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RARE METAL GRANITES IN THE STRUCTURES OF THE RUSSIAN SECTOR OF PACIFIC ORE BELT

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Data are presented on the geology of areas of rare metal granites proliferation in the Russian sector of the Pacific Ore Belt that make one take a fresh look at the East Asian granitoid area to update its metallogeny. History is reviewed of studying rare metal granites of the Russian Far East. As a rule, these are found in the vicinity of major tungsten-stanniferous ore deposits, except much later than discovering the former, at the stages of their assessment and survey. Rare earth granites are usually missed by the geologists during the early stages of regional geological surveys due to their small size, weak eroding and external similarity with earlier granites. Using the examples of the Central Polousny, Badzhal and Kuyviveem-Pyrekakay regions the structural and geological conditions are characterized of localization of rare metal granites. Comparative analysis of geological situations made it possible to formulate the areal character of manifestation of rare metal granites; their confinedness to late Mesozoic orogenic arched uplifts of bogen structures above deep granitoid batholiths; positioning in the areas where longitudinal and transversal deep laying faults cross; gravitation to the environs of pre-Cambrian median masses. Similarity of structural-geological conditions for manifestation of the well-studied ore-containing granites serves to confirm the hypothesis on the joint stage of late Cretaceous rare metal magmatism in the Russian sector of the Pacific Ore Belt and the existence in the region of a magmatic super-province – the Far East belt of rare metal granites that includes the Novosibirsk-Chukotka, the Yana-Kolyma and the Sikhote-Alin rare metal – granite provinces.

Key words: rare metal granite, strucutres, fault, orogenic arch, intrusive complex, Pacific ore belt, the Far East.

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Introduction. Lithium-Fluorite granites are found in many tungsten-tin ore provinces of Europe, Australia, Africa and both Americas, saturated with accessor minerals in industrial amounts that are responsible for generating ore carrying solutions [4]. Rare metal granites (RG) of Central Asia have been known in Russia for long [12, 13]. The current paper considers the geological position of the youngest and least studied rare metal granites of North-East Asia that were discovered in the Russian Sector of the Pacific Ore Belt (POB) [3]. Their wide proliferation and closeness to the largest rare metal deposits of the region define the topicality of this study. The history of studies of rare metal granites in the POB cover a short time interval including the second half of the XX century. The first publication of finding granites enriched with topaz and lithium mica was by N.I. Tikhomirov (1941) in his summary of "GlavSevMorPut" expeditions to the Chukotka north. Direct indication on the presence of RG in the Far East belongs to V.G. Rub (1971). One may judge on findings of similar granites in the North-East by the monographs by B.L.Flyorov (1971, 1976), L.N. Indolev (1979), V.I. Kovalenko and Yu.D. Nedosekin (1980, 1988), and as for the south of the Far East, these were the studies by M.G. Rub (1956-1982) [2]. During the last few decades, the intrusions of lithium-fluoric granites were identified in many promising ore regions of the Russian East and the neighboring areas of China, Korea and the US, in the immediate vicinity of their largest tungsten-stanniferous ore deposits. As a rule, these are discovered much later than the discoveries of ore deposits took place, while the latter were assessed and surveyed. Rare metal granites are usually missed by the geologists during the early stages of regional geological surveys due to their small size, weak eroding and external similarity with earlier granites in which they are often deposited. Cases of direct positioning of ore bodies in the RG are an exclusion (consider the deposits of Kesterskoe, Odinokoe, Voznesenskoe, etc.). The honor of identifying RG belongs to the researchers from academic bodies and universities of Russia and China who studied the Tigriny, Voznesensky, and other massifs in Primorye [5, 6, 10, 11], Arga-Ynnakh-Haisky, Omchikandinsky, Levo-Erikitsky, Nevsky and other in Yakutia and the Sea of Okhotsk Area [5, 9, 11, 12], Verkhneurmiisky in the Amur Area [2, 5, 6, 11], Severny and Iultinsky in Chukotka [2, 7], Leizyling, Souchou and other in China [15-18 et al.] (Fig. 1). Ongonites were found in association with RG in the leading rare metal ore deposits [2, 6, 9, 15, 18]. It is suggested that rare metal granites are present at deep horizons of a number of major deposits: Deputatsky (Yakutia), Dubrovsky (Primorye), Pyrkakaysky and Iultinsky (Chukotka) [2, 5, 6].

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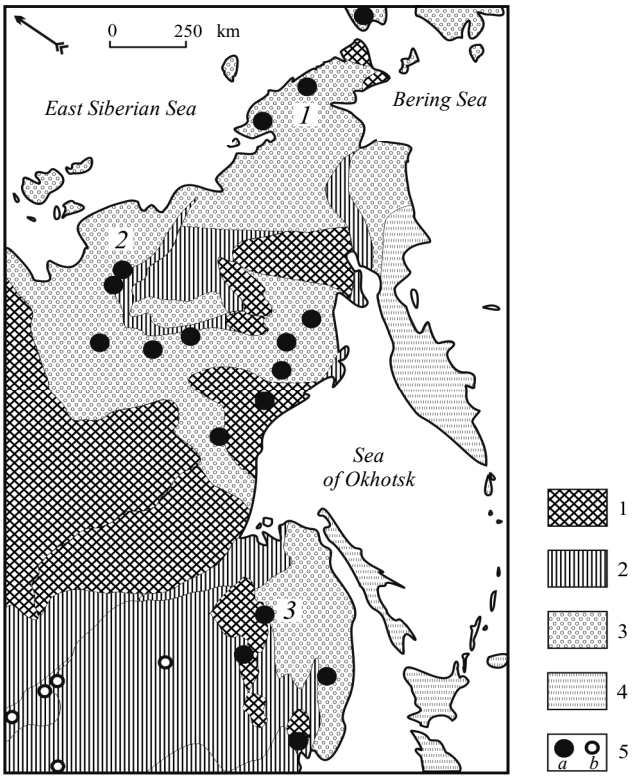


Fig. 1. Areals of rare metal granites of the Russian sector of the Pacific Ore Belt

1-4 are the structural complexes: pre-Cambrian (1), Paleozoic (2), Mesozoic (3), Meso-Kainozoic (4); 5 – areals of intrusive complexes with rare metal granites: *a* – the Far East Belt, *b* – the Central Asian Belt

Typical RG areals: *1* – Kuiviveem-Pyrkakai; *2* – Central-Polousny; *3* – Badzhal

Methodology and study methods. The term rare-metal granite is used in the study to indicate granites of specific composition and origin to which deposits of rare metals of magmatic and post-magmatic genesis gravitate [14]. By way of scientific methodology foundation the study used the systematics of rare metal granite formations by S.M. Beskin – Yu.B. Marin (1976-2013) [4]. The model is used of deep cellular structures by I.N. Tomson and M.A. Favorskaya (1973; 1992), augmented by the concept of ore-magmatic systems (OMS) of the Far East by V.G. Gonevchuk [6]. The basic principle of the study consists in complexing geological information at various levels of substance organization: the mineral, the rock type and the formation. Study techniques: geological mapping of basic ore nodes, regional and interregional correlations of granitoid formations, formation analysis. To solve petrological problems the technique was used of electronic petrography based on combining the optical and electronic microscopy techniques for studying matter (SEM, EMPA, CL, TOF-SIMS).

Geological Situation Conditions for localization of rare metal granites. In comparison with rare metal granites of Central Asia, Europe and other parts of the globe the RG of the Far East are studied poorly. The erosion cross-section of most intrusions is not large: they include buttes and roof pendants, they are often "blind" and are found in the depth in the course of mining stanniferous ore deposits. The level of study of intrusion RG complexes within the region varies quite widely manifesting both agreeing and differing features.

The RG of the *Central Polousny region* lying in the interfluve of Yana and Indigirka in the eastern part of Polousnensky synclinorium of the Chersky-Polousny brecciation zone (Fig. 1) are studied relatively well. The Central Polousny fold block structure belongs to the Polousny (Northern Yana) megaorogene expressed as the ridge of the same name and the Northen Plutonic Belt concentrating major bodies. Sedimentary layers are formed by terrigenous rocks of verkhoyansk complex of Perm-Yura. In the north, in the Primorye lowland and the central part of Polousna Orogene fields are found of early Cretaceous effusive rocks lying on the Mesozoids. Mesozoic shale and sand folded layers are separated into blocks by the systems of magma controlling breakup faults. The longitudinal sub-latitude system of faults controls the positions of early Cretaceous Plutons of adamellites and granodiorites, while the crosswise sub-meridian structure – that of late Cretaceous minor intrusions and dikes of granites, granite-porphyry, leuco-granites, quarz syenites and monzonites [5, 8, 12]. Poly-stage nature and telescoping character of magmatism and similarity of rocks from late phases of granitoid complexes complicate significantly separating the granitoids of Yakutia. The scheme that is most popular goes like this: 1) quarz-diorite minor intrusions of the Nera-Bohapchinsky complex (granodiorite-granite formation, late Yura); 2) batolites of high alumina granites of the Kolyma complex (granite formation, late Yura – early Cretaceous); 3) major massifs of andesine amphibole containing biotite granites and adamellites of the Okhotsk complex (granite formation of early to late Cretaceous) and minor massifs of monzogranitoids (monocite – granite formation, late Cretaceous); 4) medium intrusions of tinny sub-base biotite granites of Omsukchansk complex (granite formation, late Cretaceous).

Thus a homodrome evolution of magmatism is observed: from diorite (tonalite) – granodiorite and granodiorite-granite associations to granite – leuco-granite and base (sub-base) granite associations [5]. Rare metal granites cap the evolution of magmatism forming late intrusions that are the richest in bases

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and rare elements that were imbedded during the late Cretaceous activation of sedimentary and magmatic complexes. The RG areal includes the Omchikandinsky ore node with granite massif of the same name that bursts through the axial part of the anticline fold in the Yura shale-sandstone depth of Deputatsk folder zone.

The Omchikandinsky intrusion is related by its common contact zone with the Maksogolokhsky intrusion and to gather with it they form a massif of 160 km^2 stretching sub-latitudinally. Rocks from three complexes take part in forming that massif. The most ancient magmatic rocks are presented by the early Cretaceous limestone base granitoids of the Argaemneken gabbro-granodiorite-granite complex. The principal phase is formed by large and average grain porphyry-type biotite granites that change to finer grain faces in the endo-contact zone. Watersheds demonstrate spreads of fine grained pegmatoid leuco-granites that form capricious bodies of 0.1-2 km area with numerous apophyses. In the center of the massif at the crossing of sub-latitudinal and sub-meridional break-up faults of the Chokhchur-Chekurdakh zone there lie small bodies – apicals of the Polar stock of late Cretaceous RG presented by the fine-grain albite-microcline leuco-granites with zinnwaldite and topaz, the tungsten-stanniferous metallizing associated with it spatially. Endo-contact zones of lithium-fluorite granites are characterized by the presence of striations and schlierens of mica and fluorite-mica-albite composition up to 15 cm in size. Zinnwaldite granites are separated from their accommodating biotite granites with stocksiders. Areas where RG surface have zwitters proliferating both on leucogranite and the RG. They form metasomatic bodies and vein aureola of tungstenite-cassiterite-quarz veins and stockworks.

To the north of Omchikandinsk massif there sits the Odinoky sub-volcanic intrusive of 0.4 km^2 area formed by late cretaceous ultra-rare metal granite porphyry that may be considered to be ongonites. The body of ongonites protrudes north-eastwards according to the stretching of the Odinoky centroclinal fold. Its position is controlled by the crossing of NE and NW breaks that feather the sub-latitudinal Deputatsky deep-laying fault. The meridional fault connects the sub-volcano with Omchikandinsky pluton. Ongonites are intensely substituted with tin ore zwitters – fine grain siderophyllite-topaz-quartz greisens with cassiterite. Greisenization is developed across the whole stock, apophyses, and accommodating rocks, but it is most intense in fractionation zone of the NW direction, the tin ore sub-contact stockwork of the Odinoky deposit associated with it [9, 12].

The Badzhal region, belonging to the Khingan-Okhotsk tanniferous magmatic area of the Amur province (Fig. 1) did not manifest any rare metal granites for quite a long time, despite the wide distribution of greisen deposits. The region is expressed on the surface as the Badzhal orogenic dome belonging to the Bureino-Badzhal mega-dome that sits on the contact between the Bureinsky median massif and the Sikhote-Alin folds system, underlined by the Badzhal-Yamal focal structure (the plume) that is the largest granitoid paleofocal in the Far East [2]. Volcanic-pluton formations are positioned over the granite crypto-batholite of 125 × 80 km footprint; the Earth crust here increases to 80 km depth. The central part of crypto-batholiths, to the East of the Verkhne-Urmiisk massif features a group of second order gravitation minima that correspond to the area of alaskite core of crypto-batholite and blind cupola of leuco-granites.

A unique feature of the Badzhal region is the accumulation of acidic volcanic and plutonic rocks, outstanding in its scope, that is hard to explain even from the point of view of crust palingenesis. The area of the Badzhal zone is 5,350 km^2, the depth of volcanites reaching 1.5 – 2 km. The Badzhal magmatic areal includes infrequent early and late Cretaceous intrusions of monocites, sienites, sub-base gabbroids of the Dayan complex and diorites and granodiorites of the Lucksk complex. Late cretaceous intrusions of biotite granites and leuco-granites of the Badzhal complex are sharply overwhelming augmented with smaller massifs of monzonites, dioritesgranodiorites and granites of the silinsky (levoyarapsky) complex. The general tendency in the evolution of magmatism consists in the growing role of rhyolites and granites co-magmatic to them and in the growing baseness and potassium content of granitoids. The principal magma controlling faults of the volcanic zone are oriented in the NE and sub-meridional direction inherited from their folds foundation. At their crossings with transversal NW faults, including the Orokotsk, the Gerbin and the Bolodzhoksk ones there sit the volcanic plutonic structures with manifestations of monocitoid and rare metal granite magmatism, as it appeared, plus the principal ore nodes and the largest Pravourmiisk deposit [5, 6, 8, 12].

Rare metal granites that immediately precede the tin ore mineralization were not identified in the Badzhal region before 1987-1990 when the expedition by the Leningrad Mining Institute headed by

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Prof. Yu. B. Marin did some dedicated mapping of the territory of the Vekhneurmiisk ore node. The identified dikes of sub-base albite granites in the eastern exo-contact of the Verkhneurmiisk massif enriched with lithium and fluorine breaking through all the granitoids known earlier The conclusion was made on the presence of ore bearing lithium-fluorite granites in that region that were soon discovered there [2].

The areal of Pravourmiisky complex is positioned in the middle course of River Irungda-Makit at the crossing of the NW Orokotsk and the latitudinal Pravourmiisky disjunctive zones (Fig. 2). It resides in the epicenter of one of the protrusions of the Badzhalsky cryptobatholith and is accomodated by the «Urmiisk Base Zone» identified by V. G. Kryukov in 1987. The Pravourmiisk complex includes the weakly eroded Dozhdlivy cupola of medium grained RG located at the estuary of a spring of the same name, a small (250 × 800 m) dike-shaped body of fine grained RG in the upper stream of the Lesnoi spring and low power dikes of ongonites. The total area of the RG surfacing is less than 1 % of the total Badzhal zone area. Zonality of the areal is identified: this is the Dozhdlivy cupola of zinnvaldite granites that is apparently an eroded outcrop of ridge-like intrusion stretching in sub-latitudinal direction along the Pravourmiisky fault and bordered by the dike field of ongonites. The ongonite intrusive dike belt is limited on its flanges and in the North by the clusters of dikes of monzogranite- and – granosienite porphyry of th Silinsky complex positioned in the break-up zones of the NNW stretch. Epicenters of the RG intrusion are marked by areals ofbiotite and hastingsite propylites.

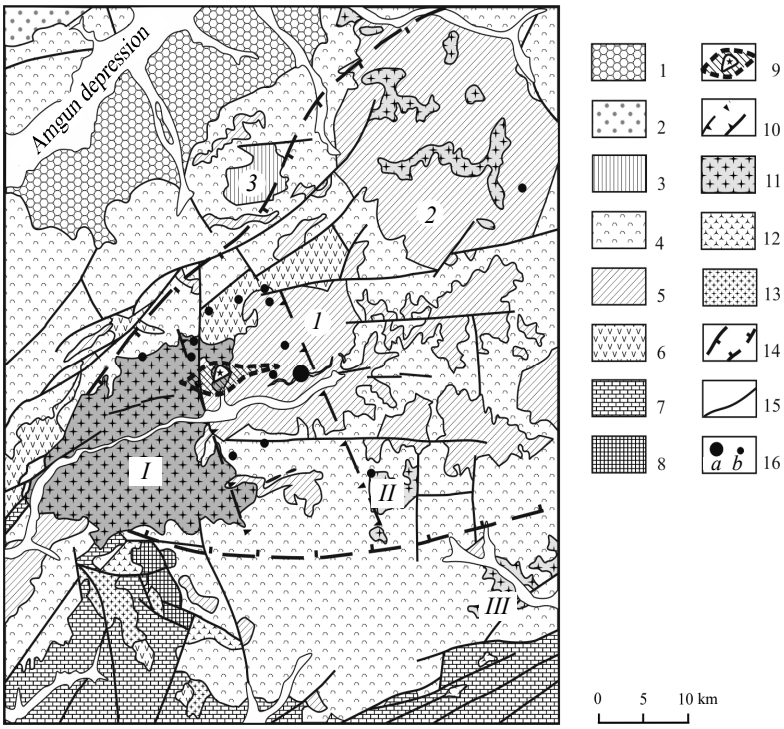


Fig. 2. Rare Metal Granites in the Structures of the Badzhal region (the Amur Province)

1 – Oligocene-Miocene conglomerates, sandstones, argillites of the Verkhneamgun depression; 2-5 – upper Cretaceous vulcanites: 2 – ignimbrites of trachy-rhyolites, trachy-rhyodacites, 3 – sub-volcanic trachy-andesites, quartz monconite-porphyry, 4 – ignimbrites and tufa of rhyolites, rhyodacites, 5 – sub-volcanic rhyolites, rhyodacites, granite-porphyry; 6 – lower Cretaceous andesites, andesi-dacites and their tufa; 7 – Devon-Perm terrigenic and clay rocks, limestones of the folded foundation; 8 – low Properozoi gneiss, amphibolites, quartzites of the Burein massif; 9-11 – upper Cretaceous intrusive formations: 9 – the areal of rare metal granites with the Dozhdlivy cupola of lithium fluorite granites (the Pravourmiisky complex), 10 – the Orokotsk zone of monzonitoid magmatism (the Silinsky complex), 11 – biotite-hornblende granites, biotite granites and leuco-granites (the Badzhal complex); 12 – lower to upper Cretaceous granodiorites, quartz diorites (the Laksk complex); 13 – late Paleozoi granites and granodiorites; 14 – the second order local gravitation minimum boundaries (the area of the largest thickness of Badzhal crypto-batholite); 15 – break-upfaults; 16 – major deposits (*a*) and ore manifestations (*b*)

Roman figures indicate plutons *I* – Verkhneurmiisky; *II* – Synchuginsky, *III* – Yarapsky. Arab figures denote extrusives: *1* – Urmiisky, *2* – Gerbinsky, *3* – Kurkaltinsky

The Dozhdlivy massif of RG was studied in root outcrops of lower stream of the Dozhdlivy spring at the western flange of Pravourmiisky ore field. Mapping by the deluvial sediments along the slopes of the Badzhal ridge has made it possible to identify the extension of the massif of lithium fluorite granites to the west into the endo-contact area of Verkhneurmiisk massif. Survey studies have demonstrated that the Dozhdlivy cupola submerges to the east and is changed at daytime surface by the steeply falling Geophysical dike of zinnwaldite-albite granites of 60-150 m strength which is traced in the upper flow of spring Alyonushkin in the northern flange of Pravourmiisky ore deposit. Therefore the RG shape a weakly eroded ridge-like intrusion that features an eastern declination. Accommodating rhyolite ignimbrites in the exo-contact area of the intrusion have undergone recrystallization, microclining and zwitterization, while in the RG itself along its contacts with biotite granites and rhyolites striation is developing as well as the zones of graphic pegmatoids and stocksiders.

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An important aspect of Pravourmiisky rare metal granite areal consists inwide development of tin ore topaz siderophyllite zwitters and tourmaline metasomatites that predominantly form smoothly sloping metasomatic streaks and streaky zones like ore bodies, like the bodies of Pravourmiisk ore deposit and ore manifestations of Alyonushkin, Omot-Makit, Volfram-Makit, Dozhdlivoe. Weak zwitterization embraces the eastern part of Verkhneurmiisk massif and the adjacent are of the Urmiisk caldera.

Among the les studied rare metal granites one should mention the lithium fluorite granites of *Kuyviveem-Pyrkakai region* in Chukotka (see Fig. 1), which were described in detail in the pages of this magazine [1].

Discussion. Large igneous provinces (LIP) merge together magmatic areals characterized by common geodynamic causes and geitectonic development conditions, similar substance composition and rock age. When identifying petrographic provinces the intrusive faces of rocks are of particular importance, because they enable one to contour the area of magmatic activity of a given type independent of the level of erosive cross-section of the region. One of the objects of regional correlations used to identify LIP gradually become the rare metal granite manifestations, in particular the intrusive complexes of lithium fluorite granites and ongonites, due to their substantial individuality, zonal positioning and short-time formation [14]. Studies by S.S. Smirnov, E.A. Radkevich, M.I. Itsykson, N.P. Romanovsky, V.G. Sakhno and other researchers have demonstrated that, despite their tectonic inhomogeneity and the presence of ancient blocks and transversal structural zones, the Pacific Ore Belt has common structural features and history along its whole stretch. Ore bearing regions and provinces of the Far East of Russia are brought together by manifestations and similarity of their late Mesozoi rare metal magmatism which developed in the result of tectonic and magmatic activization of fold structures (Fig. 1).

The comparative analysis of structure of the territories where RG developed, including the regions described above points to similarity of structural and geologic conditions for localization of rare metal granite complexes. In every case we see a concentration of late Cretaceous minor intrusions of topaz zinnwaldite granites of lithium-fluorite type in orogenic cupola rises above the deep granitoid batholiths, fixed negative gravitational anomalies that sometimes open up onto the surface as leuco-granite massifs. RG areals are localized at crossings of longitudinal and transversal deep faults. In many cases the orogens including lithium-fluorite granites are the neighboring rigid structures of median massifs. The similarity of geological position of rare metal granites in the Russian sector of Pacific Ore Belt points to their common origin and makes it possible to trace a super-province of rare metal granite magmatism in the outer part of the Pacific Ore Belt – the Far East RG Belt stretching from Lake Hanka in Primorye Province to the Arctic Shores of the East Siberian Sea. The belt includes the Novosibirsk-Chukotka, the Yana-Kolyma and the Sikhote-Alin rare metal granite provinces. In the region of Yam-Alin and the Shantar Islands the Far Eastern RG Belt locks with the transversal more ancient Central Asian rare metal granite belt. In the north it has its extension in the Alaska, and in the south it may be traced at least as far as the ridge of Nangling in South China [2, 3]. There is certain similarity between the Pacific areals of RG and zonal LIPs of Central Asia: the position of complexes of lithium fluorite granites is controlled by major batholiths of leuco-granites [14]. The difference lies in weak eroding of intrusive systems: batholiths stay in the depth and are fixed here due to negative gravitational anomalies while the RG are positioned not on the periphery of areals, as in Central Asia, but above the cupola of cryptobatholiths. Association of RG with the derivatives of more mafic monzonitoid magmas testifies probably to their formation due to partial fusion of continental crust in the course of the uplift of basic mantia magmas.

Conclusions. The data presented on the geology of areas of rare metal granites proliferation in the Russian Sector of the Pacific Ore Belt that make one take a fresh look at the East Asian granitoid area to update its metallogeny. Studies conducted have made it possible to identify similarity between the structural geologic conditions of localization of the RG: 1) the areal character of manifestation of rare metal granites; 2) their confinedness to late Mesozoic orogenic arched uplifts of bogen structures above deep granitoid batholiths; 3) positioning in the areas where longitudinal and transversal deep laying faults cross; 4) gravitation to the environs of pre-Cambrian median massifs.

Similarity of structural-geological conditions for manifestation of the well-studied ore-containing granites serves to confirm the hypothesis on the joint stage of late Cretaceous rare metal magmatism in the Russian sector of the Pacific Ore Belt and the existence in the region of a magmatic super-province – the Far East belt of rare metal granites that includes the Novosibirsk-Chukotka, the Yana-Kolyma and the Sikhote-Alin rare metal – granite provinces.

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