Министерство образования и науки Республики Казахстан

ВОСТОЧНО-КАЗАХСТАНСКИЙ ГОСУДАРСТВЕННЫЙ
ТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ им. Д. Серикбаева

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GEOLOGY AND MINERAGENY OF THE CENTRAL ASIA

Учебно- методическое пособие (курс лекций)
для докторантов специальности 6D070600 - Геология и разведка
месторождений полезных ископаемых

Усть-Каменогорск
2011

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УДК 553.411

R. Seltmann Geology and minerageny of the Central Asia: Курс лекций по дисциплине. B. Dyachkov, M. Mizernaya – Ust-Kamenogorsk: EKSTU, 2011. – p. 44

Methodical instructions are intended for independent work of doctoral students: 6D070600 – “Geology and exploration deposits of minerals” by preparation for a lectures and a practical training.

Dr. Reimar Seltmann, Natural History Museum, UK

Dr. Reimar Seltmann graduated from the Technical University (Mining Academy) in Freiberg/Saxony (East Germany) where he specialized in exploration geology (MSc diploma 1984). His PhD thesis (1987).

Addressed decision-making criteria during prospecting of rare-metals (Sn, W) in the German Erzgebirge and aspects of resource evaluation under self-sufficient conditions of the former Eastern block.

From 1987 he worked as a project team leader at the Central Institute for Physics of the Earth (CIPE) of the East-German Academy of Sciences and specialized in the metallogeny of mineralized porphyry breccia pipes.

Since 1999 he has worked as a petrologist and economic geologist at the Natural History Museum in London (UK), where he initiated and coordinates as director the newly formed Center for Russian and Central EurAsian Mineral Studies (CERCAMS). Following his involvement in a number of INTAS projects jointly with his colleagues from the former Soviet Union, his principal research interest became the granite-related metallogeny of Transeurasian magmatic belts, particularly case studies from the regional scale of magmatic provinces to individual world-class deposits such as Muruntau, Kalmakyr, Kumtor etc.

Reimar was the leader of the IGCP project #373 (1997-2002) on ‘Anatomy, textures and magmatic-hydrothermal transition processes of ore-bearing felsic systems in Eurasia’. In result, he was senior guest editor of ‘High-level silicic magmatism & related hydrothermal systems’; (OUP, Journal of Petrology, December 1997, 38, 12) and co-editor of ‘Tectonics & Magma 2001’(Zeitschrift fuer Geologische Wissenschaften, Berlin, 29, 5/6, 2001 &; 30, 1/2, 2002). Currently he is the leader of the follow-up IGCP project #473 ‘GIS metallogeny of Central Asia’; (2002-2007) that focuses its research on crustal geotraverses and deposit case studies applying GIS platforms. The project resulted in a series of Geology and Mineral Deposits GIS packages on Central Asia, Mongolia, Afghanistan, Urals and others that were compiled as collaborative efforts of the CERCAMS network aiming mining industry, government and academia.

Professor Boris Dyachkov, East Kazakhstan State Technical University named of D.Serikbaeva.

In 1958 B.A.Dyachkov has finished the Rostov State University. In 1969 he has received a candidate's degree at Institute of Geological Sciences named of K.I.Satpaev. The topic of his scientific work: «Intrusive magmatism and metallogeny of the East Kalba».

In 1986 he has received a doctor's degree.

In 1994 B.A.Dyachkov has been selected by a member-correspondent of National academy of Sciences of Republic Kazakhstan on a speciality «Geology of ore deposits». Since 1996 it is the full member of Academy of mineral resources of Republic Kazakhstan.

B.A.Dyachkov is the leading expert in the field of regional geology and metallogeny of the ore deposits. He was the supervisor of studies and the executive of some large scientific themes of the international and republican level («the Big Altai», etc.).

Since 1992 B.A.Dyachkov works as the professor at the East Kazakhstan State Technical University named of D.Serikbaeva.

Since 1996 it is selected by a member of the International association on genesis of ore deposits – IAGOD.

Ass. Professor Marina Mizernaya, East Kazakhstan State Technical University named of D.Serikbaeva.

1975-1980 Tomsk Polytechnic Institute, Tomsk, Russia, full-time course of specialty – Geology. Diploma in Higher Education, specialty – hydrogeologist.

1992-1995 “A” Level: post graduate course at the East Kazakhstan State Technical University.

2001 г. she has received a candidate's degree (Candidate’s Geology-Mineralogy Science). The topic of the scientific work: “Shyngit rocks of the East Kazakhstan”. 2005 «Certificate of International Society for Engineering Education, State Technical University

1982-1992 Work as a Hydrogeologist at the Hydrogeological department, Vladimir, Russia. 2002-2011 The Head of Geology and mining engeenering subdepartment of EKSTU, Ust-Kamenogorsk, Kazakhstan. Her principal research interest became the environmental geochemistry, geology and metallogeny of the ore deposits.

СОДЕРЖАНИЕ

1 THE CENTRAL ASIAN OROGENIC BELT

1.1 Geologic evolution

The Central Asian Orogenic Belt (CAOB, also known as Altaids) is one of the largest accretionary orogens on Earth and evolved over some 800 million years from the latest Mezo proterozoic to the early Triassic. It contains a record of geodynamic processes during one of the most important episodes of continental growth in Phanerozoic time.

The CAOB stretches from the Ural Mountains to the Pacific Ocean, occupying an area of about 5.3 million square kilometers, about 11% of the Asian surface area. It is bounded on the north by the Siberian craton and on the south by the North China craton and the Tarim craton, which provides substrate for the Tarim Basin. The CAOB encompasses parts of six nations: China, Mongolia, Russia, Kazakhstan, Kyrgystan, and Uzbekistan. It includes mounain ranges north of Tibet, inluding the Tian Shan(Chinese for "heavenly mountains") where a good example of Paleozoic arc accretion is exposed. The Altai Mountains of Russia, Kazakhstan, northwest China and western Mongolia also expose a complex accretionary terrane. CAOB rocks are also well exposed in Kazakhstan, the South Gobi Range of southern Mongolia, the Beishan and Inner Mongolia of northern China, the Sayan Mountains of southern Siberia just north of Mongolia, the ranges of Buratia in southern Siberia south of Lake Baikal, and in the Far East of China and Russia.

Geologic evolution **- t**here has been much discussion about the tectonic evolution of the CAOB over the last two decades, and these interpretations fall into two general groups.

One group of researchers suggests that the belt grew, in the Neoproterozoic and Palaeozoic, from the margin of the Siberian craton to the south through accretion of island arcs and Precambrian continental blocks until the evolution was terminated through collision with the North China and Tarim cratons in the latest Paleozoic to early Mesozoic (Windley et al., 2007; Kröner et al., 2007; Xiao et al., 2010). The original paleogeographic position of the continental blocks is debated, but some studies suggest a Gondwana affinity of many allochthonous terranes (Dobretsov et al., 2003; Dobretsov & Buslov, 2007), whereas others infer a Siberian or Tarim origin for the same blocks (Kuzmichev, 2001; Rojas-Agramonte et al., 2010). The second group of researchers regards the CAOB as mainly composed of a huge Paleozoic subduction-accretion complex (Sengör et al., 1993), which accumulated against a single, long magmatic arc.

The CAOB, like other major accretionary orogens, consists of:

accretionary wedges; island arc, forearc and back-arc systems, largely dismembered ophiolites, oceanic plateaux; blocks of older continental crust, ranging in age from Archaean to Neoproterozoic;

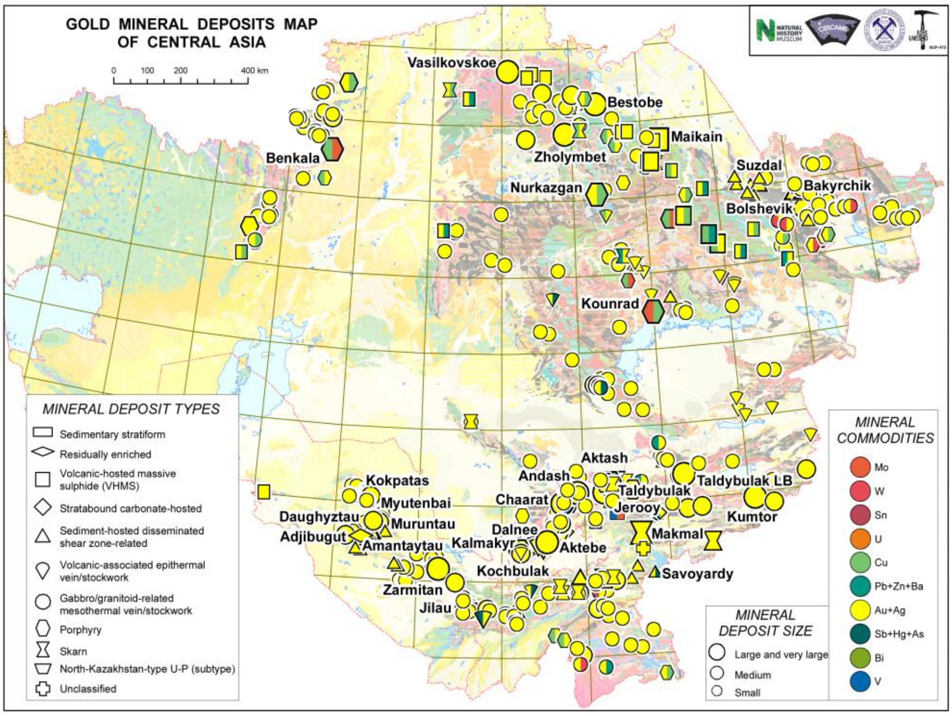

Fig. 1 Gold deposits map of Central Asia

synorogenic granite and metamorphic rocks including exhumed HP-UHP metamorphic rocks, clastic sedimentary basins.

Permian post-collisional granitoids and intraplate igneous suites. Large-scale late Paleozoic shear zones follow the orogenic grain.

There are many controversies about CAOB tectono-magmatic evolution. One is the problem of juvenile versus recycled crust in the formation of CAOB igneous rocks. On one hand, the CAOB is considered to be the most important site of juvenile crust formation since the Neoproterozoic, because during its amalgamation, which involved terrains of different geodynamic origin overlain by magmatic units, massive amounts of granitic magmas were generated with juvenile Nd isotopic signatures (Jahn, 2004). However, recently obtained detrital and xenocrystic zircon ages confirmed an important role for older crust in the orogen's evolution (e.g., Rino et al., 2008; Safonova et al., 2010; Rojas-Agramonte et al., 2011) (figure 20).

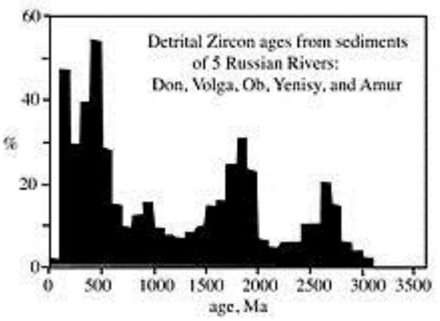

Fig. 2 - U-Pb ages of detrital zircons from sediments of five Russian rivers, after Safonova et al. (2010). Note 4 age peaks, from most to least important: 1) Paleozoic (250-500 millions of years old (Ma)); 2) Paleoproterozoic (~1.8 billion years old (Ga)); 3) Archean (~2,7 Ga); and 4) Neoproterozoic (530-1000 Ma). Many Paleoproterozoic ages come from surrounding cratons, Paleozoic ages mostly come from CAOB and Urals.

The modest Neoproterozoic and huge early-middle Paleozoic zircon age spectra matche CAOB crustal growth very well but older peaks of ~1.8 Ga and ~2.7 Ga suggest the involvement of older crust.

2 GEOLOGY AND METALLOGENY OF RUSSIA

2.1 Production, structure and trade

The mineral industry of Russia is one of the world's leading mineral industries and accounts for a large percentage of the Commonwealth of Independent States' production of a range of mineral products, including metals, industrial minerals, and mineral fuels. In 2005, Russia ranked among the leading world producers or was a significant producer of such mineral commodities as aluminum; arsenic; asbestos; bauxite; boron; cadmium; cement; coal; cobalt; copper; diamond; fluorspar; gold; iron ore; lime; lithium; magnesium compounds and metals; mica, sheet, and flake; natural gas; nickel; nitrogen; oil shale; palladium; peat; petroleum; phosphate; potash; rhenium; silicon, sulfur; titanium sponge; tin; tungsten; and vanadium.

In 2005, the Russian economy benefited significantly from high oil, gas, and metal prices. Oil revenues accounted for about 14% of the GDP. Following the mineral fuel industry, the next leading branch of the mineral industry, in terms of its contribution to the national economy was the metallurgical sector, which contributed 19% of the value of industrial production, accounted for 11.1% of the value of industrial capital stock, and employed 9.3% of the industrial labor force. In 2005, a total of 1,071,000people were employed in the mineral extraction sector and made up 1.6% of the country's labor force. Investment in mineral extraction and metallurgy accounted for about 20% of total investment in the Russian economy.

A new subsoil law remained under discussion as of 2005. The current law of 1992, as amended, does not impose any special restrictions on companies with foreign participation, with the exception of diamond and radioactive materials, but this appeared likely to change to the disadvantage of foreign companies, especially those interested in investing in large or strategic deposits, such as the Udokan copper deposit or the Sukhoi Log gold deposit.

As proposed, the new mining law under discussion would include certain restrictions on foreign participation, limiting it to 49% for some commodities. This restriction would apply to deposits with large reserves of more than 150 metric tonnes (t) of oil, 75 billion cubic meters of gas, 10 t of copper, and 700 t of gold; to strategic raw materials, which include diamond, nickel, high-purity quartz, rare earths, and uranium; and to mineral deposits located near defense and military facilities and frontier areas. Also, discussions were underway to lower the quantity of reserves from the above specified quantities for restricted deposits.

Production. In 2005, the value of mining and quarrying production, including extraction of mineral fuels, increased by 1.3% compared with that of 2004; when mineral fuels are excluded, it fell by 3.2%.

Structure. Production in the mineral sector was highly concentrated as of 2005. For more than 10 minerals, the majority of production was conducted by one company. Gazprom controlled almost the entire production of natural gas in Russia, Noril’sk Nickel Mining and Metallurgical Company (MMC) produced more than 90% of Russian nickel and platinum-group metals (PGM), and ALROSA Company Ltd. produced almost all the country’s diamond. The Ministry of Natural Resources reported that the copper and other mineral industries also are highly concentrated, but that the situation is better for coal and alluvial gold. Despite this concentration, Russian metallurgical and mining companies were medium-sized compared with those in other countries; in the steel sector, Russian producers are generally smaller than their international counterparts.

Trade. The value of mineral exports to the Russian economy has been increasing in recent years; and, in 2005, the minerals sector accounted for more than 70% of the value of exports. Mineral fuels were by far the leading category of exports in terms of value. In 2005, mineral products accounted for about 12% of the total value of imports, of which metals imported from both inside and outside the CIS accounted for more than 70%.

2.2 Mineral Resources of Russia

Approximately 20,000 Russian mineral deposits have been explored, and more than one-third of these have been mined (figure 3). The Ministry of Natural Resources cited serious problems in the sector, which included the depletion of reserves and the low discovery rate of new reserves. The system of reporting reserves in the Soviet Union (and which Russia very often employed for its resource reporting) was based on establishing drilling parameters to ascertain the certainty of reserves. Unlike the method used in market economy countries, this method does not include the use of market-based economic criteria to establish the feasibility of developing these resources using current technology at prevailing market conditions. Thus, reserve data based on the Soviet method cannot be compared to market economy definitions of reserves. Furthermore, Soviet data on reserves for many mineral resources was either kept secret or was difficult to obtain, and the same holds true for Russian mineral resource data. By 2005, however, Russian companies had begun to seek exposure to Western markets and stock exchanges to raise money in larger quantities and more cheaply than in Russia. A number of state secrecy laws were repealed, which has led some Russian companies to start reporting their reserves and resources according to the Australasian Joint Ore Reserves Committee (JORC) code of the Australasian Institute of Mining and Metallurgy.

2.2.1 Metals. Aluminum. RUSAL was Russia's leading domestic aluminum producing company and, along with SUAL, which was the second ranked domestic aluminum producer and the leading domestic bauxite producer, controlled all Russian aluminum, alumina, and bauxite production enterprises. Plans for RUSAL called for merging its resources with that of SUAL and with Swiss-based Glencore International AG to become the United Company RUSAL. This merger would start a new stage in the development of RUSAL and make it the global leader in aluminum production.

RUSAL was investing to expand and modernize its production facilities. It was engaged in commissioning the Khakas Aluminum Smelter with a capacity of 300,000 t/yr. Plans for RUSAL also called for modernizing the Sayanogorsk aluminum smelter in 2006 to increase output of aluminum and alloys and to modernize the Nikolayev Alumina refinery in Ukraine to increase output to 1.6 Mt/yr of alumina. RUSAL also planned to continue to expand production capacity at the Achinsk alumina refinery, increasing its output to 1.1 Mt/yr of alumina. Included in the company's investment project portfolio is the Komi Aluminum project, which was initiated by SUAL. The project foresees the development, construction, and operation of a bauxite-alumina complex in the Komi Republic, using material from the Middle Timan bauxite deposit. The design capacity of the complex was 6 Mt/yr of bauxite and 1.4 Mt/yr of alumina. The completion of this project would considerably reduce the Russian aluminum industry's dependence on foreign countries for raw material supplies.

2.2.2 Copper. More than 50% of Russia's copper metal production was produced by Noril'sk Nickel from ore mined by the company. The remainder came from a much smaller amount of ore mined in the Ural Mountains and a large amount of secondary material. As nickel-rich ores at Noril'sk Nickel become depleted, Noril'sk Nickel will switch to mining larger quantities of ores, which will be primarily copper-rich ores that have a higher copper content relative to their nickel content than the nickel-rich ores, but are lower in metal content for both metals. This change could increase copper output as Noril’sk Nickel tries to maintain its level of nickel production. Noril’sk Nickel’s strategy up to 2010, however, appears to be to maintain its production of nickel-rich ores which may delay the significant increase in copper production.

The leading copper producer in the Ural Mountain region—the Urals Mining and Metallurgical Company (UMMC)—controls a large number of mining and metallurgical enterprises in the Urals. The company was planning to develop its raw material base and to increase its output of copper in concentrate to 105,000 t in 2010 from 72,000 t in 2003. Mine output in the Urals would also expand as mine development takes place at the Russian Copper Company Limited, which was the country’s third ranked copper producer and which also controlled mining and metallurgical enterprises in the Ural Mountain region. Development of the large Udokan deposit in Chita oblast was still on hold. Reserves at Udokan and neighboring deposits were reported as ranging from 10 to more than 20 Mt of copper in ore at grades of between 0.7% and 4% copper.

2.2.3 Gold. Russia was having a difficult time expanding gold production because reserves at existing enterprises were being depleted and gold mining companies were experiencing greater difficulties in obtaining licenses to mine new deposits. Formerly, local Government entities could issue such licenses, but in 2005, these licenses could be obtained only through the Russian Ministry of Natural Resources based in Moscow. Placers contain 18.2% of the country’s reserves but they were being significantly depleted, and most existing placer mining operations were unlikely to survive beyond 2011. However, placers still contributed nearly 50% of annual production. In 2005, no new gold deposits were put into production.

More than one-half of Russia’s hard rock gold resources occur in the Maiskoye, Natalkinskoe, Nezhdaninskoe, Olimpiada, and the Sukhoi Log deposits in Siberia and in the Russian Far East. More than 66% of Russian gold production comes from just six eastern regions (Amur, Irkutsk, Khabarovsk, Krasnoyarsk, Magadan, and Sakha-Yakutia). During the past 4 years, foreign companies have controlled 15% to 18% of Russian gold production, which was the largest share held for any commodity in the Russian mining industry. These foreign-held enterprises produced a total of between 30 and 36 t/yr of gold. Among Russia’s leading gold producers, Bema Gold Corp., Highland Gold Mining Ltd., High River Gold Mines, Kinross Gold Corp., and Peter Hambro Mining Plc, were foreign-listed and/or foreign-controlled companies. Projects being developed by these foreign firms were expected to contribute significantly to the growth in Russian gold production in the next 5 years and could increase Russia’s gold output to about 250 t/yr if they are all successfully developed. The most advanced international gold project was the Bema Gold Corp.’s development of the Kupol deposit, where production was scheduled to start in 2008. Significant byproduct gold was produced by mining operations of UMMC in the Ural Mountain region and Noril’sk Nickel’s operations in East Siberia on the Taimyr Peninsula (165,000 ounces in 2005).

2.2.4 Iron and Steel. Russia is the world’s fourth-ranked steel producer after China, Japan, and the United States. Russia shares the lead with Japan as the world’s leading steel exporter. From 1998 to 2005, Russian steel production increased by more than 50%. Between 1998 and 2005, investment in the steel sector greatly increased, which improved economic indicators for steel enterprises and enabled them to improve product quality. Nevertheless, the steel sector was still in need of investment to improve its ability to compete and to expand production capacity. According to a Russian analysis, the country’s steel mills can be divided into three categories based on the level of technology they employ. The mills in the first category are the country’s three largest (Magnitogorsk, Severstal, and Novolipetsk), which also have the highest levels of technology. For example, this first group of mills has the lowest percentage of open-hearth production, the highest level of continuous casting, and produces the highest quality assortment of steel products. The second tier steel mills consist of the Chelyabinsk, the Nizhniy Tagil, the Kuznetsk, the Oskol, the Uralsk, and West Siberian mills. The country’s leading steel holding company was Evraz (a Luxembourg-registered steel company) that had holdings that include three of the leading steel mills in Russia (Kuznetsk, Nizhniy Tagil, and West Siberian). Russia’s third ranked steel producer, Severstal, was discussing a merger with Arcelor of Luxembourg, in part to thwart a hostile takeover bid for Arcelor by Mittal Steel of India, which was consolidating steel mills worldwide.

2.2.4 Iron Ore. Russian steel companies relied on iron ore from domestic deposits. These deposits often were owned by more than one Russian steel company. In 2005, steel companies were acquiring iron ore producers to help make their companies more vertically integrated. Russia’s iron ore mines and iron and steel works often were located far apart. Almost 60% of iron ore reserves are located in the Kursk magnetic anomaly (KMA) in European Russia and about 15% are located in the Ural Mountains region. High-grade reserves at the open pit operations in the KMA were becoming depleted, although the area hosts significant lower grade resources in the weathered zones. These zones were estimated to contain 4 Gt of reserves and up to 60 Gt of potential resources, but exploiting such low-grade ores would require expensive beneficiation technology.

Iron ore output was expected to be in the range of 100 to 105 t/yr by 2010. A further limited increase in iron ore production was projected to the year 2020 without a significant expansion of the resource base. The resource base for iron ore was not considered very attractive for investment because of the low grade of the ores, technological problems related to mining and processing the ores, and taxation issues.

2.2.5 Nickel. In Russia, which was the world’s leading nickel producing country, more than 90% of nickel was produced by Noril’sk Nickel, which mined deposits of mixed sulfide ores mainly near Noril’sk in East Siberia, but also on the Kola Peninsula. The projected long-term ore output for Noril’sk Nickel in 2005 was raised to 22 Mt/yr.

The 2005 level of production was 14 Mt of ore. With metal prices and demand at very high levels, the new higher projections were in accord with Noril'sk Nickel's marketing strategy. To maintain and increase output levels, Noril'sk Nickel was planning to switch to mining a greater proportion of cuprous and disseminated ores rather than nickel-rich ores, which were being depleted. Noril'sk Nickel also was developing new mines to replace depleted reserves of nickel-rich ore. The company's cuprous ore reserves, which are abundant, have a much lower nickel content and a somewhat lower copper content, and the disseminated ores are lower in all base-metals content than the nickel-rich ores. The nickel-rich, cuprous, and disseminated ores, however, are not greatly dissimilar in their PGM content.

The Skalisty Mine, which is located on the Taimyr Peninsula, was under development as of 2005; it was expected to achieve its design capacity of 1.2 Mt/yr of nickel-rich ore in 6 to 7 years. Skalisty was scheduled to produce 310,000 t of ore in 2004. Development of the Gluboky Mine, which is located on the Taymyr Peninsula, was in the planning stage; the mine was scheduled to come onstream to mine nickel-rich ore by 2013-14. Gluboky and Skalisty would produce a combined 2 t/yr of nickel-rich ore.

Despite its development plans, obstacles were preventing Noril'sk Nickel from making major investments in developing its facilities. The investment in its nickel operations that was planned for the period up to 2010 would result in only modest increases in production, although a significant reduction in production would be averted.

2.2.6 Platinum-Group Metals. Noril'sk Nickel's operations (located mainly on the Taymyr Peninsula) in East Siberia and also on the Kola Peninsula produce more than 90% of the country's PGM output. About 10 t/yr of PGM consisting almost entirely of platinum was mined from alluvial deposits throughout the country.

In 2004, Russia repealed the law that kept PGM production data secret and, in 2005, repealed the law that kept PGM reserve data secret. The Government published reserve figures for its major PGM holdings at the Noril'sk Nickel complex in 2005. Based on an independent audit carried out by Micon International Co. Ltd. according to the Australian Joint Ore Reserves Committee (JORC) Code, Noril'sk Nickel's reserves of combined proven and probable reserves of all six platinum group elements (iridium, osmium, palladium, platinum, rhodium and ruthenium) at Noril'sk Nickel's holdings in East Siberia as of December 31, 2004, were reported to be 81.791 million troy ounces. Proven and probable reserves were reported to be 62.183 million troy ounces of palladium and 15.993 million troy ounces of platinum with ore grades that ranged from 5.5 grams per metric ton (g/t) to 11.1 g/t. Measured and indicated mineral resources were reported to be an additional 141 million troy ounces of palladium and 40 million troy ounces of platinum. These reserves are adequate for Noril'sk Nickel to maintain current levels of palladium and platinum production for more than 20 years.

Despite Noril’sk Nickel’s development plan to significantly increase ore extraction, the company was proceeding more slowly than its stated plans would indicate and it appeared that through 2010, Noril’sk Nickel would try to keep output levels at about the 2005 level.

2.2.7 Industrial minerals. Diamond

ALROSA accounted for 97% of Russian diamond production and about 25% of world rough diamond production in 2005. Its major mining operations were located in the Sakha Yakutia Republic but, in 2005, the company began production at the Lomonosov diamond deposit in the northern European part of the country in Arkhangelsk oblast. The company had five mining and beneficiation enterprises in Sakha Yakutia—the Aikhal, the Anabar, the Mirnyy, the Nyuruba, and the Udachnyy.

In 2005, ALROSA was able to maintain its level of mine output through its program of gradually switching to underground mining to extract low-grade diamond ore reserves. ALROSA had started underground operations at the No. 7/8 Block of the Internatsiolnal’nyy underground mine and was continuing construction of underground mining at the Mir and the Udachny Mines. To maintain stable operations, ALROSA would need to increase its ore reserves by carrying out intensive prospecting for new diamond deposits. The company planned to increase its investment in exploration significantly. A new Mirny Exploration Expedition was established to concentrate on exploration.

On June 28, 2005, full-scale mining was initiated at ALROSA’s Lomonosov Division OAO Severalamz in the Arkhangelsk region with the commissioning of ore treatment plant No. 1 at the Lomonosov deposit. The plant was designed with the capacity to process about 1 Mt/yr of ore. Diamonds from the deposit are of gem quality, which accounted for the high appraisal value of the reserves at $12 billion. The diamond deposit’s effective life was estimated to be about 50 years from the time the plant was put into operation.

The OJSC Apatit enterprise, which is located on the Kola Peninsula, was the leading producer of apatite concentrate in Russia and one of the world’s leading suppliers of phosphate raw material; its core activities were the mining and beneficiation of apatite and nepheline-syenite ores at 10 deposits that have estimated combined reserves of 3.5 Gt. The development plan for Apatit to 2015 assumes an optimal level of apatite concentrate production of 8.5 Mt/yr that would require levels of ore extraction of 27 to 28 Mt/yr. To maintain output, the enterprise would need to develop underground mining significantly. In 2001, the percentage of ore mined underground was 38%; by 2015, this percentage was expected to increase to 75%. Investment to renovate the beneficiation complex, reduce energy expenditures, reduce emissions harmful to the environment, and acquire new equipment to improve labor productivity was also needed.

2.2.8 Phosphate Rock. The OJSC Apatit enterprise, which is located on the Kola Peninsula, was the leading producer of apatite concentrate in Russia and one of the world's leading suppliers of phosphate raw material; its core activities were the mining and beneficiation of apatite and nepheline-syenite ores at 10 deposits that have estimated combined reserves of 3.5 Gt. The development plan for Apatit to 2015 assumes an optimal level of apatite concentrate production of 8.5 Mt/yr that would require levels of ore extraction of 27 to 28 Mt/yr. To maintain output, the enterprise would need to develop underground mining significantly. In 2001, the percentage of ore mined underground was 38%; by 2015, this percentage was expected to increase to 75%. Investment to renovate the beneficiation complex, reduce energy expenditures, reduce emissions harmful to the environment, and acquire new equipment to improve labor productivity was also needed.

2.2.9 Mineral Fuels and Related Materials. Projections of Russia’s fuel production are based on the country’s Energy Strategy for Russia for the Period up to 2020 issued in 2003 by the Ministry of Energy of the Russian Federation. This strategy envisions three potential scenarios: optimistic, moderate, and critical. The optimistic scenario is characterized by the growth of GDP at the rate of 4.7% to 5.2% annually, by a sevenfold increase of investment in fixed capital for this period compared with the 2000 level, and by high world prices for oil and gas. The oil prices envisioned by this strategy in 2003, even for the optimistic scenario, were about one-half of the 2005 oil prices. The moderate scenario is characterized by a GDP growth of 3.3% to 3.4% annually to 2020, an increase of investment in fixed capital by 3.6 times, and fixed prices for oil at a little more than one-half of the optimistic scenario and gas prices about 20% lower than in the optimistic scenario. The critical scenario is characterized primarily by low world oil prices.

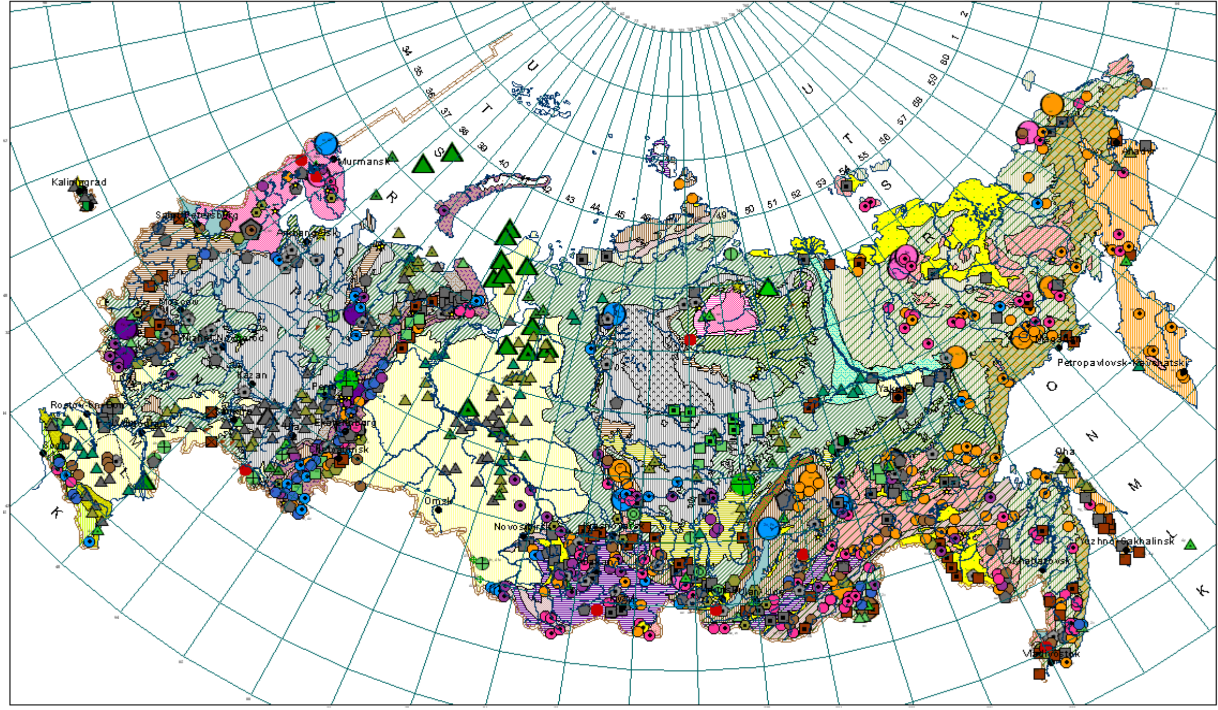

Fig. 3 - Regions of Cercams investigations shown over the mineral resources map of Russia

Coal. The Energy Strategy for Russia for the Period up to 2020 foresees the need for coal production to increase to between 310 and 330 Mt by 2010 and to between 375 and 430 Mt by 2020 to meet expected domestic demand. Russia has 22 coal basins with 114 coal deposits that are unevenly distributed across the country. In 2005, the country had 241 operating coal mines, which included 104 underground mines and 137 open pits with a total production capacity of 315 Mt/yr. Total coal reserves registered in the State Register of Reserves were estimated to be about 200 Gt, and registered reserves in the explored categories A+B+C1 in the reserve classification system that was used in the Soviet Union and later Russia were reported as 106 Gt. These include coal reserves in operating coal mines, in mines under construction, and in areas explored in detail for new mine construction. As foreseen in the country’s energy strategy program, coal production must increase by 10 to 15 Mt/yr between 2005 and 2010 and by a total of 105 Mt by the year 2020. Although the creation of additional coal production capacity through upgrading and expansion of existing mines and development of new mines was possible based on reserves, doing so would require a level of investment in the coal sector far in excess of the historic level of investment in the past 5 years and casts doubt on the feasibility of the planned expansion. At current rates of investment coal production capacity by the year 2020 would be in the neighborhood of 375 Mt/yr. This optimistic investment scenario would depend to a large extent on an increase in foreign investment, particularly from Chinese, Japanese, and South Korean companies.

Natural gas. The country's energy strategy predicts natural gas production to range between 635 to 665 billion cubic meters in 2010 and between 680 and 730 billion cubic meters in 2020. These gas production goals were to be achieved by development in the traditional gas-producing regions, the main one of which was West Siberia, and in the new oil- and gas-producing provinces in East Siberia, in the Russian Far East, in the European North including offshore in the Arctic Sea, and on the Yamal Peninsula. Along with the development of big fields, the strategy recommends development of small gas fields, primarily in the European part of the country in the Ural Mountains, the Volga, and the North West regions.[1]

Almost all the country’s gas production was under the control of the company Gazprom. Gazprom’s natural gas production forecast called for only modest production growth of about 1.3% by 2008. Growth in Russia’s natural gas sector has been slowed primarily by aging fields, state regulation, Gazprom’s monopolistic control over the industry, and insufficient export pipelines. Three major fields in Western Siberia—Medvezh'ye, Urengoy, and Yamburg—accounted for more than 70% of Gazprom's total natural gas production, but these fields were in decline. Although Gazprom projected increases in its natural gas output between 2008 and 2030, most of Russia's natural gas production growth was expected to come from independent gas companies, such as Itera, Northgas, and Novatek.

Reassessment of the energy strategy has been ongoing since the strategy was issued in 2003. A Gazprom subsidiary issued a report recommending a change of export strategy for the Russian gas industry. It determined that Russia should decrease exports of natural gas to European markets and concentrate instead on developing new gasfields to keep up with domestic demand, which was rising faster than was envisioned in the 2003 report and could necessitate the development of new gasfields on the Yamal Peninsula and in other places.

Petroleum. The Energy Strategy for Russia for the Period up to 2020 includes several scenarios that predict a range for Russian oil production of between 445 and 490 Mt/yr by 2010 and between 450 and 520 Mt/yr in 2020. Oil production and growth was to be centered in the traditional oil-producing regions, such as in West Siberia, the North Caucasus, and the Volga region and in new oil and gas Provinces in the European North (Timan-Pechora region), in eastern Siberia and the Russian Far East, and in the south in the North Caspian region. Although the base of the country's oil production for this period would remain the West Siberian oil and gas province, priority areas for new development were to be in the eastern and the southern regions of the country. New field developments were likely to produce almost all Russia's annual oil growth in the next 5 years and would likely produce more than one-half of the country's oil in 2020. In the next 5 years, new field developments at the Middle Caspian project at Kurmangazy (OAO Lukoil Oil Co.); the Komsomolskoye and the Vankorskoye projects (OAO Rosneft Oil Co.); the Prirazlomnoye project (Gazprom); the Sakhalin Island projects; the West Salymskoye project (Shell Joint Venture); and the Timan Pechora project (OAO Lukoil Oil Co. and ConocoPhillips) would help compensate for production decreases at older fields.

2.2.10 Uranium. Uranium mining in Russia was conducted entirely by the corporation JSC TVELs ore mining enterprises, and in particular by open pit mining at its subsidiary JSC Priargunsky Industrial Mining & Chemical Union and also by in situ underground leaching at its subsidiaries CJSC Dalur in the Kurgan region and JSC Khiagda in Buryatia. Annual uranium production was about 3,400 t, of which more than 90% was produced by Priargunsky. Uranium-bearing ores and solutions were processed to generate uranium concentrates, which were shipped for further reprocessing at the JSC Chepetsky Mechanical Plant.

The country's annual natural uranium consumption amounted to approximately 9,000 t. According to projections, the demands for uranium by the nuclear industry in

Russia will grow by 1.7 times. The “TVEL Uranium” program was launched by TVEL Corporation to further develop uranium production up to 2010; an increase in ore mining to 4,300 t of uranium in 2010 was envisioned. Mining was being developed at the JSC Dalur enterprise in the Kurgan region, which produced about 200 t of uranium in 2005. The enterprise planned to increase production by 15% to 20% annually to produce 1,000 t by 2010. The construction of mine No. 6 at the Priargunsky deposit had been started to increase ore production.

The JSC Khiagda enterprise was developing a pilot mining operation to mine the Khiagdinskoye deposit in Buryatiya using underground well leaching. Khiagda commenced commercial operations in 2005 and Khiagda planned to have the capacity to produce 1,000 t/yr of uranium by 2012. Total reserves at the JSC Khiagda site reportedly amount to 100,000 t of uranium.

The Russian Ministry of Natural Resources has developed a draft of a long-term program “On the Exploration and Prospecting of Subsoil Reserves and Reproduction of the Mineral Resource Base for a Period until 2020,” but despite this draft, Russia appears to have no clear strategy for developing its mineral resources. Rather, the country is intensively extracting its fuel and nonfuel mineral reserves, which is leading to the depletion of the majority of these reserves before the year 2020, if not much sooner.

In 2004 and 2005, Russian steel companies presented initial public offerings (IPOs) in the Western markets. This trend of presenting IPOs is set to continue in other sectors of the mineral industry. Consolidation of assets is also a recent trend, which is evident with the creation of Russia’s leading aluminum producer, United Company RUSAL, through such consolidation.

There is also a trend to internationalize Russia’s mineral enterprises. Russian companies, such as ALROSA, Noril’sk Nickel, and RUSAL, are acquiring major foreign assets. Many of Russia’s leading companies aspire to become major international players. Although Severstal’s bid for Arcelor (which would have created the world’s largest steel company) appears to have failed, it is unlikely to be the last such bid from a Russian corporation.

3 GEOLOGY AND METALLOGENY OF MONGOLIA

3.1 Geological structure of Mongolia

Mongolia occupies the heart of the Central Asian Mobile Belt, and an interior portion of the Eurasian Plate. Mongolia has grown in mainly Paleozoic through the accretion of younger terranes and micro-plates to an ancient core in Siberia.

Precambrian:

The microcontinental composite blocks containing high-grade rocks constitute a significant proportion of the continental crust of the Central Asian Mobile Belt. The largest of them are named the Dzabkhan, Khangai, Tuvino-Mongolian and Altai.

Paleozoic:

Paleozoic are divided into Neoproterozoic-Cambrian-Early Ordvician (Caledonian), Ordovician-Early Carboniferous (Hercynian) and Carboniferous-Permian (Indosinian). Other some Paleozoic strata are considered Superimposed Paleozoic troughs.

Paleozoic granitoids:

Paleozoic granitoids and related volcanic rocks are products of continental margin magmatism. Some of them are related to porphyry copper deposits.

Mesozoic granitoids:

Mesozoic granitoids are mostly anorogenic and alkalic. Some of them are related to REE deposits.

Mesozoic volcanic rocks:

Mesozoic volcanic rocks are distributed in eastern Mongolia, and are related to relaxation and rifting of the continent.

Jurassic-Cretaceous:

Jurassic and Cretaceous strata are non-marine sediments. Dinosaurs fossils have been found in them. Coal deposits in them are mined.

Cenozoic:

Cenozoic is non-marine sediment. Placer deposits are distributed in fluvial sediment.

Cenozoic volcanic rocks: Cenozoic basalts along deep crustal fractures occur locally. Seismic activity along such fractures continues today.

3.2 Mineral Deposits in Mongolia

3.2.1 Gold. Gold mineralization is widespread throughout Mongolia. The most significant gold mineralization is associated with geologic events during Permian, Triassic, and Jurassic. The extensive placer gold deposits were formed in early Cretaceous, Neogene, Pliocene, and Holocene.

3.2.2 Base Metals. Copper-molybdenum mineralization in Mongolia occurs primarily in three types of deposits, late Paleozoic to early Mesozoic Cu-Mo porphyries, Cu-Ni magmatic segregations, and Paleozoic to Mesozoic stratabound copper.

Mongolia also has a large number of middle to late Mesozoic Pb-Zn deposits.

Erdenet Mine: The Erdenet copper-molybdenium mine is the largest mine in Mongolia and has been operated by a state-owned Mongolia-Russian joint venture since 1978. The deposit, considered to be a typical stockwork-type Cu-Mo porphyry deposit, is located within a large intrusive porphyry system where four ore-bearing stockwork zones have been identified. Over 400 million tonnes of ore at an average head grade of 0.79% Cu have been mined.

In 2001, 24 million tonnes of ore were mined, producing 460,000 tonnes of Cu concentrate, containing 27% Cu and 3,000 tonnes of Mo concentrate, containing 50% Mo. In 1997, a 3,000 tonne capacity SX-EW plant was constructed by Erdmin to process to treat low-grade oxidized ores and produce copper cathodes.

Oyu Tolgoi deposit: This copper-gold deposit has the potential to become the second largest mine in Mongolia. The deposit was originally explored by BHP and subsequently taken over by Ivanhoe who are continuing exploration.

The deposit is geologically composed of Silurian-Devonian andesitic and basaltic rocks with interbeded terrigenous rocks. They are intruded by porphyry stocks and dykes that are syn- and late mineral in their emplacement.

Surven-Suhait copper deposit: It is one of seven porphyry copper-molybdenum occurrences within Tsagaan-Suvargiin district. The mineralization occurs within an extensive late Devonian-early Carboniferous intrusive syenite massive. Commercial ore reserves of the deposit have been estimated at well over 200 million tones at 0.54% copper and 0.079% molybdenum with minor gold and silver.

Ulaan zinc and lead deposit: It is located in northeast Mongolia. It represents an intricate fluidized-explosive structure consisting of four breccia pipes. The deposit contains 68.1 million tones of ore estimated to contain 2.0 % zinc, 1.2% lead, 53g/t silver, and 0.21 g/ton gold.

3.2.3 Asgat silver deposit. It is located in northwest Mongolia near the Russian-Mongolian frontier. Silver and accompanying base metals mineralization in the area is concentrated in 11 ore-bearing zones with several radiating apophyses. There are 23 million tones of reserves with 268 g/t silver, 0.82% copper, 0.036% antimony and 0.042% bismuth.

3.2.4 Fluorite. Fluorite mineralization is widespread throughout Mongolia. Mongolia is one of the largest fluorite producers in the world. An annual production of fluorite is over 600,000 tons. Economically important mineralization took place in late Jurassic to early Cretaceous. The fluorite mineralization occurs in two economic types, epithermal vein and metasomatic ore bodies.

Bor-Undur Mine: The largest series of deposits at Bor-Undur have been mined since 1982 by the Mongolrostsvetmet. The Bor-Undur ore field is a tectonic block bounded by faults on all siddes. In the core of the block, Triassic granites are cut by a system of dykes and dyke-like bodies, which are composed of fluoritized breccias of trachy-rhyolites.

3.2.5 Rare earth elements and some other rare metals. Rare earth elements (REE) in Mongolia are primarily associated with felsic and alkalic rocks of late Paleozoic, early Mesozoic, and late Mesozoic. Known deposits of REE are subdivided into REE mineralization with alkalic granitoids and volcanoplutonic complexes (metasomatic zones) and associated with tungsten (W) veins and stockwork mineralization in granitoids, and Tin (Sn) veins and skarn mineralization in granites and carbonate rocks.

Halzan-Buregtei rare earth element deposit: It is located in 50km northeast of the Aimag center of Hovd. Complex tantalum-niobium-zirconium-REE mineralization is associated with a late Paleozoic (Carboniferous) alkaline granitoids.

Ondor-Tsagaan tungsten and molybdenum deposit: It is located in central Mongolia. The deposit is localized in a synclinal fold and accompanied in lower Devonian quartz-sericite, quartz-biotite-chert, and shale emplaced by gabbro-diabase bodies. The reserves of the deposit are 186 million tones at grades of 0.17% oxides of tungsten and 0.018% molybdenum.

3.2.6 Uranium. Uranium deposits were associated with coal deposits. Uranium mining in Mongolia began in 1989 with the opening of the Mardai open-pit mine in eastern Mongolia and was operated as a Russian-Mongolian venture until 1993. In 1998, a Mongolian-Russian-American joint company reopened the mine, but due to low market price the mine was closed shortly afterwards.

Phosphate

A large phosphate-bearing basin is located in the north-central region of the country. Estimated phosphate reserves in the region are 2,400 million tons.

4 GEOLOGY AND METALLOGENY OF GREATER ALTAI (KAZAKHSTAN)

4.1 The geotectonic position of the Greater Altai

According to the geotectonic position the Greater Altai geological structures are located in the Central Asian (or Kazakhstan-Okhotskij) global mobile belt of a sub lateral direction embracing geo-structures of Kazakhstan, Northern China and Mongolia. Within its border the structures of the Greater Altai are located on the north-western flank of Altai-Alashan curved shape mobile zone that envelop the Siberian platform from the south-west and the south.

The territory comprises the Rudny Altai, Kalba-Narym zone, West Kalba and Zharma-Saur which are considered in the Irtysh-Zaisan geosynclinal fold systems. The board structures of the north-east are the Rudny Altai caledonides (Charyshskij, Holzunskij-Chuiskij-Sitsikheskij and Tsunu-Chinkheskij structural zones), and the caledonides of Chingiz-Tarbagatai fold system are on the south-western part (Fig.1). On the south-eastern flank of the Greater Altai structures is narrowing sharply due to the thrust from the Djungarian array and West-Siberian plates. The north-western flank can be observed up to Russia and is mostly blocked by loose cover of the Kulundinskij cavity. The total length of the territory in up-to-date coordinates is more than 100 km at an average width of 300 km.

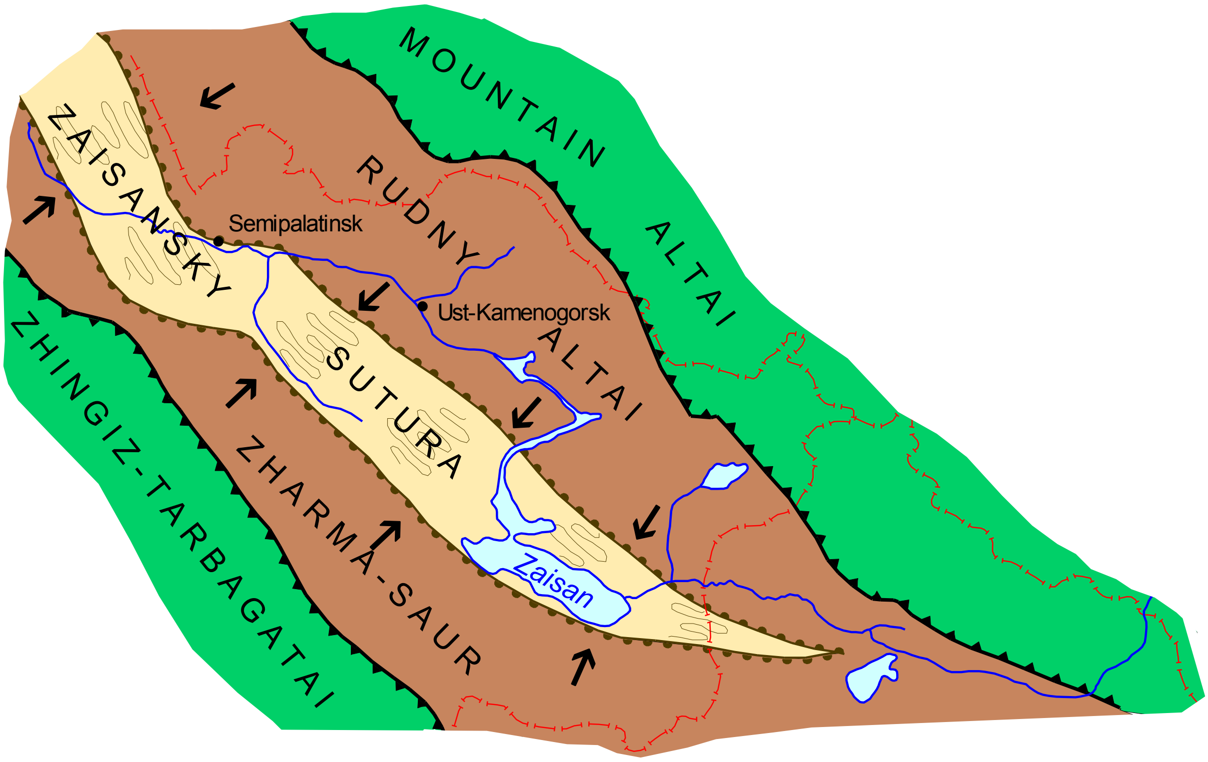

Fig 4. Main geological structures of Great Altai

Minerals of the Greater Altai are the natural stocks of huge deposits containing non-ferrous and precious metals and other resources. By processing these minerals copper, zinc, lead, gold, silver, platinum, titanium, rare and dissipated elements can be obtained. On the basis of these metals and elements the mining industry infrastructure with plants, towns and villages has been established in this region. For the purpose of mining industry enterprises sustainable work the metals stock should be continuously renewed.

Thus, high rates and volumes of exploration for the last ten years have led to the exhaustion of easily-discovered deposits. The scientific ideas in the field of geology governing for many years, particularly geosynclinal concept of fixism came to their self-exhaustion. That is why the methodology of metallogenic research, forecasting and new deposits exploration needs to be improved. New approaches to the geology, ore deposits depth-geological forecasting criteria development are required, especially in the exploration of loose and concealed deposits (up to 1000-1500 m).

4.2 Geotectonics and metallogeny

The overall progress of Earth sciences, new data on paleomagnetism, paleoclimatology, new mobilist hypothesis emerging in the 60th of the last century (plate tectonics, mantle plumes, terranes, new global tectonics) have determined the necessity for reviewing the traditional paradigms on tectonic and metallogenic evelopment of the given region. In this connection on the basis of global mobilism hypothesis the practical material generalization in the field of geology, geophysics and the Greater Altai and adjoining territory metallogeny has been carried out. This provided the identification of new principles for metalliferous geological structures development and the deposits formation under different geodynamic circumstances (Geodynamics…, 2007; Greater Altai…, 1998, 2000; Shcerba et al., 2000). As a result of research activity productive mineragenical levels and patterns have been determined with the perspective for non-ferrous, precious and rare metals exploration and the directions of exploration works have been defined.

4.2.1 Geodynamic development. The Greater Altai is a holistic geostructure of a vast territory, including the geological structures of the Rudny Altai, Kalba-Narym, West-Kalba, Zharma-Saur and nearby territories of Russia and China. In the tectonic outline it is a linear fault-fold structured pattern in the system of Central-Asiam mobile belt. The space is located between the stable continental arrays –Gornoaltaiskii (on the north-east) and Kazakhstanskij (on the south-west).

From the point of global mobilism, huge geological structures nucleation and formation in Kazakhstan, Siberia, Ural and other regions are connected with the break of the Eurasian continent into separate plates, geoblocks, arrays and xenoliths at the period of late Proterozoic. They were drifting in the Paleoasian ocean and made significant horizontal relocations. According to the paleomagnetic and geological features, the lithospheric plates and xenoliths relocations are supposed to originate from the east to the west (with clockwise rotation). The Greater Altai structures are possibly the xenoliths of the ancient paleo-continent (Eastern Gondvana). In the process of the Paleoasian ocean evolution, some xenoliths joined, perhaps, the Siberian craton, others formed the Kazakhstan microcontinent which then at the Devonian and Early Carboniferous periods were separated from the Gornyi Altai by Irtysh-Zaisan paleobasin (Greater Altai…, 1998).

The Greater Altai as a unified structure has transformed into the stage of the Hercynian collision (in Early Carboniferous and later) as a result of subsidence and interfacing of Kazakhstan continent borders and Siberian sub-continents which were divided by Zaisan sutural zones (Dyachkov et al.,2009). In later tectonic cycles the formed structure was complicated in the process of late-Hercynian intraplate rifting and then stabilized at the Mesozoic and Cenozoic periods. The modern Greater Altai structure is considered as a system of earlier separated blocks that are parallel to the structural-formation zones or collage terranes. The emerged tectonic structures (Altai Mountains, Rudny Altai, Kalba and others) are limited by deep faults, sutural zones and are differentiated according to the development geodynamics, geological structure and metallogeny specifity.

In the process of paleo-geodynamic reconstruction the geodynamic model of the Greater Altai formation has been developed. It is a modern type of structural-formation zone sub-parallel systems distinguished by deep faults. This geodynamic model of lithosphere rhythmic tension and compression having significant horizontal relocations of lithospheric plates by interlayer surfaces of the upper mantle, characterizes the Altai type of the Siberian and Kazakhstan subcontinents global interaction. The Greater Altai unique structures and its metallogeny are due to the geological processes grandiosity and duration.

This article considers the peculiarities of geological development, depth structure and leading types of the Greater Altai deposits having been formed under different geodynamic conditions. The overall geological formations development direction at the Precambrian was at the oceanic rifting mode, then in the early (rifting and insular), medium (collision) and late (post-collision) stages of the Caledonian and Hercynian cycles. This process terminated by the continental rifting and stabilized in the Mesozoic and Cenozoic. The indicators of paleo-geodynamic and landscape-geological conditions are the certain geological formations reflecting their emergence pre-conditions.

In the Precambrian cycle, at the oceanic rifting mode the pre-Riphean crystalline basement of small arrays destruction took place. They were split into separate fragments and blocks and then moved Within the Greater Altai the fragments of the Precambrian basement are fixed in the Charsk-Zimunai zones and Irtysh zone of collapse. They are complicated tectonic-metamorphic structures with intensive dynamo-metaphoric reformations of rocks that are suppressed by folds, thrusts and polycyclic metallogeny. They contain schists, gneisses, amphibolites, granite-gneisses with hyperbasite protrusions and serpentinite melange blocks. In hyperbasites there are magmatic deposits of Cr, Ni, Co (Pt) which form Charsk ore-bearing level with later form gold mineralization.

In the Caledonian volcanic arcs of basalt-andesite-dacite series with iron-manganese and gold-chalcopyrite deposits (Akbastau, Kosmurun, Mizek) were formed at the side structure of Chenghis Tarabagatai in rift-insular-setting of an early stage (C_1-O_3) (Table 1).

On the Greater Altai territory and in the Altai Mountains there was a marine mode with the formation of calcareous-siliceous-terrigenous elements. At the medium stage (O_3-S) there emerged the tendency for Irtysh-Zaisan small oceanic-basin degradation due to the growth of accretion zones in Gorno-Altaiskij and Kazakhstan continental arrays. The collision magmatic front was located in the doming spreading zones with the formation of gabbro-diorite-granodiorite intrusions (O-S, S_2) at the focal parts of Chenghis Tarbagatai and Rudnoaltaysko-Ashalinskij zones. The mineralization is represented by Fe, Cu, Zn, Mo, Au. The most productive level of pyritic copper-zinc ores was located in the active Kazakhstan suburbs and is connected with O_{2-3} insular-arc basalt-andesite volcanism (Mines Akbastau, Kosmurun, Mizek in Chenghis Tarbagatai).

At the final stage (S_1-D) the unified caledonian structure of the Greater Altai under general rotation of the Siberian continent and its adjacent folded structures in a northern direction was formed. In the process of the Greater Altai borders intraplate activation in the Altai Mountains, granodiorite-granite intrusions D_2 (Mo, W, Bi) emerged, and in Chenghis Tarbagatai - arrays of granite granosienite-leykogranitovoy series (D_2-D_3) with a poor rare-metal mineralization appeared.

The Hercynian cycle was marked by a repeated division and spreading of the Caledonian continental borders and the formation of a secondary Irtysh-Zaisan oceanic basin with a large magmatism and mineralization. At the early stage the main ore-bearing structures of the Rudny Altai formed under the rifting and insular-arc geodynamic conditions in the process of echeloned deep faults system activation. This contributed to the inflow of mantle basaltic magmas and mineralizing fluid flows into the upper parts of the granule cells. Major industrial chalcopyrite and pyrite-polymetallic deposits are genetically connected with an intensively displayed Devonian basalt-andesite-rhyolite volcanism. The most productive deposits are volcanic arcs of round structure flanking the Caledonian paleo-elevations and having long volcanic process and mineralization (Ridder Sokolnoe, Maleevskoe, Nikolaev, etc.)

At the medium stage (C^1-C^3) as a result of geodynamic mode change and prevailing compression (in the Early Carboniferous and later) the unified geological structure of the Greater Altai formed after the Gorno-Altaiskij and Kazakhstan continental borders collision, their connection took place in Zaisan sutural zone. This stage was implanted by syncollision gabbro-diorite-granodiorite intrusions, small hypabyssal intrusions and dikes of gabbro, diorite, granodiorite containing Cu, Ni, Au, Ag. In Zaisan sutural zone in the mode of rhythmic-pulsating tectonic movements of tension and compression the belts of gold-bearing small intrusions and dikes of Kunushskij complex (C3) are located. The diagonal systems of cross-cutting faults of late-collision stage with gold objects in the terrigenous-carbonate and black shale sequences (Bakyrchik, Suzdal, Kuludzhun, etc.)were the ore-controlling elements. At the late stage (C_3-T_1) under the conditions of intraplate activation of deep faults the granitoid belts with rare metal and rare-metal-rare earth mineralization - Ta, Nb, Be, Cs, Sn, W, Mo, Zr, Tr et al (deposits Bakennoe, Belya Gora, Verkhnee Espe, etc.) have formed.

The Cimmerian and Alpine cycles of the Greater Altai epihercynian structure development had a noticeably relative mobility in the Triassic and Jurassic, were significantly stable in the Cretaceous-Paleogene and during activation in the Neogene-Quaternary. This period is characterized by the formation of deposits in weathering crusts (Au, Ni-Co, Zn-Ni), placer gold, ilmenite, tantalite, cassiterite and other minerals. So, the geodynamic development of the Greater Altai mobile belt reflects a long and complicated history of geological structures formation in the process of collisional displacement of the Siberian and Kazakhstan subcontinents and the Irtysh-Zaisan paleo-basin degradation. It also emphasizes the intensity of ore-magmatic processes and metallogeny.

As a result of tectonic-magmatic processes polycyclic development the main periods of mineralization have been determined. They reflect vertical and lateral mineralization zoning in the frames of ore belts and the region of the Greater Altai.

4. 2. 2 Deep structure. The deep structure of the given region is considered according to the complex of geological and geophysical data (gravimetric, magnetic prospecting, seismic exploration and other activities) and is characterized by multilayered crust (MC) and upper mantle (M). According to the modern interpretation of geophysical material MC has the power equal to 50-55 km and includes heterogenic linear –mosaic blocks complicated with deep faults (Greater Altai…, 1998; Shcerba et al.,1984).

The upper mantle is characterized with the inhomogeneous structure and stratified to a depth of more than 250 km. In its structure there is supposed to be an undepleted mantle (pyrolytic) and drained including spinel containing dunites and harzburgites, garnet eclogites and alpine hyperbasites. The surface of the M is under the depth of 40-55km and is immersed in different directions. According to the works of V.N.Lyubetskoj, G.P. Nakhtigal and other researchers there is a scheme of asthenosphere layer topography where the ore-belts are marked and the asthenosphere topography location. The highest elevation of the asthenosphere layer (Semipalatinsk, Zaisan) of the north-west direction is in the Zaisan sutural zone, i.e. in the Kazakhstan and Gornoaltaiskij borders collision zone (Fig.2). The elevation of the Mokhorovich surface is fixed on the north-western flank of the sutural zone (Gornostaevskij) and on the south-eastern part (Zaisanskij) (Fig.3). Stratified asthenospheric zones in the upper mantle, deep faults system dissection are obviously the consequence of magmatic chambers generation, their metallogenic specialization and activation of geodynamic processes in the multilayered crust. The consolidated multilayered crust of the Greater Altai comprises four layers: meta basalt, meta diorite, meta granite and sedimentary.

The power of the meta basalt layer is 20-24 km and is up to 28 km at the crest thickenings of the north-western direction. Here there are also linearly elongated modern thermal anomalies . Deep faults (Charsk-Zimunaysky, Terektinsky and Baiguzin-Bulak Sirektasky), falling in different directions penetrate into the upper mantle and form marquee-type structures.

The meta diorite layer is represented by deeply metamorphosed rocks of the Precambrian (the average density of 2.8 g/cm3, the wave velocity 6,4-6,6 km/s). Its greatest power (12-16 km) is noticed in Kalba-Narym, Beloubinskij- Sarymsaktinskij and Sirektas-Sarzanskij zones). In Zaisan suture the power is minor and is 4-12 km. According to G.P. Nakhtigal in the meta diorite layer there are the lower edges of the most magnetically active objects and the root parts of the large granitoid plutons.

The meta granite layer embraces the metamorphosed Caledonian formations and major arrays of granitoids. It is exposed on the surface of Genghis Tarbagatai, Aleisk and the Rudny Altai and Sinyuhinskij blocks, fragmentary it can be viewed in the Irtysh, Sirektas and Sirektas-Sarzan zones, and also in the Charsk block. The maximum power of the layer (up to 12-14 km) is in Kalba-Narym and Beloubinskij-Sarymsaktinskij zones.

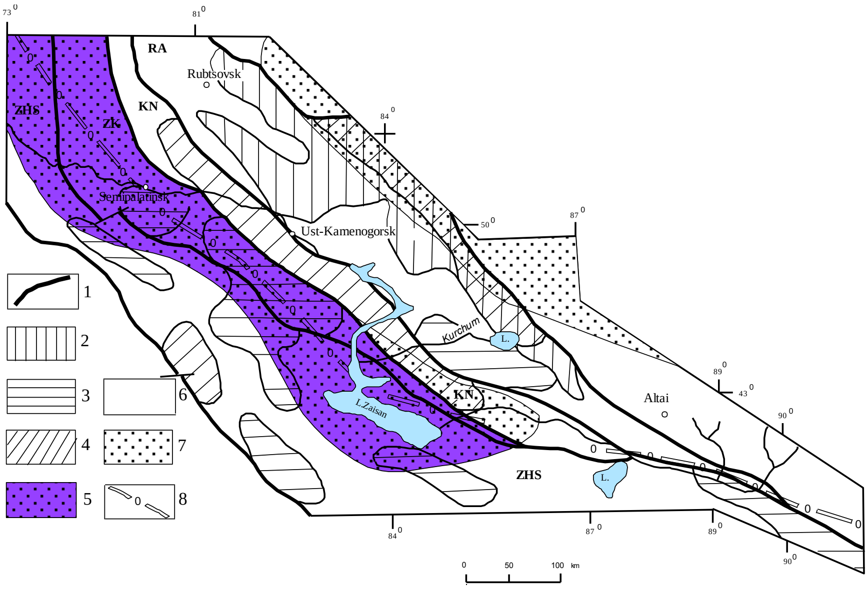

Fig. 2 Great Altai ore belts and asthenosphere layer’s topography

1- borders of the region, 2-3: Hercynian stage ores (1- rifting stage and island-arc borderland stage, 2- collision stage, 3- postcollision stage); 5-8: asthenosphere layer topography (5- elevation of the asthenosphere layer, 6-slope of the elevation , 7- depression, 8- depression axis. Ore belts: RA- Rudny Altai, KN-Kalba-Narym, ZK- West Kalba, ZHS- Zharma-Saur.

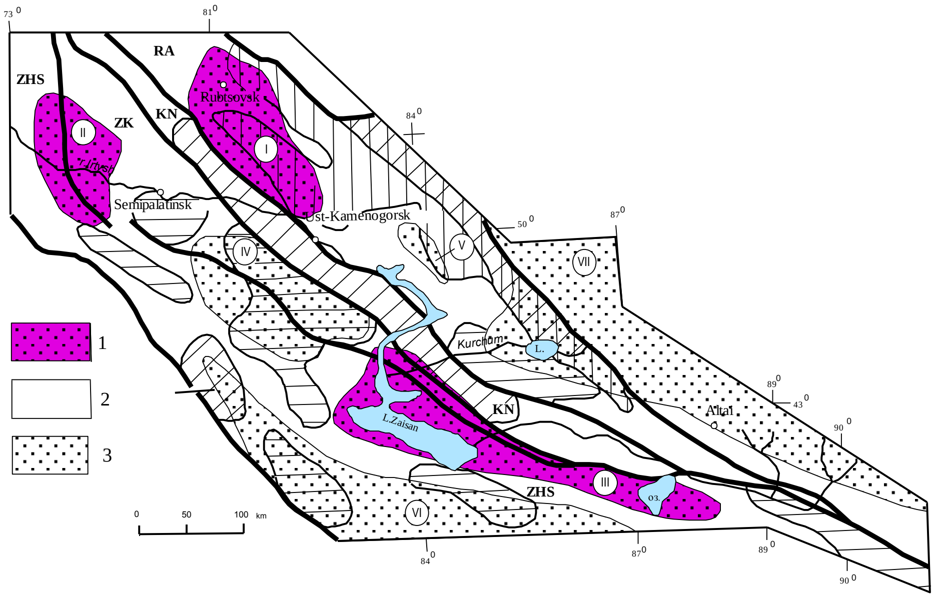

Fig. 3 Greater Altai, ore belts, and relief of the Moho surface
1-3 the Moho layer topography: 1-elevations, 2- slopes of elevations, 3- depressions; elevations: I-Rubtsovskij, II- Gornostaevskij, III- Zaisaskij; slopes: IV-Kalbinskij, V-Bukhtarminskij, VI-Saur-Manrakskij, VII- Gornoltaiskij

Sedimentary layer is formed by non- metamorphosed Paleozoic and Mesozoic and Mesozoic-Cenozoic sediments. According to F.S. Moiseenko (1981) it is divided into two sub-layers: volcano-genic-sedimentary and loose sedimentary cover. The powers of the hercinides volcano-genic-sedimentary sub-layer.is 0-9 km with minimum values (0-3 km) on the elevations (Rudnoaltayskij, Kurcch-Kaldzhirskij, Tersayrykskij) and with the maximum values in troughs. The loose sediments with the power of 50-100 m and up to 400 m and moreare in hollows and troughs (Zaisanskij, Kulundinskij, etc.).

4.2.3 Zoning. The Greater Altai territory as it was mentioned above embraces the geological structures of the Rudny Altai, Kalba-Narym, Zapadnaya Kakba, Zharma-Saur and adjacent regions of Russia and China. The bordelines are north-western deep faults on the north-east (Loktevsko-Karairtyshskij fault). It divides the structure of the GA from the Gornyj and Chinese Altai and borders with Genghis – Tarbagatai on the south-west of Genghis Saur. The total length of the geological structures is more than 1000km at the width of 300 km.

According to the geotectonic zoning and considering the adjacent territories of Russia and China, the Greater Altai is subdivided into two major sub-regions:

1) South –Western Altai Xinjiang, formed in the active borders of the Sibirean platform (on the north-east) and
2) Zharma-Saur-Baganur, located on the board of Kazakhstan microcontinent (on the south-west)

The borderline between the given sub regions lies on the Charsk-Zimunai deep fault or sutural joint. The junction area coincides with Zaisan sutural zone or Irtysh Zaisan, Ob-Zaisan according to other authors (V.N.Lyubetskoj, B.S. Uzhkenov, A.V.Smirnov).

The South-Western Altai-Xinjiang subregion embraces the geological structures of the Rudny Altai, Kalba-Narym zones and Western Kalba. In the Rudny Altaithre are three tectonic zones (from the north-east to the south-west): Beloubinsko-Sarymsakty-Kurtinskaya, Rudnoaltaysk-Ashalinskaya and Irtysh Fuyunskaya and from the Kazakhstan side their reflections are Beloubinsko-Sarymsaktinskaya, Rudnoaltayskaya and Irtysh zones. The last one with the terrane tectonic position corresponds with the sutural zone, dividing heterogeneous tectonic blocks (terranes) of the Rudny Altai and Kalba Narym. The Zharma-Saur-Baganur subregion is divided into three tectonic zones: Sirektas-Sarsazan-Kobukskaya, Zharma-Saur-Haratunguskaya and Charsk-Zimunayskaya zones. On the territory of East Kazakhstan they are Sirektas-Sarsazanskaya, Zharma-Saur and Charskaya zones respectively.

The Genghis Tarbagataiskiy belt bordering with the GA on the south-west comprises two tectonic zones: West Genghis and East-Genghis. On the north-east of the Altai Mountains the Charyshskaya, Holzun-Chuysko-Sitsiheskaya and Tsunhu-Chinhenskaya zones flank the Greater Altai.

There are four ore-belts according to the metallogenic zoning within the Greater Altai:

1. Rudny Altai copper-polymetallic (Fe, Mn, Cu, Pb, Zn, Au, Ag, etc.).
2. Kalba-Narym rare-metallic (Ta, Nb, Be, Li, Cs, Sn, W).
3. West-Kalba gold-ore (Au, Ag, As, Sb).
4. Zharma-Saur polymettalic (Cr, Ni, Co, Cu, Au, Hg, Mo, W, Tr).

In the structure of ore belts the ore bearing minor structures are considered: metallogenic zones (sub-zone), ore area, ore zone, ore node and ore field and also, deposits, ore occurrences and points of mineralization.

The main features of the geological structure and minerals of the given ore belts are displayed in the work (Dyachkov et al., 2009).

4.2.4 Metallogeny peculiarities

The discussed region is characterized by the variety of mineral types differentiated in genesis, age, scale of mineralization and other features. Below the peculiarities of the Greater Altai main ore-bearing structures metallogeny are being considered (Table 1).

In the Precambrian cycle in the oceanic rifting mode the destruction of the pre-Riphean small arrays crystal basement took place, they were divided into separate blocks-fragments and moved on the weakened slip surfaces with further complicated litho-mélange accretion. Within the GA the fragments of the Precambrian basement are fixed in the Charsk-Zimunai zone and the Irtysh zone of collapse. These are complicated tectonic-metamorphic structures with intensive dynamic-metamorphic transformations of the rocks, intense folding, thrust faulting, and polycyclic metallogeny. The crystalline schist, gneiss, amphibolite, granite gneiss with protrusions and hyperbasite blocks of serpentinite melange are typical of these structures.

The Precambrian metallogeny has not been studied well yet. Under the oceanic rifting the hyperbasite bodies with the primary mineralization (Fe, Mn, Cr, Co, Ni, Cu, etc) have been formed in the deep faults. In the process of collision they were squeezed into the upper floors of the structure in the form of hyperbasite and plates serpentinite melange protrusions (Charsk and Irtysh zones).

In the Charsk zone magmatic chrome formation has grown. It is associated with the serpentinized hyperbasites, blocks of ophiolites and metamorphic rocks in the structures of the melange. It is represented by small blocks and lenses of chromite and disseminated ores in serpentinites, which are considered as fractured fragments of larger bodies, the initial bedding has been defined yet (Andreevskoe, Suuk-Bulak, etc.) The estimation of these deposits is still incomplete. Insufficient studies of the Charsk mélange, identification of new hyperbasite bodies by geological and geophysical data, possibility for ore bodies clustering in sutural area allows to further study the Charsk zone.

In the Irtysh zone of collapse there is a golden metamorphic formation represented by gold-manifestations of Polevaevskij-Predgornenskij ore zone (Zolotar, Polevaevskij, Avrorinskij, etc.) Earlier they were considered as small quartz vein sites with limited prospects. Later, they were referred to a more prospective metamorphic-hydrothermal type of gold mineralization connected with dynamo-metamorphic and contact-hydrothermal regeneration of shale (increased content of carbonate and gold) in the process of the Irtysh zone of collapse transformation into the collision stage. According to the conditions of mineralization these objects are corresponded to the metamorphic types of deposits by Ya.N.Belevtsov (1982).

The acquired data testify the fact the greenschist sequences are the primary source of gold that then was mobilized in the process of regeneration. Another source is ore-bearing fluids connected with the intrusive magmatism (small granodiorite intrusions, dikes of plagiogranite porphyry, quartz porphyry and albitophyre). Besides the quartz veins containing pyrite, chalcopyrite and gold, the great importance is given to mineralized zones of increased gold content. They are silicified, tourmalined, pyritized and carbonated host rocks of a significant length with abnormal ore elements contents (Ag, Cu, Pb, Zn, etc). Significant sizes of these zones in length and depth provide a new approach to the evaluation of the Irtysh zone of collapse in gold mineralization. The main prospects of this zone are not quartz vein objects, but more prospective deep-bedded gold-sulfide zones. In this connection the re-evaluation of the known ore objects depth, new deposits survey in the concealed structures is expedient.

In the Caledonian cycle in the border structure of the Genghis –Tarbagatai under the rifting and insular-arc geodynamic conditions of an early stage ($€_1$-O_3) the volcanic arcs of basalt-andesite-dacite series of iron-manganese and gold-chalcopyrite deposits (Akbastau, Kosmurun, Mizek) have formed. On the Greater Altai territory there is a marine mode with the formation of calcareous-siliceous- of basalt and terrigenous structures.

In the middle collision stage (O_3-S) the overall tendency for the Irtysh-Zaisan small oceanic basin degradation from the growth of the accretion zones on the Gornoaltaiskij and Kazakhstan continental arrays. Collision magmatic front is located in arc up-lifts of spreading zones with the formation of gabbro-diorite-granodiorite intrusions (O-S, S_2) in local parts of the Genghis –Tarbagatai and Rudnoaltaiskij-Ashalinskij zone. The mineralization is represented by Fe, Cu, Mo, Au.

At the final stage (S_1-D) the unified Caledonian structure of the Greater Altai has formed under the conditions of total rotation of the Siberian continent and adjacent folded structures in the north direction. In the process of intraplate activation in bordering parts of the GA granodiorite-granite intrusions D_2 (Mo, W, Bi) have located in the Altai Mountains and arrays of granite granosienite-leykogranite series (D_2-D_3) with poor rare-metal-rare earth mineralization in the Genghis Tarbagatai.

In the early Hercynian stage the most powerful tectonic and magmatic processes of the Devonian times took place in the Rudny Altai being active continental suburbs of Altai-Sayan folded area. Here under the influence of tectonic stress (compression and tension) the system of contiguous sub parallel deep faults of north-west direction, penetrating in the activated upper mantle, has formed. The activation of deep faults (pushings) in the rifting and insular-arc geodynamic conditions was accompanied by a powerful basaltic volcanism and unique copper-pyrite and pyrite-polymetallic deposits with rich complex ores formation (Cu, Pb, Zn, Au, Ag, Pt, etc.). That is why the Rudny Altai is considered as a unique gold-copper-polymetallic belt including original rudnoaltayskii pyrite deposits together with the famous world types (Kuroko, Ural, Cyprus, filizchaysky and others).

As a result of the Altai geologists long-term research the certain tendencies of ore-bearing geological structures and pyrite-polymetallic deposits formation and location have emerged.

1. In the Devonian the suburbs of the ancient Altai continent underwent the destruction and were fragmented into a grid of deep faults, separate longitudinal plates and blocks were spread, displaced and drawn apart giving way to the deep fluid flows, mantle and intracortical magmas. Subsequent oncoming movment of the Kazakhstan array was accompanied by convergence of micro-continents and blocks, insular arc, their accretions and bonding into a single continental formation (Zoneinshein, 1990). Such “altai” type of inter-continental structures formation was due to the formation of longitudinal astenoval in the upper mantle as a result of moving lithospheric blocks trans-pressing and astenomass injection and fluid-flow into the deep faults (Greater Altai…, 1998). This process was accompanied by formation of prevailing complicated homodrom magmatites and local antidrom bimodal volcanic series connected with intracortical basaltic centers. The emerged geological structures in the final geodynamic modes (collision compressions, sub-vertical tensions, horizontal movements in the tectonic zones, etc.) were significantly transformed and complicated with pyrite-polymetallic ores (Shcerba et al.,1984).

The location giant halos of magmatites and deep zones of earth crust according to the geophysical data (Lyubetskij et al., 1994) allows us to presuppose the existence of local fluid-saturated systems at the depth of 60-80 and 160-180 km with complicated real differential in the past [11], possibly, these are north-western removals of the Northern-Asian superplumes (Greater Altai…, 1998; Yarmoluk et al., 2000).

Accumulation of fluids and concentrated migration of ore saturated flows is supposed to be the main feature for the potential productivity index of the ore-forming system of the Rudny Altai. The existence of favorable structural elements contributed to the deposition of ore material and the deposits formation.

2. The main pyrite deposits are concentrated in the rod Rudnoaltaiskij-Ashalinskij zone, limited by the Irtysh and North-Eastern zones of collapse. The given zone is characterized by increased femic index of the EC section, has high magma saturation and mineralization density. The location of the pyrite mineralization is clearly correlated with the elevation of the upper mantle, meta-basalt layer, and the Proterozoic and Caledonian basement blocks. The main pyrite-polymetallic and polymetallic zones in the EC deep section are related with the thickened parts of the meta-basalt layer (power is 20-24 km) and concentrated over the crest show of the mantle surface relief (depth is 40-43 km).

The ore-formation model reflects the connection of the pyrite deposits with the Devonian volcanism, multi-staged ore process and multi-layered mineralization distribution (with vertical ore range up to 1000-1500 m). The deposits are bound with the group of basalt-andesite-rhyolite formations differentiated and forming several ore-bearing geo-chronic levels from D_1e to D_3fm_1. The most productive formations are – emskij (Fe, Mn, Pb, Zn (deposits Kholzunskij, Ridder-Sokolnyj)), ems-eifelskij – Zn, Pb, Cu, Au, Ag (Tishinskij, Zyryanovkij), eifel-zhivetskij – Cu, Zn, Pb (Orlovskoe, Maleevskoe), zhivetskij – Cu, Zn, Pb, Au (Artemyevskoe, Nikolaevskoe) (Shcerba et al.,1984: Bespaev et al., 2000).

The ore formation took place under the sub-marine conditions, obviously at ascending vadose-hydrothermal system of solutions with povenil source of metals (Fe, Cu, Pb, Zn, S, Au, Ag, etc) and dissolved gases (CO_2,N_2, H_2S, S, Cl, etc.). There are two ore types according to the formation way: 1) stratiform (volcanic-sedimentary) and 2) hydrothermal-metasomatic, represented in a majority of industrial pyrite-polymetallic deposits (Zyryanovskoe, Maleevskoe, Tishinskoe, etc.). The volcanogenic-ore centers, volcanic domes and volcano-tectonic depression, the nodes of faults intersection, horizons of carbonaceous clay and calcareous shale and others are referred to the ore-bearing structures. The most productive structures among them are the Devonian volcanic arcs of a ring structure surrounding the Caledonian paleo–elevations (Sinyushinskoe, Revnyushinskoe, Alejskoe) and characterized by the length of the volcanic processes and ore-formation (deposits Ridder-Sokolskoe, Tishinskoe, Zyryanovskoe, Nikolaevskoe, etc.).

The main role in the deposits location is given to sub latitudinal ore-controlling faults (Leninogorskij, etc.), especially in their intersection nodes with the breaks of other directions, where there were volcanogenic-ore centers. The characterizing feature of this phenomenon is the linear-nodal distribution of Devonian volcano-tectonic structures with pyrite-polymetallic deposits in the longitudinal ore zones

(Leninogorskaya, Zyryanovskaya, Orlovsko-Belousovsky, etc.) (Fig.4). The spacing of ore nodes (at the intersection of the north-western faults with meridional and sublatitudinal faults) is 20-40km. Reconstructed ore zones of considerable sizes (longer than 100 km, at width of 10-20 km), with ore nodes contain major reserves of Cu + Pb + Zn of all known deposits of the Rudny Altai.

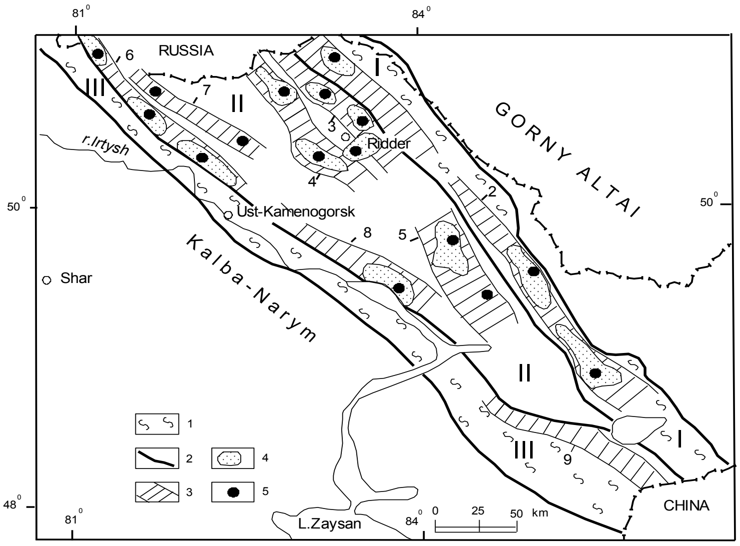

Fig. 4- Metallogenic demarcation of the Rudny Altai

1- Shear zone, 2- boundaries of metallogenic zones, 3- ore zones, 4- ore districts, 5- copper-base-metall polymetallic deposits
Metallogenic zones: I-Belay Uba-Sarymsaqtinskij, II-Rudnoaltay-Ashalinskij, III-Irtysh-Fuyungskij.

Ore zones: 1-Gyslaykovskij, 2-Yuzno-Altaiskij, 3-Leninogorskij, 4-Tishinskij, 5-Zyryanovskij, 6-Shemonaikhinskij, 7-Orlovsko-Belousovskij, 8-Bukhtarminskij, 9-Dzhaltyrsko-Alexandrovskij.

Major ore area are: Leninogorskij, Zyryanovskij, Priirtyshsk,ij Rubtsovskij and Zmeinogorskij contain major reserves of copper, lead and zinc (Ridder-Sokolnoe, Tishinskoe, Orlovskoe, Nicholaevskoe, Artemyevskoe, etc.). In the south-eastern extension in China there are well-known deposits such as Ashaly, Timurty (Fe, Pb, Zn), Koktal (Fe, Pb, Zn) and others. This is considered to be an important verification for the unity of ore-bearing structures in the border region of Kazakhstan and China (Bespaev et al., 1997, Shcerba et al., 2003).

Forecasting-metallogenic studies show that in the Rudny Altai the industrial pyrite deposits formed under the rifting and insular-arc conditions in the process of a powerful rhythmic-pulsating volcanogenic mineralization of the Devonian period. The pyrite-polymetallic and copper-polymetallic have belt distribution in the longitudinal ore zones of considerable sizes. The former preserves significant prospects for mineral resources increase at certain ore-bearing geo-chronic levels, within a flank and deep horizons of known ore nodes, ore fields and deposits. The medium stage of the Hercynian cycle (C_1-C_3) differed by the sharp change of the geodynamic mode (prevailing compression), closing of the Irtysh-Zaisan paleo-basin, exertion of folding and thrusting major phases, accretion of structures and collision of Kazakhstan and Gornoaltayskij arrays. The result of it was the collision of two continental suburbs having formed a single coherent structure of the Greater Altai. In large volumes the sin-collision gabbro-diorite-granodiorite intrusions have infiltrated, volcanic-plutonic belt and molasse formation have localized. In the region geological structure under the collision geodynamic conditions the magmatic copper-nickel, copper-porphyric and hydrothermal gold deposits formed.

In the Rudny Altai the most powerful intrusive magmatism emerged in the focal part of the deep mobile zone (above the elevations of the meta-basalt layer and anomalous upper mantle). The large arrays of multi-phase gabbro-diorite-granodiorite of plagio-granite series have formed (Zmeinogorsk complex C_2-$_3$). The tectonic broken apical zones of separate gabbro-granitoid massifs have undergone hydrothermal-metasomatic changes and are prospective for the detection of copper-porphyric and gold deposits.

The Sekisovskoe deposit refers to the gold-telluride formation of propylites Berezite-type. It is represented by brecciated gold-sulphide mineralized zones and stockworks in the magmatites of the Zmeinogorsk complex. The faults of the north-western direction associated with the Irtysh zone of collapse had the ore-controllling importance. According to Yu.A. Kostin, G.G. Freiman, G.I. Dudukalov and other researchers, increased tectonic dislocations of rocks fixed by brecciated and crushed textures of rocks are characteristic of the ore fields. Ore-explosive breccias in the form of gabbro, diorite and plagiogranites debris cemented by the bulk of propilite and berezite content with the gold-sulphide mineralization are also one of their features. The types of the ore-bearing meta-somatites depended on the original rocks content: 1) propylites-sulphide (by gabbroids, diorites) and 2) beresites-sulfides (by plagiogranites and porphyries), on which the ore-bearing quartz and carbonate-sulfide veins have laid.

The ore-formation was accompanied by Fe, Cu, Pb, Zn, Au, Ag, Bi, So_3, CO_2 entry and Si, Na exit. Gold and silver in beresites and propylites content are positively correlated with Pb, Zn, Bi, Cu, and in pyrite-quartz veins content and quartz meta-somatites have another correlation of Au Mo (+0,76). Ore bodies in the mineralized zones are characterized by lenticular or column forms due to the conjugation breaks nodes; mineralization is disseminated and veinlet-disseminated. The main ore minerals are pyrite, sphalerite, chalcopyrite, gray ores and gold, minor are arsenopyrite, magnetite, ilmenite, rutile, tetradimit, bismuthinite. Non-metallic minerals are quartz, calcite, sericite. All types of ores are enriched with pyrite (over 17 kg / m). The gold is represented by two types:: 1) free, having irregular, vein-like and elongated forms, performing fissures in pyrite and quartz, and 2) finely dispersed in pyrites (Au - 10 g / t, Ag - 100 g / t, Bi - 290 g / t). The deposit has an industrial value.

On the south-eastern flank of the Rudny Altai drastic narrowing of the structural-formational and metallogenic zones, associated with tectonic compression in the process of Jungar and Siberian plates collision is notices.

The emerged structures of conjugation, converging into a single virgational beam in the south-eastern-part of the Lake Markakol differ by complicated geodynamic development, intense exertion of magmatism and metamorphism, and diversified mineralization (Fe, Cu, Pb, Zn, Au, Ni, W, etc.). In the Irtysh sutural zones quartz-vein gold deposit of Mank in genetic linkage with small intrusions and dikes of diorite-granodiorite composition (C_3) emerged, the analogue of it is gold-ore deposit Dolonosai on the Chinese territory.

This fact allows to mark the single ore field of Mank-Dolonosai on the bordering territory and this area should be thoroughly studied.

In the Zaisan sutural zone in the process of complicated geodynamic development the Charsk-Gornostaevskij ophiolite belt of a planetary rank has formed. It fixes the zone of the mantle deep fault. Here, there are also zones of melanging, fold-thrust structures, olistostrome complexes, auriferous small intrusions and dikes infiltrated. The collision geodynamic conditions turned out to be favorable for different gold-ore deposits formations. The leading deposit is gold-arsenic-carbon type in the black shales, covering the largest reserves of gold deposits in Western Kalba (Bakyrchik, Bolshevik, Glubokij Log, etc.) (Bakyrchic…, 2001). The ore-containing deposits are sediments of molasse limnic coal-bearing formations (bukonskaya formation of $C_{2\text{-}3}$), exposed to intense dynamometamorphic and hydrothermal-metasomatic changes in the zone of deep faults (Fig.5). The ore bodies are represented by broken, fragmented and silicified black shales with abundant inclusions of gold-bearing pyrite and arsenopyrite. The main ore-minerals are pyrite, arsenopyrite and gold. The gold content is 8-9 g/t at average. The deposits have an industrial importance.

Gold-vein-disseminated type also has a practical value. It is characterized by the concentration of gold in the hydrothermally altered carbonate rocks of the island-arc type volcanic-carbonate-terrigenous formations (deposits Suzdalskoe, Mirazh, etc.) (Greater Altai…, 1998; Dyachkov et. al., 2009; Kovalev et. al., 2009). Ore bodies have formed as a result of dzhasperoid silicification of limestones, and are represented by mineralized zones, nests, veins and stockworks.

The main minerals are pyrite, arsenopyrite, gold, and rarely –stibnite. The gold content in indigenous ores and weathering crusts is 8-10 g / t. According to the range of features the deposit is compared with the famous “karlinskij” type of ore-mineralization in the carbonate formations (Rafailovich, 2009).

In Zharma-Saur intense tectonic-magmatic activity of the collisional stage, was accompanied by intensive development of the gabbro-granitoid intrusionswhich were located in ring structures in the focal part of the deep mobile zone (Saur complexes C_1, maksutskij C_{2-3}, sayadyrminsky C). Magmatic formations are characterized by metallogenic specialization on Cu, Ni, Co, Au, Ag, Mo. The wide development of ore-bearing intrusive formations indicates at the possibility to detect hidden and buried deposits (Bazarskij deflection, Severnoe Prizaysanye, etc.).

There are certain prospects for exploring gold in Zhanan-Boko-Zaisan ore zone where the gold-sulfide deposits exploration with primary ores as well as in weathering crusts is forecasted (sites Kempir, Zhanan, Akzhal-Boko and others).

In Kazakhstan, the copper-porphyry deposits are an important source of copper and molybdenum (Kounrad, Bozshakol, etc.). In eastern Kazakhstan the largest deposits are porphyry- copper fields of Aktogai, Aydarly, as well as other known objects - Shar, Kyzyl Kain, Kensal, etc. These deposits are characterized by significant resources of copper, molybdenum, perhaps gold, and can make a significant contribution to the economy of the region. Low metal contents did not give the opportunity to assign them to categories of industrial deposits in the past. The emergence of new technologies opened new possibilities of exploiting deposits with poor content of ores.

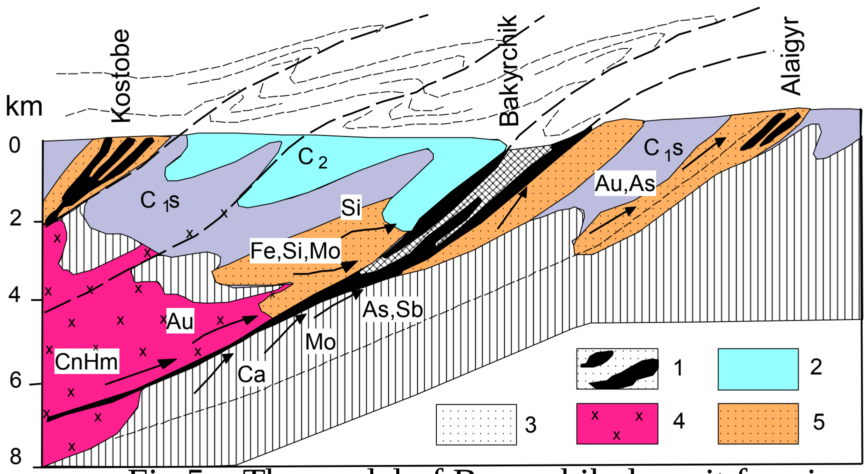

Fig.5 – The model of Baqyrchik deposit forming

1-surface of gold bearing carbonaseous molasses (C_{2-3}), 2- submurin molasses (C_2)., siltstone-sandstone formation (C_1), 3- volcano-silica, volcano-terrigenous formation (D_3-C_1), 4- plagiodranit-granodiorite formation (C_3), 5- zones of the mineralizations .

Copper-nickel mineralization is genetically related to small intrusions gabbronorite-diorite-diabase (C_{2-3}). On the Maksut deposit the ore-bearing fields are melanocratic gabbro and gabbro-diabases, which are associated with solid and disseminated pyrrhotite-chalcopyrite-pentlandite ores in the form of tabular and lenticular deposits, connected with the bottom of the cup-shaped array. The main ore-field has the length of 1000 meters and the power of 21.5 m at an average content of Cu 0,47%, Ni 0,35%. The exploration works are carried out at the moment. There are real prospects of detecting new sulfide Cu-Ni deposits within Maksut-Petropavlovskij-Kharatungskij belt of disseminated gabbroid intrusions (C_{2-3}), bordering with a large deposit of Kharatung or Kolotong on the south-east flank (Bespaev et al., 1997, Shenghao et. al., 2003). This increases the possibilities for the similar deposits exploration on the Kazakhstan territory as well.

The facts mentioned above indicate that in the middle Hercynian formation range in the Greater Altai region the sin-collision intrusive formations were prevailing (up to 60-80% from the total volume) over volcanogenic and sedimentary elements. The magmatism evolution in each tectonic rhythm was carried out in homodrome sequence (from basalts, gabbroids to rhyodacite, granodiorites and plagiogranites) and the mineralization change in time range respectively: Cu-Mo-Au (C_1) → Cu-Ni-Au (C_{2-3}) → Au-Ag-Sb-Bi (C_3).

The later stage of the Hercynian cycle was marked by the shift of collision geodynamic mode to post-collision or orogenic mode (P_1-T_1). At this stage ascending crest-block movements, intensive processes of intraplate tectonic-magmatic activation, accompanied by the outbreak of granitoid magmatism with rare metal and rare-earth profile of mineralization were dominating (Ta, Nb, Be, Li, Cs, Sn, W, Mo, etc.). The largest granitoid belts are Kalba-Narymskij, Tigereksko-Chernevinskij and Akbiik-Akzhaiyauskij. They formed in zones with increased siality of the continental Earth crust (Kalba-Narymskaya, Beloubinsko-Sarymsaktinskaya and Sirektas-Sarzasanskaya). The granitoids of the Permian age (Kalbinskij, Monastyrskij, Zharminsky and other complexes) are prevailing in their composition. The magmatism evolution was in the overall tendency for the leucocratic alkalinity of granitoid series increase. Every petrochemical type of granitoids formed under certain geological conditions and was characterized by its ore potentia (Dyachkov et. al., 2009).

The Kalba-Narymskij granitoid belt is the main ore-bearing structure of the region having regional development (length is more than 500 km). It is characterized by sialitic profile of the Earth crust section with an increased power of meta-granite layer and of the Earth crust in general. The large scale of granitoids distribution emphasizes the fact that there are rather a lot of energy and material resources for rare-metal mineralization processes. The structural metallogenic model of the given belt reflects the connection of ore-magmatic systems with deep zones in the Earth crust and the upper mantle and, consequently, the granitoid belt has formed as a result of long-term deep evolution of the lithospheric element.

In the Kalba-Narym there are following ore-formation types of deposits:: 1) pegmatitic rare metal (Ta, Nb, Be, Li, Cs, Sn), represented by major industrial deposits (Bakennoe, Belaya Gora, Yubileinoye, etc.); 2) pegmatitic beryl, microcline, in which minerals are blocking microcline and quartz, muscovite, beryl and columbite (deposits

Asubulak, Lobaksaj, Nizhny Laybulak etc.); 3) albite-greisen tin-tantalum (apogranite) in hidden granite dome, potentially prospective for the identification of Ta, Be, Li, Sn (Karasu deposit); 4) greisen-quartz-vein tin-tungsten represented by ores of wolframite, scheelite and cassiterite (deposits Cherdoyak, Palattsy, Kaindy, etc.); 5) clastogene Tantalum - Tin - Tungsten forming placers of tantalite, cassiterite, wolframite, scheelite and monazite.

The carried out studies show that ore-generating ability of granitoids together with petrologic factors depend on geodynamic conditions of arrays formation and scale ore-bearing melts degassing. From these positions there are various ore-magmatic parts determined. They are close to ore-bearing fluid systems (Letnikov, 2000). There are the following favorable conditions and criteria for rare-metals mineralization forecasting:

1) mobile geodynamic conditions of granite arrays formation and this contributed to the intensification of mineralization process under non-equilibrium PT conditions and the formation of industrial deposits of rare-metal pegmatites (Central Kalba ore region);
2) determination of ore-controlling role in latitude deep faults of prolonged activation, particularly favorable nodes are their intersections with the faults of other areas, where the most important ore fields have formed (Asubulakskoe, Belogorsk, Ognevsko-buoys and others);
3) Apical parts and over-intrusive zones of granite arrays, their apophasis, hidden domes and tectonically weakened zones, ore nodes in the thickened parts of the granite intrusions, over the magma-feeding roots or at their peripheries are the most perspective structures for the mineralization concentration;
4) establishing the genetic relationship of rare metals from each intrusive phase of Kalba complex at the spatial confinement of the main rare-metal - pegmatite mineralization (Ta, Nb, Be, Li, Cs, Sn) to the granites of I phase with increased base (deposits Bakennoe, Yubileinoye, Belaya Gora, Verkhnyaya Baymurza etc.)
5) identified petrographic, petrochemical and mineralogical and geochemical criteria for ore content evaluation of different age granitoid complexes and their intrusive phases.

On the continental border, in zones of sub-continental earth crusts (Zapadno-Kalbinskaya, Charsko-Gornostaevskaya) and in the faults of sutural zones on the surroundings of the Greater Altai (North Eastern zone of collapse, Genghis Saur suture) the subalkaline granite granosienite (Zr, Ti, Sn, Be) and alkali granite (TR, Zr, Nb, Ta) intrusions have localized. They are connected with deeper crust and mantle centers. The known ore objects refer to the epi magmatic Niobium - Zirconium - rare-earth formations (Verhnee Espe, Azutau).

At present the most important objective of the region is exploring new deposits of rare and rare-earth metals considering modern tendencies of world geological science and market economy development.

The Cimmerian cycle (T-Pg_2). The Cimmerian formations emerged under the continental rifting mode and had an autonomous development. They are represented by Semeitau volcanic-plutonium association (T_1) of a contrast content and high alkalinity (trachybasalt-trahiriolites and subvolcanic analogues), trap formations J_2 (lugovskij complex), northeastern belts of colored dikes from gabbro-diabase to quartz porphyries (mirolyubovsky, Bugaz complexes) and molasse coal-bearing formations (T_3-J_1,J_2). The latter unify sedimentary-coal-bearing strata imposed animations (Kendyrlykskaya, Zhemeneiskaya, Abaevskaya, etc.). At the ending stage of the tectonic stage under the epigerian plate stabilization mode the silt-clay variegated hematite - kaolin deposits K_2-Pg_2 have accumulated on the vast territory and have the power of 200 m (north-zaisan formations).

In a humid subtropical climate the Paleozoic and older rocks formed with crust of weathering. In the Charsk-Gornostaevskij ore zone the Ni-Co and mercury bearing weathering crusts of a nontronite type have formed on the serpentinized hyperbasites as well as ore-bearing crusts in ore-containing rocks and ores (Semipalatinsk Priirtyshie). In the Zapadno-Kalbinskij belt the Zr-Ti weathering crusts of kaolin type developed with sub-alkaline granites (Karaotkel deposit). The Cimmerian cycle had a destructive character. Huge masses of loose material together with the disseminated ore element were taken into the Kulundinskaya and Zaisanskya depression, West Siberian Plain and smaller intermountain depressions.

Alpian cycle (Pg_{2}-$_{3}$-Q). During the Alpian cycle, the given region was an area with intense denudation with removal of products of destruction to the West Siberian Plain and large depressions forming continental sedimentary formations (Paleogene-Neogene-Quaternary period). They are widely developed in the Zaisan basin, Semipalatinskoe Priirtyshye, intermountain depressions and lake basins differing by some lithologic ore peculiarities and deposits power.

In the sedimentary cover there are also sustainable ore minerals placers (gold, ilmenite, tantalite, cassiterite, etc.) which are subdivided into alluvial, deluvial and proluvial according to the genesis. Some of them were explored (Kurchumskaya – Au, Satapaevskaya – Ti, Asubulakskoe – Ta, etc.).

So, on the basis of the global mobilism hypothesis, the overall tendencies of the Greater Altai geological and metallogenic structures formation located in the system of the Central Asian mobile belt have been identified. Modern structures – the Rudny Altai, Kalba-Narym, Zapadno-Kalbinskaya zone and Zharme-Saur are the fragments, xenoliths of the ancient paleocontinent (terranes collage) that were drifting in the paleoasian ocean and joined into one single formation during the Hercynian collision stage in the process of a complicated interaction and the Kazakhstan microcontinent and the gornoaltaiskij border of the Syberian platform interfacing. Now it is a system of sub-parallel structural formational and metallogenic zones divided by deep faults and differing in the geodynamic development and the peculiarities of the geological structure and metallogeny. From the point of mobilism the common trend of the Greater Altai geological structures development and minerageny, under different geodynamic modes and conditions for the long period (from the Precambrian up to Quaternary) has been defined. The identified trends of the deposits connection with certain geodynamic modes based on the principles of ore-formation analysis speak for the fact that there is a genetic connection between geological and ore formations considering the geological formations as the indicators for certain paleogeodynamic and landscape geological conditions.

The research shows that the energy potential of the ore-forming processes in each ore belt theoretically tends to be one certain value. In the Rudny Altai belt in the Early Hercynian stage under the rifting insular arc conditions (on the continental crust) the powerful processes of basaltic vulcanization were accompanied by the major copper-pyrite and pyrite-polymetallic deposits formation in East Kazakhstan(Fe, Cu, Pb, Zn, Au, Ag, Pt, etc.). The scope of ore-content of the following medium (collision) and late (post-collision) periods was weakened. The Zapadno-Kalniskij zone had the largest tectonic-magmatic activity during the medium collision stage, and it was rich with ore minerals (Au, Ag, As, Sb), under appropriate depressed development of other stages metallogeny. The example of this is the Kalba-Narym rare-metal belt where the energy potential was accumulated in the early and medium stages and then it passed into the late stage (post-collision) in the form of granite magmatism flash and the deposits of rare-metals related to it (Ta, Nb, Be, Li и др.). In this regard, the study of mineragenetic specialization of geodynamic conditions along with detailed structural - elemental studies of geological formations and ore sites, is one of the main methods of forecasting and search for new deposits, particularly in poorly studied, and closed areas.

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