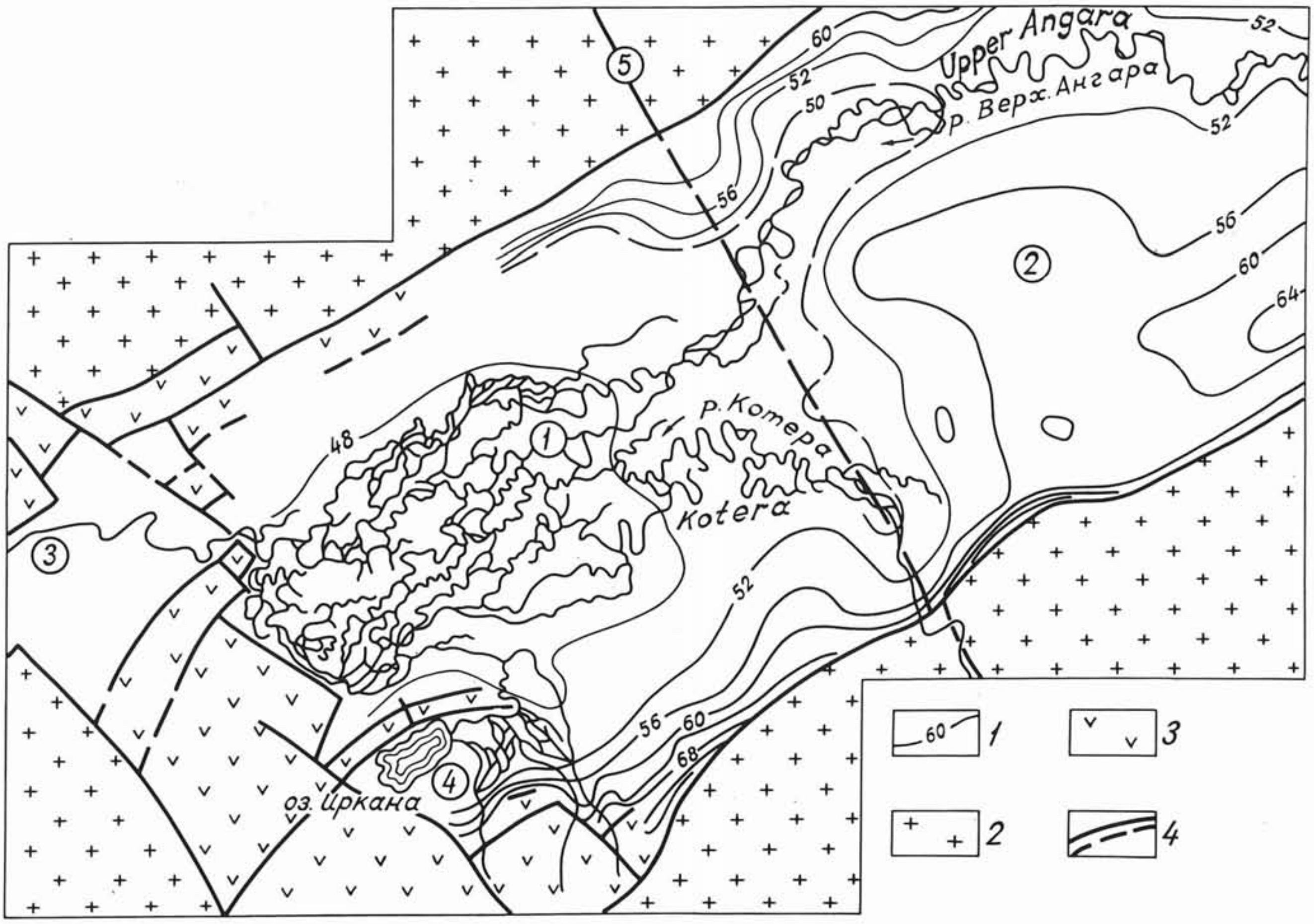

FIG. 9 - River pattern in the Upper Angara basin.
1 - basin bottom, main isohypses of tectonic relief are drawn in 40 m (figured in tens of metres); 2 - dismembered mid-mountains with alpine forms (block uplifts); 3 - mid-mountains and low mountains in the interbasin uplift, marginal and intermediate steps; 4 - young faults. Figures in circles mean the zone of intermediate young subsidences (1) and uplifted «sandy» step (2), straight stream of river in the interbasin uplift (3), area of local subsidence (4) and transverse Kotersky fault (5).

tonic scarps (fig. 5, 15). They came into being due to small-amplitude vertical movements. Horizontal movements prevail there. Conjugate geniculate curves of the valleys indicate, for example, dextral movements with an amplitude up to 2 km in the rear segment of the Primorsky fault and sinistral movements in the Tunka fault. Blocks of the Baikal, Barguzin and Upper Angara basins are diplaced southwestward to their surrounding uplifts on the side of the maximum extension of the rift zone lithosphere in the South Baikal area.

The third element of the slopes of the rift valleys is inclined piedmont plains, no more than 4 km wide, composed of rudaceous sediments of fans. The inclined piedmont plains are located above the narrow zones of steep (up to 45°) inclination of the basin basement surface. This indicates existence of recent displacements which are parts of the wide zones of marginal faults of the basins. At piedmont plains seismodislocations are distributed. In the mountain side terraces are divided into several levels (fig. 13). Narrow zones of the inclined piedmont plains are morphological expressions of lower parts of marginal tectonic scarps buried under young sediments. Thus, fault slopes of rift valleys are the complex and symmetrically built formation which consist of three main elements: (1) tectonic scarps, (2) piedmont plains and (3) summit slopes (fig. 16).

In the wide fault zones at the slopes of the basins, narrow and long intermediate steps are located between separate displacement surfaces (ZAMARAYEV & MAZUKABZOV, 1978) (fig. 17, 18). An evolutionary row of the intermediate steps, from high blocks with rugged mountain topography to those which have undergone denudational destruction and covered by piedmont sediments, is well seen in the sections of the Obruchev fault virgations on the western Baikal shore and at the NW slope of the Barguzin basin (fig. 19). The extension of the rift basin is due to plunge of marginal blocks of conjugated uplifts. This is a major process in the Baikal-type orogenic evolution (FLORENSOV, 1965).

There are two main varieties of neotectonic forms

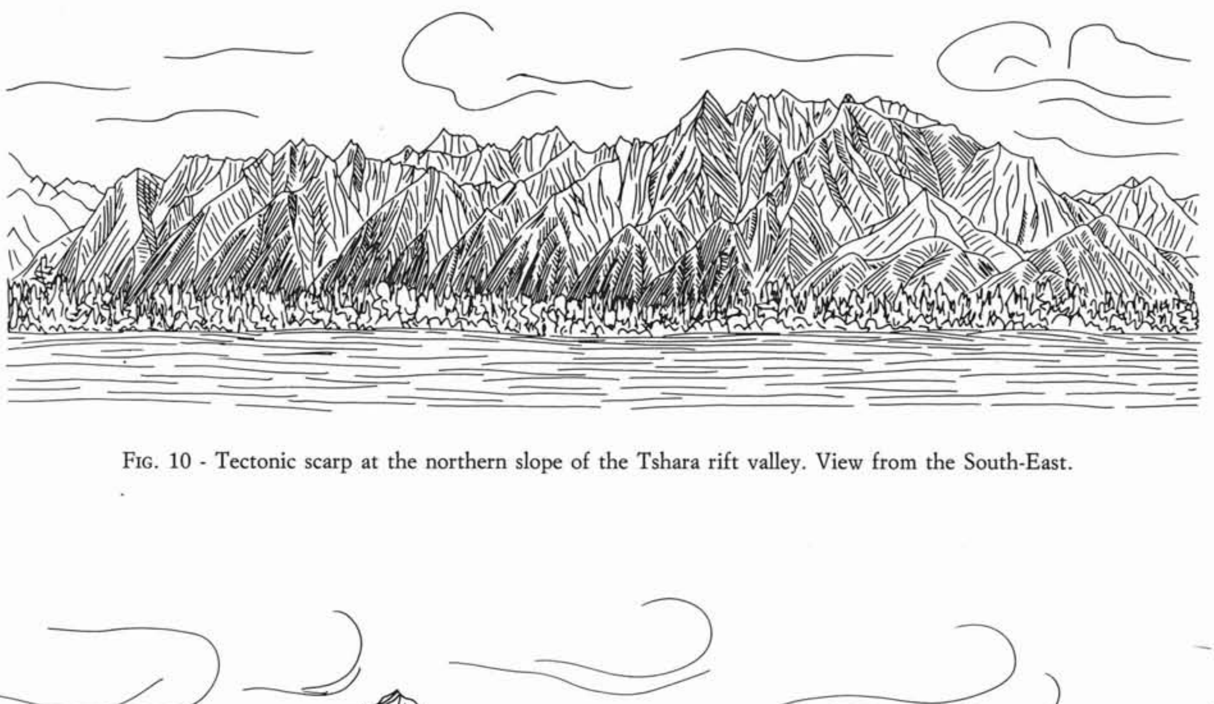

FIG. 10 - Tectonic scarp at the northern slope of the Tshara rift valley. View from the South-East.

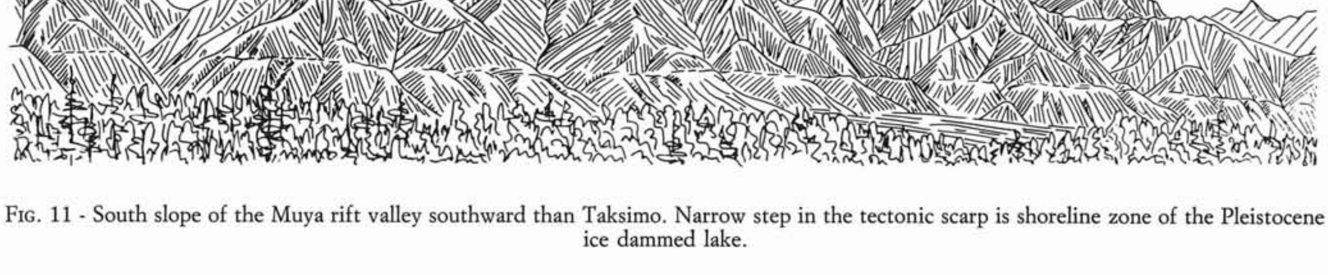

FIG. 11 - South slope of the Muya rift valley southward than Taksimo. Narrow step in the tectonic scarp is shoreline zone of the Pleistocene ice dammed lake.

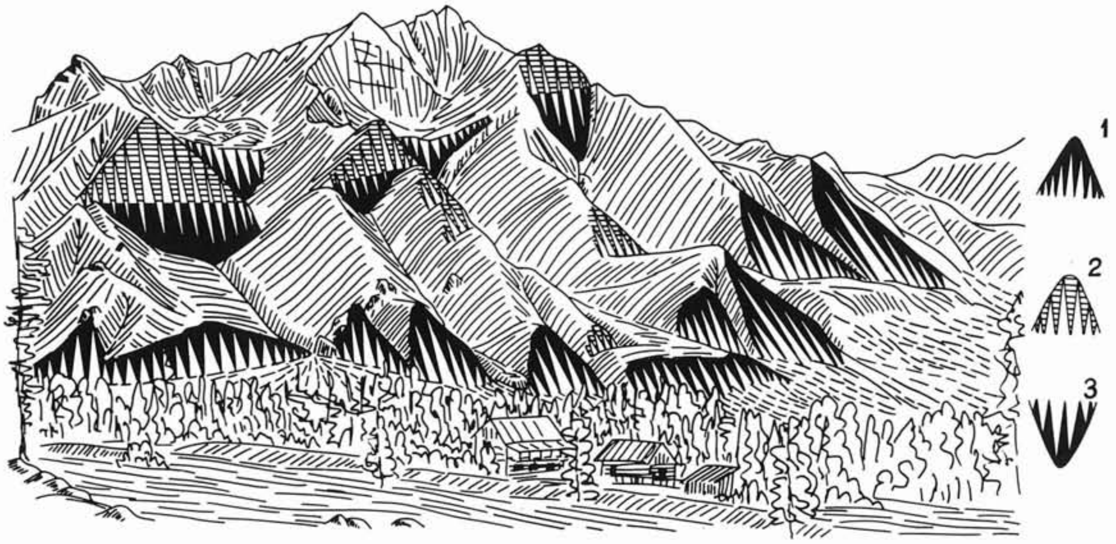

FIG. 12 - Basal (1), summit (2) facets and antifacets (3) at the northern slope of the Tunka basin eastward the Kyngarga valley. View from the south.

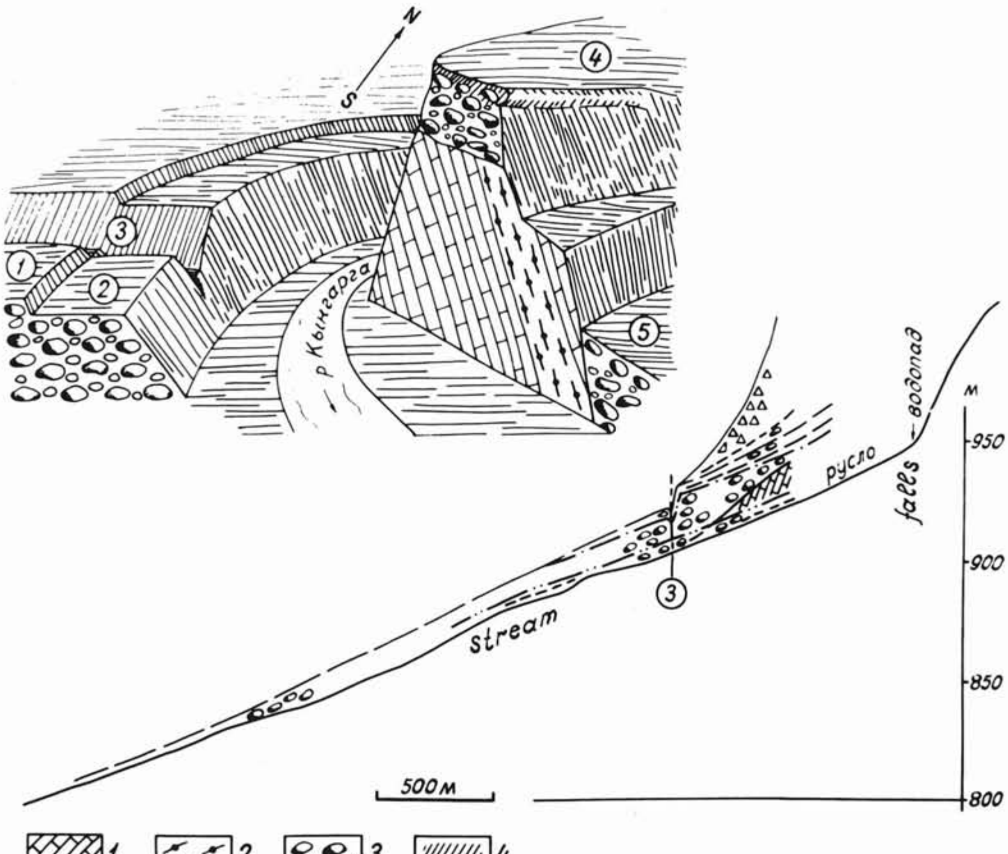

FIG. 13 - Tectonic deformation of the Kyngarga valley terraces near the Arshan spa.
A - fault dislocation near mineral source; B - terraces at the right side of the river Kyngarga. 1 - breccia marbles; 2 - crystalline schists; 3 - boulders; 4 - travertine. Figures in circles show terraces of 18 metres (1) and 14 metres (2) high; tectonic scarp and trench (3); socle terrace of 40 metres high (4) and its subsidenced part of 12,5 metres high (5).

FIG. 14 - The Primorsky fault scarp at the western slope of the Baikal rift valley near Shida village. Narrow steps on the scarp are formed owing to slipping down the lamellar blocks along the gentle low-angle displacers. View from the East.

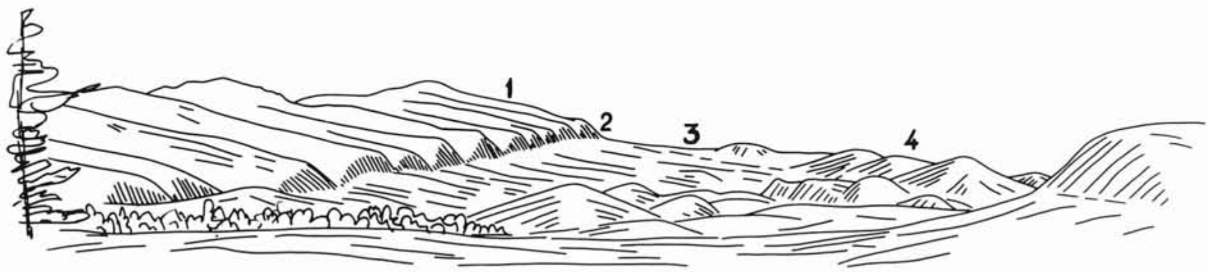

FIG. 15 - Slope of the Baikal rift valley near Elantsy village. Wide and high summit slope (1), low fault scarp (2), piedmont (3) situated in the subsidence between the Primorsky ridge and low mountains of the Priolkhonsky large step. View from the South-West.

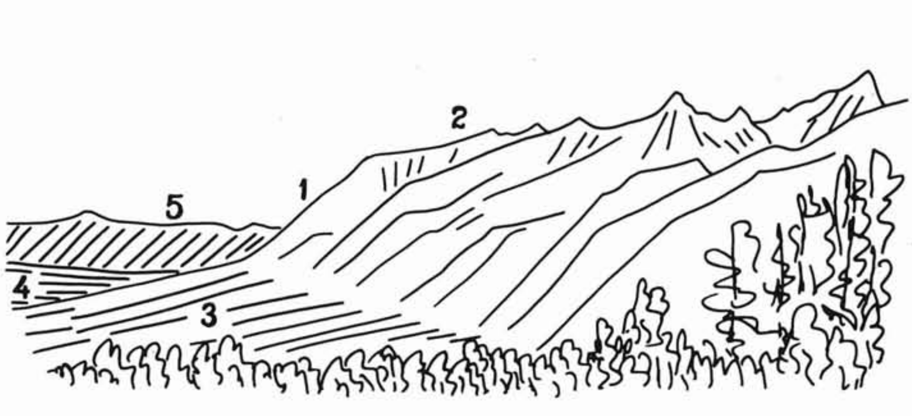

FIG. 16 - Profiles of fault scarp (1), summit slope (2) and piedmont (3) at the northern slope of the Tunka basin westward the arshan spa. 4 - bottom of basin; 5 - the Nilovsky transverse spur. View from the East.

FIG. 17 - The Ulun intermediate step at the western slope of the Barguzin rift valley. View from the East.

FIG. 18 - The Kovokta intermediate step at the south-eastern slope of the Upper Angara rift valley. View from the North-East.

separating basins (interbasin uplifts). The first one covers transverse and diagonal horsts, e.g. the inclined Nilovsky and Elovsky horsts (spurs) in the Tunka system of basins (FLORENSOV, 1960). From the East the horsts are limited by high fault scarps (fig. 8, 20). In the West their surfaces are gently slope to the Tunka and Khoitogol basins.

The other variety of interbasin uplifts covers complexes of longitudinal and diagonal horsts, steps and stepped block uplifts (e.g. interbasin uplift between North Baikal and South Baikal basins). It embraces (1) residual steps in the mountain relief or submerged steps; (2) relative uplifts between basins (submarine Akademichesky ridge); (3) actively elevating inclined horsts (fig. 21). The residual steps form an evolutionary row of elements at different stages of transformation under the plunge conditions, which followed the uprise within the rift shoulder. This is true of the submarine Akademichesky ridge, where ancient weathering crust occurs. Between the steps and the rifts inclined active horsts or stepped block uplifts are located, within which small basins composed of Neogene sediments are raised due to inversion of tectonic regime (fig. 21).

Interbasin uplifts divided the North Baikal and the Upper Angara basins composed of tectonic steps and horsts with different height, graben-valleys and small basins (fig. 22).

Other interbasin uplifts have similar structure. Small basins with thick (hundreds of metres) sedimentary filling are parts of them. Such are the Mondy and Bystraya basins in the Tunka area. These basins underwent inversional uprise accompanied by erosional dissection of their bottoms (fig. 23).

Large tectonic steps are structurally alike interbasin uplifts, but located between the basins and marginal tectonic scarps of the rift valleys. Usually they replace interbasin uplifts along their strike or are in the places where the transverse fault systems cross the rift valleys (fig. 24, 25) or at the rift zone terminations. The situation in the north-eastern part of the rift zone (fig. 26) clearly shows the significance of these morphotectonic elements in the rift zone structure.

THE RIFT SHOULDERS

The rift shoulders are the systems of inclined horsts and asymmetric block uplifts accompanying large basins and forming the NW wing of the rift zone (fig 3, 5). Its recent structure is simple. It consists of single or double chains of inclined horsts and block uplifts. These forms are separated from the axial part of the rift by high tectonic scarps (fig. 27). They are gently inclined to the Siberian platform. Individual block uplifts and horsts are separated from each other by narrow suture subsidences along zones of transverse faults.

In the central segment of the rift zone a simple chain of the inclined horsts and asymmetric block uplifts of the Primorsky and Baikal ridges are located (fig. 5-III, IV; 27). At the flanks of the rift zone double chains of the same forms are distributed (fig. 5-I).

In the marginal part of the Siberian platform between the rift shoulders and the system of folds of the Predbaikal down-warp there are neotectonic forms resulting from the rifting influence on the surrounding areas. They are inclined piedmonts (fig. 5-V), arched uplifts of the Onot uplift type and systems of tectonic steps. They supplement the rift shoulders and take part in its general uprise.

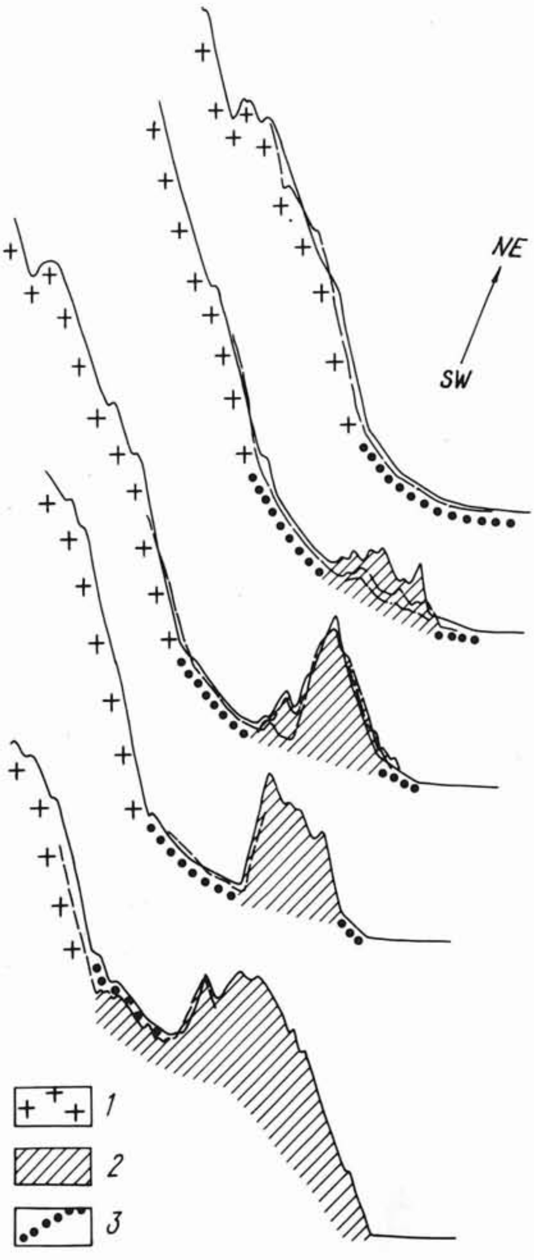

FIG. 19 - Transverse profiles of the Ulun intermediate step showing its consecutive destruction and filling up of alluvial fan sediments. 1 - tectonic scarp; 2 - intermediate step; 3 - piedmont. Vertical scale is 10 times the horizontal one.

THE MARGINAL ARCHED CURVE

The SE wing of the rift zone consists of the Khamar-Daban, Ulan-Burgasy, Ikat, Kalar and Udokan uplifts (fig. 2, 5). They consist of the structural forms regularly distributed and indicating existence of arches with large radius of curvature. The height of the arch relative to the bottoms of the rift valleys amounts to 2500 km. The gentle plunge of the basement surface at the SE wing of the basins increase the height of the curve. Its width varies from 60 to 120 km and becomes less (to 45 km) in the places where the curve at the crest is limited by high tectonic scarps or near large transverse faults where the curve is reduced.

An arched curve of the SE wing of the rift differs from the arches of the Selenga-Vitim zone (fig. 5-II). With similar morphological appearance the marginal arch is wider and higher. The inclination of the summit surface at the arch wings amounts to as much as 10° at its foot.

Faults with dips to the axial surface are typical of the arch structure. These faults divide the wings of arches into inclined block systems (fig. 28, 29).

There are compound relations between the marginal arch and the rift valleys. The angles of the large rift valleys entering the arch indicate their growth at the cost of the latter. Inversional uprise of the marginal parts of the basins conjugated with the arch can be seen. Dual relations between the basins and the marginal arch are reflected in the nature of young faults striking along its boundary. Young faults are distributed dipping to the basin side as a result of active subsidence of rift valleys. Such faults are wide and incorporate many small-amplitude displacers. Other systems of young faults consist of faults dipping to the axial segment of the arch. They are a cause of formation of the steps of the summit surface at its wings.

FIG. 20 - Eastern slope of the Nilovsky interbasin uplift (in the centre and on the left) and northern slope of the Tunka rift valley (on the right). View from the East.

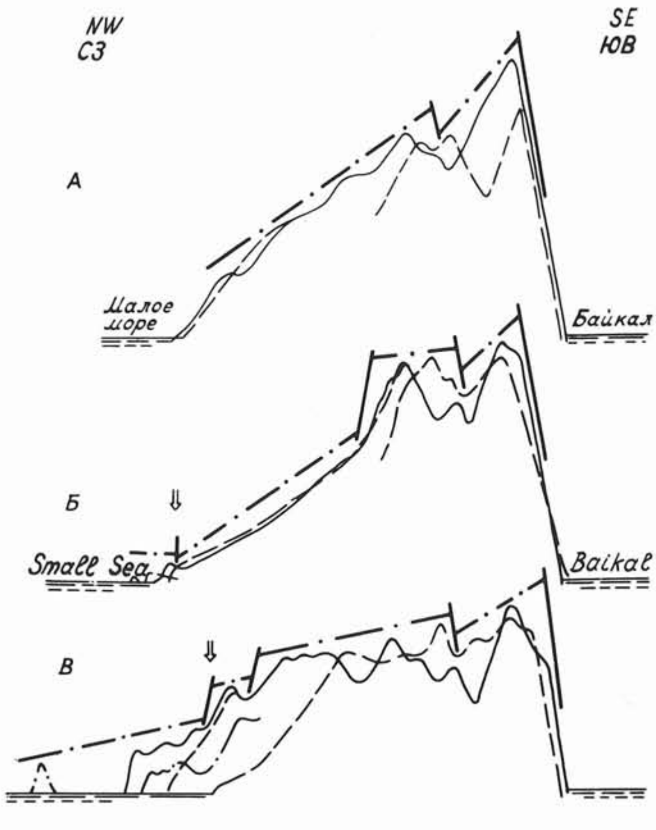

FIG. 21 - Transverse profiles of the Olkhon uplift and their structural interpretations (thick lines). Arrows show boundary of the uplift and Malomorsky residual step. Vertical scale is 10 times the horizontal one.

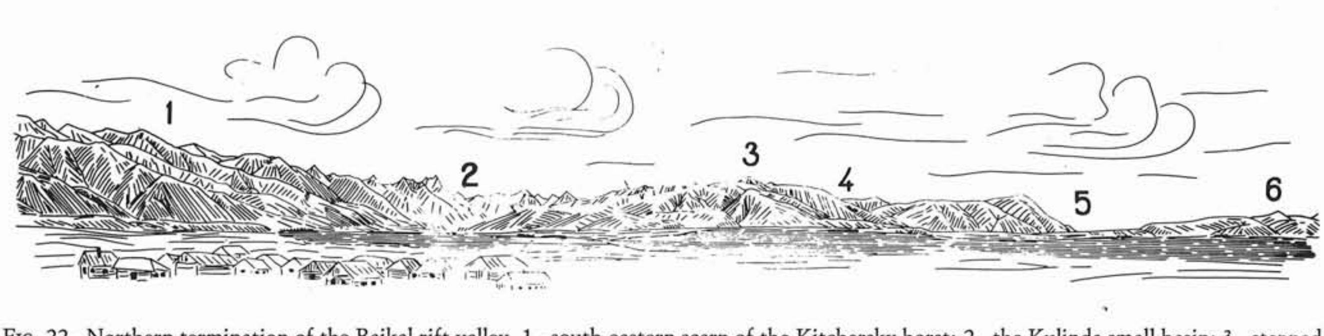

FIG. 22 - Northern termination of the Baikal rift valley. 1 - south-eastern scarp of the Kitchersky horst; 2 - the Kulinda small basin; 3 - stepped uplift of the south-western termination of the Upper Angara ridge; 4 - the Dzhelinda intermountain step; 5 - small basin located along the river Upper Angara; 6 - low tectonic step in the piedmont of the Barguzin ridge. View from the South.

FIG. 23 - Northern part of bottom of the Mondy small basin uplifted in form of the tectonic step system. Moranens lie on the tectonic step surfaces. View from the South.

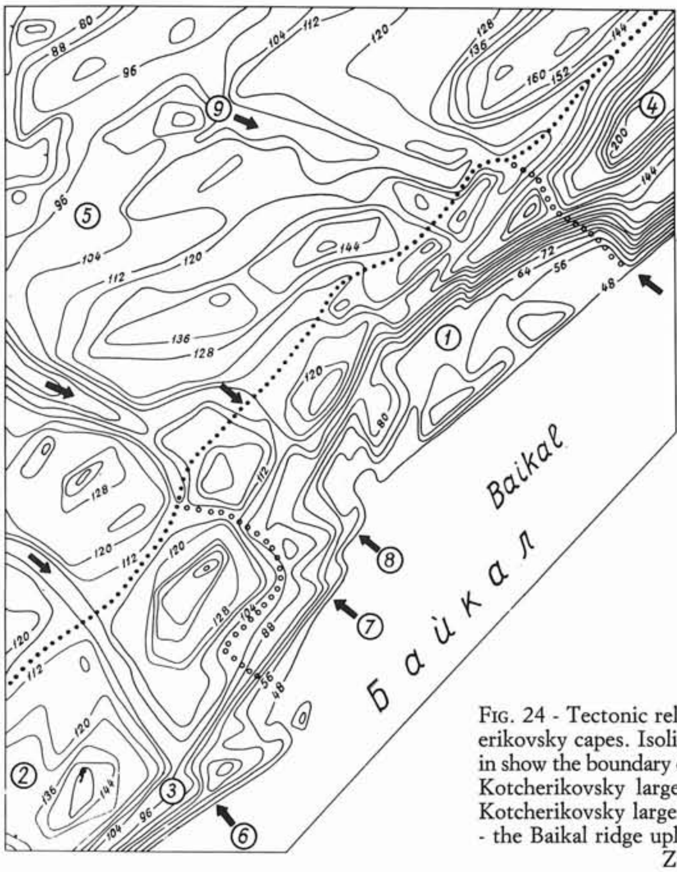

FIG. 24 - Tectonic relief of the western coast of Lake Baikal between the Arul and Kotcherikovsky capes. Isolines are drawn in 80 metres and figured in tens of metres. Circles ink in show the boundary of the Baikal rift zone, hollow circles show the boundary of the Kaltygey-Kotcherikovsky large step. Arrows show the main transverse faults. 1 - the Kaltygey-Kotcherikovsky large step; 2 - the Primorsky uplift; 3 - the Zunduk intrermediate step; 4 - the Baikal ridge uplift; 5 - marginal part of the Siberian platform. Transverse faults: 6 - Zunduk; 7 - Tchantchura; 8 - Onguren; 9 - Anay.

FIG. 25 - Large tectonic step on the western coast of the lake Baikal from the Kaltygey cape (on the left) to the Rituy cape (on the right). Inclined horsts and small basins are behind them (in the centre), the Baikal ridge uplift is located in the second plan in the centre and on the right. View from the South.

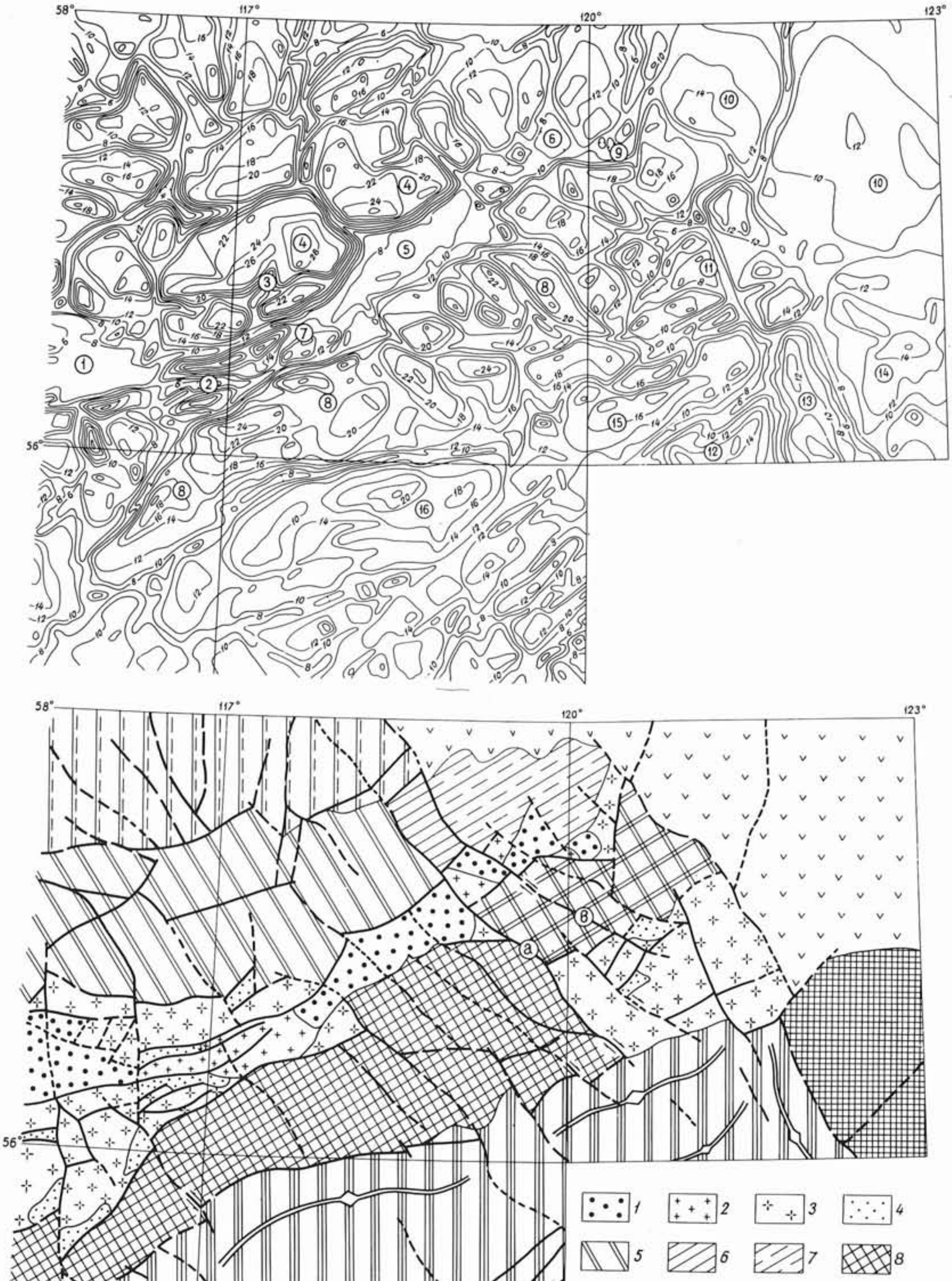

FIG. 26 - Tectonic relief of the north-eastern termination of the Baikal rift zone (above) and its structural interpretations (below). - 1 - basins; 2 - interbasin uplifts; 3 - large tectonic steps; 4 - small basins; 5-7 - rift shoulders including normal inclined ones (5), inclined shoulders along the rift zone strike (6) and experienced the block disintegration (7); 8-9 - arches of the south-eastern rift zone wing including the block disintegration (9); 10 - large domal uplift; 11 - zone of linear warping and its similar domes (12); 13 - block fields; 14 - marginal part of platform. Figures in circles designate: the Muya (1), Konda (2), Upper Sulban (3), Tshara (5), Tokko (6), Tsharnoda (9) basins; the Kodar uplift (4), Muya-Tshara interbasin uplift (7), Kadar-Udokan domal uplift (8); Priolekmian step (11), marginal part of the Siberian platform (10), South-Dyryndian (12), Tshelbauss (13), North-Dyryndian (15) and Yankan (16) domes; Stanovoye large domal uplift (14). Transverse faults: Khani-Sulumat (a) and Evonokit-Tokko (b).

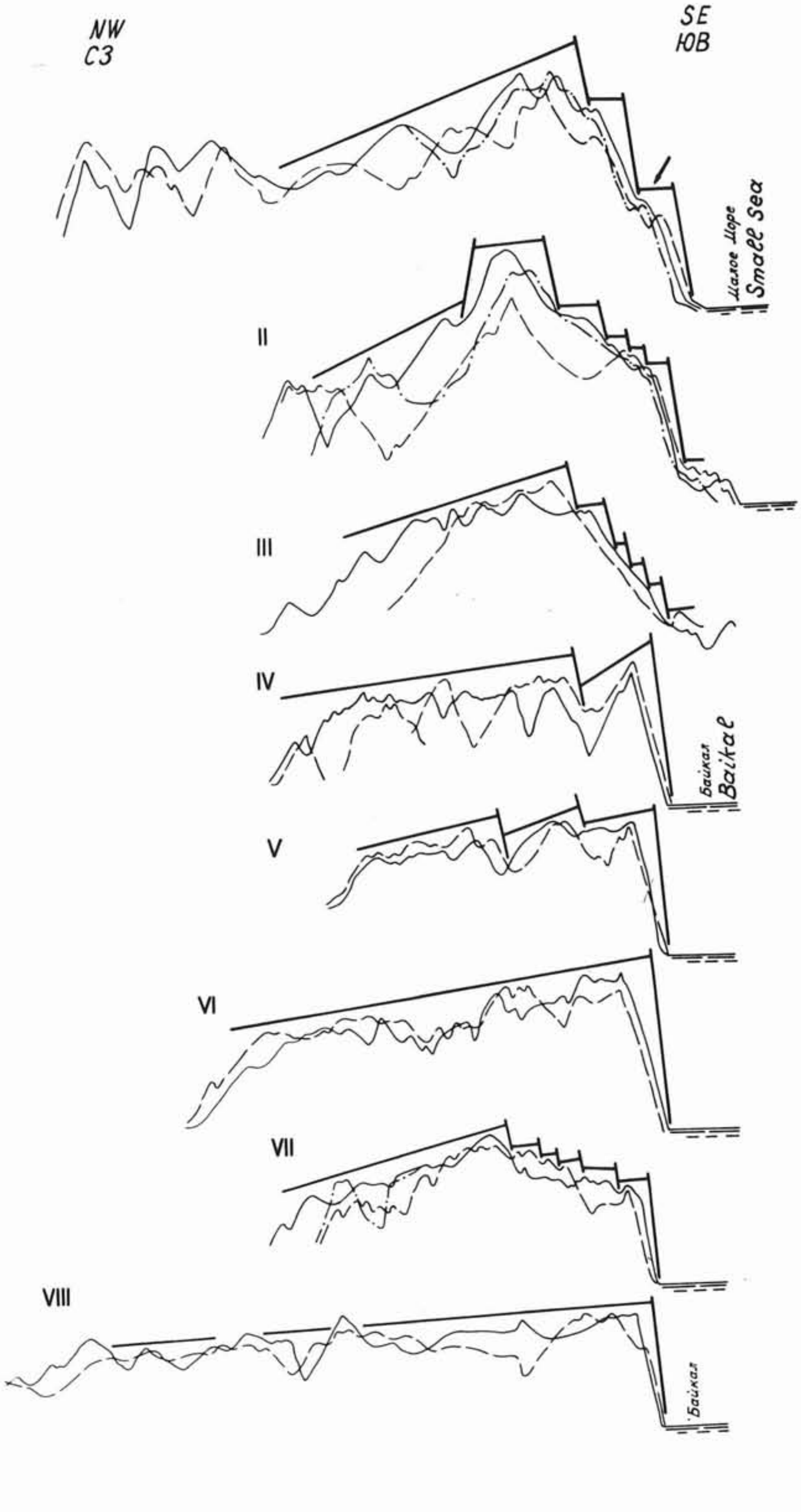

FIG. 27 - Transverse profiles of the Primorsky uplift and their structural interpretations (thick lines). I-III - northern part of the Primorsky ridge, IV-VII - southern part of this ridge, IV-III - the Olkhonskoye plateau southward the river Angara outlet. Vertical scale is 10 times the horizontal one.

INTERIOR BLOCK UPLIFTS

In the interior parts of the rift zone stepped block uplifts or high horsts are distributed (fig. 2, 5). They are located between the basins (fig. 2, 5-II, III) or between the basins and the marginal arch (fig. 5-IV). They have similar structures being complexes of blocks with the heights increasing towards the central parts of the uplifts or horsts (fig. 30, 31). To the basin side the uplifts end in steep tectonic scarps up to 2 km high. From the marginal arch they are separated by narrow graben valleys or relative subsidences.

The interior block uplifts are rather high up to 3500 m (fig. 31). This results from intense isostatic uprises of the ridges over the eminence of the anomalous mantle.

SYMMETRY IN THE STRUCTURE OF THE BAIKAL RIFT ZONE

Neotectonic forms in the structure of the rift zone form stable combinations and succession in the transverse direction, namely (from NW to SE): (1) a system of inclined horsts and asymmetric block uplifts of the rift shoulders, (2) a system of rift valleys and inner stepped block uplifts, (3) a marginal arch. The above succession of structural forms, which is manifested through the rift as a whole (fig. 2, 5), is probably a private manifestation of symmetry. Conjugated pairs of structural elements are as follows: (1) rift shoulders and basins, (2) a marginal arch and basins distributed antisymmetrically to each other. These structural combinations are characterized by two longitudinal

FIG. 28 - Cuesta-like inclined blocks of the northern wing of the Khamar-Daban dome westward Turana village. View from the East.

FIG. 29 - Inclined blocks of the western wing of the Ikat dome eastward the Argoda river valley. View from the West.

horizontal axes of the second-order antisymmetry.

The neotectonic forms are distributed symmetrically along the rift zone. In the subzones the forms composing them give place to each other along the strike. The longitudinal translations of the neotectonic forms result in stability of the recent structure of the rift zone along its length.

The Baikal rift zone is divided into sections separated by transverse faults. Each section consists of similar complexes of structural elements in similar combinations (fig. 2, 5). The totality of the form strikes in the sections represents a broken line. The conjugated sections are mirrorly similar (fig. 2). There are transverse surfaces of symmetry, the major of which is located in the region of the northern termination of Lake Baikal. We term it the main transverse surface of symmetry of the Baikal rift structure. If the Khubsugul segment occupying a special position in the rift zone is exluded, one can observe a mirror similarity of the recent structures of the SW part of the rift zone to those of the NE part. It is manifested in similarity of the structural pattern and in the nature of changes in the strike of the rift zone sections. Symmetrically distributed are the Khamar-Daban and Udokan fields of Cenozoic basalts, and the interbasin uplifts. At the flanks of the rift zone, in the Tunka and Kodar-Udokan regions, the basin bottoms are uplifted.

The mirror similarity of the rift zone segments (trasnverse surfaces of symmetry), and of its flanks (major transverse surface of symmetry) have a peculiar feature. The rift zone fragments are divided by transverse faults with a shift component, therefore the transverse surfaces of sym-

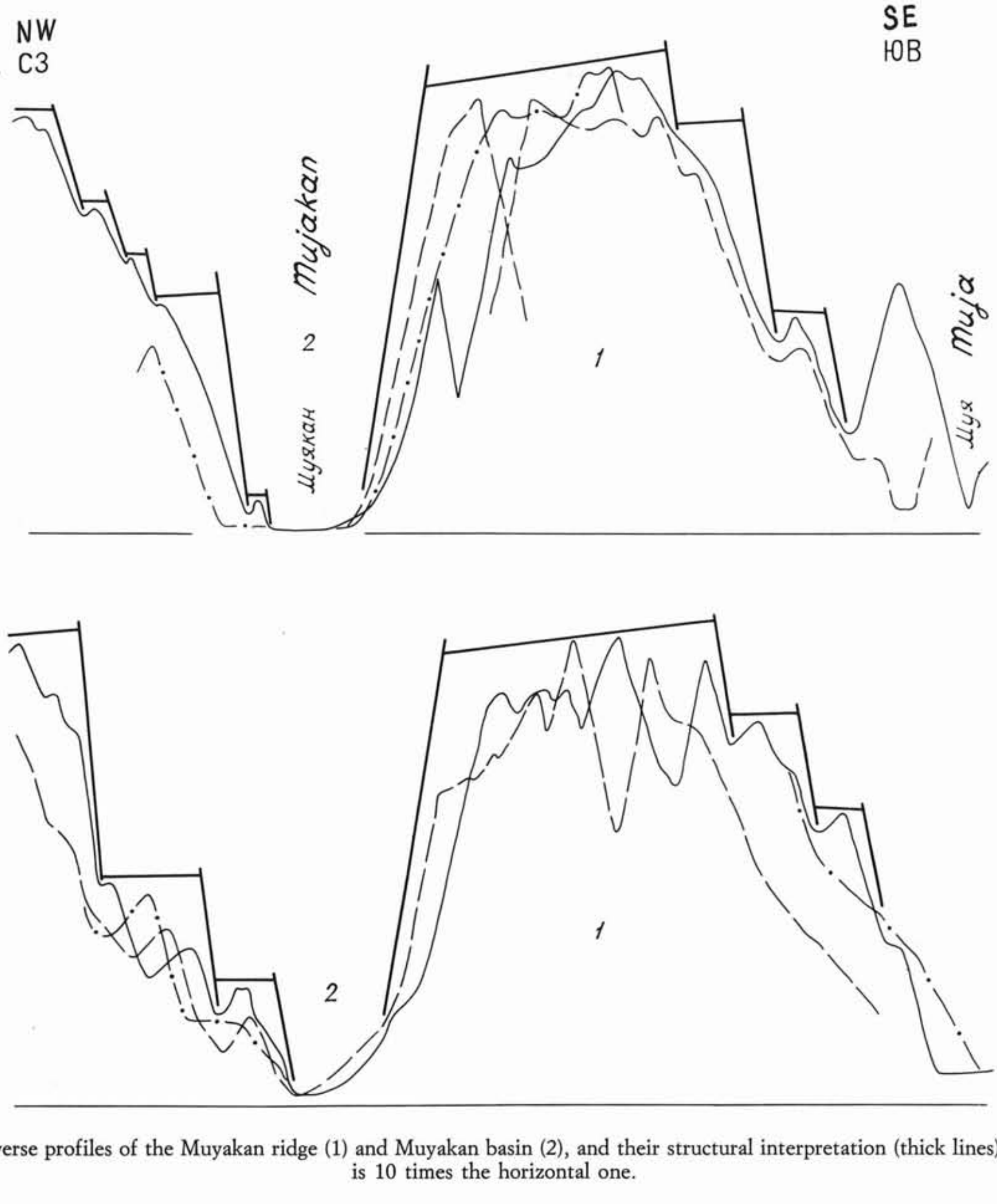

FIG. 30 - Transverse profiles of the Muyakan ridge (1) and Muyakan basin (2), and their structural interpretation (thick lines). Vertical scale is 10 times the horizontal one.

FIG. 31 - The Munku-Sardyk block uplift west of the Mondy basin. View from the East.

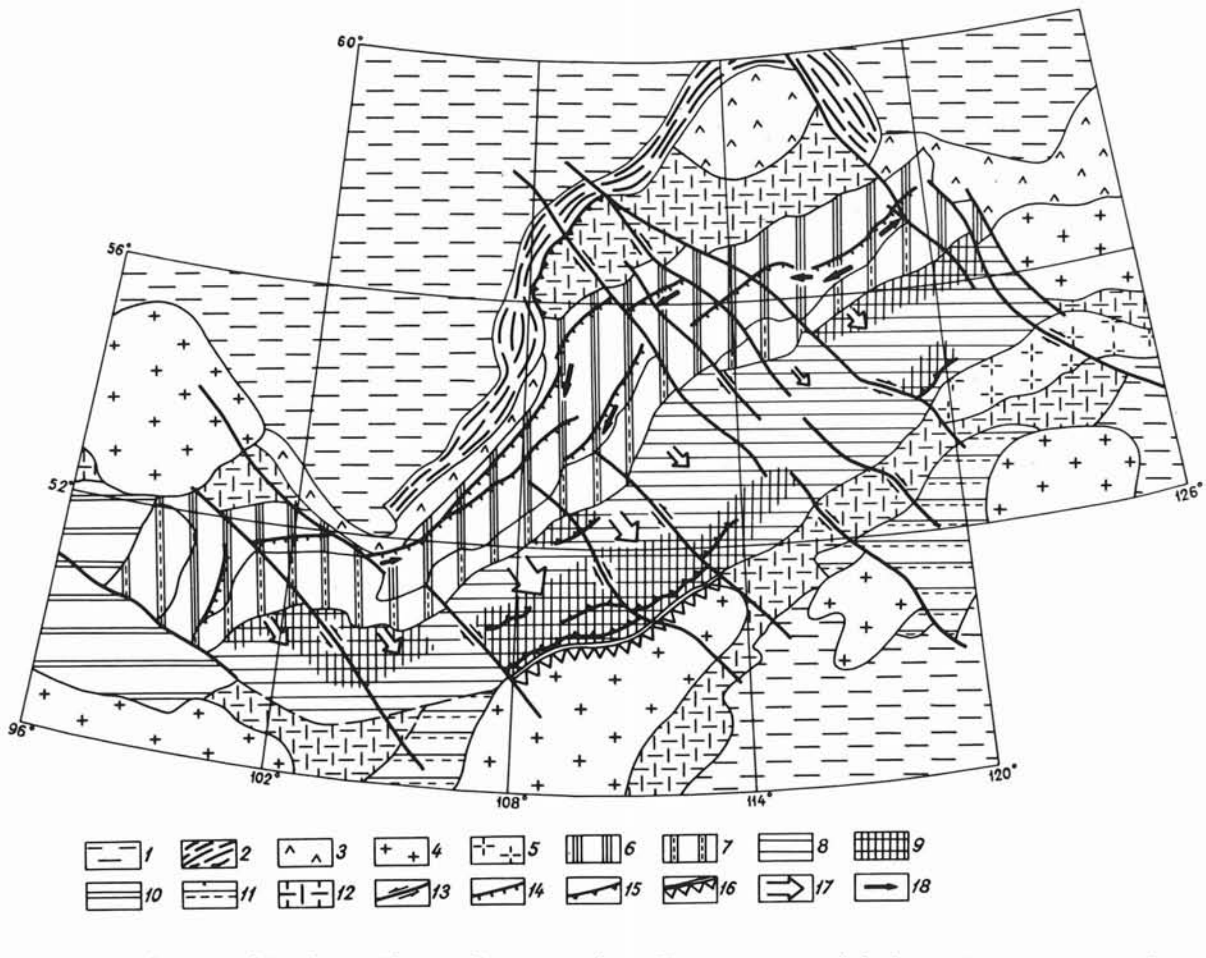

FIG. 32 - Cenozoic geodynamics of South-East Siberia and its surroundings. Tectonic regimes of platform regions: 1 - common slow uplift; 2 - fold-forming in the marginal parts of platform; 3 - block and domal uplifts. Tectonic regimes of the recent orogenic regions: 4-5 - domal uplifts including recent ones (5); 6-7 - rifting above anomalous mantle eminence including domal uplift (7); 8-9 - linear warping of upper lithospheric layers under conditions of transverse compression compensating the tension in the Baikal rift zone with the areas of maximum intensity of this process (9); 10-11 - linear warping in the marginal parts of the intracontinental collision zone (10) or of obscure nature (11); 12 - block uplifts of marginal parts of the orogenic belts. 13-16 - ruptures including the strike-slip faults (13), faults (14) and thrusts (15), suture (16). 17 - horizontal geoblock displacements of different intensity, 18 - longitudinal displacements of the rift valleys.

metry have elements of sliding reflection. Together with the prevailing longitudinal translations of the forms in the subzones this indicates that elements of symmetry of infinite forms (SHAFRANOVSKY, 1968), as well as regular changes of neotectonic forms of the transverse direction are typical of recent structure of rift zone.

The major feature of the dissymmetry in the recent rift zone structure are as follows: the Khubsugul segment located in the interior part of the Mongolo-Siberian mountain belt occupies a special position; other manifestations of dissymetry are ruptures of longitudinal translations of neotectonic forms (Angara outlet region, fig. 1), or their reduction, for example, at the NE termination of the rift zone (fig. 26).

The recent structure of the rift zone with its symmetry features coexists with the elements of the deep-seated structure, as they are believed to be, according to geophysical data. The following elements of the deep-seated structure are significant: (1) uprise of the asthenospheric roof below the Mongolo-Siberian mountain belt (ROGOZHINA & KOZHEVNIKOV, 1979), (2) vertical eminence of the anomalous mantle below the Baikal rift zone (ZORIN & OSOKINA, 1982; Sketch on the deep-seated structure..., 1977), (3) subhorizontal branch of this eminence striking to the south-east (The bowel below Lake Baikal, 1981).

The NW wing of the rift zone is located over the vertical boundary of the anomalous mantle eminence. The central rift subzones (systems of basins and interior block uplifts) are distributed above it. An arch of the south-eastern rift zone wing corresponds to the areas of translation of the vertical eminence of the anomalous mantle to a subhorizontal layer. The Selenga-Vitim zone of linear warping conjugated with the rift zone is located above the horizontal branch of the anomalous mantle eminence. Distinctly expressed paragenesis of the deep-seated structure and the recent structure indicate that P. Curie's universal principle of symmetry may be used as a methodological basis for constructing the explanatory model of the Baikal rift development.

The Baikal rift zone is located in the marginal part of the large socle uplift of the Mongolo-Siberian mountain belt, which is the geomorphic expression of asthenolith lying under this mountain belt. There are three local uplifts of the rift zone socle (fig. 4), which are located asymmetrically. Fields of Cenozoic basalts are distributed at the uplifts of the rift zone socle. It is probable that there are unknown peculiarities of anomalous mantle structure (local uplifts of its roof or shares?), which elicited basalt volcanism and isostatic local uprises of the rift zone socle.

GEODYNAMICS OF THE BAIKAL RIFT ZONE

The models of origination and evolution of the Baikal rift zone are based on recognition of the piedmontant role of transverse subhorizontal extension of the lithosphere (FLORENSOV, 1965; LAMAKIN, 1968; ZORIN, 1971; FLORENSOV & LOGATCHEV, 1975). There are some additions to the geodynamic rift zone model resulting from the analysis of its morphotectonics. They are as follows (fig. 32): longitudinal translations of neotectonic forms along the rift zone and manifestations of dissymetry being insignificant indicate identical development of its parts. Representations on subdivision of the rift zone into the central subzone of extension and the flank transform subzones do not correspond to paragenetic association of the recent structure and the deep-seated structure. The Baikal rift zone is uniform along the whole of its length.

Maximum extension of the lithosphere in the rift zone area is observed above the asthenospheric upswelling (ZORIN & OSOKINA, 1961). The lithospheric blocks move mainly to the south-east. The rift basin openings are different in various sections and maximum in the central part of the rift zone in the Lake Baikal area. The major faults came into being due to extension of the rift zone located above the subvertical margin of the anomalous mantle eminence. The inclined horsts of the rift shoulders are situated behind those faults. Concentration of tensile stresses near the north-western and northern slopes of the rift valleys results in formation of narrow intermediate steps, their destruction and basin expansion connected with this process.

The arch of the south-eastern wing of the rift zone is confined to the area of transition of the asthenospheric upwelling to a flatlying layer. Southeasterly subhorizontal transverse compression, which compensates the extension of the lithosphere in the rift zone, prevails in the upper parts of the lithosphere.

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