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Mineralogical Criteria for the Prediction of Gold Mineralization in the Structures of the Siberian Craton

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Abstract: Generalization of the results of the study of placer gold and the mechanisms of its distribution in the east of the Siberian Platform made it possible for the first time to reveal that the ore sources of gold-bearing placers were mainly mineralization of the gold-sulfide formation formed under the influence of hydrothermal metasomatic processes occurred in deep fault zones. It is determined that the gold-bearing hydrothermal-metasomatic formations of the gold-sulfide rock formation are amagmatic, near-surface, low-temperature and spatially confined to deep faults. These formations are widespread in terrigenous-carbonate strata and sand deposits of PZ-MZ age and are observed in the zones of brecciation, silicification, and ferruginization. The analysis of the mechanisms of distribution of hydrothermal-metasomatic gold-bearing formations in the east of the Siberian Platform, based on previously conducted research of predecessors and our field observations, allowed us to establish the following. In the northeast, hydrothermal-metasomatic formations occur in the field of development of the Zhigansky fault, the Molodo-Popigai and Anabar-Eekite fault system, in the central part of the east of the Siberian Platform, the Vilyui paleorift (Kempendyai dislocations), and in the southeast in the Baikal-Patom thrust belt in ancient faults (Bappagai, Khorinsky, etc.). Metasomatites of hydrothermal origin form extended narrow formations along ancient faults activated in the Mesozoic, as well as conformable deposits in the Vendian, Cambrian carbonate strata, Jurassic and Cretaceous sandstones. It is proved that these formations are amagmatic and are not related to the widespread magmatism of the basic composition, which is confirmed by the homogenous mineral composition of metasomatites, independent of the composition of magmatic bodies spatially located with them. Zones of metasomatites with gold mineralization contain Au from 0.5 to 3.0 g/t, and in isolated cases up to 24–32 g/t. Gold is represented from finely-dispersed to visible fine, with a size from 0.01 to 0.5 mm or more. It is known that hydrothermal-metasomatic processes on the territory of Central Aldan contributed to the formation of large deposits such as Kuranakh, Tabornoye and others. It is possible that the identified gold-ore metasomatites, developed along the zones of regional faults and not confined to magmatic formations, widely occurred both in the northeast and in the southeast of the Siberian Platform, represent a huge metallogenic potential.

Keywords: placer gold; placers; mineralogical and geochemical features; indicator signs; deposit; metasomatites; deep faults; gold content; Siberian platform

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1. Introduction

The gold content of the east of the Siberian Platform has been known since the end of the XIX century, but the types of ore sources and their location have not yet been established. A.G. Rzhonsnitsky [1], V.A. Obruchev [2] and V.N. Zverev [3] searched for the primary sources related to the widespread magmatism of basite composition. V.I. Timofeev [4], Y.N. Trushkov et al. [5] and B.R. Shpunt et al. [6] believed that the primary sources were local quartz-carbonate gold-bearing veins of the Early Proterozoic age and metamorphosed Proterozoic conglomerates confined to the outcrops of the crystalline basement. V.I. Timofeev [4] and V.A. Mikhailov [7], analyzing the history of the geological

evolution of the Vilyui syneclise, expressed the opinion about the possible formation of ore sources as a result of the occurred Mesozoic tectonomagmatic activation.

The search for gold deposits was carried out by the largest geological organizations of VSEGEI, NIIGA and our Institute of Geology, and they were mainly aimed at identifying ore sources of the Precambrian stage of ore formation of low-sulfide gold quartz types of deposits and ancient conglomerates of the Witwatersrand type, as well as the Mesozoic stage of ore formation associated with widespread basitic magmatism. The search for such types of gold deposits has not been successful, since the found gold contents in magmatic bodies and in their contact zones of different composition and age are determined at the clarke level, or amounted to the first tens of mg/t [8,9]. In general, traditional methods of prospecting and forecasting of gold deposits did not contribute to the discovery of new gold ore objects in the studied area [4–11]. In this regard, it became necessary to develop new criteria for forecasting and searching for gold deposits in closed territories overlain by sedimentary deposits of MZ-KZ age.

2. Materials and Methods

In order to predict the type of ore source and determine its location, a mineralogical method developed by us is proposed—the study of typomorphic features of placer gold and mechanisms of its distribution [12]. The article is based on the results of studying the mineralogy of placer gold and the mechanisms of its distribution in the east of the Siberian platform. The objects of study in the east of the Siberian platform were placer occurrences of gold in the northeast of the Anabar-Olenek (more than 100 objects), in the central part of the Lena-Vilyui interfluve (200 objects) and in the southeast of the middle Lena basin (100 objects). For several decades, during field work, tray sampling of alluvial deposits and panning for placer gold were carried out, then it was extracted by conventional methods and studied under binoculars (shape, size, surface, etc.) and on modern devices in order to identify the chemical composition, microinclusions and other parameters.

It is proved that placer gold carries enormous information, both about the endogenous origin of gold and about its change in exogenous conditions, depending on the environment [13]. Based on the study of morphology (size, shape, surface) of placer gold, chemical composition (fineness, impurity elements) and microinclusions, it became possible to predict the type of ore source and the stages of ore formation [14,15]. The use of this method made it possible, for the first time, to develop criteria for predicting the types of gold deposits and to link them with certain geological structures [16,17].

Based on the identification of a complex of indicator signs of placer gold, for the first time in the east of the Siberian Platform, sources characteristic of gold-sulfide deposits formed in sedimentary deposits of PZ-MZ age due to hydrothermal-metasomatic processes occurred in deep fault zones are predicted. The indicator signs of placer gold of hydrothermal-metasomatic formations include lamellar and lumpy gold particles, ranging in size from dust-like to 0.5 mm and higher with a wide variation in fineness of 600–900‰ and a constant Hg content (up to 6%). At some sites, the presence of up to 40% of spongy aggregates consisting of intergrowths of small gold particles (up to 0.01 mm) with iron hydroxides is noted. Sponge varieties have a low fineness (660−730‰) and a constant trace impurity of Hg (>2%). The internal structures are mostly mono- and coarse-grained with thin and intermittent high-grade shells; sometimes they have unclear zoning, spotty heterogeneity, porosity, multiphase, granulation and disintegration. Microinclusions of quartz, calcite, pyrite, arsenopyrite, tellurides, selenides and rare earth phosphates are found in gold. It has been established that the above indicator signs are characteristic of primary sources of gold of the gold-sulfide formation observed in hydrothermal-metasomatic rocks.

Study of typomorphic features (morphology, chemical composition, microinclusions, internal structure) native gold was carried out using well-known mineralogical and geochemical methods. All analytical work was carried out in the laboratory of physical-chemical methods of analysis, DPMGI SB RAS (Yakutsk, Russia). The study of the morphology, surface structures, and internal structure of the gold particles was carried out

using a scanning electron microscope "JEOL JSM-6480LV" (Japanese Electron Optics Laboratory, Tokyo, Japan), stereoscopic microscope "LEICA MZ6" (KaVo, Biberach an der Riss, Germany) and an ore microscope "JENAVERT SL 100" (Carl Zeiss AG, Oberkochen, Germany). The trace element composition of native gold was analyzed on an X-ray microanalyzer, "JXA-50A", "JSM-6480LV" (Japanese Electron Optics Laboratory, Tokyo, Japan). The content of impurity elements in it was studied by the atomic emission spectrography. Microinclusions in native gold were identified using a scanning electron microscope "JEOL JSM-6480LV", with an energy-dispersive spectrometer Energy 350 of Oxford Instruments (London, UK). Software Oxford Instruments INCA the microanalysis Suite Issue v.4.17. Quantitative analysis and processing of the results were carried out using the XPP method in the software INCA Energy (Software Oxford Instruments INCA the microanalysis Suite Issue v.4.17, London, UK).

3. Results

Based on the developed indicator signs of placer gold (shape, size, chemical composition, microinclusions and internal structures), previously identified ore occurrences in the east of the Siberian platform of the Molodo-Popigai and Anabar-Eekite fault systems, in the south-east of the Vilyui syneclise (the zone of Kempendyai dislocations), and also in the south-east in the junction zone of the Baikal-Patom thrust belt, belong to the hydrothermal-metasomatic rocks of the gold-sulfide mineralization (Figure 1).

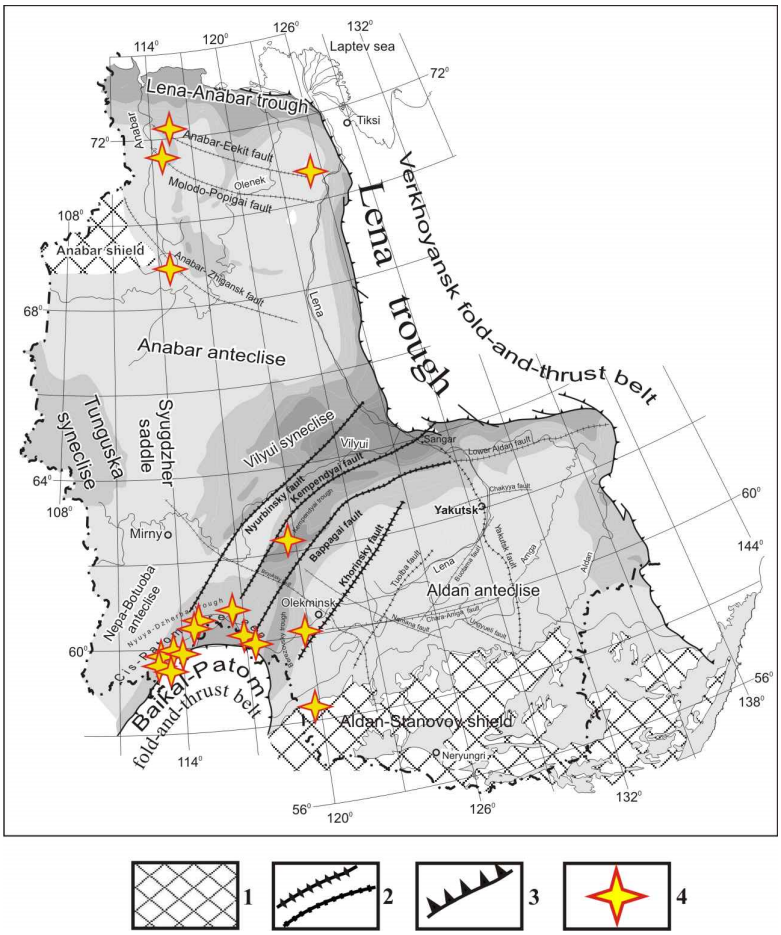

Figure 1. Mechanisms of the distribution of hydrothermal-metasomatic formations revealed as a result of the analysis of the location of placer gold of gold-sulfide-quartz mineralization. The basis is a relief map of the crystalline basement of the east of the Siberian Platform [18]: 1—areas of outcrops of crystalline basement rocks on the day surface; 2—faults; 3—front of the Phanerozoic orogenic belts; 4—supposed gold-bearing hydrothermal-metasomatic formations.

The analysis of the mechanisms of placer gold distribution in the east of the Siberian Platform showed that the primary sources are gold-sulfide mineralizations, occurred in hydrothermal-metasomatic formations, which is confirmed by earlier studies of predecessors. Predecessors [4–7,19–24] scientists have provided scattered data about gold ore sources identified in the Paleozoic sedimentary carbonate deposits and the Mesozoic sandy deposits (Table 1). The results of my study of the mineralogical and geochemical features of placer gold allowed me to refer to the previously identified mineralization in sedimentary strata of PZ-MZ age to gold-bearing hydrothermal-metasomatic formations of gold-sulfide mineralization.

Table 1. Gold ore occurrences in the supposed hydrothermal-metasomatic formations of PZ-MZ age (east of the Siberian platform).

No.	Gold Ore Sources and Their Location	Researchers
1	In the Olenek uplift, ore occurrences were manifested along faults in the Permian basal conglomerate breccias and brecciated gritstones with a gold content of up to 1.8 g/t.	B. R. Shpunt et al., 1976 [6]
2	In the Kempendyai dislocations and in the basin of the Vilyu River, gold-bearing sideritized rocks with visible gold in deposits of MZ age (J, K).	V.A. Mikhailov et al., 1974 [9]
3	In the valley of the Vilyu river, in the sources of the Jurassic rivers and Cretaceous deposits of the Kempendyai dislocations, gold-barite and gold-calcite veins, sometimes with pyrite mineralization with a gold content of up to 1.4 g/t, were found.	V.I. Timofeev, 1965 [4]
4	In the basin of the Vilyu and Tung rivers, propylitized sandstones of the Jurassic	T.N. Kirina, 1966 [20]
5	Hydrothermal-metasomatic ores, hydrothermal argillizated rocks, as well as mineralized zones of the faults were found in the area of the Kempendyai dislocations.	V.A. Mikhailov et al., 1980 [7]; V.A. Mikhailov, Y.H. Protopopov, 1994 [21]
6	In the basin of the middle Lena, the Nyuya, Dzherba, Namana, Biryuk rivers, etc., in the Cambrian and Mesozoic brecciated silicified and limonitized carbonate rocks located in fault zones, the gold content was found to be from 0.1 to 1.8 g/t.	M.V. Mikhailov, B.F. Filatov, 1966 [22]
7	In the interfluve of the middle Lena and Bol. Patoma, numerous gold-bearing sulfide ore occurrences (Kuranakh type), confined to the faults, with a gold content of 0.1 g/t, were found in the rocks of the Lower Cambrian.	Y.N. Trushkov et al., 1975 [5]; M.A. Chumak, V.I. Timofeev, B.R. Shpunt, 1967 [23]
8	In the faults of the Lena-Chara zone, the silicified limonitized carbonate rocks belong to the ore metasomatites of the Kuranakh type, which caused the gold content of alluvial deposits.	V.V. Elovskikh, 1969 [24]

Gold-bearing hydrothermal-metasomatic formations spatially confined to deep faults (such as gumbaites, jasperoids, sideritized carbonates, argillizated rocks, propylites, etc.) have been identified in the terrigenous-carbonate strata of the Paleozoic and Mesozoic of the east of the Siberian Platform. These formations in the carbonate and terrigenous-carbonate strata of the platform regions have been known for a long time and have been well studied [25,26]. According to D.S. Korzhinsky [27], gumbaites are quartz-K-spar, and jasperoids are siliceous–quartz hydrothermal-metasomatic rocks. Contact-metasomatic formations compose ring-shaped and arc-shaped bodies around massifs on the Proterozoic or Mesozoic granitoid complexes. The identified hydrothermal-metasomatic formations in the eastern part of the Siberian Platform are not classical rocks, since they are not formed in the framing of magmatic bodies, and they form gold-bearing linear fields of the northeastern direction up to 200–300 m long, with a thickness from 0.1 m to 15–20 m, controlled by a system of faults of the second order; therefore, it is proposed to identify them as gumbaites, jasperoids.

It has been established that hydrothermal-metasomatic formations are widespread, they are pragmatic and are not related to widely occurred magmatism of the basitic composition). These zones are confined mainly to ancient faults, thrust belt (Baikal-Patom thrust belt), expressed by a series of small tectonic structures (grabens, faults, thrusts, etc.) and are characterized by brecciation, silicification and limonitization of sedimentary rocks. The detected zones of metasomatites with gold mineralization contain Au from 0.5 to 3.0 g/t, and in isolated cases up to 24–32 g/t.

In the field it has been revealed that in the north-east hydrothermal-metasomatic quartz-K-spar formations (such as gumbaites) occur mainly in the Paleozoic carbonate rocks, spatially associated with the Zhigansky fault, the Molodo-Popigai and Anabar-Eekite fault systems. In the central part of the east of the Siberian platform in the Vilyui paleorift (Kempendyai dislocations) they (sideritized carbonates, argillizated rocks, propylites) are observed in terrigenous-carbonate and sandy deposits of PZ-MZ age, and in the south-east (such as gumbaites, jasperoids) in carbonate deposits of the PZ age of the Baikal-Patom thrust belt (Pilkinsky thrust, Urinsky anticlinorium) (Figure 1). It was found that metasomatites have a homogenous mineral composition that does not depend on the composition of spatially associated Paleozoic and Mesozoic igneous formations.

Metasomatites (gumbaites, jasperoids, sideritized rocks, argillizated rocks, propylites) of hydrothermal origin form extended narrow formations along ancient faults activated in the Mesozoic, as well as conformities in the Vendian, Cambrian carbonate strata, Jurassic and Cretaceous sandstones, and are observed in the zones of brecciation, ferrugination and silicification. Hydrothermal gold-bearing metasomatites are characterized by modified carbonate and sandy rocks of PZ-MZ age with gold-bearing and sulfide mineralization, represented by gold-quartz-K-spar-pyrite association. Gold is recorded from finely-dispersed to visible fine, ranging in size from 0.01 to 0.5 mm or more. These formations form small placers in the northeast of the Siberian Platform in the Bol. Kuonamka, Mayat, Polovinnaya rivers, in the central part of the Vilyui syneclise at the headwaters of the Kempendyai, Tonguo, Chebyda, Namana rivers, in the south-east at the mouth of the Vitim river, in the left-bank tributaries of the Peledui, Kamenka, Romanovsky, Harsa, Halamanda and others.

Supposed occurrences of gold-bearing hydrothermal-metasomatic formations in the northeast of the Siberian Platform based on the identification of gold of gold-sulfide mineralization.

The Mesozoic vein formations of a stockwork nature with a gold content of 0.2 g/t previously identified by V.I. Timofeev and co-authors [28] on the Olenek uplift, and ore occurrences discovered by B. R. Shpunt et al. [6] in the Permian sedimentary deposits, belong, in our opinion, to gold-bearing hydrothermal-metasomatic formations.

Based on the analysis of the mineralogical and geochemical features of gold and the mechanisms of its distribution, it is assumed that in the north-east of the Siberian Platform, in the Molodoy-Popigai and Anabar-Chekist fault systems, potential primary sources of placers are near-fault hydrothermal-metasomatic formations, which are developed mainly along terrigenous-carbonate rocks of the Paleozoic age [15,16,29]. According to the results of the study, it was revealed that gold has certain features typical of gold-bearing hydrothermal-metasomatic formations. Gold is represented from dust-like to 0.1–0.5 mm or more, scaly, lamellar and lumpy forms with a porous surface with a greenish tinge, with a wide range of fineness; regarding the impurity elements, there is an increased mercury content of up to 2%, sometimes up to 6% (Figure 2). The porous surface, greenish tint and increased mercury content indicate that this gold was supplied during the uprise of hydrothermal solutions along deep faults and was deposited in terrigenous-carbonate rocks.

Gold-bearing hydrothermal-metasomatic formations are characterized by a linearly elongated arrangement in the sedimentary deposits, spatially linked to fracture zones. For example, in the Molodo-Popigai fault system, in the basin of the Ebelyakh river (Morgogor river), placer gold content was formed, apparently, due to gold-bearing hydrothermal metasomatic formations, where the origin of rivers occurred along the faults in MZ time (Figure 2) [29].

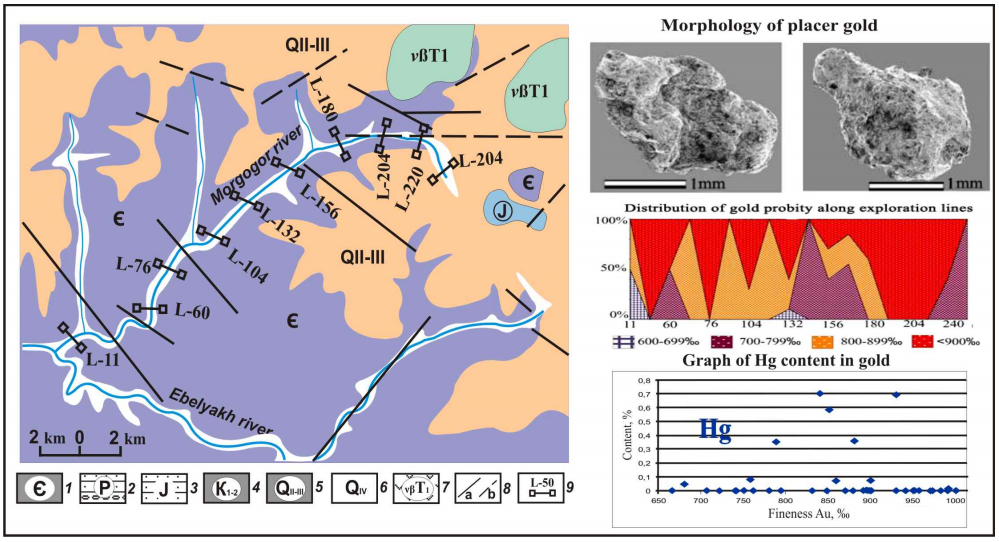

Figure 2. Mineralogical and geochemical features of placer gold of the Morgogor river. Deposits: 1—Cambrian; 2—Permian (sandstones, lenses and interlayers of claystones, siltstones, conglomerates and gritstones); 3—Jurassic (siltstones and sandstones); 4—Cretaceous (soft sandstones, lenses of gritstones); 5—Neopleistocene (pebble beds, sands, silty loams and sandy loams); 6—Holocene (alluvial formations); 7—Early Triassic intrusions of dolerites; 8—faults: a—identified, b—assumed; 9—prospecting lines.

According to I.B. Rubenchik et al. [30], the valley of the Morgogor river is formed along a fault (thrust), which is recorded on the zone of brecciation, ferruginization and silicification, the width of the fault is from 3 to 50 m.

The most productive gold-bearing apocarbonate hydrothermal-metasomatic formations, according to B.B. Gerasimov et al. [31], can be found in the Zhigansky fault (Bol. Kuonamka), Molodo-Popigai (middle course of the Anabar river—Billakh, Ebelyakh, Morgogor, Mayat rivers) and Anabar-Eekite (lower course of the Anabar river—Polovinnaya rivers) zones. According to epigenetic mineral associations, he recognizes quartz-K-spar and siliceous-quartz hydrothermal-metasomatic rocks, which are found along the Cambrian dolomites. Quartz-K-spar hydrothermal-metasomatic formations are represented by a finely-dispersed rust mass composed of pyrite decomposition products (hydrous ferric oxides). Potassium feldspar (PFS) is characterized by small sizes and crystalline forms, can be traced in microzones of crushing and microcracks of dolomites, and in veinlets of siliceous-ferruginous-aluminosilicate composition. Ore minerals, native gold, pyrite, arsenopyrite, sphalerite and galena were found in these veinlets.

A characteristic feature of siliceous-quartz hydrothermal-metasomatic formations is their primary oolitic structure [31]. Quartz is represented by colloform-flow particles, as well as chalcedonic formations. Ore-disseminated mineralization is composed mainly of pyrite and hematite, while chalcopyrite and galena are noted in a subordinate amount. Gold is found in free native form, sometimes in association with pyrite. Its size ranges from the first microns to 15 microns, and mercury is found in its composition from 0.5 to 2.6%.

Supposed occurrences of gold-bearing hydrothermal-metasomatic formations in the central part of the east of the Siberian platform (Vilyui syneclise, Kempendyai dislocations) based on the identification of gold of gold-sulfide mineralization.

Placer gold of gold-sulfide mineralization is found in the Early Jurassic sandstones, where hydrothermal-metasomatic formations in the form of sideritized rocks, argillizated rocks and propylites are identified. Indeed, in the central and southwestern parts of the Vilyui syneclise, sideritized rock outcrops were previously found in the Jurassic and Cretaceous sediments [4,5,19,20,23]. Discovery of sideritized rocks of hydrothermal origin in fracture zones in the form of interlayers, lenses and nodules with a thickness of 0.15–1.0 m with a content of 0.4 g/t of gold indicates the generation of gold-bearing

hydrothermal-metasomatic formations. In this regard, we assume the formation of gold-bearing hydrothermal-metasomatic formations in the area of the Kempendyai dislocations (Figure 3), spatially confined to deep faults, which is confirmed by the presence in placer gold of an increased mercury content of up to 2% and microinclusions of quartz, pyrite and arsenopyrite, characteristic of gold-sulfide ore occurrences.

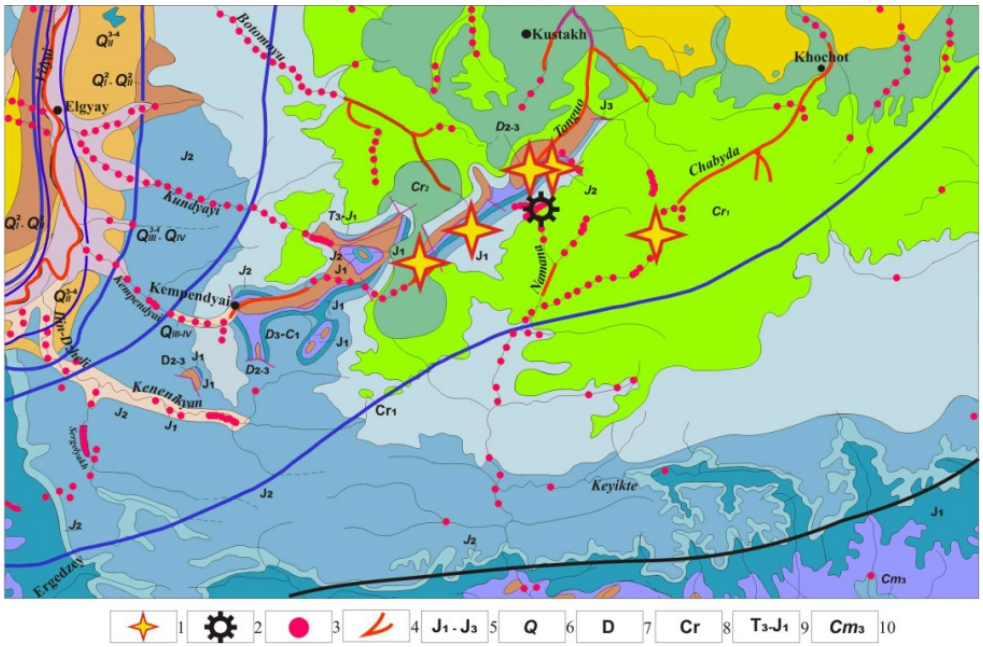

Figure 3. The location of placers in the area of the Kempendyai dislocations, whose sources were hydrothermal metasomatic formations (sideritized siltstones, argillizated rocks, quartz-carbonate veins). Conventional symbols: 1—ore occurrences; 2—volcanic pipe; 3—stream sediment samples, containing gold; 4—explored placers. Deposits: 5—Quaternary; 6—Cretaceous; 7—Jurassic; 8—Triassic; 9—Devonian; 10—Cambrian. The scheme is based on the map of the gold content of Western Yakutia, 2001, scale 1: 1,500,000.

According to V.I. Timofeev et al. [28], ore gold content was formed in this territory in the activated zones of the Vilyui syneclise (Kempendyai dislocations) due to the occurrence of tectonic-magmatic activation of the MZ age. In pyritized limestones and veins, assay test has determined a gold content of up to 1 g/t. The confinedness of veins to the cracks of the basal horizons of the Lower Jurassic sediments and the composition of sulfide mineralization indicate the hydrothermal-metasomatic formation of these deposits. In addition, according to V.I. Timofeev [4], T.I. Kirina [20], M.A. Chumak et al. [23], Y.N. Trushkova et al. [5], the gold content was found to be up to 1.4 g/t in the Early Jurassic and Cretaceous deposits in quartz-calcite-barite veins and pyrite veinlets. Typical ore minerals are pyrite, magnetite, chalcedony quartz, calcite, barite; monazite and cinnabar are occasionally noted, which also indicates the generation of gold-bearing hydrothermal-metasomatic formations.

Supposed occurrences of gold-bearing hydrothermal-metasomatic formations in the southeastern part of the east of the Siberian Platform (Baikal-Patom thrust belt, middle Lena basin) based on the identification of gold of gold-sulfide mineralization.

Many researchers [5,11,22,23] predicted primary gold ore occurrences in the faults of considerable extent (Figure 4). They suggested that the gold content of the alluvial deposits of the middle Lena basin was formed due to gold-bearing metasomatites spatially located near ancient faults. They refer the silicified and limonitized carbonate rocks of the Cambrian and Ordovician with visible gold from 0.5 to 3.0 g/t [5] to metasomatites.

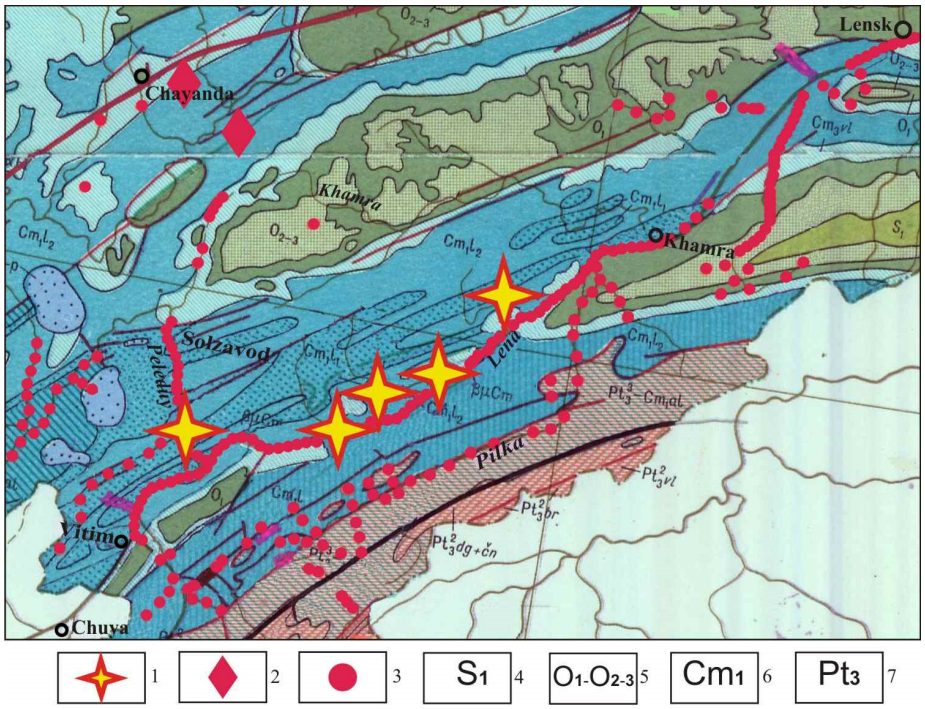

Figure 4. The proposed objects of gold-bearing hydrothermal-metasomatic formations of the Baikal-Patom thrust belt (Pilkinsky thrust), which caused the formation of placers in the basin of the middle Lena River on the section of the Vitim-Hamra rivers: 1—supposed ore sources; 2—ore occurrences; 3—stream sediment sample), containing gold. Deposits: 4—Silurian; 5—Ordovician; 6—Cambrian; 7—Upper Proterozoic. The scheme is based on the map of the gold content of Western Yakutia, 2001, scale 1: 1,500,000.

The proof of this assumption is the following results obtained by us while studying the mineralogical and geochemical features of placer gold in this territory. In the south-east of the Siberian platform, in the Middle Lena basin at the mouths of the Bol. Patom and Kamenka rivers (Urinsky anticlinorium), brittle spongy gold (up to 40%) with a high mercury content is found, indicating the presence of hydrothermal-metasomatic formations spatially confined to the deep Bappagai fault (Figure 5) [32].

The discovery of numerous small Paleozoic and Mesozoic quartz veins intruding Proterozoic deposits indicates that the ore gold content in the interfluve of the Lena and Bol. Patoma rivers is formed as a result of the influence of hydrothermal-metasomatic processes. The data of previous researchers also confirm the spatial connection of gold mineralization with deep faults. Indeed, in the south-east of the Siberian Platform in the basin of the middle Lena (Peledui, Nyuya, Namana, Dzherba, Srednaya, Malaya Russian, Kubolakh, Chara rivers), numerous gold-bearing occurrences are found in the Cambrian brecciated and limonitized quartz-siliceous rocks (jasperoids, gumbaites), spatially confined to the faults (Table 1). Hydrothermal-metasomatic formations are linked to the faults and tectonic zones of the second (fine) order, or are recorded at the boundaries of various stratigraphic strata (especially Cambrian and Jurassic), or simply in some carbonate strata in interlayers and horizons enriched with terrigenous material. These formations are represented by limonitized, silicified differences in carbonate rocks with a significant amount of mottled clay. They can be traced along the Durnaya, Kamenka, Halamanda, Harsa rivers, in the basins of the Nyuya, Peledui, Dzherba, Namana, Biryuk, Olekma, Chara rivers, etc. According to the genesis, A.I. Kazarinov [33] attribute these formations to hydrothermal ones, altered by metasomatic processes. Gold-bearing quartz veins, small magnetite ore occurrences and sulfidized fine-grained dolerites have also been identified in this area. They have Au content from 0.1 to 1.5–2.0 g/t. In this regard, in the studied area, M.A. Chumak et al. [23] suggested the possibility of the formation of the Mesozoic ore deposits

of the Kuranakh type in areas of intense fracturing of Middle Paleozoic carbonate rocks confined to ancient faults.

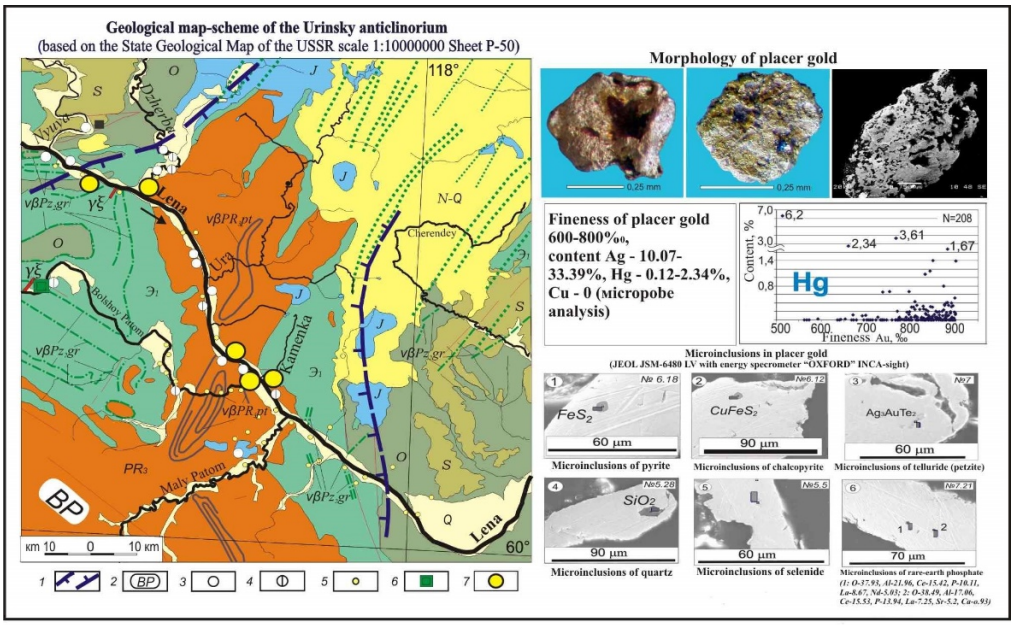

Figure 5. Mineralogical and geochemical features of placer gold of the mouth of B. Patom. 1—boundaries of the Urinsky anticlinorium; 2—Baikal-Patom fold-thrust belt; 3–5—the content of placer gold in placer occurrences: 3—100–200 mg/m^3; 4—50–100 mg/m^3; 5—minimal < 50 mg/m^3; 6—ore occurrence; 7—places of heavy mineral sampling of placer gold.

4. Discussion

In general, based on the study of the mineralogy of placer gold, it was revealed that the main sources in the east of the Siberian Platform were gold-sulfide mineralization observed in hydrothermal-metasomatic formations. It has been established that the formation of gold-bearing hydrothermal-metasomatic formations with gold-sulfide mineralization in the Paleozoic and Mesozoic terrigenous deposits, in the zones of brecciation, ferruginization and silicification, is related to the occurrence of tectonic-magmatic activation in the studied area.

When studying the mechanisms of the distribution of gold of gold-sulfide mineralization, it was found that gold is spatially confined to the intracontinental paleorifts of the east of the Siberian Platform: Udzhinsky—in the north-east; Vilyui—in the south-east and in its central part, as well as to the ancient deep faults, repeatedly regenerated in the Mesozoic period. E. E. Milanovsky [34] asserts that the ancient rift zones of the east of the Siberian Platform were regenerated in the Meso-Cenozoic time. He refers to the Udzhinsky aulacogen rift zone, which developed from the Riphean to the Mesozoic inclusive, and to the inversion folded structure of the Urinsky anticlinorium, which was formed on the site of the Riphean aulacogen of the same name.

The confinedness of the Meso-Cenozoic tectonic-magmatic activation to these paleorifts is argumentatively proved in the works of V.I. Timofeev [4] and V.A. Mikhailov [7]. Indeed, the Tabasyndskaya anticline and 12 small folds formed due to the impact of the Mesozoic tectonic-magmatic activation were identified in the zone of the Kempendyai dislocations (Vilyui paleorift).

The data obtained made it possible to identify search features for predicting gold-bearing hydrothermal-metasomatic ores of the gold-sulfide mineralization in the east of the Siberian platform. These include: geodynamic—confined to deep faults; structural—thrust zone; stratigraphic—carbonate rocks of PZ and sand rocks of MZ age; ore minerals—invisible micron gold, iron oxides, sulfides, tellurides, cinnabar, and rare earth minerals; vein minerals—quartz, carbonate, calcite, and fluorite; heavy minerals—cinnabar, monazite,

realgar, and auripigment. It is proved that the main search feature for predicting gold-sulfide primary sources is placer gold itself, with certain indicator features characteristic of gold-sulfide deposits.

Based on the performed mineralogical and geochemical studies and mechanisms of distribution of placer gold, and analysis of earlier published literature, for the first time in the east of the Siberian Platform, the formation of gold-ore metasomatites of gold-sulfide mineralization, widely developed in terrigenous-carbonate strata, spatially confined to the zones of regional faults and unrelated to magmatic formations, is proved. It has been established that hydrothermal-metasomatic formations of gold-sulfide mineralization are widespread both in the south-east and in the north-east of the Siberian Platform. These formations with a gold content from 0.5 to 3.0 g/t, and in isolated cases up to 24–32 g / t, are observed in the zones of brecciation, ferrugination and silicification) in the form of silicified carbonate rocks (jasperoids, gumbaites) with disseminated sulfide mineralization, as well as sideritized rocks, argillizated rocks and propylites.

It is proved that in the northeast of the Siberian Platform in the Zhigansky Fault, the Molodo-Popigai and Anabar-Nikitsky fault systems and in the southeast of the Baikal-Patom thrust belt (middle Lena basin), near-fault hydrothermal-metasomatic formations of gold-sulfide mineralization, which are compared with the metasomatites of the Central Aldan, can be potential primary gold-bearing sources. The similarity of the indicator features identified in placer gold (spongy gold, high Hg content, the presence of microinclusions of tellurides, sulfides, selenides and rare-earth phosphates) with the gold of the Kuranakh ore field makes it possible to predict ore sources of gold-sulfide mineralization in hydrothermal-metasomatic formations in the east of the Siberian platform.

In this regard, in the east of the Siberian platform, the formation of deposits of gold-sulfide-quartz mineralization of the Kuranakh type in the southeast is assumed for the first time, and in the northeast—of the Karlin type. Such zones of metasomatites (such as jasperoids, gumbaites, argillizated rocks, and propylites), occurred in terrigenous carbonate strata of PZ-MZ age, spatially confined to deep faults, according to M.M. Konstantinov [35], and deserve special attention in the search for deposits of the Karlin type. Indeed, the recent works of A.V. Molchanov et al. [36] also confirm our research. The authors, based on the analysis of geology, geophysical and geochemical studies, predict for the first time that this territory is a new promising metallogenic province in search of deposits of the Karlin type.

5. Conclusions

Thus, for the first time, on the basis of the mineralogical method developed by us—the study of the mineralogy of placer gold and the mechanisms of its distribution in the east of the Siberian Platform—it is proved that the main ore sources are gold-sulfide mineralizations, formed due to hydrothermal metasomatic processes, which may represent a huge metallogenic potential in this area.

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