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THE MAIN FEATURES OF MORPHOSTRUCTURE OF THE TRANSREGIONAL AMUR - SONGHUA - HUANGHE FAULT ZONE IN EAST ASIA①

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ABSTRACT: The cooperative Russian-Chinese morphostructural investigations have been carried out during the last several years along the transregional fault zone——Amur - Songhua - Huanghe Lineament, which is stretching from the lower Huanghe (Yellow) River across the Bohai Sea to Liaohe - Songhua and further along the lower Amur River to North Sakhalin (more than 3000 km). It is the wide fault zone (some hundred km) that has been created in Paleozoic or Precambrian. The series of morphostructures of central type (MCT) or "ring-morphostructures" have been identified here. They are from 500 - 800 km to 20 - 30 km in diameter, and have different structure, age, origin, morphology and geological history. MCT are principal modern structural elements of the earth's crust and the study on them are producing new geological-geomorphological data and new ideas about structure and evolution of the region. MCT was created in Precambrian-Phanerozoic and experienced repeatedly tectonic-magmatic activation during their long-term history. Amur - Songhua - Huanghe Lineament is a seismic active linear structure both in China and in Russia, especially in the areas of intersections with deep faults of gigantic MCT of East Asia. The authors propose that a continental margin extension process, continuing from Paleozoic (Precambrian?) is a major factor in the morphostructural development of the Amur - Songhua - Huanghe Lineament. The received materials may be used for investigations in prospecting geology and geomorphology, studies on natural resources and for decision of other applied problems.
KEY WORDS: morphostructure, fault zone, East Asia

During the last several years the Russian-Chinese cooperative morphostructural investigations were carried out along the transregional fault zone which stretches more than 3000 km, from lower stream of the Huanghe River, across the Bohai Sea, Liaohe depression, then along

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the Songhua and the lower Amur valleys to the North Sakhalin and probably to the central part of Okhotsk Sea basin. It's one of the largest fault zones in the eastern margin of Asia. On the territory of northeastern China the most part of this zone is known as Tan-Lu fault zone which has been studied by Chinese geologists for many years. Some Chinese and Russian investigators have supposed that Tan-Lu fault zone continues to stretch from northeastern China to Lower Priamurie (Zhang, 1993; Nikolaev, 1993; Nikolaev *et al.*, 1989; Guo, 1993; Xu *et al.*, 1987). But for the first time the Amur – Songhua – Huanghe lineament on the whole has been determined on the space photos(Kulalov, 1978, 1980; Solovyov, 1978). Morphostructural investigations along the lineament's area has been carried out by collaborators from Pacific Institute of Geography, Russian Academy of Sciences (Vladivostok, Russia) and Changchun Institute of Geography, the Chinese Academy of Sciences (Changchun, China). Some new data about morphostructure and evolution of this transregional fault zone as well as some problems connected with it have been identified.

I. METHODS OF MORPHOSTRUCTURAL INVESTIGATIONS AND MATERIALS

The objects of structural-geomorphological (morphostructural) investigations are the morphostructures of the earth's crust that are geological structures of the earth expressed in relief. The methodological base and method of morphostructural analyses have been created through the works of many geologists and geomorphologists of Russia and other countries. At present time the principle of "geological-geomorphological conformity" has been determined (Khudyakov, 1977), which is the base for various geomorphological studies. The geomorphological "form" (relief) of morphostructures is narrowly connected with geological "matter" (structure and substance) of them.

The morphostructural maps are the main results of the morphostructural studies of different scales and contents. They have been used for geological prospecting works, and geographical, nature resources, ecological and many other investigations. The process of compiling morphostructural maps has been begun from revealing and studying the various morphostructures of the region. The main role has been played in the space photos of different scales and contents. There are some rules for using space photoes to morphostructural mapping: it is necessary to have a set of space photoes of different scales and contents; the morphostructural deciphering must be step to step (from spacephotos of small scale to space photos of large scale); the largest morphostructures have been deciphered in the first turn; then compiling the classification of morphostructures of the region.

The morphostructural deciphering of topographical maps is the necessary addition to the deciphering of space photoes. It is necessary to have a complete set of topographical maps of different scales and correct constantly results of morphostructural deciphering of topographic maps and space photoes. The morphostructures on the topographic maps have been deciphered as a rule, on the pattern of rivers and peculiarities of relief and landscape. The morphographic and morphometric analyses of topographic maps for some regions are the essential addition for those materials. The geophysical and geological data are very important for morphostructural studies. They contain information about conformal and correlative geological complexes forming the morphostructures as well as deep structure, genesis, evolution and other main features of them. The morphostructures which have been determined in the process of morphostructural analyses have been marked on the map. The classification and legend for morphostructures have been compiled also. It is also possible that the special morphostructural maps may be used for conducting various applied investigations.

The morphostructural maps compiled with the positions of "geologic-geomorphologic conformity" and with the wide using of remote sensing materials contain new information about geologic-geomorphological structure of the region. For example, on the Far East of Russia the following data have been determined.

(1) The wide development of the morphostructures of central type (the same as ring, circular, heart morphostructures), the different size, genesis and age.

(2) The transregional fault zones stretching for hundreds and thousands of kilometers, "dissecting" the continental margin.

(3) The regional hierarchic systems of morphostructures.

(4) A very long and inherited geological development (from Precambrian, Paleozoic and Mezosoic) of the large regional morphostructures.

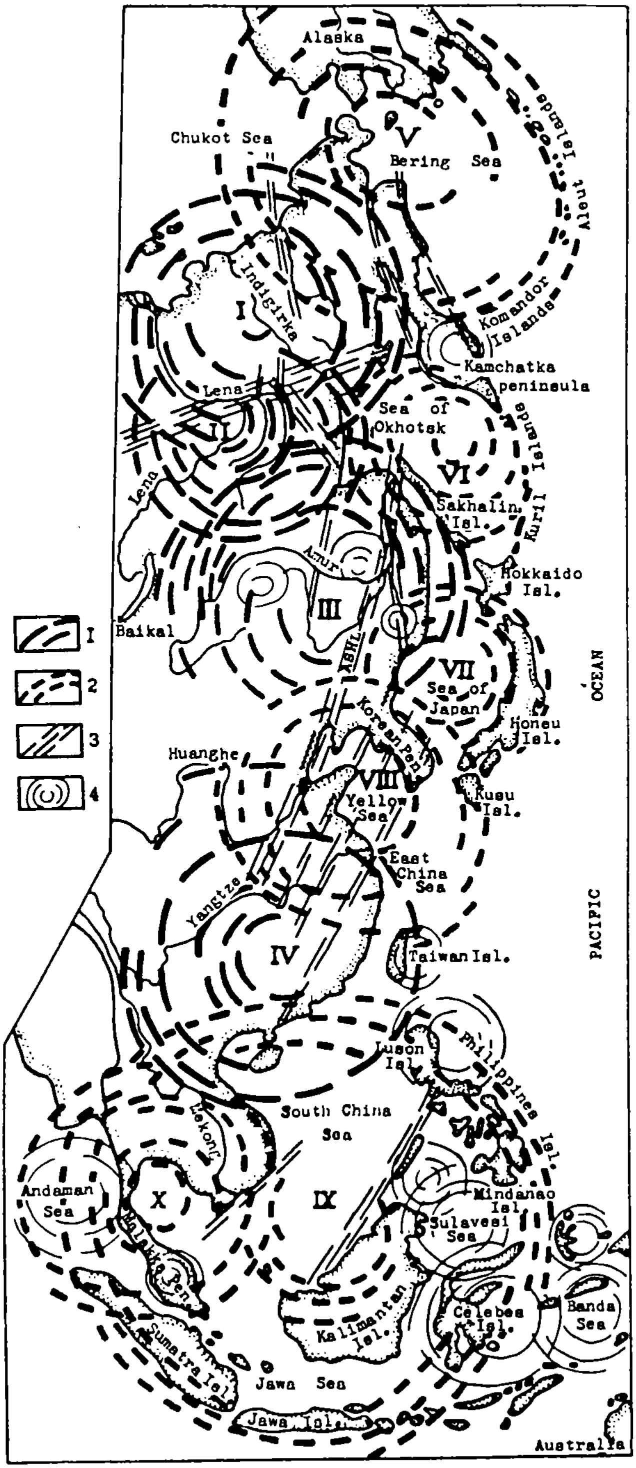
During the time of compiling morphostructural map-scheme of Amur – Songhua – Huanghe Lineament (ASHL), the series of space photoes (Russia and America) were used as well as the Landsat images of China and northeast China (The Landsat Image Map of the Northeast China, 1989; The Landsat Image Map of China, 1992). Simultaneously the morphostructural deciphering of topographic maps (scale 1:200 000 to 1:2 500 000) have been made. The numerous geological, geophysical and other materials have been used also in morphostructural analyses. The various morphostructures, which had been revealed by these works, were marked on the topographic map (scale 1:500 000) and then the working morphostructural map-scheme (scale 1:2 500 000) has been compiled. The catalogue of morphostructures of central type has been made. Thus, an integrated morphostructural analysis of space photoes, topographic and geological maps, tectonic maps, geophysical data, literary sources has been allowed to discover a lot of morphostructures of different type, order, genesis, structure and age, the majority of them are unknown earlier. Let us examine the most interesting peculiarities of structure and evolution of the main morphostructures and zone of lineament in whole.

II. AMUR – SONGHUA – HUANGHE LINEAMENT ON THE BACKGROUND OF THE MEGAMORPHOSTRUCTURES OF EAST ASIA

Amur – Songhua – Huanghe Lineament (ASHL) stretching more than 3000 km is a transregional linear megastructure which dissects the East Asia continental margin and interacts with the regional megamorphostructures. The most interests from latter is the gigantic morphostructures of central type (mega-MCT) 2000 – 4000 km in diameter, and the transregional fault zones determine the main features of the geological and geomorphological patterns of the region. These mega-MCT have been discovered on the Far East of Russia and along the eastern margin of Asia by Russian investigators (Khudyakov *et al*., 1982; Kulakov, 1978, 1980, 1986, 1987; Solovyov, 1978; Zolotov, 1976). Mega-morphostructures of central type are easily distinguished by their hydrological network, relief pattern and geological evidences, clearly visible from satellite images. The mega-MCT form the system along the eastern margin of Asian continent, including the basins of marginal seas, and can be divided into two classes (Fig. 1). There are continental and marginal-continental morphostructures, they are different in certain characteristics and in respect of their geological-tectonic evolutionary trends (Kulakov, 1986). The most important features of mega-MCT are the radial and concentric structural patterns caused by the existence of a framework of deep faults. The patterns and stable spatial positions of mega-MCT have been preserved from the Precambrian up to the present, in spite of repeated transformation of the geological structure and relief. Each mega-MCT is closely related to its neighbors. Their margins overlap with each other, forming co-called "areas of interference", where "contrary arc" structures are developed (Solovyov, 1978; Zolotov, 1976).

The mainland-type mega-MCT in Archaean and Proterozoic were distinguished as the largest dome uplifts with complex structures and mountainous relief. Strong dislocation and metamorphism of the precambrian formations, saturation with intrusive rocks and some other peculiarities testify that these mega-MCT in Archean-Early Proterozoic have been developed in the constructive style. In Palaeozoic and Mezosoic they passed through various evolutionary stages and the several phases of tectonic and igneous activity. The marginal-mainland mega-MCT occupy the sea basins of East Asia. Most of them are characterized by the existence of a central uplift, for example: Yamato uplift in the Sea of Japan, Oceanological Institute uplift in the Sea of Okhotsk and so on. These mega-MCT have been existing probably from Precambrian, but the present morphostructural image (as a large sea-basin) was received from Jurassic-Cretaceous period when the intensive tectonic subsidence of megastructures has begun and continued into the Cenozoic era. The systems of radial-concentric deep faults of mega-MCT played a prominent part in the formation of a new morphostructural plan, including tectonic and magmatic activity.

ASHL has been cutting the mainland Amur mega-MCT, the marginal-mainland Korean mega-MCT and small part of the East China mega-MCT (Fig. 1). The megamorphostructures of course have been exerting influence on geologic-geomorphological structure of ASHL. First of all the radial-concentric deep faults of mega-MCT have been influenced over linear structure of it. For the most part it has been sensed in lower Priamurie and North Sakhalin, where concentric faults of Amur mega-MCT were cut by ASHL, forming the various fault-blocks, volcanic and other morphostructures into lineament zone and near it. The same situation occurs in the south - western part of ASHL where concentric deep faults of Korean and East China



Legends

1. Mainland

Ⅰ. Yano-Kolyma

Ⅱ. Aldan

Ⅲ. Amur

Ⅳ. East China

2. Marginal-Mainland

Ⅴ. Bering

Ⅵ. Okhotsk

Ⅶ. Sea of Japan

Ⅷ. Korea Pen.

Ⅸ. Malay

Ⅹ. Siam

3. Transregional Peri-Pacific faults zones

ASHL Lineament

4. Second and third-order MCT (300 to 1000 km in diameter)

Fig. 1 The Scheme of the primary megamorphostructure of East Asia mega-MCT are crossing the lineament. They control the many peculiarities of geological structure in Bohai Sea region, lower Huanghe basin and surrounding areas. We are supposing even that middle segment of Tan-Lu fault zone (to the south from Bohai Sea) in reality is a fragment of concentric deep faults of Korean mega-MCT (Fig.1,2). And the most southern segment of the Tan-Lu zone acquires the north eastern strike and has been coincided here with the large fault zone stretching along the lower stream of the Yangtze River. Thus, on the basis of new ideas about regional morphostructure of East Asia we consider that Tan-Lu fault zone in whole is the complex geological structure which has been uniting the following heterogeneous fault zones: Amur-Songhua-Huanghe Lineament, concentric faults of Korean mega-MCT (fragment) and fault-zone of north eastern strike in the region of lower Yangtze (fragment). We believe that a new view on the structure of Tan-Lu fault zone and surrounding areas are the essential addition to existing data and will be useful for the following geological, geographical, prospecting and other investigations.

III. THE MAIN FEATURES OF STRUCTURE AND EVOLUTION OF ASHL

The morphostructural map-scheme of ASHL on the scale of 1:2 500 000 has been compiled (Fig.2). It contains in principle the new data about morphostructure of this transregional fault zone. First, it has been determined that ASHL continue from north east China into lower Priamurie and farther to the Sea of Okhotsk. It is a gigantic linear morphostructure which controls the most important features of geologic-geomorphologic structure and natural processes over the vast areas in Russia and China. ASHL cross the various geological and morphostructural regions and zones and therefore has sufficiently complex structure. The main morphostructures of the lineament are the faults and morphostructures of central type. The all other types of morphostructures and first of all the fault-block morphostructures (positive and negative) are derivatives of these two main types.

The faults of ASHL have been well studied in Northeast China. The most important of them is Tan-Lu fault zone, its north part is a component of ASHL. Tan-Lu fault was the object of investigations of many Chinese geologists. The most full data about Tan-Lu fault has been represented in collective monography by Xu Jiawei(1987) with collaborators. According to materials of Chinese investigators the Tan-Lu fault zone has a width to more than 80 km and contains several faults. In many places the fault zone is similar to rift valley structure. There are also the specific structures and geological formations testifying about numerical and various tectonic deformations into and off fault zone. For example, the mylonites, cataclastic breccia, pseudotachylites, fault gouge with tectonized pebbles as well as sinistral shear-bending structures, secondary wrench fault systems, extension fractures, vortex structures, thrust and nape and other structures are widespread along the fault zone(Guo *et al*., 1993).

Northeastward from Shenyang City, the Tan-Lu fault zone has been divided into two branches: Mishan – Fushun and Yilan – Yitong fault zones, which continue further to the

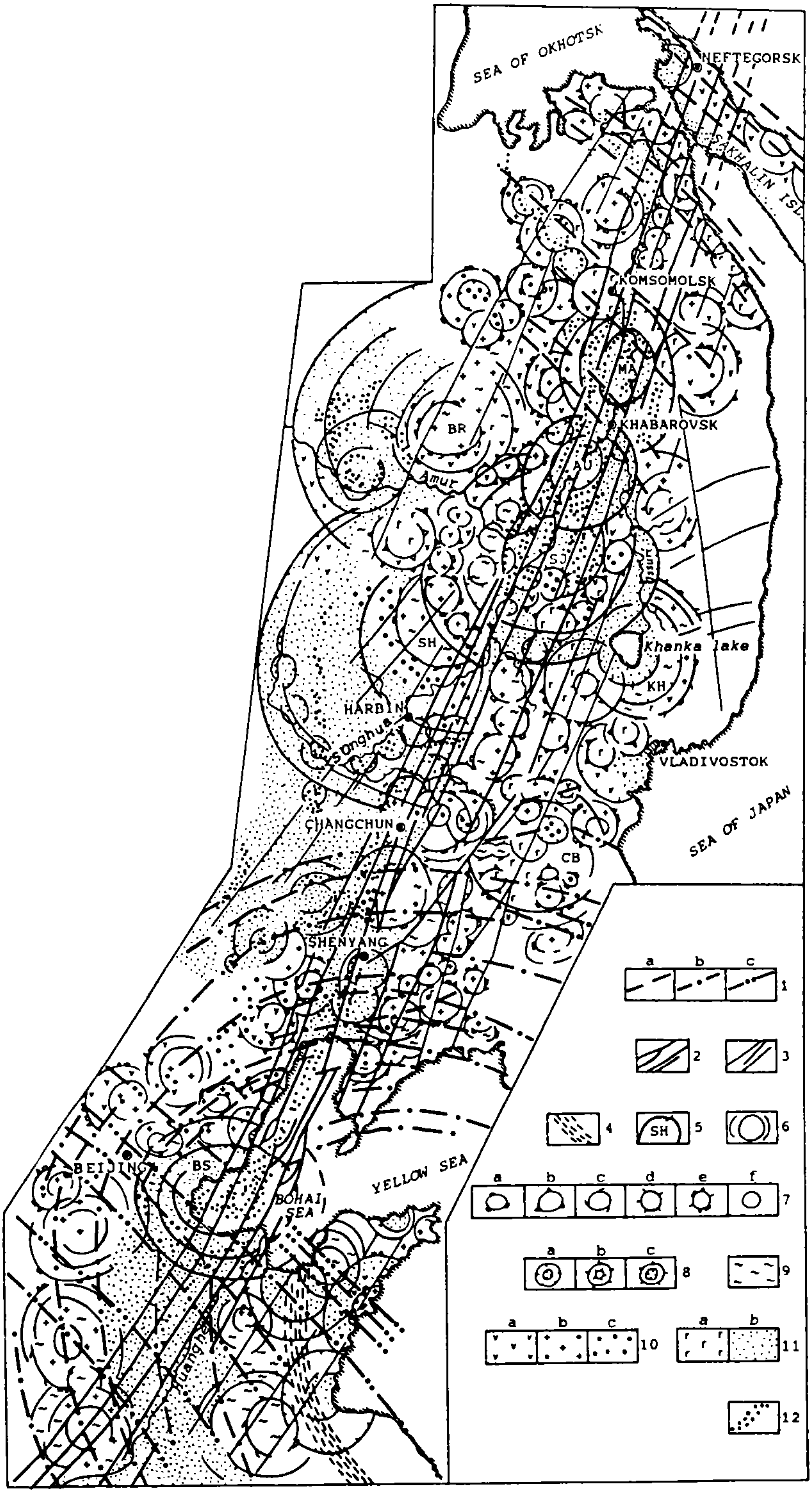


Fig. 2 Morphostructural map-scheme of ASHL

(Legends in the following page)

Legends

1. Fragments of the concentric deep faults of gigantic morphostructures of central type (mega-MCT) of East Asia

a——Amur b——Korea c——East China

2. Deep faults of central ("axis") part of the ASHL

3. The system of subparallel faults of northeastern strike and other faults

4. Tan - Lu fault zone

5. Morphostructures of central type of the 2nd order (names into centre)

BR——Bureya (diameter 800 km) SH——Small Hinggan (d 650 km) SJ——Sanjiang (d 500 km), BS——Bohai Sea (d 400km) MA——Middle Amur (d 300 km) AU——Amur - Ussuri (d 250 km) KH——Khanka (d 300 km) CB——Changbaishang (d 300 km)

6. Morphostructures of central type of the 3 - 4th order (30 to 200 km in diameter)

7. The main genetic types of MCT

a——intrusive b——volcanic c——metamorphic d——tectonic e——complex f——unknown

8. The main geomorphological types of MCT

a——large negative (ring depressions of various structure) b——large positive (domes, swells and so on) c——complex (mixed) forms

9 - 11. Geological formations conformable of morphostructures of ASHL

9. Metamorphic rocks of Archean - Paleozoic

10. Mesozoic rocks a——volcanic b——intrusive c——sedimentary

11. Cenozoic rocks a——volcanic b——sedimentary deposits

12. Mesozoic - Cenozoic sedimentary deposits of large thickness (2 - 3 km and more) in depressions

lower Amur region (Guo *et al*., 1993; Xu *et al*., 1987; Atlas of Maps of China, 1971; Geological Map of China, 1971; Geological Map, 1992; Geodynamic Map, 1992; The Landsat Image Map of the Northeast China, 1989; The Landsat Image Map of China, 1992; Zhang Wenyou, 1993; Tectonic Map of the Linear Structure on the Territory of China, 1981). Besides, on the landsat image maps and various space photoes as well as on the deciphered topographic maps, some geologic and tectonic maps (Ma *et al*., 1987; Ye *et al*., 1987), the series of faults of northeastern region and submeridional strike have been determined. These faults forming the complex system closely connected with the main Tan-Lu fault zone and increase the width for two - three times. The south western part of ASHL (in the Bohai Sea and lower Huanghe region) has been crossed by the concentric faults of Korean and East China mega-MCT. The series of faults which are subparalled of central zone have been revealed also here. The pattern of faults of this region is more complicated on the whole in comparison with others.

ASHL in the lower Priamurie region has been traced with confidence by geological, geomorphological and landscape data. Besides, the faults of lineament have been deciphered very well on the space photoes and topographic maps of different scales as well as on the geological maps. Faults have been distinguished even on the wide alluvial plains in the Amur - Songhua - Ussuri confluence region. The large faults are stretching along Amur River and from mouth of Songhua and Ussuri to the northeastward up to Udyl-Kizi depression and further acrossing Tatar Strait and Amur Bay to North Sakhalin. Besides there are the series of large faults on the left side of the Amur River which are well known for Far East geologists. The main of them has been marked on the geological maps, deciphered on the space photoes and topographic maps and has been well expressed in the relief of the region. Valleys of large rivers and separatings of them, the linear mountain ranges of northeastern strike have been controlled by these large deep faults. There are several analogous faults on the right bank of the Amur, but they have been expressed here not so good as that on the left bank.

All these northeastward faults on the opinion of Russian geologists are the deep and ancient faults. For example, the Hinggan Fault which is stretching from the valley of Middle Amur across Badjal Range to the mouth of Amur, has been formed in Paleozoic and was active in Mesozoic and Cenozoic. The series of dikes of basic and acid rocks, zones of cataclastic rocks, volcanic zones (the largest of them is Badjal volcanic megastructure), Miocene and Pliocene-Quaternary plateau-basalts are characteristic for this fault as well as the linear anomalies of magnetic field and linear gravity minimums(Beltenev, 1982; Kulakov, 1980). The neighboring fault, the Kursky fault which separates the Badjal and Djaki-Unakhta-Yakbyana ranges, has been formed in Paleozoic too. The numerous zones of cataclastic, quartz reefs and boudinage, the rapid change of facies and thicknesses of deposits, the alternation of Paleozoic and Mesozoic structures testify the high activity of fault in Phanerozoic(Beltenev, 1982; Kulakov, 1980). There are analogous data about other northeastward faults of lower Priamurie.

Thus, there is a system of deep northeastward faults in this region, which are situated at a distance 10 – 50 km from each other. They form a very wide fault zone (upto 400 – 500 km) expanding the main structural-tectonic regions of South Far East of Russia-Bureya massif, Amur-Okhotsk and Sikhote-Alin geosynclinal-folded systems. By the north-western boundary of this zone is probably the deep fault stretching along the valley of the Bureya River and farther to the Urgal River and Upper Bureya. The south eastern boundary is situated on the right bank of the Amur into basin of Gur and Tumnin rivers. This wide fault zone has a complex geologic-geomorphological structure and extends to the territory of northeastern China. The central part ("axis") of this zone is stretching along the Amur Valley and has been represented by several subparallel faults. The width of "axis" zone is near 150 – 200 km. Thus, the real analogy with the regions of eastern China take place where the series of faults of mainly north strike forming the whole large system on the margin of the continent have been identified by Xu Jiawei and his colleagues(Guo, 1993; Xu, 1987).

On the territory of lower Priamurie the system of faults of north western strike are also widespread. They cross the ASHL and control many features of geology and morphostructure of the region. For example, the sharp bends of the Amur River after Udyl-Kizi depression have been caused by the influence of these faults. Besides, the linear zones of depressions, metamorphic and weathered rocks, series of intrusion and effusion, the traces of horizontal and vertical tectonic movements and other peculiarities of geological structure and geodynamics are characteristic for them. It is the fragments of the concentric deep faults of Amur mega-MCT that cover the whole Amur basin. These faults are very ancient, the most of them have existed from Precambrian and experienced repeatedly tectonic-magmatic activation during their long-term geological history.

The analogous faults, the fragments of concentric deep faults of the mega-MCT of East Asia, exist on the south western part of ASHL. In the Bohai Sea region and basin of lower Huanghe River the series of faults of submeridional, subaltitudinal and northwestern strikes have been determined (Atlas of Maps of China, 1971; Chen, 1988; Geological Map of China, 1971; Geological Map, 1992; Geodynamic Map, 1992; Qin *et al*., 1990; The Landsat Image Map of the Northeast China, 1989; The Landsat Image Map of China, 1992; Tectonic Map of the Linear Structure on the Territory of China, 1981). These are fragments of the concentric faults of Korean and East China mega-MCT. They have been influenced by the geologic structure and morphostructure of the Bohai Sea depression and adjoining regions. In particular a thick deposit of Cenozoic in sea depression (upto 7 000 – 13 000 m) is a result of intensive tectonic subsidence of the all central areas of Korean mega-MCT – the basin of Yellow Sea, which took place during Upper Mesozoic and Cenozoic. Some concentric faults of Korean mega-MCT form the south part of Tan-Lu fault zone to the south of Laizhou Bay. The analogous faults of East China mega-MCT control many features of morphostructure and geological structure of the southwestern part of Bohai Sea as well as of the wide region of Lower Huanghe River. These faults have been deciphered on the space photoes, space image maps, topographic map and some of them on the geologic and geophysic maps(Qin *et al*., 1990; Guo *et al*., 1993; Atlas of Maps of China, 1971; Chen *et al*., 1985; Geological Map, 1992; Geodynamic Map, 1992; The Land Image Map of the Northeast China, 1989; The Landsat Image Map of China, 1992; Zhang, 1993; Tectonic Map of the Linear Structure on the Territory of China, 1981). So, the formation of the Bohai Sea depression from this point of view is a result of interaction of the ASHL and Korean mega-MCT. The series of deep faults of ASHL form the block-faults negative morphostructures (depressions) and the mega-depression of Bohai Sea. At the same time the fragments of concentric deep faults of Korean and East China mega-MCT form the "boundaries" of mega-depression on the northeast and southwest. Besides, the latter has influenced the inside pattern of the Bohai Sea mega-depression forming the "transverse" structures of various type. It is clear on the basis of geologic and geophysic materials of Bohai Sea(Qin *et al*., 1990).

Thus, ASHL has the following characteristics: (1) The system of deep faults of northeastern strike forms the strict ASHL (the "axis" zone and accompanying of it). (2) The systems of concentric deep faults of the Amur, Korea and East China mega-MCT of East Asia are crossed by the lineament in many places and its pattern has been complicated. There are also some faults of regional and local rank which are not of essential significance for morphostructure of ASHL.

The other type of the main morphostructures of ASHL is the morphostructures of central type (MCT). For the first time the series of MCT (or "ring morphostructures") have been identified for this region. They have been placed into the lineament zone or near it. MCT has been identified and deciphered certainly on the space photoes, topographic maps, geological maps and other materials. They are expressed very well in the modern geological structure and relief and landscapes of the earths surface. MCT are the new structural elements of the earths crust. They have been studied intensely in Russia in the last 10 – 15 years. MCT control many important peculiarities of geological-geomorphological structure of the different regions as well as ore deposits, oil and gas fields, and influence various natural processes taking place in the deep and on the surface of the earth and so on. Therefore MCT are very important for zone of ASHL and must be studied as soon as possible and intensively in the nearest years.

MCT of ASHL region are very various by size, origin, structure, age, geological history and other peculiarities. The main of them are shown on the morphostructural scheme of ASHL. There are some orders of MCT. The lst order, gigantic MCT of East Asia (Amur, Korea, East China and other mega-MCT) have a diameter of 1500 – 2500 km and are mentioned above. The MCT of the 2nd order have a diameter from 250 km to 800 km. The largest of them are Bureya MCT (d 800 km)and small Hinggan (d 650 km), the central parts of them are situated sideward from "axis" zone of ASHL. But the series of other large MCT——Sanjiang (d 500 km), Amur – Ussuri MCT (d 250 km), Middle Amur MCT (d 300 km), Bohai Sea (d 400 km)——are situated directly along the lineament and spatial and genetic relationships existed between them. It is remarkable that these MCT are negative morphostructures large depressions of complex structure with the mountainous ranges only on the periphery of them. A large thickness of Upper Mesozoic and Cenozoic deposits (upto some thousands m) are characteristic for them. Every MCT is the large complex system of the main fault-blocks morphostructures which have been created by intensive vertical movements of blocks along the deep faults of the lineament as well as radial-concentric faults of MCT.

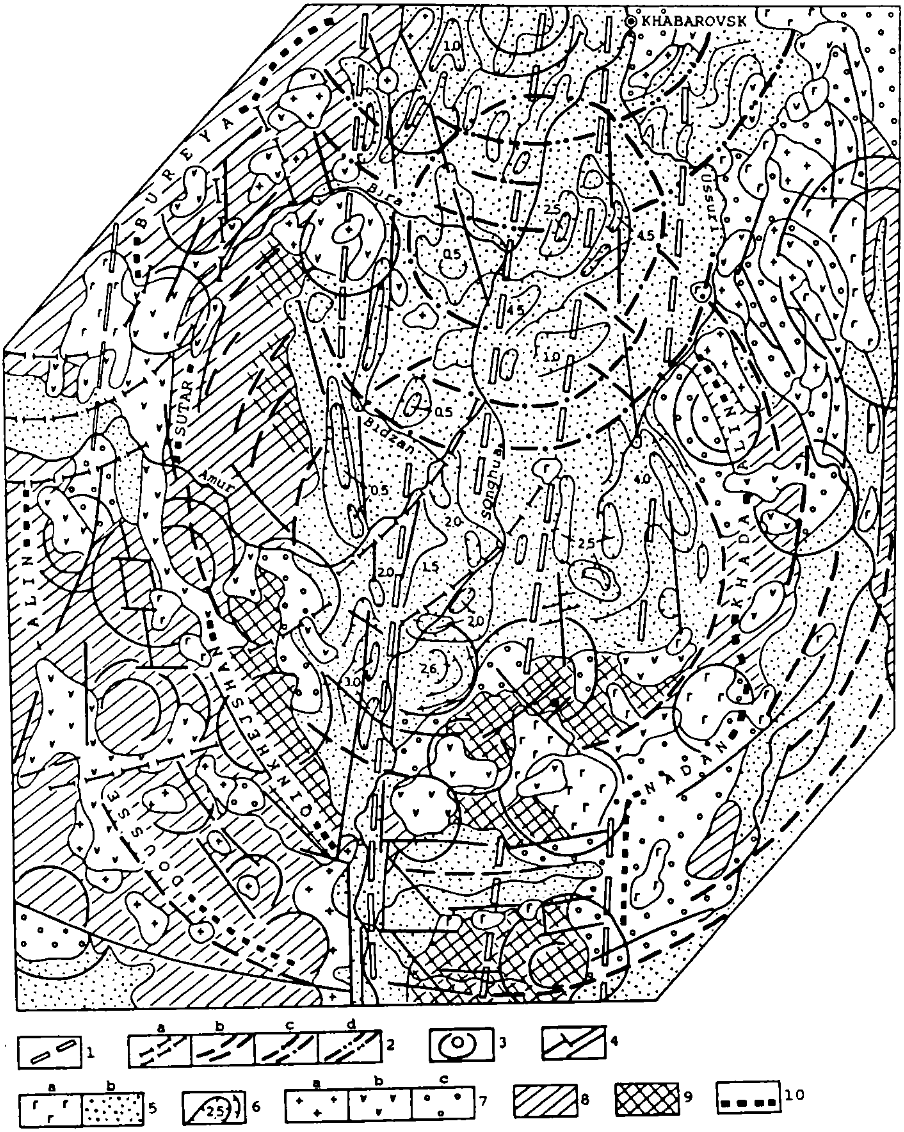
Bureya megastructure is very well known for Russian geologists. The western and northern boundaries of it were tracing the Zeya River and their tributaries while the eastern boundary is not so clear, because the ASHL is cutting here the eastern part of MCT. At the same time Bureya MCT has been deciphered with confidence on the space photoes as well as by geologic and geomorphological materials. In morphology it is a gigantic dome of complex structure which has been composed mainly by granitoids of Lower, Middle and Upper Paleozoic and Lower Triassic and Jurassic. The Proterozoic metamorphic rocks have been spread along the periphery of dome also. Besides, the remains of covers of gneiss, metamorphic sedimentary and effusive rocks of Precambrian, Cambrian, Silurian, Devonian ages and ancient gabbroids exist in some places. The folded sedimentary formations of Silurian, Devonian, Permian-Carbonic, Triassic and Kretaceous periods of large thickness are widespread on the periphery of MCT. The numerous geological data testify that Bureya megamorphostructure has been existed from Precambrian and the long and complex geological history was characteristic for it. Probably it was a large positive morphostructure (dome) from Silurian. The vertical movements of nucleus of the dome took place in Paleozoic-Mesozoic and Cenozoic. At the present the Zeya-Bureya wide depression with the cover of sedimentary and volcanic deposits of Cretaceous – Cenozoic age are situated in the central area of Bureya MCT.

Small Hinggan MCT is also very large morphostructure which has the complex geologic-geomorphological structure. The central part of it is situated between the Amur and Songhua rivers, northward from Harbin City. The northern, western and southern boundaries of the megastructure are going along the Amur, Nunzsiang, Songhua rivers, but the eastern part of MCT has been dissected by ASHL and therefore the exact boundary is not clear here. Besides, the margin of Small Hinggan MCT has been overlapped by margins of neighboring Bureya and Sanjiang MCT. On morphology the megamorphostructure is a large dome with mountainous relief into central and northern parts but with a wide depressions and plains in the western and southwestern regions. The metamorphic, intrusive and effusive rocks mainly of Precambrian, Paleozoic and Mesozoic occupy the central area of MCT. The sedimentary, volcanic-sedimentary, volcanic formations of different composition of Paleozoic, Mesozoic and Cenozoic are widespread in the other territory of MCT. It is remarkable that the large thickness of Mesozoic-Cenozoic deposits into grabens along concentric faults of MCT, the numerous zones of metamorphic rocks, the covers of effusive, the cenozoic volcanostructures and other signs which testify about intensive tectonic-magmatic activity of megamorphostructure. In our opinion Small Hinggan MCT was created mainly in Paleozoic or Precambrian, but the modern morphostructural image of it is a result of Mesozoic-Cenozoic geological evolution. Besides, the essential influence on it by ASHL took place.

The scheme of the structure of Sanjiang and Amur-Ussuri MCT are shown here (Fig. 3). The "axis" zone of ASHL cross the centre of Sanjiang MCT and just as the system of concentric ranges forms the boundaries of megastructure. The Amur-Ussuri MCT is not so large (d near 250 km) and is a satellite morphostructure which is situated on the intersection of lineament and concentric faults of Sanjiang MCT. The maximum thickness of Mesozoic-Cenozoic deposits into these MCT are from 2.0 km to 4.0 − 4.5 km. It is remarkable that Mesozoic, Paleozoic and Proterozoic geological complexes along the periphery of Sanjiang MCT are situated in accordance with the pattern of concentric faults.

The analogous structure is characteristic for Middle-Amur MCT which occupies the wide Middle-Amur depression between Khabarovsk and Komsomolsk cities on the Lower Amur as well as the systems of ranges on the left and right banks of the river. Middle-Amur depression is a complex "mosaic" megastructure where the thickness of Upper Mesozoic − Cenozoic deposits in some places (for instance in Pereyaslav graben near Khabarovsk) is near 2.7 km. A lot of grabens and gorsts of different sizes, structures and patterns as well as the covers of basalts and paleovolcanic structures are widespread here (Varnavskiy, 1971).

The Bohai Sea MCT is situated on the southwestern part of the Bohai Sea. It has been determined on the space photoes and by geologic-geophysic data about structure of sea-basin. The concentric pattern of geophysic fields and considerable thickness of Eogene and Neogene deposits are characteristic for it. It is remarkable that this MCT is situated on the intersection area of ASHL and concentric faults of the north eastern margin of the East China mega-MCT. Therefore it is possible that the Mesozoic − Cenozoic deposits in central area of MCT may be



1. The main deep faults of ASHL
2. Concentric faults of megastructures of central type
   a——Bureya b——Sanjiang c——Amur – Ussuri d——Middle Amur
3. MCT of 3 – 4th order (30 – 200 km diameter)
4. The main faults shown on geological maps
5. Cenozoic volcanic (a) and sedimentary (b) geological formations
6. Thickness of Mesozoic – Cenozoic deposits into depressions (km)
7. Mesozoic geological formations a——intrusive b——volcanic c——sedimentary
8. Metamorphic (in the main intrusive) rocks of Paleozoic
9. Metamorphic intrusive rocks of Proterozoic
10. The main mountain – ranges and names of them

Fig. 3 Scheme of geological – geomorphological structure of the Sanjiang MCT very thick and consequently it is interesting for prospecting works. Thus, the Sanjiang, Amur – Ussuri and Middle-Amur MCT have been filled by Upper Mesozoic-Cenozoic sedimentary and volcanic deposits which are "correlative formations" for them. These formations testify only about the stage of "tectonic subsidence" of morphostructures but not about all geologic history of them. The real age of creation of MCT is more ancient.

The geological formations of Mesozoic and Paleozoic, which are "conformal" with MCT and are bedding in accordance with the system of concentric deep faults, are a base for supposition about Paleozoic age of MCT. We consider that they were large positive morphostructures (domes, swells or ring image) in Paleozoic, but in Mesozoic the gradual destruction and tectonic subsidence of central areas of them took place especially in Upper Mesozoic and Cenozoic. This process is a result of change of regional geodynamic situation in that time. Probably the activation of tectonic movements as consequence of main extension of the earth crust along ASHL took place in Upper Mesozoic – Cenozoic.

The analogous structure and paleomorphostructural evolution are characteristic for Khanka MCT, which has been expressed very well in relief and geological structure of the region. Large Khanka Lake is situated in the centre of MCT and a system of concentric deep faults has outlined. The nucleus of MCT consisted mainly of Paleozoic granitoids, metamorphic rocks of Lower Proterozoic and weak metamorphic rocks of Upper Proterozoic and Cambrian. On the periphery of it Paleozoic and Mesozoic geosynclinal formations and Mesozoic – Cenozoic depression with volcanic deposits are spread. The central part of MCT has been subsided and the Cenozoic depression and Khanka Lake has been formed here (Zolotov, 1976). Khanka MCT has been created in Paleozoic or Upper Proterozoic and it was a large dome during Paleozoic. But in Mesozoic the destruction of it has begun and the tectonic subsidence of central area in Cenozoic took place.

Thus, the same features of morphostructural evolution for series of a large MCT connected with ASHL have been determined. It is characteristic for the following MCT: Bureya, Sanjiang, Amur – Ussuri, Middle-Amur, Khanka and Xiao – Hinggan. Firstly these MCT are ancient geological structures and have been created in Precambrian – Paleozoic. The secondly they have developed in one and the same style——from the large domes or swells in Paleozoic to the large depressions of the complex structure in Upper Mesozoic – Cenozoic.

Besides, the series MCT of 3rd – 4th order (diameter from 30 upto 200 km) have been arranged in ASHL. They are various in the structure, origin, age, morphology. An intrusive, volcanic and complex MCT is prevailed here. In many cases they form the "rows" of MCT under the control of deep faults of ASHL. The systems of linear and arc ranges have been formed like this. For example, the Badjal Range in Lower Priamurie is volcanic linear megastructure. It consists of some mainly volcanic MCT which creat the "row" of them. Volcanic MCT widespread in a region, to the limits of East – Sikhote – Alin volcanic belt. In many cases they have been associated with intrusives of different size, matter and age. The morphology of MCT of 3rd – 4th order is very various: negative morphostructures (depressions) with a large thickness of sedimentary and volcanic deposits up to domes, swells and complex ring and other forms. These MCT have been created mainly in Mesozoic and some of them in Cenozoic.

Above-mentioned data on MCT of the region has been permitted to make some new conclusions about geological history and geodynamics of ASHL. There are different opinions on the time of creation of Tan-Lu fault zone (which is considered as fragment of ASHL) from Precambrian to Mesozoic. In the last several years the conclusions about Mesozoic (Jurassic – Cretaceous) age of Tan-Lu zone are prevailed (Guo, 1993; Xu, 1987). But in Lower Priamurie (Russia) the large deep faults northeastward forming the system of faults of ASHL has been created in Paleozoic and were active in Mesozoic – Cenozoic(Beltenev, 1982; Nikolaev *et al*., 1989) and others. These deep faults prolonged to the northeastern China territory. Besides, data on the series of MCT of the 2nd order which have spatial and genetic relationships with ASHL are testified about Precambrian – Paleozoic age of them. Therefore we consider that ASHL was existing from Paleozoic or maybe even from Precambrian. In Mesozoic – Cenozoic the stage of high tectonic – magmatic activity of the lineament took place and the modern geomorphological image of it has been formed. This transregional fault zone as well as other analogous zones over the eastern margin of Asia is the result of extension of the earth's crust in this region which last very long geological time: from precambrian to present days (Kulakov, 1986, 1987).

The next large problem is the geodynamics of ASHL during its geological history. In the development of Tan-Lu fault zone three stages have been determined (Xu *et al*., 1987). The first stage (Upper Jurassic – Lower Cretaceous) was the epoch of forming fault zone with large sinistral horizontal movements. The second stage (Upper Cretaceous – Eogene) was the epoch of extension and differential vertical movements with small sinistral and dextral displacements. At last, from the Eogene to the Present, compression and small displacements along the fault zone took place. Apparently these regularities are also real for Amur – Songhua – Huanghe fault zone (lineament). But in our opinion it is necessary to take into consideration of the influence of megastructures of central type (the 1st – 3rd order) on the geodynamics of ASHL. The some specific peculiarities of development are characteristic for them. The gigantic MCT of East Asia (Amur, Korea, East China mega-MCT) are very ancient morphostructures with numerous phases of tectonic-magmatic activity, centrifugal and centripetal movements of rock mass and formation of various dislocations. For mega-MCT the so called "zones of interference" are also characteristic, where "contrary arc" structures are developed (Solovyon, 1978; Zolotov, 1976). They occupy the wide areas of mega-MCT and have influences on geological and geomorphological pattern. The same peculiarities were also peculiar for MCT of 2nd – 4th order. Thus the whole geodynamic picture of ASHL is very complex and it is necessary to take into consideration of the influence of many factors of different orders and power. Besides, the regional geodynamic situation has been changed repeatedly during the long geological history of morphostructures of the ASHL. Therefore only detail geological and morphostructural studies can give later on the real picture of complex and changing geodynamics of ASHL region. It is possible that some modern notions about geodynamics of Lineament, for example on a large horizontal displacemens along it, will not be confirmed or will be explained by other reasons.

The problem of seismotectonic activity of ASHL is very interesting and actual. It has been well studied in the northeastern China, but there are not so much data for the Russian territory. On the Lower Priamurie the several large faults of northeastern strike were known as seismoactive structures (Nikolaev, 1993; Nikolaev *et al*., 1981, 1989) which are the elements of ASHL. Some years ago on the right bank of the Amur River lower of Komsomolsk City the typical seismogenic-gravity form of relief——the large "block of slide"——has been identified on the aerophotos. The similar forms which has been created by the strong earthquakes (8 balls or more) are widespread in the Pribaikalie, Zabaikalie, Middle Amur Basin as well as on the shores of Sea of Okhotsk, Sea of Japan and other areas (Alekseev *et al*., 1975; Kulakov, 1980, 1986; Nikolaev, 1981, 1986; Solonenko, 1981). A strong earthquake in spring of 1995 at Neftegorsk town (North Sakhalin) on our opinion is a result of seismic activity of ASHL. Besides, the North Sakhalin is an area of intersection of the deep faults of lineament with the concentric deep faults of the eastern margin of gigantic Amur mega-MCT and it is the main cause of high seismisity here. Therefore it is necessary for modern maps of seismic activity for Lower Amur region to compile on the morphostructural base in order to determine the areas of high seismic rick. Analogous works are also recommend for some regions of the northeastern China.

IV. CONCLUSION

The joint investigations of Russian and Chinese geomorphologists on the territory of neighboring countries are very effective. The existence of ASHL (length more 3000 km and width to several hundred km) has been determined where the Tan-Lu fault zone (northern part) is only segment of it. For the first time the series of morphostructure of central type (ring-morphostructures) of the different order, age, origin, structure have been discovered here. The results of cooperative works produced new ideas about geologic-geomorphological structure and evolution of the earth's crust on the lineament zone and region in the whole. Besides, these materials may be used as the basis for investigations in the fields of prospecting geology and geomorphology, studies of natural resources and various geomorphological processes, rational utilization of natural resources and other applied problems which are characteristic for territory of ASHL in Russia and China. Therefore we invited the investigators to take part in the cooperative studies of this gigantic natural object.

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