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Geodynamic evolution of the Central-Asian and Mongol–Okhotsk fold belts and formation of the endogenic deposits

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ABSTRACT: This paper deals with the geodynamic evolution and some problems of metallogeny of the Central Asian and Mongol–Okhotsk fold belts. It has been established that throughout its history (from Proterozoic to Cenozoic) all known types of geodynamic settings existed. It has been found, that each setting has a strictly specified geodynamic structure, a number of tectonic structures, magmatic and metamorphic complexes and related mineral deposits. Each geodynamic setting has its own well-defined structural-magmatic and metallogenic zonation. Metallogenic analysis performed on the basis of paleogeodynamic reconstructions for short intervals suggests a position of the ancient borders of the litospheric plates. Magmatic and metallogenic activity was found along and around the boundaries of these plates. This analysis also suggests additional criteria for prediction and search for minerals within Transbaikalia and Mongolia.

Key words: Geodynamic, volcano–plutonic belt, magmatism, rift structure, oceanic crust, metallogeny, deposits

1. INTRODUCTION

Geodynamics is a new scientific line in the study of the Earth that stands on the synthesis of tectonics, geochemistry, petrology and geophysics. New achievements in the studies of geodynamic settings of various areas of the Earth, based on the methods of plate tectonics, provided a new approach to the tectonic and metallogenic analysis of territories.

Investigations into magmatic rocks of different compositions in folded areas of the Earth showed that geochemical features of rocks depend mainly on the type of geodynamic condition under which they formed rather than on their age. Each geodynamic setting was established to possess a strictly specified geodynamic pattern, set of tectonic structures magmatic and metamorphic complexes and related mineral deposits. Each geodynamic setting has its own specific structure-magmatic and, correspondingly, metallogenic zonation, caused mainly by a decrease in the alkalinity of magmatic rocks from frontal to back parts of active continental margins and island volcanic arcs. In some places this zonation is disturbed because of the activity of sources of magmatism of different geodynamic origin in tectonically uniform structures. These specific features of magmatism must be taken into account in metallogenic constructions.

In this paper we made an attempt to show that the modern metallogeny of the Altai–Sayan–Mongolo–Transbaikalian region is due to the geodynamic evolution of tectonic structures and magmatism, during which various ore-forming systems existed. The major attention is focused on magmatic factors determining the metallogeny, whose geochemical properties depend mainly on the geodynamic conditions of their formation. We think that ancient borders of lithospheric plates, which, by analogy with modern plates, are active zones of occurrence and concentration of volcanic and plutonic processes and related mineral deposits, were of particular importance.

This paper is a detailed review, presented at the International Symposium of IGCP Project No 411 Geodynamic processes of Gondwanaland-derived terranes in Eastern Asia: their crustal evolution, emplacement and natural resources potential (Seoul, Korea, Aug. 28–Sept. 2, 2000).

In the process of writing of the review, especially in exercising of geodynamical reconstructions, numerous published materials of russian and foreign scientists were widely used (Zonenshain et al., 1990; Scotese and McKerrow, 1990; Sengor et al., 1993; Gordienko, 1987,1994; Parfenov et al., 1995; Pechersky and Didenko, 1995; Metcalfe, 1996; Khain and Seslavinsky, 1996; Gordienko and Kuzmin, 1999 and others).

2. GEODYNAMIC EVOLUTION

Our investigations has been show that the territory of the Central Asian and Mongol-Okhotsk fold belts went by complex and prolonged way of geological development. Within this vast territory the following kinds of geodynamic settings of the Precambrian and Phanerozoic were studied out: mid-ocean spreading zone and transform fault zone, active and passive continental margins, ensimatic and ensialic island arcs, marginal and inner-continental rift zones and intra-plate magmatic areas. But their role in various periods, especially in the Precambrian, was ambiguous.

The Precambrian (Archean–Proterozoic) geological history of this region still has a lot of unclear and contradictive aspects. If we base on the global reconstructions (Zonenshain et al., 1990; Gordienko, 1994; Khain and Seslavinsky, 1996), well see that Siberian continent together with other large Early Precambrian massifes was a part of a supercon-

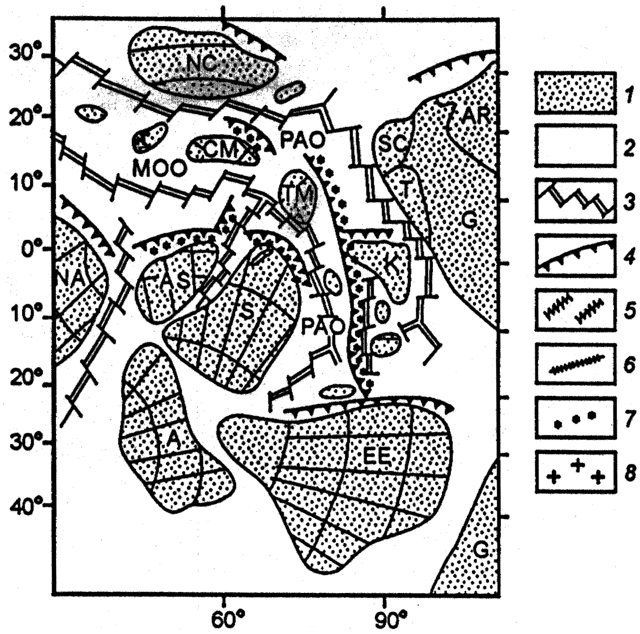

Fig. 1. Global paleogeodynamic reconstruction of the Vend–Early Cambrian time (Zonenshain et al., 1990; Gordienko, 1994). Here and Fig. 3–5: 1=continents and microcontinents, 2=oceanic basins, 3=spreading zones and transform faults, 4=subduction zones, 5=continental rifts, 6=collision zones, 7=volcanism of island arcs and active continental margins, 8=granite plutons and zones of granitization. Continents and microcontinents; S=Siberia, NC=Northern China, NA=Northern America, EE=Eastern Europe, G=Gondwana, SC=Southern China, T=Tarim, AR=Australia, A=Arctica, AS=Aldan–Stanovoy, K=Kazakhstan, EA=Euroamerica, SG=Southern Gobi, IC=Indochina, KB=Khingan–Bureiya, OM=Okhotomorsk, TM=Tuva–Mongolian, CM=Central Mongolian, LA=Laurasia. Oceanic basins: PAO=Paleoasian, MOO=Mongol–Okhotsk, UO=Uralian, PT=Paleotethys, PP=Paleopacific.

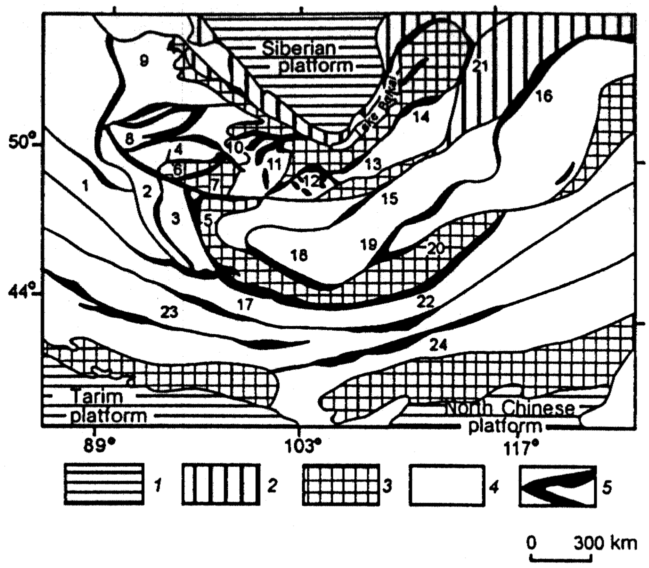

Fig. 2. Present locations of the Late Proterozoic–Paleozoic ophiolite belts of the Central-Asian and Mongol–Okhotsk fold belts. 1=sedimentary cover of the Precambrian platform, 2=marginal uplift of the Siberian platform basement including pericratonic troughs (Baikal–Patom's, etc.), 3=uplifts of the Pre–Late-Proterozoic basement, 4=Mainly Caledonian and Hercynian structural-formational complexes of the variuos geodynamic origin, 5=ophiolite belts (numbers are on the scheme). Late-Proterozoic–Early Paleozoic ophiolite belts: 1=Terektin, 2=Kobda, 3=Tsaganshibetin, 4=West–Sayan, 5=Dzabkhan, 6=Khankhukhe, 7=South Tuva, 8=Kurtunshibin, 9=Kuznetsk–Alatau, 10=Iya, 11=Il'chir, 12=Dzhida, 13=Bayanulan, 14=Abagin, 15=Bayangol, 16=Prishilkinsky, 17=Ikhebogdin (Khantaishir), 18=Bayankhongor, 19=Middle Gobi (Adatsag), 20=Kerulen, 21=Baikal–Muya. Middle Paleozoic: 22=Undurshilin (Dzolen–Gurbansaikhan), 23=Gobi Altay. Late Paleozoic, 24=Solonker.

tinent Rodinia and disintegrated close to the end of the Proterozoic. This resulted in the forming of the Paleoasian and Mongol–Okhotsk oceans as well as some continents, microcontinents and island arcs (Fig. 1).

Oceanic associations widely spreaded in the **Late Proterozic–Early Cambrian** by their composition and structure correspond to geodynamic settings of marginal seas and island arcs. Full ophiolite sections are situated in many places of the Central-Asian region (Fig. 2). Along with metamorphosed ultrabasic rocks and gabbros those sections often consist of sheeted dike complexes composed of diabases and gabbrodiabases. These all indicate their spreading nature. The volcanic part of the Vend–Early Cambrian sections consists mainly of pillow-lavas of basalts with three petrochemical series: tholeites (NMORB type), sub-alkalic high-titanium (WPOIB), and differentiated calc-alkalic (IAB).

Volcanic associations of the Vend–Early Cambrian differentiated series were formed in volcanic island arcs. There are two types of island arcs. The first type of the island arc volcanic associations consists of different type of calc-alkalic volcanic series. In the basic structure of these arcs, an important role belongs to ancient blocks of continental crust, i.e., ensialic island arcs. In the structure of the second type of volcanic arcs an important role belongs to the rocks of the boninite type formed in primitive (ensimatic) island arcs, occurirng at the oceanic floor.

Formation of continental crust in southern folded frame of the Siberian platform finished by the end of the Lower Paleozoic time by the intensive collision processes and formation of granitoid batholiths. At the end of Silurian time this resulted in the appearing of the continental margin of an ancient continent the Siberian continent. This margin bordered on the Mongol–Okhotsk and Paleoasiatic oceans and, according to L.P. Zonenshain et al. (1990), transformed into the Paleotethys ocean. From the Early Devonian the interaction between continental margin and oceanic plates was active and brought to formation of different aged post-accretional volcano–plutonic belts and areas of magmatism in active continental margins (Gordienko, 1987).

Thus, in the **Middle Paleozoic** (Devonian–Early Carboniferous) along the south (in present coordinates) margin of

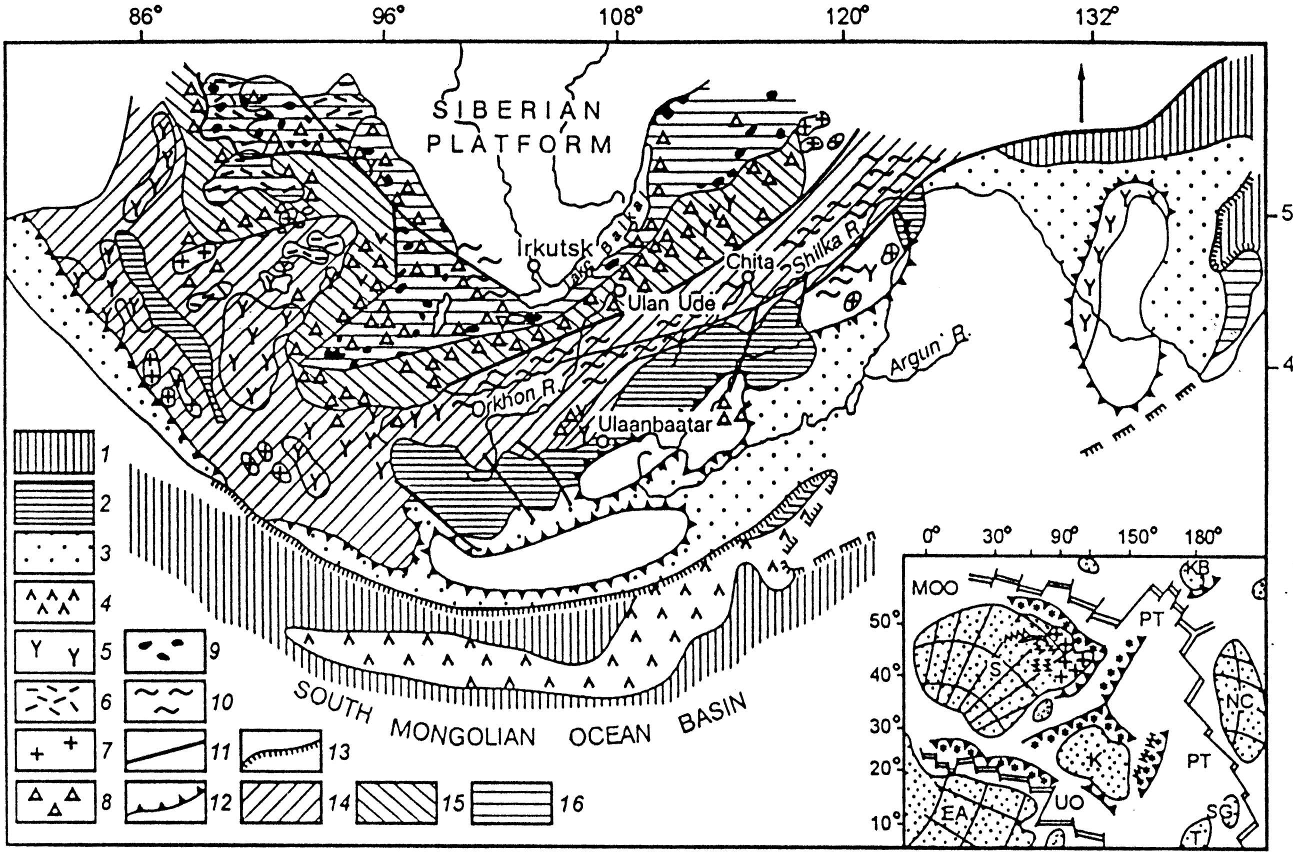

Fig. 3. The Middle Paleozoic (Devonian–Early Carboniferous) tektonomagmatic scheme for the folded framing of the southern Siberian platform. 1=mainly oceanic complexes, 2=deep-water flysch silt-clay sediments with volcanics of the main composition, 3=shallow-water terrigenous and carbonate–terrigenous sediments, 4=marine volcanogenic calcalkalic series (island-arc complexes), 5=continental calcalkalic volcanite of the normal and acid composition (differentiated series), 6=continental volcanogenic series of bimodal composition, 7=calcalkalic granites and granodiorites, 8=subalkalic granites, quartz syenites and syenites, 9=alkalic-gabbroid and alkalic-granitoid complexes, 10=ultrametamorphic granitoids, 11=faults, 12=epicontinental shelf sea borders, 13=supposed border between the continent and the ocean, 14–16=zones of the rocks extention: 14=of the normal rank, 15=of the subalkalic and normal rank, 16=of the subalkalic and alkalic rank. On the inserted map: global paleogeodynamic reconstruction for the Late Devonian. Legend see on the Fig. 1.

the Siberian platform the extended Sayan–Transbaikal volcano–plutonic belt (more than 2000 km long and 200 to 800 km wide) belt (Fig. 3) was formed. In the cross section of the belt, in lateral rows of magmatic formations one can see increasing of total alkalinity (mainly Potassium) and decreasing of Strontium isotopic initial ratio ($^{87}Sr/^{86}Sr$) in volcanic and especially in plutonic rocks in deeper part of active margin of the Siberian continent. This corresponds well to the Andean type of active continental margins.

Geodynamic development of Central Asian and Mongol–Okhotsk belts in the **Late Paleozoic** (Middle–Late Carboniferous, Permian and Early Triassic) depended on interaction of the Siberian continent and the Paleotethys ocean. This ocean, as it is clear from Carboniferous end reconstructions (Zonenshain et al., 1990; Gordienko, 1994; Metcalfe, 1996) increased to its maximum size and kept its submeridional orientation. On the north the Paleotethys ocean was connected with the Mongol–Okhotsk ocean, while the Siberian and the North-China continents were situated in different paleo-latitudes. At that time, on the northwestern margin of Paleotethys an extended subduction zone (Solonker zone of Southern Mongolia), falling beneath the Mongolo-Siberian continent, existed. (Figs. 4 and 5).

The subduction zone subsequently developed from the Middle Paleozoic, gradually moving towards the South-East. Along the eastern margin of continent in the Early-Middle Carboniferous the geodynamical setting of west-pacific ocean type (island arcs and marginal seas) existed. In the Late Carboniferous and in the Early Permian this setting was changed by the new active continental margin of the Andean type, where volcano–plutonic belts were formed (Selenga–Vitim, Central–Mongol, South–Mongol belts) (see Fig. 4). Later, in the Late Permian and in the Early Triassic, the geodynamic setting became more complicated because of the riftogenic volcano-tectonic structures formation in the rear of active continental margin (see Fig. 5).

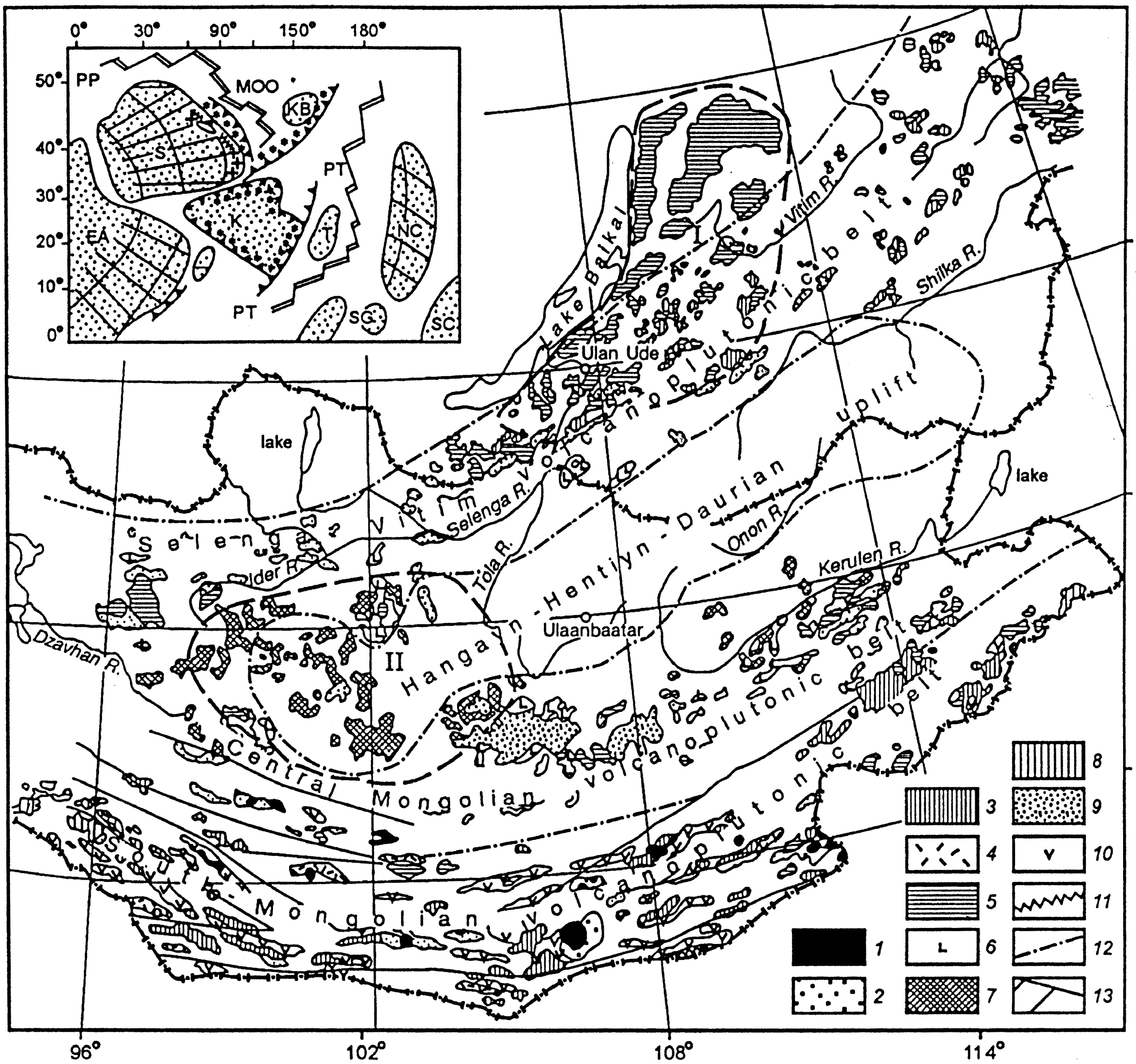

Fig. 4. Map of the present distribution of the magmatic formations of the Middle–Late Carboniferous–Early Permian and paleogeodynamic reconstruction of this time (for legend see Fig. 1). Magmatic formations (associations): 1=alkalic granites and syenites, 2=bimodal volcanics (trachyrhyolite–trachibasalt with comendites), 3=undissected subalkalic granites and syenites, 4=calc-alkalic rhyolites with dacites and andesites, 5=subalkalic granites, granite-granosyenites and syenite–leucogranites, 6=subalkalic basaltoids (basalt–trachybasalts with andesites), 7=diorite–granodiorite–granites, 8=diorite–tonalite–plagiogranites, 9=subalkalic rhyolites, dacites, andesites, 10=calc-alkalic differentiated volcanites (rhyolite–andesite-basalts), 11=ophiolite, 12=borders between zones with different paleogeodynamic conditions, 13=rift zones. Batholithes: I=Angara–Vitim's, II=Khangay's.

These volcano–plutonic belts were formed on the active continental margin of the Mongol–Siberian continent. Blocks of continental crust, appeared as the result of the Caledonian and the Early Hercynian accretion and collision, became the basement for those belts. The South Mongolian belt of riftogenic and island-arc structures appeared on continental and transitional crust, which was actively forming during the Carboniferous and the Early Permian.

In temporal and lateral rows of the Upper Paleozoic magmatic formations of mentioned belts the following changes were fixed: in the South Mongolia volcanic rocks were formed in the Late Carboniferous–Early Permian, in the Central Mongolia–mainly during the Early Permian, only partly envolving the Late Permian, and in the Selenga-Vitim belt formation took place during the whole Permian period, most intensive periods were the Late Permian and the Early Triassic. In total, rejuvenation of volcano-plutonic processes from south towards north, from the Paleotethys

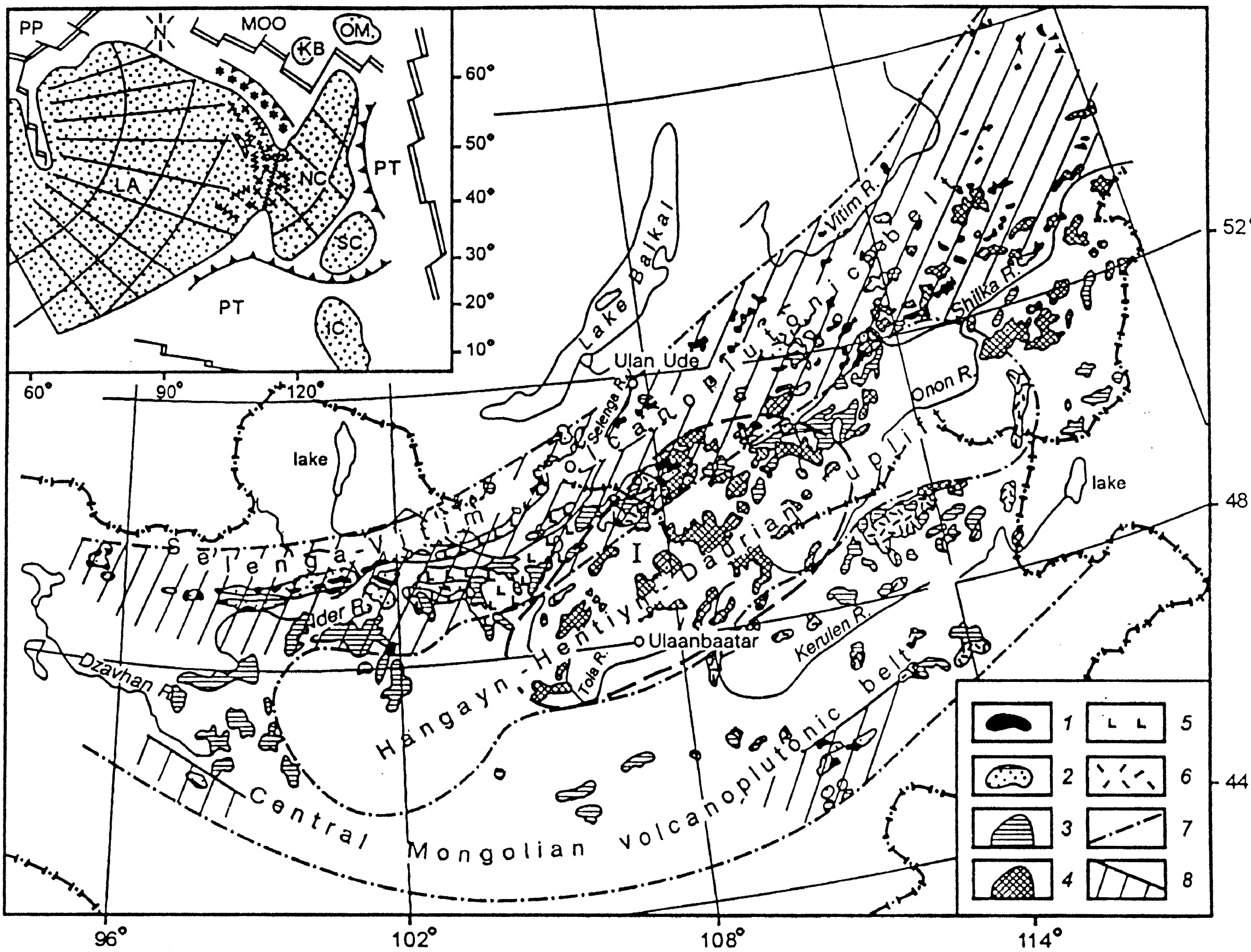

Fig. 5. Map of the present distribution of the magmatic formations of the Late Permian–Early Triassic and paleogeodynamic reconstruction of this time (for legend see Fig. 1). Magmatic formations (associations): 1=alkalic granites and syenites, 2=bimodal volcanites (trachybasalt–trachyte-trachyrhyolites with comendites), 3=subalkalic granite–leucogranites and granite-granosyenites, 4=calc-alkalic granodioryte–granites and granites in places with implemented preceding gabbroids, 5=trachyandesite-basalts and trachybasalts, 6=rhyolite-trachyrhyolites,in places with implemented andesites and basalts, 7=boundary between zones with different paleogeodynamic settings, 8=rift zones. I=Khentey batholith.

ocean margin towards depth of the Mongol–Siberian continent is evident. Along with cross-magmatic zonation in inner part of the belts some lateral age changes of magmatism took place. In the Selenga–Vitim belt those changes are evident in rejuvenation of volcanism and plutonism from south-west to north-east. Just in the same way, though in a less manifesting form, the age of volcanic associations changes from west towards north-east of the Central–Mongol belt. In every concrete case, those changes have complicated characters and that's why every volcano-plutonic belt has its special feature.

The Selenga–Vitim and the Central Mongol belts were the same by its length as the Khangay–Khentey–Daur folded system, where in the Late Paleozoic an uplift process took place. This process was accompanied by closing of sea basin, and by granitization with forming of granitoid batholithes (Angara–Vitim, Khangai, Khentey, see Figs. 4 and 5).

In summary, development of this territory from the Late Carboniferous to the Permian–Early Triassic times is characterized by active accretion and collision processes, resulted from closure of the Late Paleozoic Paleotethys ocean and the shifting of the active zones towards east to the Paleopacific.

Later the **Mesozoic** history of geodynamic development of region was already connected with interaction of the Siberian continent and the Paleopacific with it's bay the Mongol Okhotsk oceanic basin. At that time in the east of Asia, the island volcanic arcs (Uda–Murgal and others), numerous rift depressions and subductive volcano–plutonic belts (Sikhote–Alin, Okhotsk–Chukotsk and others) were forming. Along the folded framing of the Siberian platform, the large Verkhneamur volcano–plutonic belt of the Andean

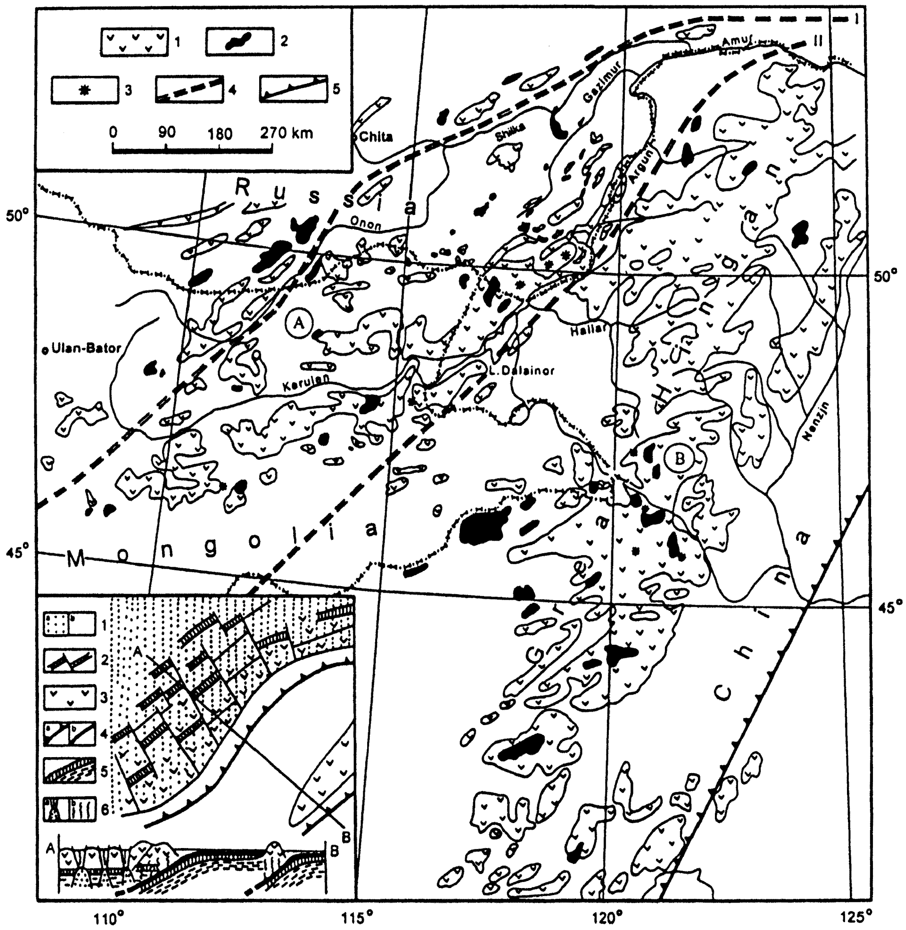

Fig. 6. Map of the present distribution of the geological structure and volcanic rocks of the Verkhneamur volcano–plutonic belt: A=the Mongol–Transbaikalian megaarea, B=the Daxinganling megaarea. The fields of the distribution of Late Mesozoic (J_{2-3}–K_1) complexes of rocks: 1=volcanogenic and volcanogenic-sedimentary, 2=subvolcanic and hypabyssal plutonic, 3=volcanic structures of central type. Zones of deep fractures: 4=Mongol–Okhotsk (I) and Dalainor–Argun (II), 5=supposed location of the junction zone of lithospheric plates (supposed subduction zones) under Songliao basin. The inserted map shows a schematic paleogeodynamic reconstruction and a section along line AB for the time of the formation of the Verkhneamur volcano-plutonic belt: 1=active margin of the Siberian continent (a) and oceanic basins of the Paleopacific (b), 2=riftogenic volcano-tectonic structures and fractures in the back of the active continental margin, 3=marginal-continental volcanic belt and island volcanic arc in the frontal part of the active continental margin, 4=sidelong subduction zones (a), Izanagi oceanic plate (b), 5=mantle and asthenosphere, 6=mantle diapir and riftogenic structure over it (a), flows of magmatic fluids (b).

type formed in the Late Mesozoic on territory of the East Mongolia, Transbaikalia and North-East China (Gordienko et al., 2000) (Fig. 6).

Geochemical analysis of the composition of products of volcanic activity and tectonic conditions of their localization suggests two great megaareas of the belt (Mongol–Transbaikalian and Daxinganling) with different geodynamic conditions of their formation. Within the Daxinganling megaarea volcanism is represented by calc-alkalic differentiated basalt–andesite–rhyolite series of the island-arc type, and the Mongol–Transbaikalian megaarea–by subalkalic bimodal trachybasalt (shoshonite)–latite–trachyrhyolite association of rocks of the riftogenic (innerplate) type. As a whole, increase of alkalic content (especially potassium) and decrease of strontium initial isotopic ratio ($^{87}Sr/^{86}Sr$) from frontal part of the belt to the back one is evident. Such conditions of formation of magmatic rocks of the belt are determined by its development on active continental margin of the Andian type. In this case, it has been established, that volcanic rocks of the Daxinganling megaarea occur in the front part of the active margin of the Siberian continent and the Kerulen–Argun microcontinent accreted to it while sidelong subduction of the Izanagi oceanic plate (Maruyama and Seno, 1986) under continental margin of the Andean type, and magmatic rocks of the Mongol–Transbaikalian megaarea–under conditons of innercontinental riftogenesis with the formation of mantle diapirs in the back of the Andean margin. Geophysical evidence, namely asthenosphere ridges under the Songliao basin and a great gravitational step along the south-eastern slopes of the ridge Daxinganling as well as seismic tomography data support the occurence of slabs of the Late Mesozoic oceanic crust in the front part of the belt (Sun et al., 1996; Van Der Voo et al., 1999). The evidence obtained allow to interpret and relate the north-eastern direction of the Mesozoic structures, numerous (more then 200) riftogenic basins and metallogenic belts of the Transbaikalia and Eastern Mongolia to geodynamic evolution of the belt.

3. METALLOGENY OF VARIUOS GEODYNAMIC SETTINGS

Having analysed data concerning geodynamic conditions under which formation of the most important endogenic deposits in the Caledonian, Hercynian and Mesozoic mobile areas (the south frame of the Siberian platform) was possible, we totally confirm the idea according to which every category of the Earth's active zone has its own definite

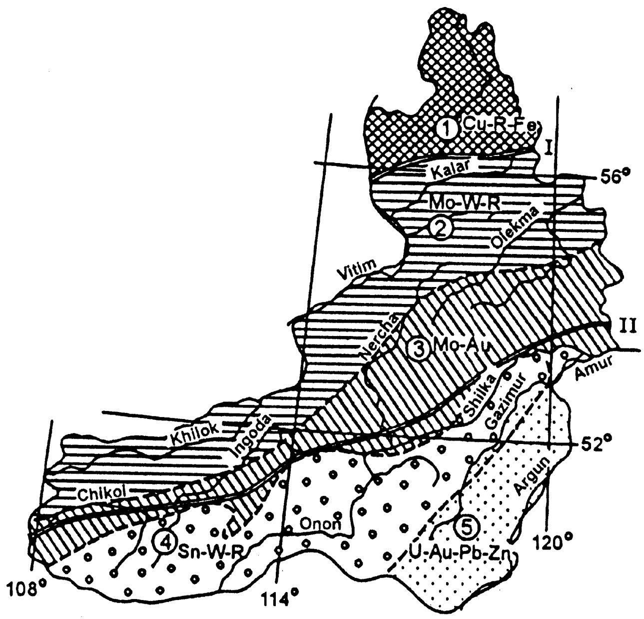

Fig. 7. Scheme of metallogenic zonation of the Chita Region. Metallogenic belts (encircled numbers): 1=rare-metal-iron-copper, 2=rare-metal-molybdenum-tungsten, 3=molybdenum-gold, 4=tin-tungsten-rare-metal, 5=uranium-gold-polymetallic. Double lines are borders of metallogenic provinces (Stanovaya (I) and Mongol–Okhotsk (II) fault zones).

complex, each responsible for special formational type of magmatic rocks. Those rocks are complicated in accordance with the laws of nature and correspond to each geodynamic setting where there is special, inherent magmatic and, respectively, metallogenic zonation.

Structural-metallogenic zonation is well shown on the Chita region metallogenic zonation scheme (Fig. 7). This zonation is connected with formation of the Verchneamur volcanoplutonic belt. Here from the Daxingan`ling megaarea to the depth of continent there are the following metallogenic belts: Jurassic–Early Cretaceous uranium-gold-polymetallic, Late Jurassic tin-tungsten-rare-metal, mainly Jurassic molybdenum-gold, Triassic–Jurassic rare-metal-molybdenum-tin-tungsten.

Besides, main metallogenic belts of the Transbaikalia are followed by fluorite, uranium, silver-gold, mercury-antimony and other ore zones, predominantly of the Cretaceous age. It is of need to know that the investigated linearity of the Chita region metallogenic belts is gradually disturbing alongside the Mongol–Okhotsk suture towards south-west where the belts are locked in a form of the zonally built areas. (Gordienko and Kuzmin, 1999).

On the Table 1 there are the geodynamic conditions for formation of the main endogenic deposits in the Caledonian and Hercynian fold zones of the Siberian platform south margin. The table 1 shows, that the main part of deposits of this period were formed in island arc and in volcano–plutonic belts of active continental margin.

4. CONCLUSION

We have analyzed geodynamic evolution of the Central Asian and Monglo-Okhotsk fold belts. Its long-term history (from Proterozoic to Cenizoic) involved all known types of geodynamic settings: mid-oceanic spreading zones and zones of transform faults, active and passive continental margins, ensimatic and ensialic island arcs, marginal and intracontinental rift zones, and areas of within-plate magmatism. They resulted from origin and further development and closure of the Paleoasian and Mongolo–Okhotsk ocean basins. These basins formed on a vast territory nearly simultaneously at the end of the Proterozoic, which is documented by coeval ophiolite complexes in Mongolia and Transbaikalia. But they were closed at different times: the Paleoasian basin by the end of the Sillurian, and the Mongolo–Okhotsk basin by the end of the Jurassic.

The continental crust resulted from accretion and collision and terminated on the most part of region by the end of the Early Paleozoic. Finally, a continental margin of the ancient Siberian continent formed here. The margin bordered the Mongolo–Okhotsk and Tethys paleooceans. Starting from the Devonian, the intense interaction of the continental margin with oceanic plates led to formation of an active continental margin of the Middle and Late Paleozoic volcanoplutonic belts of taphrogenic and subductional types: Sayan-Transbaikalian (D-C_1), Selenga-Vitim (C_3-P-T_1), Central Mongolian (C_2-P_1), and South Mongolian (C_1-P_1). Volcanoplutonic belts have a petrological and temporal structure-magmatic zonality, expressed as their rejuvenation away from the border of the Siberian continent and an increase in alkalinity and depth of magma sources from subduction zones toward active continental margins.

The Mesozoic geodynamic development of the Mongolo–Transbaikalian region included a gradual closure of the Mongolo–Okhotsk ocean basin in the Late Jurassic and formation of the Verkhneamur volcanoplutonic belt on the active continental margin of Andean type in the Early Cretaceous.

Thus, the established space-time regularities and stable tendencies in development of the Paleozoic and Mesozoic magmatism of the Mongolo–Transbaikalian region are governed mainly by recognized structure-magmatic and, correspondingly, metallogenic zonation of island arcs of the West-Pacific type, active continental margins of the Andean type and riftogenic structures and zones of within-plate magmatism related to mantle diapirism of mantle's hot fields.

The discussed materials on the geodynamic conditions of formation of the most important endogenic mineral deposits within the Caledonian, Hercynian and Mosozoic mobile belts of the southern framing of the Siberian Platform totally support conclusions, that each category of the Earth's active zones possesses a strictly defined set of the types of magmatic-rocks formations, which occur in regular combina-

Table 1. Geodynamic conditions of formation of the most important endogenic deposits in Paleozoids of the folded framing of the southern Siberian platform.

Structural element	Geodynamic setting	Magmatic zonality, associations, and formations	Ore formations and non-ore mineral resources	Deposits and occurrences
Caledonian folded area	Zone of collision of the Siberian continent, Central Mongolian and other microcontinents, island arcs, and marginal seas	Granitoid formations of andesite and calc-alkalic types. Gabbro formations	Gold-sulfide-quartz and gold-quartz Apatite-titano-magnetite and properly apatite	Olkhovskoe, Tsagan-Tsahir-Ula etc. Arsentevskoe, Kruchininskoe, Oshurkovskoe, Teleginskoe
	Island arcs	Differentiated rhyolite-andesite-basalt, gabbro-diabase, gabbro-diorit, and granodiorite-granite	Pyrite-lead-zinc Magnetite	Ozernoe, Kyzyl-Tashtyg, Mainskoe, Gurvunur, Ukyr, Magnetitovoe, etc.
	Rift zones of oceans and marginal seas	Diorite-plagiogranit and Ophiolite	Copper-pyrite Gold-sulfide Chromite, chrisotile-asbestos, nephrite, magnesite	Borts-Ula Bayan-Khongor, Ilchir, Darkhintui, Naran, Shishhid, Khantaishiri
Early Hercynian folded area	Sayan-Transbaikalian volcanoplutonic belt on the active continental margin of the Andean type	Zone of subalkalic and alkaline magmatism: trachyandesite-basalt, trachyrhyolite, contrasting trachyrhyolite-trachybasalt, phonolyte, alkali-gabbroid, and alkali-granitoid	Fluorine-rare-metal Sulfide-cassiterite and quartz-tungsten Molybdenum-tungsten Synnyrites, apatite, graphite and nephelyne ores	East Sayan, Snezhnoe Saganshulutskoe, Kydzhimitskoe, Mariktikanskoe, Altanskoe Malyi Oinogor, Shagaitegol, Zumburuk, Baiba Synnyr, Botogol, Kiya-Shaltyr, Mukhal
	Hangay-Hentey-Daurian system of the marginal-continental seas and surrounding uplifts	Zone calc-alkalic and thoeleiitic magmatism: andesite-basalt, basalt, gabbro-diabase, and granodiorite-granite	Gold-sulfide-quartz Manganese-iron-ore	Boro-Nur, Dzunmod, Kharkhirin, Tuingol Dzagin, Nalaikhinskoe
	South Mongolian island-oceanic system of the West-Pacific type	Zone of ophiolitic and calc-alkalic magmatism: tholeiitic basalt, tonalite-granodiorite, and basic-ultrabasic	Gold-sulfide Pyrite-polymetallic Chromite, nephrite, and magnesite	Edrengiinurinskoe Barun-Khurai, Modon etc. Nomin-Gobi, Gurvan-Sayhan, Dzolen
Late Hercynian folded area	Selenga-Vitim vulcanoplutonic belt of riftogenic type on the active continental margin	Zone of subalkalic and alkaline magmatism: trachybasalt, trachyrhyolite, contrasting trachybasalt-trachyrhyolite, alkali-granitoid, and monzodiorite-granosyenite-granite	Fluorite-rare-metal Molybdenite-quartz Molibdenum-tungsten Copper-molybdenum Gold-sulfide-quartz	Tashirskoe etc. Zharchikha, Khudan, etc. Bulukta Erdenet, Agsug Kudarinskoye Darasun etc.
	Central Mongolian volcanoplutonic belt on the active continental margin of the Andean type	Zone of calc-alkalic and subalkalic magmatism: dacite-andesite-basalt, trachybasalt and trachyrhyolit, and granodiorite-granite	Gold-sulfide-quartz Gold-silver Copper-molybdenum	Delgerekh, Buyantinskoe Turgenskoe Delger-Khan, Saran-Ula
	South Mongolian island arc continental system of the West-Pacific type	Zone of calc-alkalic and tholeiitic magmatism: Andesite-basalt, monzonite-granosyenite-granite, and ophiolite	Copper-molybdenum gold-silver Lead-zinc Chromite	Tsagan-Suburga, Narin-Khuduk, etc. Mantach cluster Solonkerskoe

tions with each other. Therefore, each geodynamic setting has its own, specific magmatic and, correspondingly, metallogenic zonation.

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