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Article

Criteria for Determining the Genesis of Placers and Their Different Sources Based on the Morphological Features of Placer Gold

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Abstract: Based on the identified typomorphic features of placer gold, a set of determined morphogenetic criteria is proposed to identify the genesis of placer gold content and different sources in the platform areas, which allow more correctly selecting search methods and improving the efficiency of forecasting ore and placer gold deposits. Gold particles larger than 0.25 mm with signs of wind-worn processing indicate the formation of autochthonous aeolian placers. Gold particles with signs of wind-worn processing with a size of 0.1–0.25 mm, forming an extensive halo of dispersion, indicate the formation of allochthonous placers in Quaternary deposits. Deflationary (autochthonous) placers of native gold can be found by the halo of its distribution of toroidal and spherical hollow forms, which, of course, are the search morphogenetic criterion of aeolian placers. The presence of disc-shaped and lamellar gold particles with ridgelike edges in alluvial placers is typical for placers of heterogeneous origin, formed due to deflation of proluvial placers. The discovery of pseudo-ore gold in alluvial placers indicates the arrival of gold from intermediate gold-bearing sources of different ages and not from primary sources, which is a morphogenetic criterion for determining different sources of the placer. In modern gold placers, the presence of gold of a pseudo-ore appearance can serve as a search criterion for the discovery of gold-bearing conglomerates with high gold content. The developed method for diagnosing the genotype of placer gold by its morphological characteristics (alluvial, aeolian, pseudo-ore) can be successfully used by industrial geological organizations to search and explore ore and placer gold deposits.

Keywords: placer gold; aeolian gold; experiments simulated aeolian environment; morphological and other typomorphic features; morphogenetic criteria ore sources genesis

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1. Introduction

In the east of the Siberian Platform, unusual toroidal and spherical hollow gold particles were first discovered in Mesozoic–Cenozoic deposits [1–3]. Spherical hollow gold is widely distributed, found in sedimentary rocks from the Riphean to the Cenozoic, and is typical for all platform areas of the earth (Figure 1) [4].

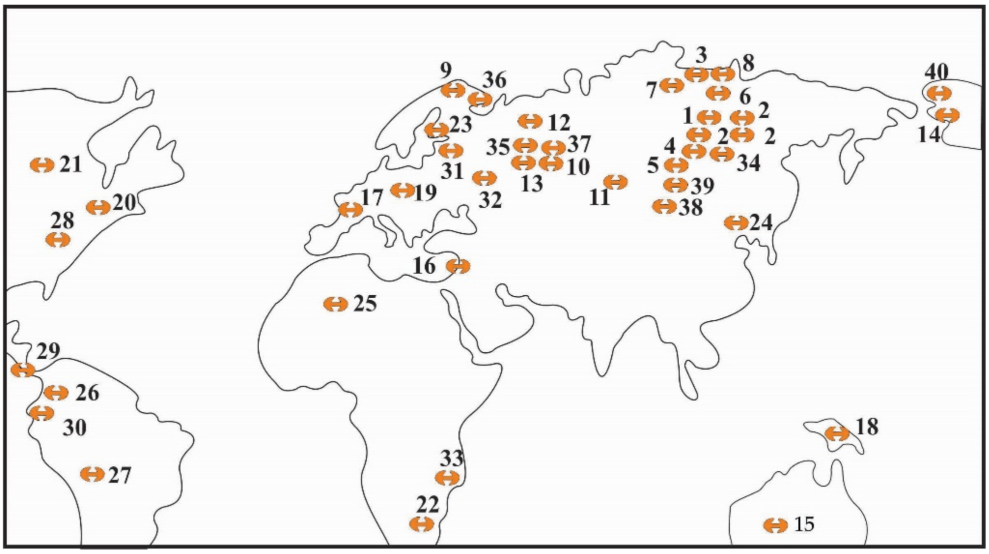

Figure 1. Scheme of distribution of spherical hollow and toroidal gold in different regions of the globe according to researchers: 1 [5]; 2 [2]; 3 [1]; 4 [6]; 5 [7]; 6 [8]; 7 [9]; 8 [10]; 9 [11]; 10 [12]; 11 [13]; 12 [14]; 13 [15]; 14 [16]; 15 [17]; 16 [18]; 17 [19]; 18 [20]; 19 [21]; 20 [22]; 21 [23]; 22 [24,25]; 23 [26]; 24 [27]; 25 [28]; 26–30 [22]; 31 [29]; 32 [30]; 33 [31]; 34 [32]; 35 [33]; 36 [34]; 37 [35]; 38–40 [4,36].

The analysis of the literature sources showed that the description of unusual forms of native gold used various terminology. Shpunt [1] introduced the concept of a tablet-like gold particle with ridgelike edges or a teardrop-shaped gold particle, flattened in the middle on both sides. According to Izbekov [2], scaly gold with ridgelike edges is named "pan-shaped". The term "toroidal" form of gold particles was first proposed by Yablokova [3]. It most successfully reflects the essence of the form. In this case, the toroid is considered as a "bagel", but without a through-hole. This term was later adopted by many researchers who studied similar forms of placer gold. When studying the spherical shape, Izbekov [2] distinguished it as "spherical hollow gold". Shpunt [1] and Yablokova [3] called such gold "teardrop-shaped, globular". Many researchers, when describing similar forms of placer gold, use mainly the term "spherical gold"; some of them distinguish spherical gold with "blebs" [22]. The terms "teardrop-shaped", "globular", "spherical" do not fully reflect the features of the structure of spherical forms. A more accurate name is "spherical hollow" gold; it characterizes not only the appearance but also the internal structure of the gold particle. Later, when studying the considered forms of placer gold, it was proposed to use the terms "toroidal" according to Yablokova [3] and "spherical hollow" gold according to Izbekov [2].

When studying the typomorphic features of spherical gold, it was also revealed that there are two types of them in nature—massive spherical gold or with "blebs", no more than 40 microns in size, clearly of endogenous origin and spherical hollow particles with a partition inside, the size of 0.1–0.16 mm, it is always found together with toroidal gold.

The genesis of toroidal and spherical hollow forms is still one of the controversial issues. Several researchers believe that the origin of such forms of native gold is related to chemogenic processes [1,3,19,20,22,27,28,37]; others explain their genesis by the mechanical transformation of flake gold in hydrodynamic conditions [2,21–23]. Some researchers suggest their possible biogenic [3,38], gas-condensate [39], and even cosmogenic [40] origin.

Chemogenic origin, according to data [1,19,20,22,27,28,37,41,42], there is every reason to accept the assumption of the chemogenic genesis of spherical hollow gold. However, a detailed study of its typomorphic features revealed that there are a number of facts that contradict this assumption. Experimental data indicate the deposition of gold only in the form of massive spherules no larger than 40 μm on activated carbon and sulfide minerals (sphalerite, galena, pyrrhotite and arsenopyrite). Therefore, such gold has nothing in common with hollow spherical gold, which is widely distributed in many platform areas and has an average size of an order of magnitude larger than the experimentally obtained massive spherules. In addition, in spherical hollow gold with a partition inside the cavities, there are no signs of primary crystallization and the edges of crystal growth; instead, inside the cavities at large (500–1000 times) magnifications, the thinnest (fractions of micrometers) filaments were found, which, as if overlapping each other, form a shell. In the cavities of spherical gold, no "seed" minerals have been found on which gold would be deposited, but inclusions of detrital quartz, zircon, ilmenite, rutile and other minerals have been identified. All of the above does not allow us to consider toroidal and spherical hollow gold as the product of chemical processes occurring in the weathering crust and, therefore, to accept the chemogenic hypothesis to explain their genesis.

The mechanogenic hypothesis, despite all the apparent logical validity of the origin of toroidal and spherical hollow gold in hydrodynamic conditions, has a number of weaknesses that do not allow us to explain all the nuances of the formation of spherical forms. The hypothesis of the formation of spherical gold by mechanical flattening of crystals in an water–alluvial medium [17,21] is not consistent due to the fact that in hydrodynamic conditions, gold particles flatten regardless of their original shape, which is established experimentally [43,44]. The proof of this assumption is provided by natural observations that in any placer, various forms of gold are observed in the "head", and in the "tail", only flattened gold grains are observed.

The hypothesis of the biogenic origin of the discussed morphological type of native gold was first expressed by Yablokova [3]. She believed that the formation of hollow forms is associated with the sorption of gold by the Precambrian organisms. The presence of carbon (up to 0.001%) in native gold and their similarity in shape to the Precambrian organisms confirmed this idea. Other researchers also hypothesized the biogenic origin of spherical gold during the nucleation of gold on bacterial spores with a diameter of 1–2 microns [38]. The direct proof of the validity of this hypothesis for them is a certain similarity of the spherical forms of the mineral with the appearance of Precambrian microorganisms. The main contradiction is that spherical hollow gold is observed not only in the Precambrian deposits but also in the Quaternary deposits. It is found in sedimentary rocks from the Riphean to the Cenozoic inclusive. The second proof in favor of a possible biochemogenic hypothesis for the authors was the presence of carbon in native gold. However, the discovery of carbon in spherical hollow gold does not refute or prove its biogenic origin. During the formation of hollow spherical gold, any particles can be captured, not only quartz, ilmenite, zircon but also fragments of organic origin, primarily vegetable origin. In this regard, the discovery of carbon in the cavities is not an argument for the biogenic origin of spherical hollow gold particles. Finally, the hypothesis under consideration does not explain the mechanism of formation of a large variety of forms of hollow gold.

Gas-condensate (hydrothermal) and meteorite origin. Gladkov et al. [39] suggested that the spherical gold had a gas-condensate origin.They have an almost perfect rounded shape—these are gas microchambers, they do not have dividing partitions, as in spherical hollow gold particles, and they are an order of magnitude smaller in size. The cosmogenic hypothesis is problematic [40] since the possibility of a meteorite falling into gold-bearing formations is unlikely.

It is shown above that each of the proposed hypotheses has weaknesses, and none of them reveals the essence of the process of formation of specific forms of gold particles, constantly observed on ancient platforms.

The mechanical hypothesis of the deformation of flake gold and its transformation into spherical hollow form is beyond doubt, but under what conditions does this happen? Does it occur in stream water? Or does mechanogenic transformation occur in another condition?

We have suggested that the sequence of deformation of flake gold and its gradual transformation into a toroidal and then into a spherical hollow form is more likely in aeolian conditions than in a hydrodynamic environment. Analysis of the distribution mechanism of toroidal and spherical hollow gold and comparison of its location with the geographical paleoenvironment of the east of the Siberian Platform also allowed us to confirm the hypothesis about the origin of such forms of native gold in aeolian conditions. The proof of this assumption was the fact that the sites of finds of toroidal and spherical hollow gold are well correlated with the deflation deserts mapped by Kolpakov [45].

Transformation of placer gold in ancient gold-bearing sources. In the ancient conglomerates of the Devonian age of the Timan Ridge, along with the typical placer-shaped gold particles, gold particles of the "ore" appearance were found [33], which was the reason for researchers to suggest secondary gold mineralization on the formed ancient placer [14,46].

Gold particles of placer and ore appearance of paleoplacers of the Timan Ridge were studied by us in detail. Along with placer aeolian gold, gold particles of "ore" appearance were found. Gold particles are characterized by a coarse-shagreen surface, with casts of pressing of minerals and a rounded shape, with no growth facet, it often forms pseudo-growths with quartz, ilmenorutile and garnet, which are easily destroyed (Figure 2). The occurrence of gold particles of the "ore" appearance in the placer is usually a small percentage, but sometimes, in some areas, it reaches 80%.

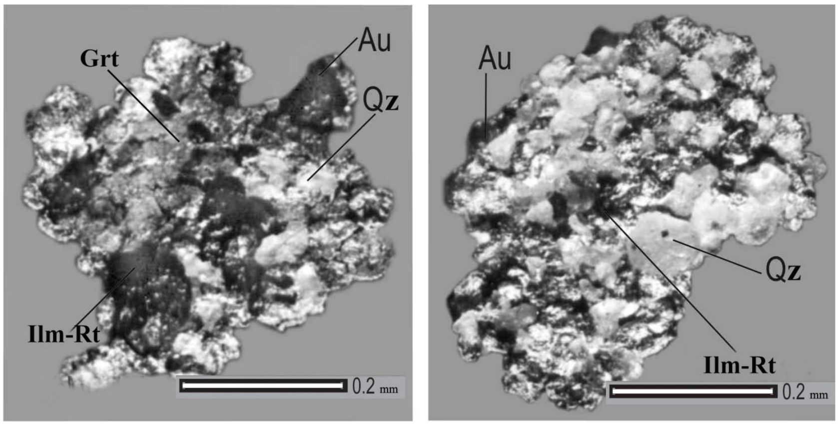

Figure 2. Pseudo-growths of native gold with quartz (Qz), ilmenorutile (Ilm-Rt) and garnet (Grt).

The presence of such native gold allowed previous researchers to assume the proximity of the primary source. However, the above-detailed analysis of individual typomorphic features of this native gold called into question the validity of its distinguishing as gold ore appearance. In this connection, it was suggested that this is placer gold, which took on a pseudo-ore appearance under the influence of the lithostatic pressure of the overlying strata, which was proved experimentally [33,47].

In view of the above, we put forward an assumption about the formation of toroidal and spherical hollow gold with a partition inside as a result of the deformation of flake gold in aeolian conditions and the formation of "pseudo-ore" gold in ancient gold-bearing sources under the influence of lithostatic pressure of the overlying strata. In order to test these assumptions, experiments were conducted that simulate the mechanism of transformation of gold particles of various shapes in aeolian conditions and in ancient gold-bearing conglomerates.

2. Materials and Methods

The article is based on the results of field, experimental and analytical studies on placer gold. The objects of study were placers from the east of the Siberian Platform, Tuva, Mongolia, gold-bearing conglomerates of the Timan Ridge (Ural), as well as the collections of placer gold of the A. E. Fersman Museum, TsNIGRI, MGA, and "VNESHMET" JSC.

In the study, a wide range of well-known mineralogical and geochemical methods for studying the typomorphic features of native gold was used [41,48]. All analytical work was carried out in the laboratory of physical-chemical methods of analysis, DPMGI SB RAS (Yakutsk). 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). In addition, experimental work was carried out on specially designed equipment by V. E. Filippov, simulating the aeolian process and the lithostatic pressure of the overlying strata.

In the course of experimental studies, the mechanical transformation of gold forms under the influence of sand–air flow under aeolian conditions and the lithostatic pressure of overlying strata on ancient gold-bearing conglomerates, was studied for the first time [47,49].

Experimental studies on the transformation of native gold in a simulated aeolian environment were carried out in several stages.

1. Experiment. First, the transformation of flake gold particles of various configurations in the plan view was studied, then more massive grains of lamellar, tabular and lumpy gold particles were studied.
2. Experiment. In addition, the transformation of endogenic native (further "ore") gold in a simulated aeolian environment was studied. For the study, a large ore gold particle was selected (half of the particle was used in the experiment, and the second part was left for comparison).
3. The experiment was conducted to identify the genesis of the gold film on quartz. For this purpose, the ore gold particle in an intergrowth with quartz was taken and placed in an experimental facility.

Experimental studies of alluvial gold transformation in simulating the influence oflitho static pressure of overlying strata.

The placer gold was covered with sand, imitating the overlying deposits, and was placed under a hydraulic press, where the minerals were pressed in at a certain pressure.

3. Results

3.1. The Results of Experimental Studies Simulated Aeolian Environment

Transformation of flake gold into toroidal and then into spherical hollow shapes. As a result of the experiment, it was possible to obtain spherical hollow forms of gold particles. After a 100 h stay in the imitation conditions of the aeolian process, the gold flakes gradually transformed into typically toroidal and then into hollow spherical formations (Figure 3). The initial stage of transformation is a thin ridge's appearance along the edge of the flake gold particle (Figure 3a). The middle stage—the flake's formation with a well-defined ridge-toroidal shape (Figure 3b). The final stage of transformation is the formation of a hollow ball (Figure 3c).

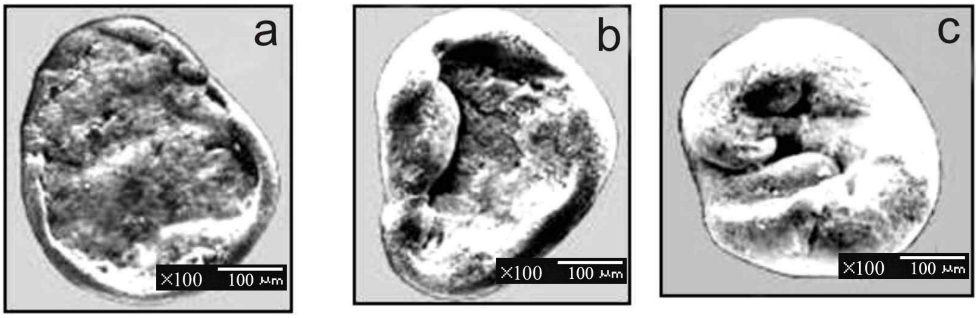

Figure 3. Sequential change of the flaking gold in the course of the experiment: (**a**) the appearance of a thin ridge along the edge of the scaly gold particle; (**b**) the flake's formation with a well-defined ridge toroidal shape; (**c**) forming a hollow ball.

It is established that the change in the shape of the gold grains in the experimental aeolian conditions depends on their initial shape (Figure 4). Toroidal and spherical hollow gold is formed as a result of the transformation of coin-shaped flakes. Scaly gold of other configurations takes on hollow formations of a more complex shape: pear-shaped, canoe-shaped, etc. (Figure 5a,b). Lamellar gold particles are transformed into disc-shaped forms (Figure 5c) and rod-shaped particles—into dumbbell-shaped ones (Figure 4). On the lumpy particles, the protrusions are smoothed out to form a foil, which in the form of the thinnest shell envelops the main core.

Shape of gold particles			
Primary		Transformed	
	Flake		Toroidal
			Spherical hollow
	Rod-shaped		Dumbbell-shaped
	Lamellar		Disc-shaped
	Ore appearance		Massive spherical

Figure 4. Transformation of gold particles of various shapes in an air–sand flow.

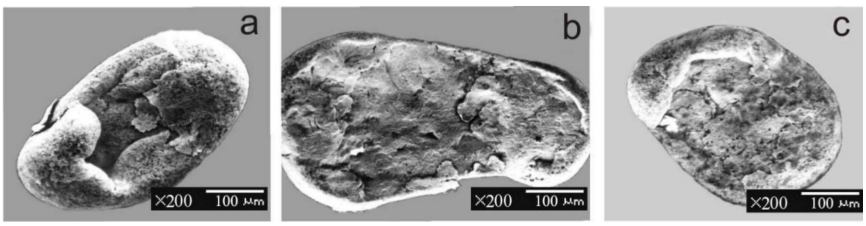

Figure 5. The different nature of the transformation of gold particles, depending on their shape in the course of the experiment: (**a**) canoe-shaped; (**b**) ellipsoid-shaped, lamellar gold particle with ridgelike edges; (**c**) tabular gold particle with a ridge.

Ore gold, after a 100 h stay in the simulated aeolian environment, also changed its shape; its protrusions smoothed out and acquired a rounded shape (Figure 6b).

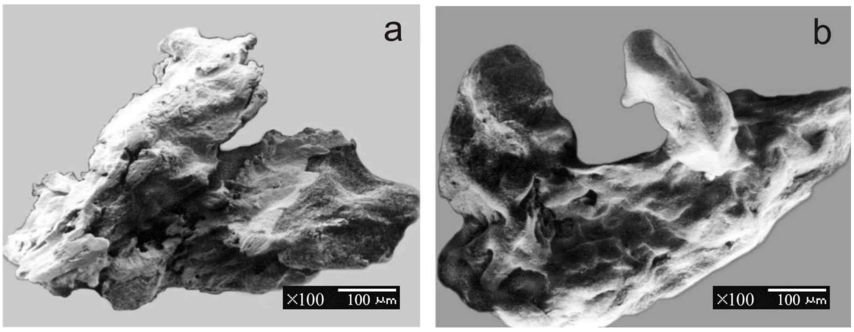

Figure 6. Transformation of a gold particle of ore-appearance in an air–sand flow: (**a**) before the experiment; (**b**) after a 100 h stay in an air–sand flow.

Transformation of "ore" gold in intergrowths with quartz in an air–sand flow. During asimulation of the aeolian process lasting 30 h, protrusions of the gold particles smoothed out, the growth facets and the shiny surface disappeared. After a 100 h stay in the simulated aeolian environment, the gold–quartz intergrowths changed even more, and the surface of the gold acquired a more distinct matte shade, characteristic of wind-worn processes (Figure 7a,b). On these intergrowths, as a result of blows with sand grains, the thinnest films of gold enveloped quartz (Figure 8a). The formed film has a filmy-fibrous surface typical for the transformed gold in aeolian processes (Figure 8b). As a result of the experiment, gold-encrusted quartz was obtained. The mechanism of formation of a filmy-fibrous surface on the intergrowths of gold and quartz is identified.

In the course of the experiments, all the gold particles were compacted, as a result, of which they decreased in size, acquired new various forms. As determined by the control weighting, their weight is practically not changed. According to the structural features, the spherical hollow forms of gold particles obtained during the experiment (Figure 9a–c) are similar to the forms of native gold of natural objects. Inside the hollow chambers, there is a "filamentous" gold (Figures 3 and 9a). In natural gold and in experimental gold, inclusions of quartz, ilmenite, zircon, etc., are observed in "blebs", the capture of grains of quartz and various minerals is recorded.

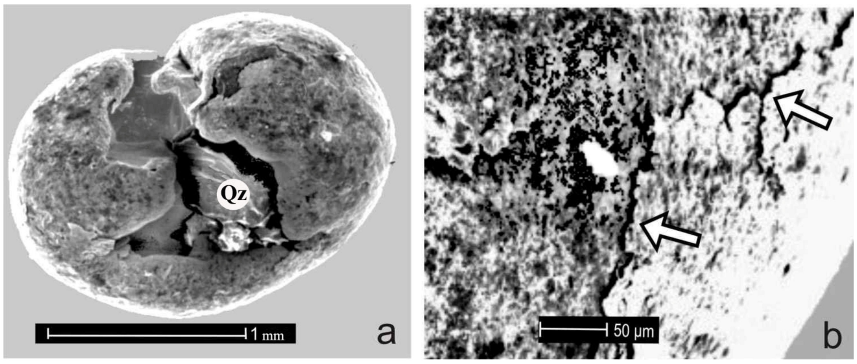

Figure 7. Intergrowth of native gold and quartz (quartz relics in the depth of the cavity, transformed into a lumpy-spherical shape in an experimental facility): (**a**) general view; (**b**) detail, the filmy-fibrous surface of gold (shown by arrows); Qz = quartz.

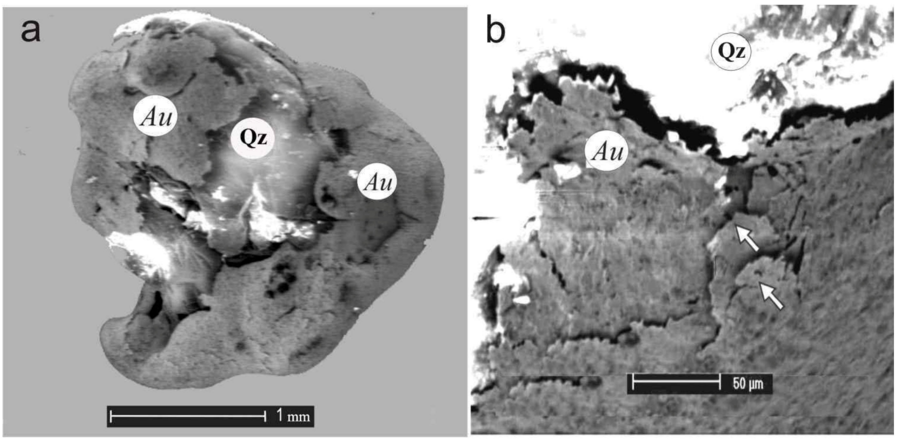

Figure 8. Gold-encrusted quartz obtained as a result of blows with grains of sand and intergrowth of native gold with quartz in an experimental facility: (**a**) general view; (**b**) detail, the filmy-fibrous surface of gold (shown by arrows); Au = gold; Qz = quartz.

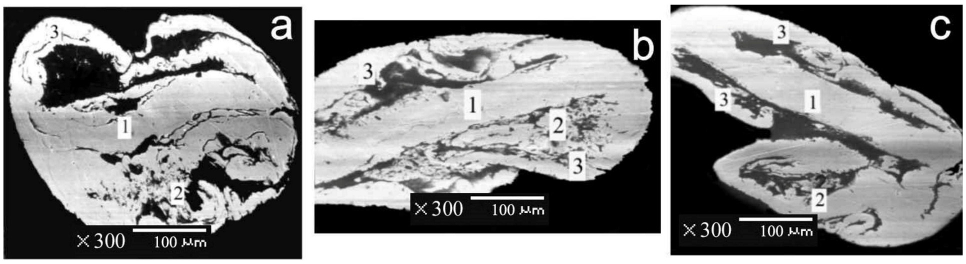

Figure 9. Cross-sections of various forms of hollow gold obtained during the experiment: (**a**) spherical hollow; (**b**) canoe-shaped; (**c**) curved; 1, internal partition; 2, filamentous twisted gold; 3, shell.

3.2. *Results of Experimental Studies on the Transformation of Placer Gold in Simulating the Influence of Lithostatic Pressure of Overlying Strata*

During the experiment, it was found that under the influence of lithostatic pressure in the simulated environment, gold particles, due to their ductility, are dented by the sand grains depressed into them and acquire a pitted-lumpy surface (Figure 10). Ragged edges and through holes appeared on them, as well as traces of pressing-in of minerals in the host deposits.

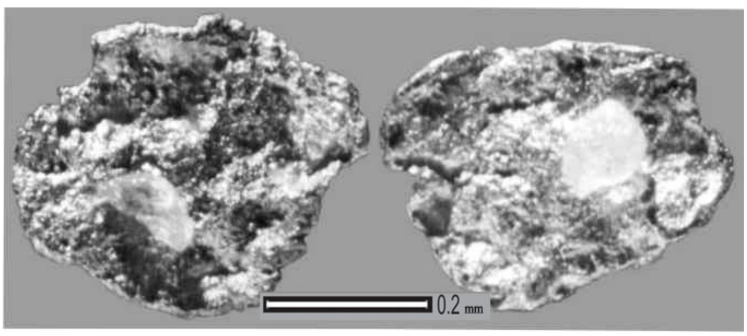

Figure 10. Surface of gold particles with casts of sand grains impressed in them.

Experimental observations of the transformation of native gold in aeolian conditions and in ancient gold-bearing conglomerates allowed us to solve a number of controversial issues that have not been clearly explained for a long time.

1. It turned out to be possible to understand and explain the origin of the filamentous gold and the formation of the shell, which many researchers took for clots of rede-

posited gold. This morphological feature is due to the continuous "bombardment" of the edges of the flakes with grains of sand so that the thinnest threads were stretched from the edges of the flakes, which, overlapping each other, formed a shell;
2. The presence of carbonaceous matter in the cavities of gold particles has led some researchers to associate the genesis of the studied forms with chemogenic processes. However, from the point of view of the conducted experiment, it is quite likely that both fragments of minerals and vegetative detritus can be found in the cavities of spherical gold particles. These inclusions reflect only the possibility of capturing the material that was present in the environment;
3. Obtained experimental data also logically explain the origin of the hollow forms of gold particles of various configurations, depending on the initial variety of morphological features of the gold particles that got into the aeolian conditions. It should be emphasized that hollow spherical forms are formed only from gold flakes. Lamellar and tabular shapes are transformed to disc-shaped forms;
4. The formation of brittle aggregates of growth of native gold with quartz, ilmenite, zircon and other minerals is quite possible under the influence of the lithostatic pressure of the overlying strata;
5. The appearance of scar furrows on the surface and through holes in the native gold occurs when simulating the processes of the effect of lithostatic pressure and tectonic displacements.

3.3. Typomorphic Features of Placer Gold under Various Exogenous Conditions

Native gold, regardless of its original shape, is flattened in hydrodynamic conditions. Identified regularity is proved for the first time by experimental studies Tischenko [43]. Therefore, in the "heads" of all classic placers [50,51], various forms of gold particles are observed, represented euhedral, anhedral, subhedral and other forms [52–54], and in the "tail" of the placer, there are only flattened lamellar forms. The surface of gold particles in hydrodynamic conditions changes from coarse-pitted to fine-shagreen–polished. On the surface of autochthonous placer gold, there are imprints of ore minerals, growth facets typical for the ore gold. Perfectly rounded alluvial placer gold is characterized by a smooth, polished surface, but at high magnifications (500–2000× and more), it has a loose porous structure.The mineralogical–geochemical properties of placer gold in hydrodynamic conditions do not change and depend on the composition of the gold of the destroyed ore source [55,56].

3.3.1. Typomorphic Features of Aeolian Gold

This section presents the results of the study of placer gold with signs of aeolian transformation, its morphological and internal structure and chemical composition on the example of aeolian gold of the east Siberian platform [57]. Depending on the shape of the gold particles and the degree of their transformation under aeolian conditions, they are divided into two groups (Figure 11).

First group—gold particles with signs of wind-worn processing, formed due to the gradual transformation of flakes of different configurations in the plan view into hollow spherical formations. Coin-shaped flakes are transformed into toroidal, and then into spherical hollow ore ellipsoid forms, into canoe-shape or irregular forms, into pear-shaped forms, etc. They are found in aeolian placers, both in the deflation zone and in the transit zone, and sometimes in accumulative aeolian deposits (dunes).

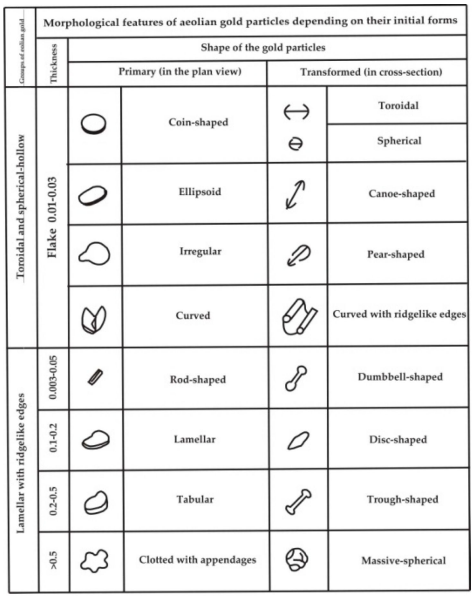

Figure 11. Morphological features of aeolian gold particles depending on their initial forms.

Second group of aeolian gold—this is the result of the transformation in aeolian conditions of massive gold particles with a thickness of more than 0.1 mm, lamellar, tabular, clotted, appendage-like initial forms. In contrast to the first group, the aeolian gold in question is generally more massive and larger, with an average particle thickness of 0.2 mm. Lamellar and tabular forms have a ridgelike edge. Sometimes the ridge is smoothed; consequently, the gold particles become disc-shaped. In the aeolian environment, massive spherical individuals are formed from clotted gold particles with processes. Gold particles of the second group are found in placers only in the deflation zone, at a relatively small distance from the source.

Characteristics of toroidal and spherical hollow gold. As shown experimentally, toroidal and spherical hollow forms are the result of the transformation of flake gold under aeolian conditions. According to the degree of aeolian transformation of the end of flakes, it is advisable to distinguish the stages of this process: initial, middle and final. At the initial stage, a thin ridge appears on the edge of the gold particle, occupying no more than a tenth of the diameter of the original flake. At each subsequent stage of transformation, the ridge increases in size, and at the final stage of transformation, a spherical hollow shape is formed (Figure 12a–c), in which up to half of the conditional diameter of the flake, the gold has passed to the formation of a rounded shell.

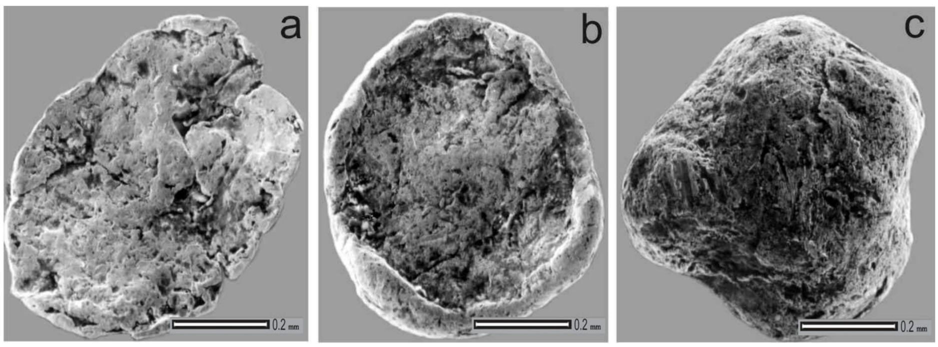

Figure 12. The sequence of the transformation of natural flake gold particles in aeolian conditions (the East Siberian platform, the size is 0.25 mm). Stages of transformation: (**a**) initial (flake with thin, ridgelike edges; (**b**) middle (toroidal shape); (**c**) final (hollow spherical shape).

Depending on the mode of aeolian activity, the process of transformation can stop at any stage or be repeated again and again until the deposits with gold are removed from the zone of influence of aeolian processes. Therefore, in the gold concentrate, all the transitional differences of gold particles are observed from thin flakes with a barely noticeable ridge along the edge to flakes with a well-defined ridge, shaped like a "ring-shaped roll"– toroid and various hollow spherical formations.

Unlike native gold from alluvial deposits, the surface of perfectly rounded aeolian gold is represented, regardless of the magnification scale, by a dense and smooth microrelief. At a magnification of 300×, a specific, film-fibrous surface is observed on this gold. With further magnification (2000–5000×), the surface of aeolian gold remains the same plane, dense and smooth with rare pores. The mechanism of formation of the film-fibrous surface is as follows: in aeolian conditions, as a result of processing with grains of sand, gold is drawn out in the form of the thinnest film, which, superimposed on each other, forms a dense film-fibrous surface.

Spherical hollow gold particles always have a partition that is significantly (2 times or more) greater than the thickness of the shell. In its internal structure, it reveals similarities with the internal structure of the original gold flake. The chambers of hollow spherical gold particles can be symmetrical and asymmetric. At 200–500-fold magnification in the scanning mode of the JEOL microanalyzer JXA-5OA (Japanese Electron Optics Laboratory, Tokyo, Japan), filamentous and weblike gold was found on the inner walls of the chambers (Figure 13a–c). Sometimes mechanical inclusions of quartz, zircon, ilmenite, as well as the remains of vegetative detritus are found in the cavities/chambers of gold particles. When observed in a scanning microscope, no facets of gold crystal growth were found in the internal cavities of spherical hollow gold particles from natural objects. Neither the primary crystallization of gold microindividuals nor the inclusion of any minerals indicating the chemogenic nature of such gold particles was recorded. The morphology of spherical hollow gold, the composition and shape of the inclusions in it clearly indicates the mechanical nature of the studied forms.

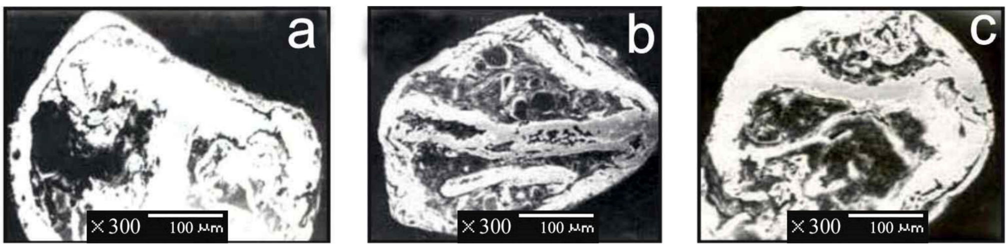

Figure 13. Cross-sections of various forms of hollow gold from natural: (**a**) internal partition; (**b**) filamentous twisted gold; (**c**) shell.

It should be emphasized that sub-spherical gold particles are formed not always in the final stage of the transformation of the flakes. Depending on the primary form of flakes, canoe-shaped and dumbbell-shaped gold particles are also formed from them. When the flake forms are transformed into spherical ones, the surface of the gold particles becomes smooth; the individuals decrease in size, their thickness and their increase (Table 1). Simultaneously with the external morphological transformations, there is a gradual change in the internal structure and fineness of native gold. As a result, each stage of changes from the flake to the hollow ball corresponds to certain typomorphic features of native gold. It is known that the degree of recrystallization and changes in the chemical composition of native gold is determined by the duration of its stay in an exogenous environment. Our studies confirmed the previously revealed fact that recrystallized fine-grained structures predominate in all varieties of modified gold particles with ridgelike edges. However, in the central parts of some relatively large, massive gold particles, areas with primary medium-grained structures and even blocks of monocrystals of the mineral were identified. High-grade shells of different thicknesses of the fine-grained structures are always developed on these gold particles.

Table 1. Typomorphic features of complex-deformed gold particles of the Lena–Viluy interfluve (east Siberia platform). Number of objects: 300.

Gold Particle Shape	Average Weight of Gold Particles (mg) by Fractions, mm		Average Size, mm	Average Thickness, mm	Average Hydro-Size, m/sec	Degree of the Surface Processing	Average Fineness, ‰ from-to/Average	Trace Elements, %	Degree of the Transformation	Main Internal Structures
	0.1	0.25								
Flake	0.009	0.05	0.25–0.5	0.02	5–6	From pitted-lumpy to polished	810–970/890	Pb-0.003 Cu-0.05 Fe-0.1 Mn-0.01 Pd-traces Ni-traces Hg-traces	Initial	Inequigranular Luder'slines, the presence of high-grade fringe, partial recrystallization
Toroidal	0.012	0.05	0.15–0.2	0.05	7–10	Thin-shagreen, polished	920–970/940	Fe-0.1 Cu-0.02 Mn-0.03 Ni-traces Hgtraces	Middle	Fine-,medium-grained, high-grade fringes, Intergranular veinlets, partial and complete recrystallization
Spherical hollow	0.013	0.05	0.1–0.16	0.1	12–17	Thin-shagreen, polished	960–990/970	Fe-0.1 Cu-0.017 Mn-0.001	Final	Fine-grained, complete recrystallization (decompression)

Toroidal gold is mainly characterized by a fine-grained structure with a partially or completely recrystallized shell. Occasionally, gold particles with well-developed fine-grained high-grade shells are observed with preserved relics of an unchanged medium-grained core with a lower fineness. The spherical hollow forms are usually completely recrystallized with the formation of the fine-grained internal structure of native gold.

When the flake forms are transformed into a spherical hollow form, the native gold is ennobled, the fineness is increased, and the trace elements are reduced (Table 1). Permanent trace elements of gold particles of flake forms are iron, lead, nickel, copper, manganese and some others. In spherical gold particles, only such trace elements as iron, copper and manganese are found.

Toroidal and spherical hollow forms of gold particles, regardless of their location, are characterized by surprisingly similar typomorphic features. They have a size of mainly 0.1–0.16 mm, high fineness >900‰ and low content of trace elements. It is found out that, in aeolian conditions, when flake gold transforms into toroidal, and then in a spherical hollow, there is a change not only in the morphology (decrease in size from 0.25 to 0.16 mm), the internal structure (recrystallization–decompression) but also in chemical composition (from 900 to 999‰). It is determined that the long period of transformation of flake gold particles into a spherical hollow form in aeolian conditions contributed to their ennobling. At the same time, there was a decrease in the variety and content of trace elements, an increase in the fineness and the formation of a high-grade shell in spherical hollow gold to 1000‰.

The main signs of deflationary aeolian gold. Native gold transformed in aeolian conditions, in addition to the considered toroidal and spherical hollow forms, is also represented by lamellar and tabular individuals that have thickenings along the periphery and form trough-shaped, canoe-shaped and boomerang-shaped morphological forms, as well as dumbbell-shaped and massively lumpy-shaped gold particles. A specific film-fibrous surface typical for gold transformed under aeolian conditions is observed on all gold grains. The size of gold grains of such forms is from 0.25 to 5.0 mm or more. The average thickness is 0.1–0.8 mm. The average grain weight is 0.5 to 50 mg; the average fineness is from 750 to 900‰. The internal structure can be coarse-grained, medium-grained, or the individual is a mono-grain. The presence of thin shells of high-grade gold is noted. The granulometric and chemical composition of massive gold with signs of aeolian transformation in other regions may be different since it depends on the type of gold ore sources. In this case, specific values are given for the placer deflationary gold of the Lena–Viluy interfluve (east of the Siberian Platform). In general, the gold in question is less chemically altered. It is characterized by a larger size and is, therefore, non-mobile, occurring only in the basal Aeolian horizon at a relatively short distance from the ore source. Such gold can form high concentrations and be of commercial interest.

According to the published data, lamellar and tabular gold particles with ridge like edges or lumpy-shaped forms with rounded appendages were found in the east of the Siberian Platform in a number of objects of the Viluysyneclise [2], Anabaranteclise [1], as well as in the Urals [12]. Since the aeolian features of deflationary gold are less evident in comparison with the morphological features of toroidal and spherical hollow gold, the halos of its distribution are not so widely found. Apparently, such gold was usually taken by researchers as a native metal of alluvial placers. However, based on the results of mineralogical, experimental and field observations, we have every reason to assert that massive gold with signs of wind-worn processing with toroidal and spherical hollow forms is found together. In a single aeolian deflationary placer, in its main part, more massive gold is mainly concentrated—lamellar and tabular forms with ridgelike edges, and in the tail part of the placer—toroidal and spherical hollow formations. Thus, it is easiest to detect a deflationary gold placer by the halo of its distribution of individuals of toroidal and spherical hollow forms, which can serve as a search mineralogical criterion of the aeolian-type of placer gold content.

In addition, deflationary gold includes rounded quartz grains encrusted with gold (Figure 14a,b), found along with lamellar forms of gold with ridgelike edges, toroidal and spherical hollow. The analysis of the literature data showed that the identified form of gold occurs together with the gold particles of aeolian appearance in placers of the Timan Ridge [33]; the Nindzhi River in Tanzania [31]; the Khuzhir gold-bearing conglomerates of the Vendian [58], in alluvial deposits of the east of the Siberian Platform [59], and in a number of other.

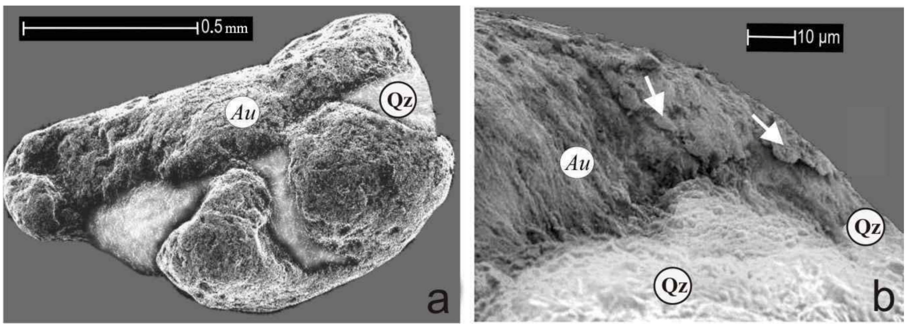

Figure 14. Gold-encrusted well-rounded quartz found in one of the placer occurrences of the Lena–Anabar interfluve: (**a**) general view; (**b**) detail, the film-fibrous surface of gold, characteristic of aeolian transformations (shown by arrows); Au = native gold, Qz = quartz.

The origin of the rounded quartz encrusted with a gold film is still debatable. Researchers who have studied similar-shaped gold particles in the Khuzhir gold-bearing conglomerates have suggested that this is the result of the precipitation of "new" gold formed during the dissolution of gold in the process of epigenesis [7,58]. Some researchers believe that the gold film on the intergrowths of gold with quartz could be formed under hydrodynamic conditions. The formation of gold-encrusted quartz in a hydrodynamic environment is impossible since, in this environment, the quartz intergrowths from ore gold are first destroyed and removed, and then the appendages of gold particles are flattened [44]. In this regard, it was suggested that the transformation of gold–quartz intergrowths resulted from blows by gold grains under the influence of aeolian processes, which was confirmed experimentally (section methodology).

3.3.2. Characteristics of Pseudo-Ore Gold

Pseudo-ore gold includes gold particles in “growth” with quartz, ilmenite, zircon and other minerals of the host deposits, as well as flake gold particles with casts of pressing-in of minerals, traces of scars, scratches and slickensides on the surface, sometimes with ragged edges or with through holes (Figure 15). The surface of such particles is coarse-pitted and fine-cellular. The size of the gold particles is 0.1–0.25 mm; it is mainly of high fineness with recrystallized internal structures.

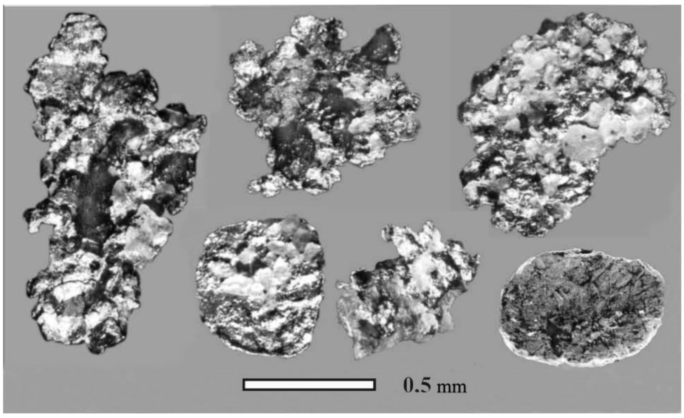

Figure 15. Pseudo-gold appearance.

The genesis of such forms of gold is explained by the influence of the overlying strata’s lithostatic pressure on the formed placer, while the minerals of the host deposits are pressed into the particles of gold. Placer gold acquires an ore appearance, which is proved experimentally (see the section methodology).

Three types of placer gold have beenare identified—alluvial, aeolian and pseudo-ore. We first discovered this process when studying native gold from Devonian placers on the Timan Ridge [33], where, as a result of tectonic processes, the formed placer was buried by thick (up to 700 m) deposits. In this regard, the placer’s gold-bearing deposits were subjected to both vertical and horizontal micromovements, which led to the deformation of the placer gold particles. Under the influence of vertical lithostatic pressure, the minerals of the host deposits were pressed in, and with horizontal displacement, scratches, furrows, and slickensides appeared on the gold particles up to the rupture of the gold particles. The process of deformation of gold particles under the influence of lithostatic pressure (vertical and horizontal micromovements), as shown above, was proved by us experimentally.

4. Discussion

The results of studying the typomorphism of placer gold and the mechanisms of its distribution in the east of the Siberian Platform are generalized for the first time. Based on the identified typical morphological features, it is pseudo-ore. In this connection, the following genetic types of placers were first identified in the studied area—alluvial modern and ancient (gold-bearing intermediate sources), aeolian (unconventional type).

In hydrodynamic conditions, gold grains, regardless of their shape, flatten, which is proved experimentally [43,44]. In the east of the Siberian Platform, flake and lamellar gold particles are observed in all alluvial bar placers. Slightly processed autochthonous ore gold in modern alluvial deposits was found locally—in the basins of the Eekit, Ebelyakh (Morgogor) rivers, the middle course of the Anabar River, as well as in the southeast in the middle Lena basin at the mouth of the Bolshaya Patom, Kamenka, and the Tokko and Torgo rivers [60,61]. For the first time, native gold of ore appearance (“Anabar” type) was identified by Shpunt [1] in the northeast of the Siberian platform. Identification of “ore” gold along the entire length of the Morgogor River (25 km) indicates the presence of an ore source in the riverbed itself [62]. The presence of gold particles of ore appearance in alluvial placers in well-rounded flattened gold particles indicates just an additional supply of gold from the ore source.

In gold-bearing deposits, placer gold does not retain its morphological features but acquires a pseudo-ore appearance [47]. It is defined that gold of pseudo-ore appearance and gold particles, which surface records the casts of pressing-in of host strata's minerals, are widely distributed in the Quaternary alluvial deposits in all watercourses of the east of the Siberian Platform (Figure 16a–f). Such native gold is found at the Lena–Viluy interfluve in the river basins of the Viluy and the middle Lena, and in areas of erosion of the Ukukut formation of the Jurassic age, and the Anabar-Olenek interfluve of the basins of the Anabar, Eekitrivers, etc. and draining gold-bearing conglomerates of different ages. Earlier, previous researchers identified this gold as ore—"beligs-khaisky" [2] and "Olenek" [1] types of native gold (intergrowth of gold with quartz, ilmenite and other minerals), which gave them the reason to assume that the ore mineralization was superimposed on the gold-bearing intermediate sources of the Permian and Jurassic age.

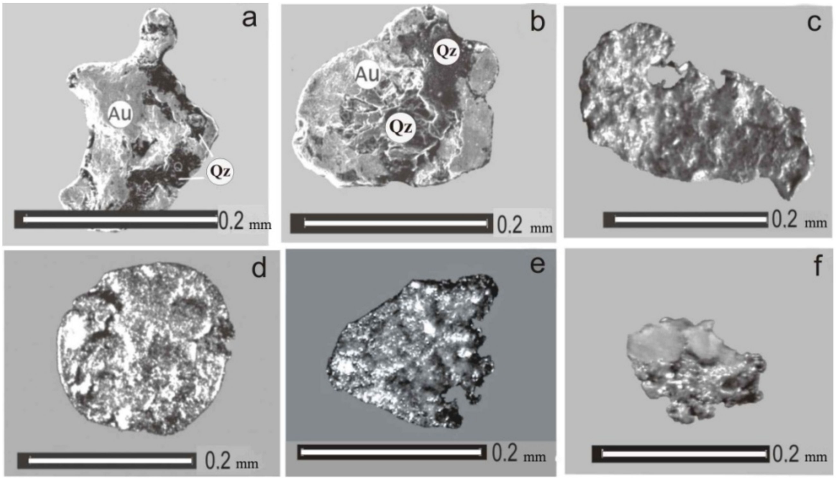

Figure 16. Pseudo-ore gold from deposits of different ages in the east of the Siberian Platform: (**a**,**b**) pseudo-intergrowths of gold (Au) with quartz (Qz), Lena–Anabar interfluve; (**c**,**d**) flake gold particles with casts of pressing-in on the surface of the minerals of the host deposits of the middle Lena basin; (**e**,**f**) flakes with ragged edges and depressed quartz on the surface of the Lena–Viluy interfluves.

Identified morphological features of native gold allowed us to refer to pseudo-ore one. This is due to the fact that native gold in ancient deposits undergoes several changes as a result of the impact of the lithostatic pressure of the overlying strata; in this case, there is a false " intergrowth" of native gold with quartz, ilmenorutile, zircon and other minerals of the host rocks, and in case of horizontal movements—the genesis of interstitial formations, splinters, hooks, needles and other forms. Pseudo-ore gold often forms aggregates, as it were, "intergrowths" of native gold with quartz and other minerals, which are not typical for intergrowths of "ore" gold since they do not have strong contacts of intergrowth of native gold with minerals (Figure 16). The surface of pseudo-ore gold from ancient conglomerates has a coarse-pitted, lumpy, fine-cellular microrelief, with casts of pressing-in of minerals of the host deposits. They differ from the primary casts of ore minerals by rounded shapes with no sharp appendages on the edges of the pits and from corrosion structures of the relief of supergene zones by a wider range of pits from 0.01 to 0.05 microns. Angular, elongated dents in the form of scars, longitudinal furrows, scratches, and areas of a mirror-polished surface are observed on the surface of gold particles.

This native gold is found in all alluvial bar placers and is represented by allochthonous well-rounded particles, mainly flake and lamellar forms with signs of pressing-in on the surface of minerals of the host deposits. They have a size of 0.1–0.25 mm, high fineness, are characterized by a practical absence of trace elements, and by recrystallized internal structure and thick high-grade shells. The presence of flaky gold with signs of pressing-in on the surface of the host deposits' minerals indicates only the supply of native gold from gold-bearing intermediate sources of various ages.

Pseudo-ore gold, along with aeolian-shaped gold particles, was also first discovered by us in the Devonian conglomerates of the Timan Ridge [33]. Previous researchers explained the presence of "ore" gold by superimposed gold mineralization on the formed ancient placer [14,46]. In this regard, intensive searches were conducted in this area to find ore sources. However, we have revealed that the gold particles of the "ore" appearance are placer gold, and they are characterized by a coarse-pitted, lumpy and fine-cellular relief, the appendages have rounded outlines, and on the edges of some "ore" gold particles, relicts of ridges and a film-fibrous surface acquired in aeolian conditions were found. Sometimes in the "ore" gold, a capture of rounded minerals and pseudo-intergrowth of gold particles with quartz, ilmenorutile, garnet, etc., is observed. The casts of pressing minerals are characterized by a rounded shape and lack of growth facets. Identified morphological features in gold indicate its exogenous nature.

In the analysis of typomorphic features of placer gold in the Lena–Viluy and the Anabar-Olenek interfluves of the East Siberian platform, previously identified by Izbekov [2]—"beligs-khaisky" and by Shpunt [1]—"olenek" types of placer gold of ore, appearance was referred by us to pseudo-ore gold [47]. Gold of pseudo-ore appearance has been found in all watercourses in the east of the Siberian Platform [60]. The presence of gold of a pseudo-ore appearance indicates that the placer occurrences were formed due to the arrival of gold from ancient gold-bearing intermediate sources and not from primary sources. Thus, identifying pseudo-ore gold in alluvial placers is a specific criterion for determining which sources formed a gold-bearing placer (gold ore or gold-bearing intermediate sources).

Based on the identification of "ore" gold, called the "olenek type" by B. R. Shpunt [1], the Yakutskgeologiya conducted prospecting work to find ore sources of native gold in the Permian conglomerates of the Olenek uplift in the Sololi River basin, in the late 80s. However, we found that there are no signs of superimposed mineralization on this object. Recommendations on the inexpediency of searching for ore sources both in the Sololi River basin in the east of the Siberian Platform and in the Devonian conglomerates of the Ichet'yuTimanRidge were given by "Yakutskgeologiya", "Polyarnouralgeologiya", Ukhta Expedition. Thus, the discovery of pseudo-ore gold indicates only the supply of native gold from intermediate sources and not from primary sources, which serves as a morphogenetic criterion for determining the provenance of the gold placer.

The discovery of gold particles with signs of pressing of minerals of the host deposits and pseudo-ore gold in the gold-bearing deposits of the Paleozoic and Mesozoic in the east of the Siberian Platform is typical for all platform areas and served as the basis for the search for gold ore sources. It should be emphasized that the native gold of the ore appearance of the Proterozoic conglomerates of the Witwatersrand has the same shape and origin [24]. The identification of pseudo-ore gold indicates just the presence of gold-bearing conglomerates but not gold deposits. Identified morphological features of pseudo-ore gold can be a criterion for determining which sources formed the placer (ore or gold-bearing intermediate sources).

In aeolian conditions, regardless of the shape, native gold tends to acquire a ball shape. As a result of experimental, mineralogical and field studies, a new morphological type of placer gold—aeolian and a new genetic type of placer—aeolian were identified and proved [63]. The unusual forms are the result of the mechanical transformation of native gold in aeolian conditions. A detailed study of the typomorphic features of aeolian gold showed that it has certain morphological forms, granulometry, chemical composition and internal structure. Aeolian gold is not only of mineralogical interest but also forms high commercial concentrations, for example, the Witwatersrand deposit [25]. It is widely distributed; it occurs in deposits from the Proterozoic to the Cenozoic and is typical for all platform areas [4].

Experimental and mineralogical studies have proved that in the east of the Siberian Platform, the types of gold particles previously identified by Izbekov [2]: "baaginsky"—

toroidal, "chokulsky"—spherical hollow (globular), "kyuellyakhsky"—lamellar and tabular with rounded edges, lumpy, Shpunt [1] "udzhinsky" (toroidal and globular) are of aeolian origin. Formation of "baaginsky","chokulsky", "udzhinsky" types of placer gold is associated with the mechanical transformation of flake gold in aeolian conditions into a toroidal and then into a spherical hollow form [49]. The origin of the gold "kyuellyakhsky" type is explained by transforming the more massive lamellar, tabular, lumpy and rod-like shapes that form trough-shaped, canoe-shaped, disc-shaped, etc., and also massively lumpy and dumbbell-shaped gold particles with a film-fibrous surface, acquired in aeolian conditions.

A detailed study of typomorphic features of aeolian gold and mechanisms of distribution in the East Siberian platform made it possible to determine that aeolian gold of toroidal and spherical hollow form (transit gold) is widely observed in the territory of the Lena–Viluy and Lena–Anabar interfluves. On some objects, there are massive gold particles (deflationary gold), lamellar, tabular with ridgelike edges, and lumpy-spherical forms with signs of aeolian transformation (Figure 17a–i).

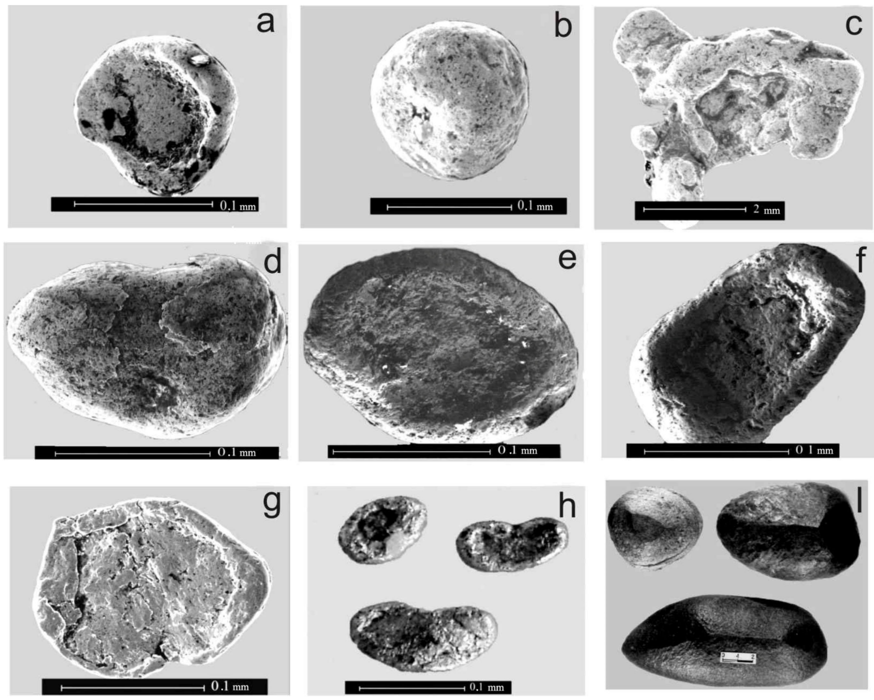

Figure 17. Gold with signs of wind-worn processing and ventifacts from the Quaternary deposits of the East of the Siberian Platform: (**a**–**c**) Lena–Anabar interfluve; (**d**–**f**) Lena–Viluy interfluve; (**g**,**h**) basin of the middle course of the Lena River; (**i**) ventifacts.

Aeolian gold (transit gold) forms high concentrations in the heads of the rivers of the Lena–Anabar and Lena–Viluy interfluves, where the basal aeolian horizons of the Cenozoic deposits formed during the Quaternary glaciation are eroded (sartanskoe, karginskoe, etc.). The producing layer overlaps the deflationary surface in a blanket-like manner and is complicated by jet fans. This layer has a low thickness (no more than 15–30 cm), is represented by pebble-gravel deposits with a low content of clay fraction, where there are gold particle sand associate minerals with signs of wind-worn processing, as well as ventifacts (Figure 17i).

The sites of the finds of aeolian gold are well correlated with the fragmentally developed surfaces of deflationary palaeodeserts, which halo can be reconstructed from the finds of ventifacts [45]. Gold particles with signs of wind-worn processing (flakes with ridgelike edges) with a size of 0.1–0.25 mm have an extensive halo of dispersion (transit) compared to aeolian gold particles larger than 0.25 mm (deflationary) since the latter isnot transported over long distances due to their massiveness (aero-size). Therefore, it is possible to discover a deflationary gold placer by the halo of the distribution of toroidal and spherical hollow gold particles, which can serve as a search morphogenetic criterion for the aeolian type of placers.

Gold particles of aeolian-type in the natural environment are most likely formed in the zone of aeolian denudation. It is assumed that the grains of sand, drawn by the airflow, bombard the golden particles brought by denudation to the surface of the day. In this regard, there is a gradual deformation of the gold particles and their transformation.

Analysis of the mechanism of distribution of gold particles with signs of wind-worn processing based on the literature data and collections provided by Russian scientists allowed us to determine that toroidal and spherical hollow forms (aeolian gold) are widely distributed on all platforms of the world and are found in sedimentary deposits from the Proterozoic to the Cenozoic (Figures 1 and 18a–i).

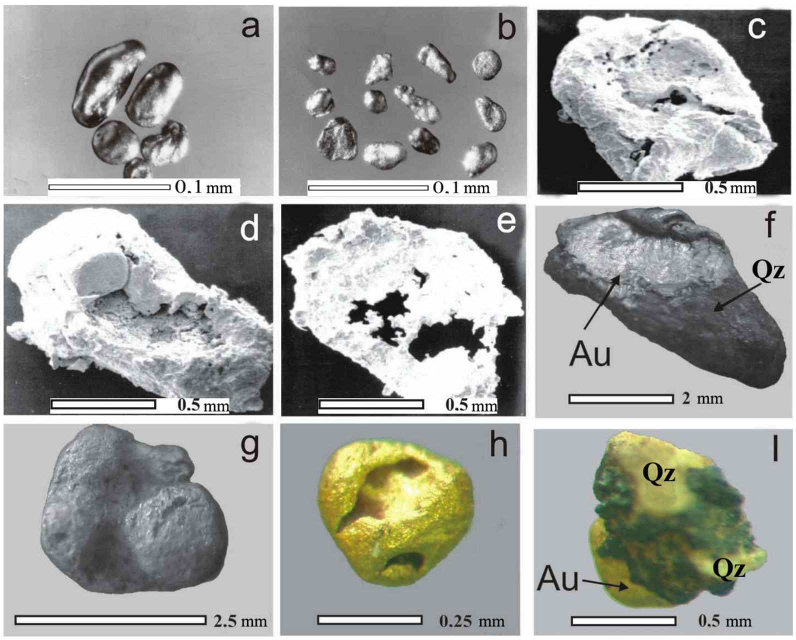

Figure 18. Gold particles with signs of wind-worn processing of platform areas, as well as on the territory of Tuva and Mongolia: (**a**,**b**) Russian [41]; (**c**–**e**) African [37]; (**f**,**g**) Tuva (TIIDNR); (**h**,**i**) Mongolia (IGM SB RAS).

Gold grains of a similar shape have been found on the Siberian, East European, North American, South American, African, and Australian platforms [4]. An extensive halo of dispersion of toroidal and spherical hollow gold was first identified in the Siberian Platform deposits of different ages. Massive gold particles with signs of wind-worn processing were found in the ancient Precambrian metaterrigenous rocks of the Baltic Shield [11] in the Northern Urals [12], in metal-bearing conglomerates of the Devonian age of the Timan Ridge [33], as well as in fluvioglacial deposits of the Cenozoic age of the Kola Peninsula [34] and in the central part of Russia [13,15,29,30,35]. Similar forms of gold particles were also found in deposits of different ages in the Scandinavian countries, France, Czechoslovakia, and Cyprus [18,19,21,26]. On the North American platform, spherical hollow forms of gold are observed in the alluvial deposits of the Alberta deposits in Canada, Abitibi—the province of Ontario and states of Oregon and Alaska—Colorado, Klondike and Nome [16,22,23]. In the south of the American platform, gold particles with signs of wind-worn processing were found in placer deposits of Bolivia, Colombia, Panama, Ecuador, and in the south-eastern part of Africa—in Mozambique, Zimbabwe, and Tanzania [22,58]. On the African platform, aeolian gold particles were found in the Baffing River basin (Republic of Guinea), in the Kangaba (Mali) deposits [28] and in the

Witwatersrand [25,64]. On the Australian platform, spherical hollow forms of native gold were found in alluvial deposits [17]. Native gold of a similar shape is found in the alluvium (Papua New Guinea) [20], in the Yinan deposit (China) [27]. Aeolian gold was discovered in Mongolia (Samar Mine) and Tuva (Tanku-Tuva).

Massive gold particles with signs of wind-worn processing are not so widely found since the alluvial signs of this gold are less evident, in contrast to the morphological features of toroidal and spherical hollow forms. In this regard, it was usually taken for alluvial gold. This gold was found in a number of objects of the Anabaranteclise [1], the Viluysyneclise [2], as well as in the Urals [12] and in Mongolia and Tuva [4,36]. Thus, gold with signs of wind-worn processing is widely distributed on all platforms of the World and adjacent territories in sedimentary deposits from the Proterozoic to the Cenozoic [4] (Figure 1).

Based on the discovery of native gold particles with signs of wind-worn processing, it is determined that aeolian placers of gold can occur both due to the direct destruction of the ore source and due to previously formed proluvial alluvial and coastal-marine placers. In this connection, in the east of the Siberian platform and in other studied territories (the East-European platform, Mongolia, Tuva, etc.), aeolian placers (autochthonous and allochthonous) and placers of heterogeneous origin (aeolian-proluvial, aeolian-alluvial, etc.) are identified. Since gold particles with wind-worn processing are not only of mineralogical interest but also form high concentrations of metal, the conclusion about the prospects of discovering aeolian placers of gold of various ages on all platforms, as well as on the territory of Tuva and Mongolia, is proved.

In general, it is determined that aeolian gold is found in both Proterozoic and Cenozoic sediments and is typical for most epochs of the earth's development, where the aeolian processes intensively occurred. At the same time, it was revealed that aeolian gold has not only a scientific "mineralogical interest" but also forms concentrations on a commercial scale. For example, the famous Witwatersrand deposit—here, the aeolian forms of gold deposits form high metal contents in specific deposits (conglomerates), where ventifacts are noted, and clay material is practically absent [25,64].

The extent of the influence of aeolian processes on the formation of placers is poorly understood. In the existing classifications, only the hydrodynamic factor of the formation of these placers is considered. However, Vernadsky [65] described the aeolian placers of gold found in Western Australia in Kalgoorlie and Kolgurla: "The richest placers lay on the very surface and towards the bottom the placer gold-depleted" (V. II p. 161–162). Shilo [66] believed that the development of the problem of the formation of aeolian gold placers deserves special attention and can serve as a basis for improving the search and exploration work for the discovery of aeolian gold placers and methods for their study. The arid climate is most favorable for the formation of gold-bearing aeolian placers. However, the literature data analysis showed that even during the glaciation, aeolian processes also played an important role in sedimentation, which affected the formation of the landscape [46] and, undoubtedly, the nature of placer formation and transformation of gold particles. We found aeolian landforms (basins) (deflation grooves, etc.) on the modern landscape of the east of the Siberian and East-European platforms, as well as on the territory of Mongolia and Tuva [4]. It is revealed that in the sediments composing these landforms, the presence of aeolian gold particles and minerals with signs of wind-worn processing and ventifacts is reported. Aeolian processes affected the formation of placers in the Quaternary and the ancient epochs of the earth's evolution. This is evidenced by the revealed signs of aeolian activity (the presence of aeolian gold particles and ventifacts, a thin producing horizon, etc.) in the Devonian placers of the Timan Ridge [33] and in the Witwatersrand field with a huge gold content [25].

Based on the discovery of gold particles with signs of wind-worn processing, it is determined that aeolian placers of gold can occur both due to the direct destruction of the primary source and due to previously formed proluvial alluvial and coastal-marine placers. In this connection, in the east of the Siberian Platform and in other studied territories (the East-European Platform, Mongolia, Tuva, etc.), aeolian (autochthonous and allochthonous) placers and placers of heterogeneous origin (aeolian-proluvial, aeolian-alluvial, etc.) are distinguished.

The presence of massive gold particles with signs of wind-worn processing in the deposits indicates the formation of an autochthonous aeolian placer in this area. Aeolian placer is characterized by a specific structure of the producing horizon, which covers the deflationary surface in a blanket-like manner, is complicated by jet fans, and has a low thickness (10–30 cm). This horizon is represented by a pebble-gravel material with a low content of clay fraction, with the presence of ventifacts and massive gold particles with signs of wind-worn processing. The formation of autochthonous aeolian placers with the presence of aeolian gold particles is possible not only in the platform areas but also in the territories of Mongolia and Tuva. The discovery of toroidal and spherical hollow gold indicates the formation of an allochthonous aeolian placer in this area. These placers are characterized by a high differentiation of aeolian gold, presence of toroidal and flake gold particles with thin ridgelike edges. Gold particles here are a transit metal and are characteristic of both autochthonous and allochthonous aeolian placers. The formation of such placers is possible both in the basins and in the deflation grooves. Gold particles of a very fine fraction less than 0.1 mm can be found in dune deposits, but they are not of commercial interest.

5. Conclusions

Based on the identified typomorphic features of placer gold, a set of determined morphogenetic criteria is proposed to identify the genesis of placers and different sources in the platform areas, which allows more correctly selecting search methods and improving the efficiency of forecasting ore and placer gold deposits. The discovery of native gold with signs of wind-worn processing in Quaternary deposits indicates aeolian placers' formation. Gold particles with signs of wind-worn processing (flakes with ridgelike edges, toroidal and spherical hollow) with a size of 0.1–0.25 mm, forming an extensive halo ofdispersionin the Quaternary deposits (allochthonous placers), were identified by us as transit gold according to sieving. Gold larger than 0.25 mm with signs of wind-worn processing (lumpy with rounded appendages with a film-fibrous surface, etc.) is less common and belongs, in terms of sieving, to a deflationary metal. This gold is not transported over long distances and forms autochthonous placers. The presence of disc-shaped and lamellar gold particles with ridgelike edges in alluvial placers is typical for placers of heterogeneous origin, formed due to deflation of proluvial placer. Deflationary (autochthonous) placers of native gold can be found by the halo of its distribution of toroidal and spherical hollow forms, which, of course, are the search morphogenetic criterion of aeolian placers.

The discovery of pseudo-ore gold in alluvial placers only indicates the arrival of gold from intermediate gold-bearing sources of different ages and not from primary endogenic sources, which is a morphogenetic criterion for determining different sources of the placer. In modern gold placers, the presence of native gold of a pseudo-ore appearance can serve as a search criterion for the discovery of gold-bearing conglomerates with a high gold content, which are ancient buried placers of various ages, for example, the placer of the Devonian age of Ichet-Yu (TimanRidge) or the Permian placer of Sololi (Olenek uplift).

Thus, the determination of the genotype of placer gold by morphological features (alluvial, aeolian) makes it possible to more correctly reconstruct the geological-geomorphological conditions of placer formation and, thereby, increases the reliability of the forecast and the efficiency of the search and mining of placers. The discovery of gold of pseudo-ore and ore appearance in the Quaternary alluvial deposits makes it possible to identify which sources formed the modern placers—ore or intermediate gold-bearing deposits (ancient conglomerates), which contributes to the improvement of the methods of search and exploration of placer and ore deposits of gold. The method developed for diagnosing the genotype of placer gold by its morphological characteristics (alluvial, aeolian, pseudo-ore) can be successfully used by production geological organizations to search and explore ore and placer gold deposits.

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