Placer-Forming Cenozoic Mud-Volcano Genetic Type of Gold Mineralization in the Lena Area, Patom Highland, Russia

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Abstract: A genetic type of Cenozoic gold mineralization related to mud volcanoes is suggested to be recognized in the Lena area. This type of mineralization has never before been distinguished in the area and is genetically related to the development of depression mud-volcano structures on the northern continuation of the Baikal rift. Geological-geophysical data and results of lithological-petrographic and mineralogical studies of the mud-volcano lithological complex, naturally occurring microscorias, and ore minerals from the loose Quaternary rocks, as well as and comparison of the chemical composition of the latter with analogous minerals from the Sukhoi Log and Pervenets gold deposits, prove genetic links of economic placer deposits in the Lena area with mud volcanoes.

Keywords: Gold deposits, mud volcanism, mud-volcano depression, gold placers, microscopy, magnetite spherules, tier ore mineralization.

1. GEOLOGICAL AND GEOPHYSICAL CHARACTERISTICS OF THE MUD-VOLCANO STRUCTURES

Gold deposits known in the Lena area are hosted in Riphean (Neoproterozoic) rocks and are overlain by loose lithological complexes of Cenozoic age that host gold placers. The latter are traditionally thought to be produced *via* disintegration and erosion of lodes hosted by Precambrian terrigenous-carbonate formations. However, the resource potential, high productivity, and composition of the gold placers are not correlated with the primary ore mineralization. Gold from several of these placers shows no similarities with this metal from the lodes [1], and it is hard to even hypothetically suggest any source gold in the placers within the framework of the traditional concept [2] of their alluvial genesis and of a lacustrine, lacustrine-glacial, moraine, and/or alluvial-diluvial nature of the rocks hosting these placers. Lithological-petrographic and mineralogical studies (Figure **1**) of the Cenozoic loose deposits filling depression structures at the Patom Highland, which were formed on a Precambrian basement, and regional geophysical data are used to recognize a new genetic type of gold mineralization that has never before been found in the Lena area: a placer-forming mud-volcano genetic type of gold ore mineralization.

A summarizing vertical section through the crystalline basement underlying the mud-volcano depressions is, according to geological-geophysical data [3-5], as follows: 0.2-9 km of Vendian-Riphean (the Late Neoproterozoic) black-shale (carbonaceous) formation with rare massifs of Paleozoic granitoids are underlain by 9-17 km of buried metamorphosed ultramafite-mafite complex of a greenstone belt (Figure **2**) and granite-gneiss domes of Riphean-Early Precambrian age.

A number of relatively shallow Cenozoic depressions (Bodaibiunskaya, Zhuinskaya, Patomskaya, Nygrinsko-Ugakhanskaya, and Marakanskaya) (Figure **3**) mapped in the course of survey and exploration operations conducted in the Lena area in the 1950s [2] show similar landform features (ring walls, shallow depressions, ridges, rolling hilly topography, and crater-lake depressions) and have a geological structure typical of mud-volcano compensational (imprinted, according to [6]) synclines. The mechanism forming mud-volcano depression was analyzed in much detail within the framework of the concept that the fluid system operates in the form of pulses of mud-volcano eruptions (the fluid-clastogenic and fluid-clastogenic-sedimentary types of lithogenesis in the interpretation [7]) with reference to the Crimean-Caucasian region [6]. Based on several criteria, depression structures in the Patom Highland that are filled with Pliocene-Pleistocene-Quaternary rocks (Ugakhanskaya Group, Akanakskaya, Khomolkhinskaya, and other formations) are attributed [8] to the system of Cenozoic depression of the Baikal Rift Zone (BRZ), which are characterized by widespread mud-volcano complexes [9].

The thickness of deposits filling the mud-volcano depressions varies from 20 to 180 km, and their lithological complexes are made up of boulder-shingle conglomerate-like breccia, including those with vertically oriented long axes of their shingles, with gravel-psammitic and carbonatized ooze beds and with

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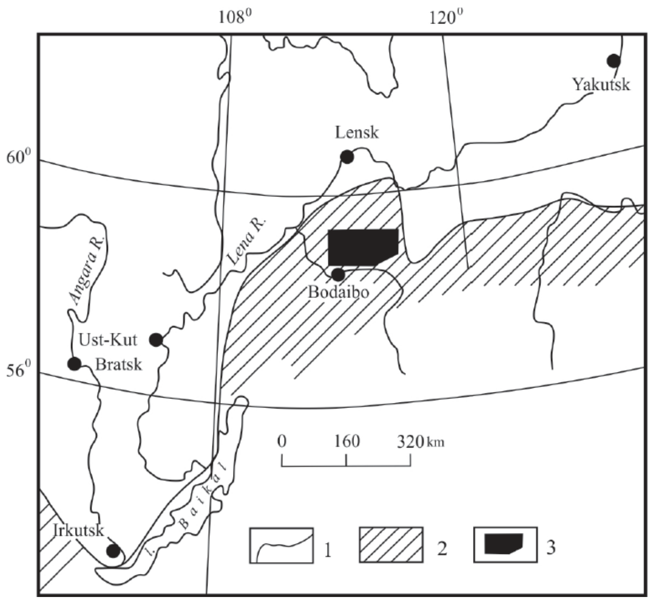

Figure 1: The research area scheme: 1 – the border of the Siberian platform; 2 – folded framing of the platform; 3 –the study sectors location area of mud volcanic lithocomplexes in the Lensky gold-bearing district.

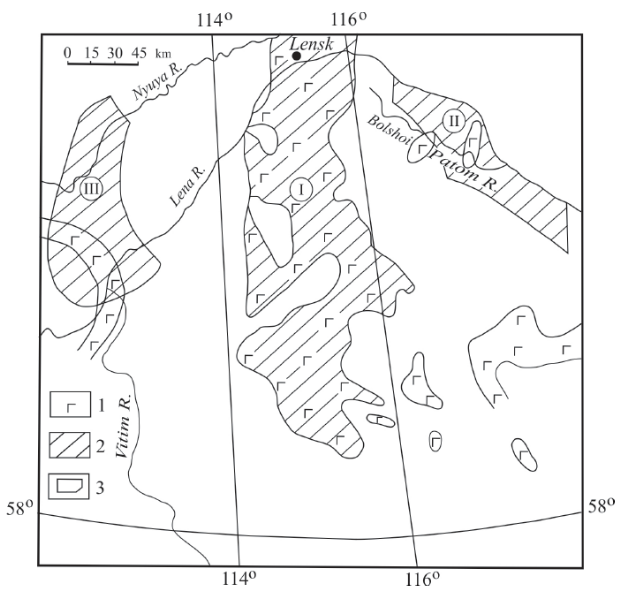

Figure 2: Location map of areas (outlined based on geophysical data [4]) underlain by rocks of the ultrabasite-basite complex in the bottom part of the Riphean unit in the Lena gold-placer mining district and adjacent structures of the Siberian Platform.

1 - Buried ultrabasite-basite complex; 2 - areas (zones) predicted to host Cenozoic gold ore mineralization (I - Vachsko-Lenskaya, II - Lena-Bolshepatomskaya, III - Nyuya-Lenskaya); 3 -study areas with compensation mud-volcano depressions hosting occurrences of Cenozoic gold mineralization (see Figure **3**) that are sources of economic gold placer deposits.

rubble-psammitic intensely carbonatized deposits with gryphon sand and with occasional shows of bitumen of the oil series. The rocks typically contain clay nodules, gryphon siderite-dolomite-ankerite and pyrite-marcasite nodules, and foreign fragments of crystalline rocks from the Riphean-Early Precambrian basement (gneisses, granites, amphibolites, pyroxenites, and serpentinites) and single grains of minerals from these rocks (olivine, hypersthene, and awaruite).

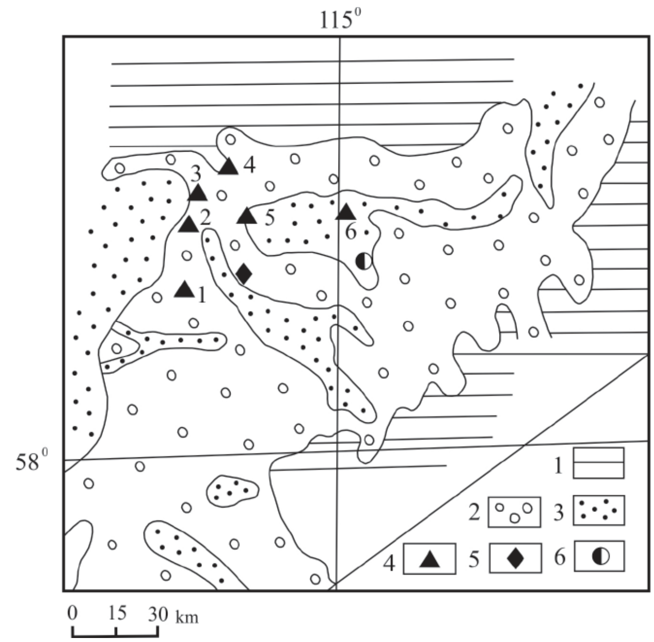

Figure 3: Location map of gold occurrences of the mud-volcano type in Cenozoic depression of the Lena district (prepared using schematic map [2]).

1- Riphean-Vendian carbonate-terrigenous rocks; 2 - depressions with the maximum subsidence amplitude; 3 - same, of lower amplitude; 4 - occurrences and areas with clastic gold-pyrite-magnetite ores (1 - Angarskoe, 2- Ust-Marakansko, 3 - Marakanskoe, 4 - Dogaldyn-Artemovskoe, 5 -Rovnyi, 6 - Ugakhan); 5 - Aunakitskoe occurrence of clastic gold-quartz ore; 6. deposit of the Novopavlovskii hydraulic section in the Nyrginsko-Ugakhanskaya mud-volcano depression (see Figure **4**).

The groundwaters of the mud-volcano complexes are hydrocarbonate-magnesian-calcic. Thermal waters in the crystalline basement beneath the depressions are hydrocarbonate-calcic, sulfate-calcic, chloride-sodic, and calcic brines [10]. The free gases are dominated by methane and contain subordinate amounts of nitrogen. At depths of 250-270 m in the black-shale basement of the depressions, drilling conducted in the 1980s has discovered a small lens of hydrocarbon gases. The heat flux within the mud-volcano depressions is 40-50 W/m^2 [11], and the temperature in the chamber zone of the mud volcanoes was estimated at ≤ 400°C. The estimated depth of the location of the foci of mud volcanoes – 10 km.

Cenozoic depressions in the Lena area and some depressions in the BRZ (South Baikal, Barguzin, and others) are restricted within the Baikal-Sukhoi Log seismic zone (whose top occurs at a depth of 1.3-5 km and whose thickness is 7.5 km), which is viewed as a modern rift structure with a high fluid content [12]. With regard for the seismicity of the zone, this provides grounds to conclude that fluid-dynamic conditions fairly favorably for mud volcanic activity occur throughout the whole length (1500 km) of this zone.

Magnetotelluric sounding in the Lena area has revealed a number of subvertical zones of anomalously high conductivity, which branch from a subhorizontal conducting layer occurring at depths of 4-10 km. The zones approach the surface (terminate at depths of 2000-15 m) and occasionally reach it [5]. These zones mark vents of cold degassing, which are structurally pronounced (according to [13]) at the surface as the aforementioned depressions. The latter are home to a mud-volcano type of gold mineralization (Figure **3**).

2. MUD-VOLCANO TYPE OF GOLD MINERALIZATION

The predicted genetic type of the gold mineralization comprises two subtypes: (i) ore-clastic vent facies and (ii) disseminated crater facies of mud volcanoes.

2.1. Ore-Clastic Subtype

The following three varieties of the gold mineralization are distinguished in accordance with the mechanisms producing them and their mineralogy.

The first variety comprises clastic (ore-clastic pyrometamoprhosed) gold-pyrite-magnetite ores in hill breccias. Clasts of these ores, ranging from a few millimeters to 10-35 cm, cluster in loose breccia-psammitic-pelitic rocks, which likely fill the vents of the mud volcanoes. Native gold occurs in the magnetite fragments as large grains, and its content reaches 400 ppm. The ores consist of 40-90% aggregates of magnetite grains transformed into martite in the margins. The magnetite is replaced by columnar maghemite, which grades into hematite. The pyrite content reaches 35%, and it is found as relict segregations with poikilitic quartz and rutile inclusions. The quartz contains 15-25 primary gas-liquid inclusions, which homogenize at 250-340^{o}C. The mineral occurs in association with plagioclase and muscovite.

The genesis of the gold-pyrite-magnetite fragments seems to be as follows. Their precursor is deep-sitting pyrite ores in the basement of the Bodaibo "synclinorium". The ores are enriched in finely divided Au, W, Sn, and Ni and have been most probably produced in the course of dynamometamorphism of the deep-sitting ultramafic-mafic associations of the greenstone belt. When the mud-volcano structures were formed, the ores underwent fluid destruction, along with their ancient host rocks of the crystalline basement (gneisses, garnet amphibolites, serpentinites, pyroxenites, mafic and acid volcanic rocks, chlorite-actinolite metasomatites, and pegmatites). Fragments of the ores and rocks were then brought to the surface by gas fluid and were *en rout* affected by pyrometamorphism, with their pyrite replaced according to the scheme: pyrite $\rightarrow$ pyrrhotite $\rightarrow$ magnetite $\rightarrow$ (maghemite) $\rightarrow$ hematite. The "burning" of the sulfides was associated with release of gold, which was then mobilized and eventually crystallized in the form of coarse-grained aggregates. Thereby the Ni-Cr signature of the ultramafic-mafic complex of the greenstone belt was preserved in the secondary ores regenerated in the course of pyrometamorphism (Table **1**).

The deep transportation of ore fragments during the active episode of the lifetime of modern mud volcanoes was confirmed by direct observations. For example, when the solid material of hill breccias is formed by certain mud volcanoes in the Kerch-Taman area, iron ore fragments as large as 20 cm across are entrained to the surface [14]. Drilling materials indicate that these fragments were captured by the fluid at a depth of 250 m, at which the lode was found.

The second variety of the ore clasts is breccias consisting of sharp-edged quartz fragments 3-5 cm across cemented by Fe hydroxides with minor amounts of quartz, sericite, carbonate, serpentine, olivine, and chlorite. The cement of the breccia was determined to contain gold, cassiterite, galena, magnetite, pyrite, ilmenite, rutile, zircon, pyroxene, biotite, and iozite spherules. These ores were found in the territory of the Rovnyi prospect. Similar to the ore clasts of the first variety, these were brought to the surface during mud-volcano eruptions from depth levels at which rocks of the ultramafic-mafic complex occur that contain gold-bearing bodies of predominantly quartz-pyrite composition. Unlike the ore clasts of the first variety, fragments of these deep-sitting ores have not been affected by pyrometamorphism when entrained to the surface but were merely influenced by the mud-volcano fluid. This resulted in oxidation of the pyrite and minor amounts of other sulfides with the formation of iron oxides and gold particles according to the mechanism forming supergene gold-bearing gossan.

The third variety of the ore clasts comprises clastic gold-quartz ores at the Aunakitskoe occurrence, which are compositionally and genetically analogous to the mud-volcano ores of the Kamenskoe deposit in the Baleiskii gold mining district [7]. The geological setting of the gold-bearing quartz veins whose clasts are found at this occurrence is uncertain.

2.2. The Scattered Interspersed Mineralization

We distinguish a separate group of disseminated gold mineralization of the crater facies of the mud volcanoes. This group includes (i) certain types of the newly formed gold, which ubiquitously *in-situ* crystallized, together with pyrite and carbonates, from the aqueous gas-bearing fluid, and (ii) certain types of gold released from the ore clasts when they were mechanically destructed and oxidized *en route* to the surface. An example of this type of disseminated gold mineralization is provided by the Novopavlovskii hydraulic section (Figure **4**) in the Nygrinsko-Ugakhanskaya mud-volcano depression.

3. EVIDENCE OF GENETIC LINKS BETWEEN THE GOLD AND MUD-VOLCANO TYPE OF MINERALIZATION

In the course of long-term exploration for gold placers at the Patom Highland, mud-volcano lithologic complexes were mistaken for supergene rocks. A typical example of this is the genetic interpretation of rocks at the Novopavlovskii hydraulic section [15].

When eroded by streams and disintegrated during weathering, the mud-volcano rocks gave rise to alluvial and eluvial gold placers.

Comparison of the particle sizes in the microscoria and accompanying ore minerals (Tables **1**, **2**) from these placers and known gold deposits with gold-sulfide (Sukhoi Log) and gold-quartz (Pervenets) ore associations hosted in Riphean carbonaceous rocks has not revealed any similarities between them, which provides circumstantial evidence of a mud-volcano genesis of most of the currently known placers in the Lena area.

Naturally occurring microscorias are unusual rocks with droplet-shaped and spheroidal particles ranging from a few nanometers to a few micrometers across, some as large as 1-2 mm, occasionally up to 3-5 mm and more). The particles consist of partly recrystallized glass matrix with inclusions of ore minerals, predominantly oxides and native metals. We also class with these rocks single silicate (glass) and ore beads, which are often zoned. These are referred to in the literature as *chilled particles*, *gepoxides*, *cosmic dust*, *glass and magnetic spherules and beads, micrometeorites*, and *microtectites*. The contents of microscoria particles in mineralogical crushed samples

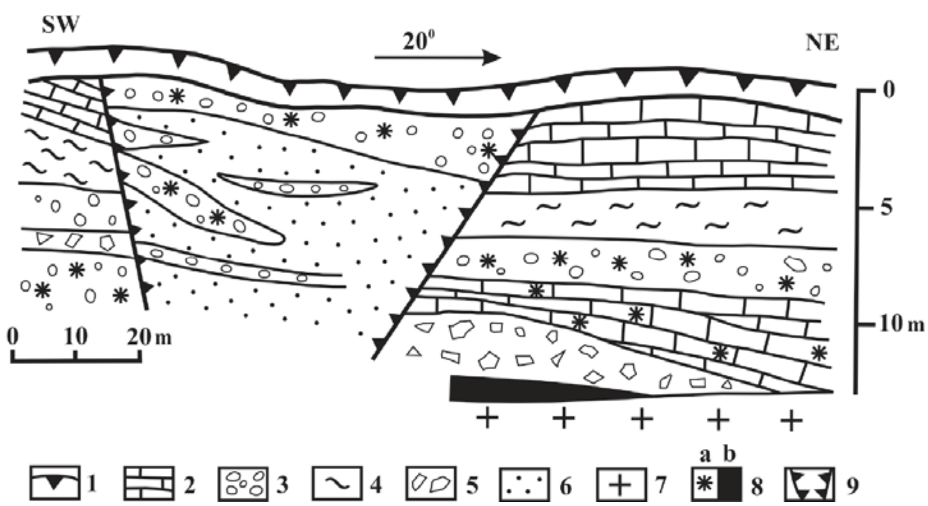

Figure 4: Fragment of the vertical section across the Cenozoic mud-volcano deposits in the Nyrginsko-Ugakhanskaya depression (prepared using data from [15]).

1 - Soil; 2-5 - lithological varieties of the mud-volcano deposits with boulders of foreign granites: 2 - rubble-psammitic intensely carbonatized rocks, 3 - boulder-shingle conglomerate-like breccia with gravel-psammitic and carbonatized ooze beds, 4 - rubble-psammitic rocks with black (pelitic) beds, 5 - debris; 6 - gryphon sand of the late episode of mud-volcano activity; 7 - Upper Riphean sandstone of the Anangrskaya Formation; 8a - disseminated gold ore mineralization in the form of large gold specks and "flows"; 8b - completely oxidized quartz-pyrite ore clasts and disseminated gold that was released during their destruction to fragments of psammitic grain size; 9 - boundaries of the vent of the younger mud volcano.

Table 1: Microprobe Analyses (wt %) of Ni-Cr-Fe Alloys and Carbides (?) in Mud-Volcano Rocks from the Marakan Prospect

Element	1	2	3	4	5	6	7	8
Si	0.30	0.34	0.39	0.05	0.02	0.01	0.02	-
Ti	-	-	0.03	0.02	-	0.03	0.05	0.04
Al	0.02	-	0.02	-	-	0.04	0.02	0.02
Cr	15.53	16.03	16.67	17.09	12.66	-	-	-
Fe	74.89	74.49	72.28	69.15	56.69	65.17	65.04	64.44
Mn	-	1.04	-	-	-	0.03	-	-
Ni	9.14	8.10	9.52	10.53	9.48	-	-	0.04
C	-	-	-	3.15	18.15	34.71	34.87	35.46
Total	99.87	100.00	98.91	100.00	100.00	100.00	100.00	100.00

1 – $Fe_{1.34}$ $Cr_{0.30}$ $Ni_{0.16}$ $Si_{0.02}$; 2 – $Fe_{1.34}$ $Cr_{0.31}$ $Ni_{0.14}$ $Si_{0.02}$ $Mn_{0.01}$; 3 – $Fe_{1.28}$ $Cr_{0.32}$ $Ni_{0.16}$ $Si_{0.01}$; 4 – $(Fe_{1.24}$ $Cr_{0.33}$ $Ni_{0.18})_{1.75}$ $Co_{0.25}$; 5 – $(Fe_{1.02}$ $Cr_{0.24}$ $Ni_{0.16})_{1.42}$ $C_{1.51}$; 6 – $Fe_{1.17}$ $C_{2.89}$; 7 – $Fe_{1.16}$ $C_{2.92}$; 8 – $Fe_{1.15}$ $C_{2.95}$.

Table 2: Microprobe Analyses (wt %) of the Glass Phase of Microscoria from Gold-Bearing Rocks in the Lena Area

Oxide	1 (6)	2 (2)	3 (4)	4 (3)	5 (16)	6 (1)
SiO_2	12.06	37.67	10.74	19.20	39.63	21.1
TiO_2	15.36	6.72	46.63	40.50	1.02	0.29
Al_2O_3	2.98	7.49	2.36	6.70	12.34	5.84
Cr_2O_3	0.04	3.46	0.16	0.12	н.о	н.о
FeO	57.64	2.05	11.81	8.90	6.35	71.8
MgO	1.09	2.19	3.70	6.36	4.89	0.64
MnO	5.61	2.60	11.16	13.30	0.15	n.d.
CaO	5.48	47.82	10.94	0.44	30.72	n.d.
Na_2O	n.d.	n.d.	0.07	1.73	2.08	n.d.
K_2O	n.d.	n.d.	0.16	2.19	0.59	n.d.
Total	100.26	100.00	97.73	99.44	97.77	100.61

Values in parentheses show the number of analyses, *n.d.* means not detected.
1 - Pervenets gold-bearing quartz vein, rim around a spheroid of native Fe (see Figure **5**); 2-4 - gold-bearing carbonaceous mylonite from the Sukhoi Log deposit; 5, 6 - mud-volcano deposits with clastic gold-pyrite-magnetite ores from the Ugakhan and Rovnyi prospects, respectively.

are comparable with those of accessory minerals in rocks (from a few specs to a few fractions of a percent).

The microscorias crystallized from melt droplets of various nature: mechanical-chemical (pseudotachylite), gas-hydrothermal (gas-emulsion), magmatic, and pyrometamorphic. The mechanisms shaping the spheroid particles (beads) of the microscorias are also different: cavitation, foam flotation, micrometer-scale liquid immiscibility [16, 17].

Microscorias are fairly widely spread in the ore-rock complexes of the Lena gold-mining district. N.T. Zubkov was the first to bring them to notice in the 1960s when carrying out pan-sampling in search for placer deposits. He found numerous spherical, conical, and pancake-shaped glass particles and native Fe, Cu, and Au in the form of aggregates with variable proportions of reo minerals and glass. The particles were found in crushed samples (hand-crushing) from gold-sulfide (from Sukhoi Log deposit) and gold-quartz (Pervenets deposit) ores of Paleozoic age and from mud-volcano gold-pyrite-magnetite ores of Cenozoic age. The glass phases from the Sukhoi Log deposit show broader compositional variations (Table **2**). Their chemical analyses were recalculated to normative minerals. The following varieties of the scoria glasses were provisionally recognized based on their predominant normative minerals: spinel-larnite, spinel-olivine-wollastonite, perovskite-tephroite, tephroite-armalcolite, olivine-armalcolite, and sanidine-tephroite-armalcolite.

In the vein ores of the gold-quartz association, rounded microscoria particles usually contain cores of spherules of native Fe (Figure **5**), which is practically free of admixtures. The glass phases of these particles are variably recrystallized and has a dendritic microtexture. Their normative mineral composition is dominated by iozite, ilmenite, fayalite, and larnite.

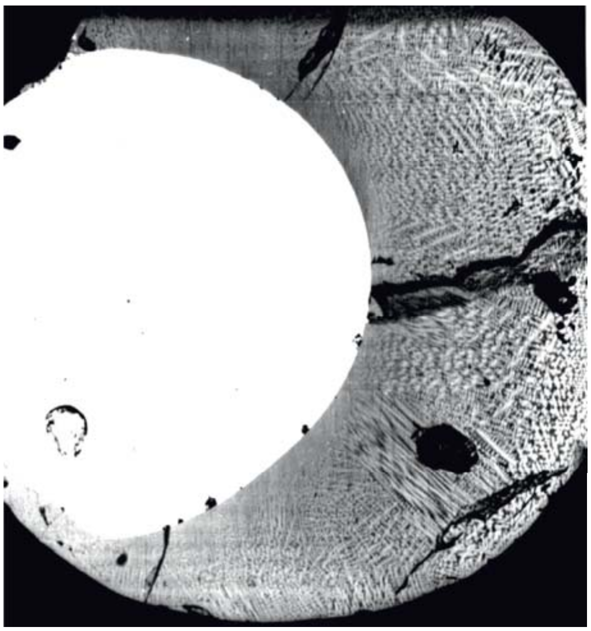

Figure 5: Cross section of a microscoria bead from the Pervenets vein. The core consists of native iron, and the zone around it is an oxide phase of pyrophanite-ilmenite-fayalite-iozite normative composition (back-scattered electron image).

The gold-bearing placers in the Cenozoic mud-volcano rocks typically abound in droplet-shaped and conical particles (up to 2-3 mm) of scoria glass (Figure **5**), which are similar to those found in the ejected material of mud volcanoes in the near-shore zone of the Caspian Sea [18]. Judging by their refraction indices, the composition of the glasses broadly varies from ultramafic to silicic. The glasses were found in association with autonomous particles of similar morphology and with inclusions of ore minerals in the glassy matrix of the microscoria. The ore minerals are native iron (sometimes with an outermost copper rim), copper, Cr-spinel, iozite, and magnetite. Spherical gold particles were also found, sometimes they were surrounded by rims of native copper.

The glass matrix of these microscorias differs from the matrix at the Sukhoi Log and Pervenets deposits in having a low TiO_2 concentration an almost twice lower MnO contents (Table **2**).

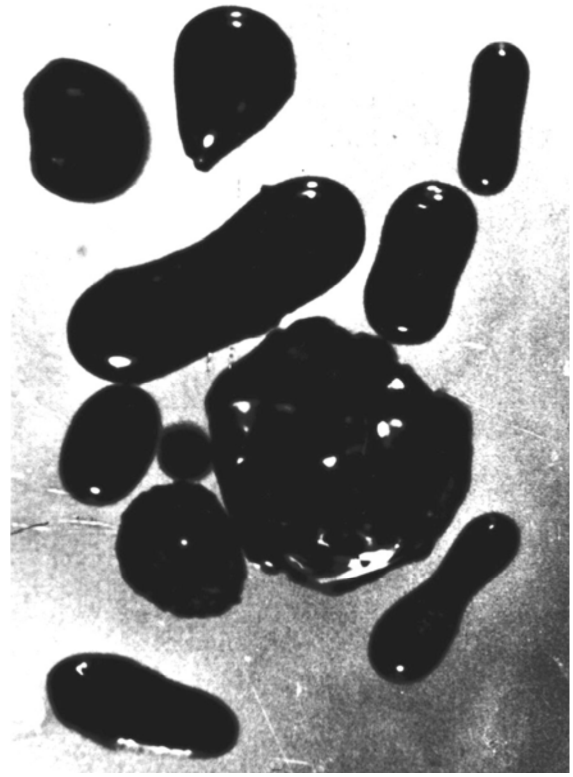

Figure 6: Typical shapes of glass particles from the placers.

The ore minerals identified in the Sukhoi Log microscorias are iozite and magnetite. The latter mineral differs from magnetite in the mud-volcano rocks in having an unusual microtexture (Figure **7**). A typomorphic feature of the mud-volcano magnetite is that it contains carbon-bearing inclusions with a low-temperature mineral assemblage typical of hydrothermal gryphon-salse episode of the activity of mud volcanoes [19].

4. THE SIGNS OF MUD VOLCANIC ORIGIN OF NATIVE GOLD PARTICLES FROM GOLD PLACERS IN THE LENSKY DISTRICT

The study of structure and composition of native gold particles from placer deposits indicated the signs, distinguishing the majority of gold particles, extracted from ore bodies of the Lensky district.

1. According to the data [20] a large number of big well-rounded gold particles (class+2 mm) contains gas inclusions in the cavities of spherical and teardrop shapes. These inclusions are fixed by tubercules, their size ranges between 0.05 and 1.5 mm in diameter in the base and from 0.04 to 0.9 mm in height. The

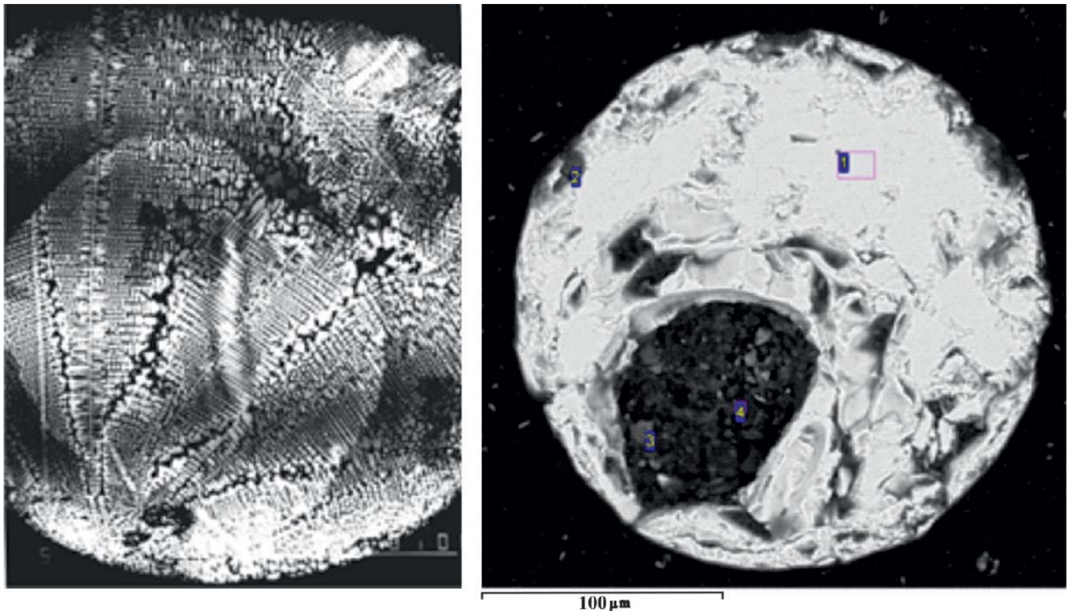

Figure 7: Magnetite spherules. Left: in ores from the Sukhoi Log deposit. The spherule has a dendritic microtexture grading into a skeletal one. Right: in ores form mud-volcano sandy-ooze rocks from the Rovnyi prospect. The spherule contain inclusions of the following normative composition: 2 - allophane (33%) + carbon (26%) + chlorite (24%) + quartz (10%) + halite (Na, K)Cl (5%) + gypsum (2%); 3 - hydromuscovite (65%) + carbon (33%) + goethite (2%).

experiments showed that such tubercules arise at T=80-460 ^{o}C [21]. Wherein, it is claimed that they could not arise in quartz veins. We assume that the rounding process of the gold particles with formation of tubercules due to thermal expansion of gas inclusions could occur only under conditions of their transportation by heated mud volcanic pulp.

2. The particles of native placer gold having spherical shape are of 3 types: 1 – monomineral (Figure **8**), 2 – coated with a copper shell, 3 – containing rounded grains of quartz.

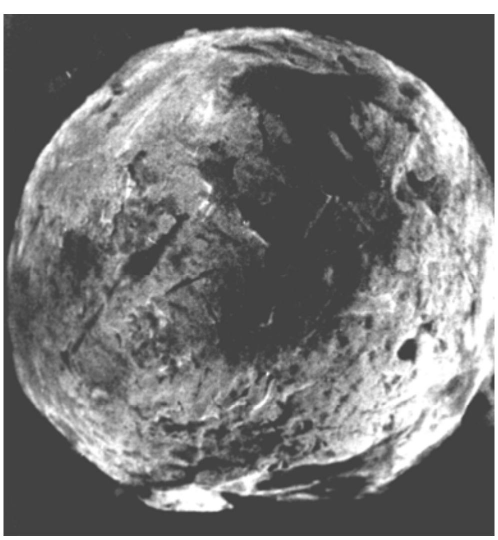

Figure 8: Spherical particle of native gold in association with the microscoria.

Spherical shape – typical for mud volcanic conglomerates of the Kamenskoye deposit [7].

On the analogy of the Kamenskoye deposit the spherules of the 1st type have pyrometamorphic genesis, typical for mineral associations of the gas-explosive functioning stage of mud volcanoes [19]. For the 2nd and the 3^{d} types of the particles, as well as for the balls of native mercury, which can go with the gold particles, their formation into crater sedimentary-hydrothermal stage of mud volcanic activity is asserted.

3. The study of native gold particles with high-grade shells showed [1] that such shells are formed not due to silver migration from the surface of the gold particles, as it occurs under hypergenic conditions, but through their accreting in different environment. Considering the fact of quartz grains accreting by outer gold shells (3^{d} type of spheroids), we can assert that such shells arise from hydrathermal solutions, circulating in the craters of mud volcanoes and depositing gold on the particles they capture. 55% of gold from the placer in the Lensky district have the values of fineness more than 920‰ [4]. The set of ore elements – impurities, except Ag, is represented in it by the association of Fe, Ti, Mn, Ni, Cu, Zn, Hg. Gold from the known ore deporits (Sukhoi Log, Pervenets, Verninskoye, etc.) is characterized by a wider range of fineness values (560-980‰) and its lower middle level

[22]. Thus the middle gold fineness of technological grade from gold-quartz-sulfide ores of the deposit Sukhoi Log is 880-890‰. Wherein, the microprobe tests of various gold grains gave the values 846-896‰. At the lower concentration level Ag (less than 80 mas.%), the concentration of Ni (up to 0.04 mas.%) and Cu (up to 0.25 mas.%) in the placer gold particles does not differ from the ore particles of the aforementioned deposits. Only Hg concentrations in the placer gold (tenths of a percent) are higher than in the ore gold (0-0.25 mas.%).

Our data suggest spatial-genetic links between gold placers in the Lena area and the mud-volcano type of ore gold mineralization of Cenozoic age.

5. SAMMARY AND CONCLUSION

The research results allow complementing the ore-forming system of the Lensky district with a new mud volcanic genetic type of ore mineralization and allocating a new Cenozoic tier of gold ore mineralization (Figure **9**). The lithocomplexes of mud volcanic structures of the north-western branch of the Baikal rift are ore-bearing. At least 90 % of gold, mined in 150 years in the area of the Lensky district, was extracted from poorly lithified mud volcanic complexes and their disintegration products. The sources of gold accumulation, localized in mud volcanic complexes, are ore-containing ingrained-streaky quartz-sulfide, ingrained sulfide zones and quartz veins of II and III tiers of ore mineralization (Figure **9**).

The Lensky district is the second after the Baleisky gold-bearing district of Russia, where large sources of gold of mud volcanic genetic type are accumulated. Both of these districts are characterized by fundamental similarity of geological-mineragenic sections, formation features of ore-forming systems. In a model section of the Baleisky district [26, 27], as well as of the Lensky, there are 3 tiers of gold ore mineralization: the upper lower Cretaceous mud volcanic, the middle Jurassic dynamic metamorphic in Paleozoic granites and the lower in a dynamic metamorphic complex on rocks of neoproterozoic age of the Onon-Shilkinsky greenstone belt. It is also shown that the sources of gold in the deposits of mud volcanic type (Kamenskoye, Taseevskoye, Baleiskoye) are ore accumulations of the middle and the lower ore mineralization tiersf [7, 26].

The results of our research led us to suggest that certain corrections should be introduced into the plans of further exploration for Au and PGE and evaluation of their reserves in the Lena area as a whole and at the Patom Highland.

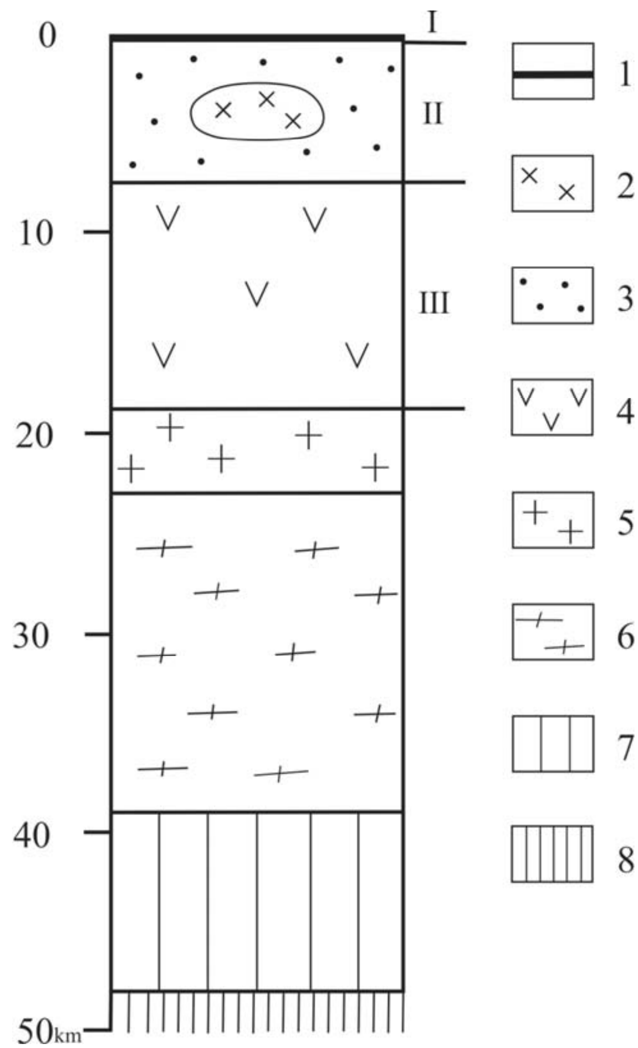

Figure 9: A deep geological-mineragenic cross-section model of the Lensky district. (the data [3-5, 23-25] were used).

I-III – tiers, age, genetic types of gold ore mineralization: I – the upper Cenozoic mud-volcanic, II – the middle Paleozoic dynamic metamorphic in carbonaceous strata, III – the lower Neoproterozoic-Paleozoic dynamic metamorphic in the rocks of the mafic-ultramafic complex of the Baikal-Patomsky green stone belt.

1 – mud volcanic lithocomplexes (Kz), probably in the lower part of (K_1); 2 – granitoids (Pz_{2-3}); 3 – carbonate-terrigenous deposits of rift passive margin of the Siberian carton with horizons, enriched with carbonaceous matter (the Neoproterozoic) in the composition of bodaibinskaya and nygrinskaya series: 4 – the zone of prevailing distribution of ultramafic-mafic rocks of the Olokitsky-Bodaibinsky rift green stone belt (the Mesoproterozoic); 5 – granitoids of the chuisk-nechersky and metamafics of the teprokansky complexes (the Paleoproterozoic); 6 – the Archean granulite-mafic complex; 7 – protrusion of activated mantle; 8 – “normal mantle”.

The first-priority tasks should thereby be as follows:

- survey weakly eroded ore-bearing mud-volcano structures and explore in detail their inner structure, lithological-petrographic composition of their lithological complexes, and ore potential;

- classify the identified ore-bearing structures according to their morphogenetic features, composition of the ore-rock complexes, and typomorphic features of the mineral assemblages and geochemical associations;

- suggest petrographic, mineralogical, and geochemical criteria for distinguishing various types of ore-bearing mud-volcano structures with emphasis placed onto the composition of the lithological and ore clasts;

- based on the aforementioned criteria, elucidate spatio-genetic relations between alluvial, eluvial, and diluvial gold placers (including depleted ones) and various types of mud-volcano edifices;

- revise and re-interpret extensive available pan-sampling data on the basis of the mineralogical-geochemical criteria suggested to identify gold ore minerals of the mud-volcano type, and predict new deposits on this basis.

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