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Lithological Prerequisites of the Concentration of Small and Fine Gold Particles in the Differentiated Alluvium

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Abstract—Comparison of the lithological indicators of differentiated alluvium in and beyond the concentration zone of small and fine gold particles (size class 0.05–1.0 mm) allowed the correlation of mineral placer formation with the sedimentary process in the river bed. The study object is represented by Quaternary alluvial sediments in different Yakutian regions that reflect the diversity of settings of recent lithogenesis in river basins. The revealed correlation makes it possible to use the classical concepts of regularities in alluvial sequences for modeling the structure of the spit-type placer.

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The accomplished study is related to an insufficiently examined field of scientific knowledge pertaining to the formation and structure of placers of "active" gold particles that can migrate in channel flows and are transported beyond the primary source erosion zone. Constraints of their concentration during the sedimentary process are debatable at present. In the modern reference literature (*Slovar* ..., 1985), this genetic ("spit") type of alluvial placers is assigned to a simplified (in terms of the accumulated scientific knowledge) "archaic" concept as recent accumulative bodies in river channel that continuously change location and configuration, ruling out their preservation in the sedimentary sequence. Such concept contradicts our finds of high concentrations of small and fine (0.05–1.0 mm) gold particles in the alluvial sediments on floodplains and terraces. It should be noted that gold particles of this dimension are the largest ones in the "mobile" fraction. Heavy concentrate aureoles of such gold particles are fixed reliably during the geological survey, and a rational method has been proposed for their extraction from alluvium samples (Lunev and Osovetskii, 1979).

PROBLEMS AND METHODS

Facts of lithologically discriminated alluvium horizons with high contents of small and fine (hereafter, SF) gold particles in the alluvium are known, but such units are differently (often contradictorily) interpreted. For example, the study of sediments in the Amur basin revealed that they are mainly concentrated in the boulder–pebble sediments that make up surficial horizons of accumulative bodies (Flerov, 1937). The coarse-clastic material of alluvium is considered a factor promoting the precipitation of gold particles. In this connection, it is noteworthy that we had also detected high concentrations of SF gold particles in sandy sediments of the Vilyui River.

Large-scale lithological sampling of alluvium was carried out in connection with SF gold concentration therein in the Upper Kama basin of the Russian Platform (Lunev et al., 1980). River sediments of this region show direct correlation between the concentration of SF gold particles, the yield of heavy mineral fraction, and the content of ore components therein. This is typical of the differentiated sedimentary sequence. However, based on the high content of clay particles, the auriferous lenses in the alluvium were assigned to low differentiated sediments characterized by chaotic distribution in the sedimentary sequence. It should be noted that the above researchers did not take into consideration the high degree of grain size sorting in the clastic material of separate sand–silt and boulder–pebble dimensions in the lenses containing gold particles. Therefore, their formation and distribution can be attributed to the sedimentary differentiation and the structure of the host alluvial formation.

The author of the present paper was a coauthor of the above-mentioned lithological work. Therefore, this correlation should be considered a continuation of the lithological work based on riverine sedimentary basins of the Yakutian region. Resolution of this problem makes it possible to use classical concepts of regularities in the formation of alluvial sequences for modeling the placer deposit. We studied the differentiated alluvium (sedimentary sequence) including all facies of river sediments. Such sequences can provide the most reliable establishment of relationship between the distribution of gold particles and indicators of sedimentary process. The trends deciphered in this way can also be traced in the "embryonal" forms of alluvial deposits. Among the lithological indicators, attention was paid to the sedimentary sequence fabric (structural indicator), grain size composition of clastic material (textural indicator), and mineral composition of the heavy fraction (mineralogical indicator). All these indicators are fixed reliably during the visual and geophysical study of alluvium, and the information obtained in this process is only supplemented with laboratory analyses.

Choice of objects for the lithological study of auriferous alluvium (central Yakutian lowland, Lena plateau, Aldan highland, and Ol'chan–El'ga midland) was dictated by diversity of the riverine sedimentation setting, which indicates the universal character of regularities in the concentration of gold particles. The study was complicated by the absence of reliable data on the distribution of SF gold particles in lithological varieties of river sediments. This situation also governed the methodological orientation of our work (Blinov, 2001). The results of this work supplemented the well-known principles of the study of auriferous alluvium formulated in works of the Useful Mineral Dressing Laboratory, Perm State University (Lunev and Osovetskii, 1979).

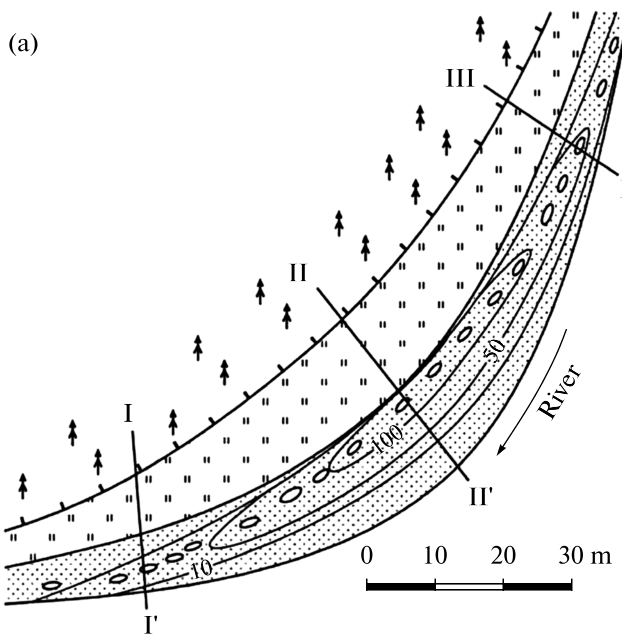
Necessity of comparing the lithological peculiarities of river sediments and the degree of gold particle concentration defined the complex sampling mode. Alluvium samples (more than 1500) were taken mainly from walls of mine workings (pits, trenches, and escarp strippings of floodplains and terraces). We took ordinary samples for the mineralogical study of bulk samples (usually 25–100 L in volume), which were enriched directly at sampling sites by our field teams using spiral gravitational devices (IRGIREDMET model). Application of this dressing apparatus was dictated by its specialization in extracting mineral concentrate of SF gold particles (Ivanov et al., 2000). Visual estimation of the Au content in river sediment samples allowed us to sort out alluvium sections and choose reference samples designed for the lithological investigation. As samples for the lithological study (the fine-clastic constituent of alluvium samples), mineral concentrates of dressed samples were studied in the laboratory using traditional methods of the grain size distribution and mineralogical analyses. At the lithological sampling sites, we examined the grain size distribution in the coarse-clastic component of alluvium samples and the petrophysical (magnetic susceptibility logging) analysis of its fine-clastic material. It was theoretically substantiated that the concentration of SF gold particles in the alluvium is confined to the channel bar (CB) facies (Blinov, 1998). This observation made it possible to specify the object for lithological study.

E.V. Shantser (1951) believed that the alluvium facies builds up during the flood season simultaneously over the entire river valley floor due to the scattering of different size clastic particles. The alluvial sediments are considered not as a chaotic alternation of lenses and layers of different lithologies but as a regular alternation of strictly defined facies (sediments). According to the above researcher, such alluvial sequence reflects the sedimentation history of the river valley. Regularity in the structure of the sequence ("normal" alluvium structure) is expressed as a sequential superimposition of beds of the finer sediments. It should be noted that Shantser noted this regularity for an equilibrium dynamic phase in the evolution of the river valley segment, where the river bed is marked by lateral (coastal) erosion and formation of alluvium of normal thickness, with the most complete development of all sedimentary facies. Therefore, precisely alluvium of this dynamic accumulation phase was chosen for study.

STRUCTURAL INDICATOR OF GOLD CONCENTRATION IN ALLUVIUM

As is known, the spiral motion of water flow is manifested in the river channel of any size and shape but most intensely at the curvature of its dynamic axis. In distal zones of such segments, the channel bar (CB) alluvium includes the above-mentioned "normal" (fine-clastic to coarse-clastic) succession of beds. This order is distorted only at curvatures of the river channel due to a unique (in intensity) transverse water circulation during floods, resulting in dislocation of the coarse-clastic material from the midstream flow zone along the channel bar slope toward the floodplain. Its depocenters correspond to levees during a drastic retardation of water current (Makkaveev, 1955). Velocity drop of the transverse (relative to river channel) water flow shows direct correlation with the ridge height and reaches maximum at the channel bar edge, where the water overflows the floodplain to make up the uppermost alluvium horizons of the CB facies. Thus, deposition of river sediments in such high water segments is characterized by distortion of the normal succession of beds: the sedimentary sequence includes rhythms characterized by coarsening rather than thinning away of the clastic material. Moreover, the coarsest clastic rhythms are recorded at the uppermost levels of the CB facies.

This statement is consistent with the hydrological observations: owing to widening of its effective area, maximal slowdown of water flow takes place precisely at the channel bar edge. Here, the river flow is subjected to hydrodynamic transformations ("kinematic effect") attributed to both deceleration of water flow and its shallowing (Chernov, 1983). This process leads to backwater flow from the floodplain, resulting in dumping of the whole coarse-clastic material at the shoal edge. In addition, the kinematic effect in this segment of the channel flow is manifested in intensification of its turbulence that also promotes the precipitation of heavy mineral particles in these zones. We recorded maximal contents of gold particles precisely



(b)

Profile	Upper edge (floodplain surface)	Lower edge (waterline)
I–I'	13.0	15.0
II–II'	37.0	5.0
III–III'	4.3	16.0

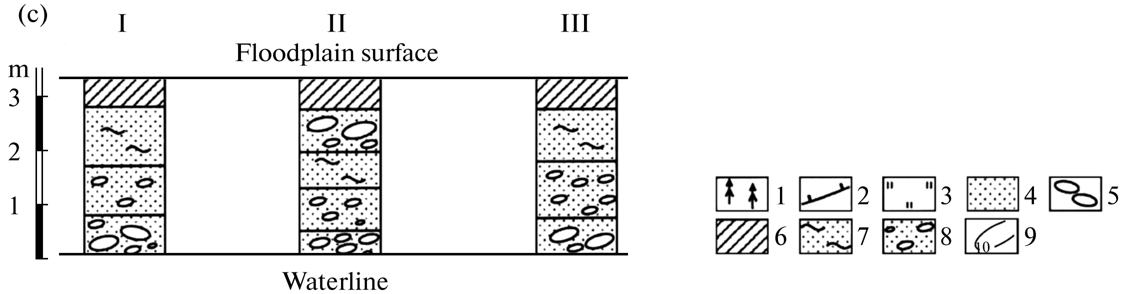


Fig. 1. Distribution of the coarse-clastic material in the plan view and cross-section of recent alluvium in terms of their gold potential (Vilyui River, middle reaches, right bank, 672 km along the channel). (a) Schematic geomorphology of the alluvium sampling area in the young floodplain segment; (b) variation of the share (wt %) of the boulder–pebble material along profiles of the channel bar; (c) lithological columns of the channel bar in the young floodplain segment. (1) Old floodplain segment; (2) edge of floodplain segments; (3) young floodplain segment; (4) recent channel bar; (5) area containing the coarsest material on the CB surface (ridge debris axis); (6) floodplain facies alluvium; (7) sand horizon of the CB facies (with silt layers); (8) horizon with large fragments; (9) isolines of the gold particle content in the surficial horizon of the recent channel bar (arbitrary units).

in such segments of the present-day channel bars. Such kinematic effect is manifested to a variable extent on the ridges of all levees formed during the accumulation of CB facies alluvium at the channel curvatures.

As mentioned above, with increasing distance from such area upward and downward the river current, sedimentary sections show the normal superimposition of beds: their top is marked by fine-grained material with subordinate gold particles. For example, Fig. 1 shows a schematic plan view and structure of one newly formed floodplain segment at the gold concentration site in the recent CB facies alluvium. Numerals show variation in the content of boulder size clasts in the transverse profiles of different segments of the channel bar extending from its upper edge to the low-water level. The highest boulder content was recorded in the debris ridge. Lithological columns demonstrate positions of the coarse-clastic horizon at different segments of the newly formed floodplain segment: this horizon occurs on the surface of the ridge crest and is enriched in gold particles. Thus, if gold aureole is developed in the present-day channel, prospecting for placer deposit should be aimed at study of the adjacent floodplain segment for detecting the given lithological anomaly. Some reports pertaining to previous prospecting works suggest that such study was carried out with iron rods. In floodplain segments of this type, exposure of the coarse-clastic alluvium horizon affects the ground vegetation in some areas. Figure 2 shows an exposure of the boulder–pebble horizon in a newly formed floodplain segment. The stony pattern of the river soil is emphasized by the vegetation composition (poplar and cedar elfin wood overgrowth).

Fig. 2. General view of the newly formed floodplain segment at lower reaches of the El'ga River (Indigirka Basin) in the small and fine gold concentration area (left bank, Belichii prizhim area).

GRAIN SIZE INDICATORS OF GOLD CONCENTRATION IN ALLUVIUM

As mentioned above, specific bedding pattern of river sediments in the SF gold concentration areas is primarily related to the river flow structure. B.S. Lunev (1967) examined peculiarities of alluvium differentiation and noted the following indicator of sediment sorting (based on the work of D.V. Nalivkin): ratio between the amounts of particles of a certain size and the amount of particles of other sizes. According to Lunev, highly sorted alluvium is typical of aggradational plains, but its formation in the channel requires the abundance of representative clastic material in the solid runoff. Taking this prerequisite into consideration, we discuss below peculiarities of the quantitative ratio of clastic particles of coarse and small classes in the river sediments with different degrees of gold concentration, as well as correlation of the modal dimension of particles. It is shown that these peculiarities are also manifested (although weakly) in the auriferous alluvium of mountain areas, where the sedimentary differentiation of clastic material has not reached the mature degree.

Grain Size Distribution Profile of the Coarse-Clastic Component of Alluvium

According to (Osovetskii, 1993), structural maturity of the coarse-clastic alluvium is expressed in modal dimensionality of the clastic size particles and decrease of the gravel size particles therein. Hence, our data on the grain size distribution in the coarse-clastic component of sediments suggest that the auriferous sediment of the CB facies corresponds to the structurally mature alluvium samples. Based on the study of grain size distribution in sediments of the Vilyui River (Table 1), we revealed the following variation trend in the ratio of size classes of clastic material along the vertical section of a sedimentary sequence in the SF gold concentration zone. Here, the content of fine-clastic material in the sediments is considered for the size class <5.0 mm.

Analysis of the obtained material suggests the following conclusion: structural maturity of sediments reflected in the grain size composition of the coarse fraction varies in different segments of the channel. For example, the present-day erosional section at middle reaches of the Vilyui River (916 km along the river channel) includes a conglomerate pile, which provides a sufficient amount of pebble size clasts in the channel. Here, the CB facies section exposed in the gold concentration zone is enriched in pebbles and is marked by abundance of boulders in the upper horizon with the highest gold content. The modal class of coarse clasts in this section is contrasting in weight and corresponds to the coarse-pebble dimension. In the lower horizon of this facies section, we recorded several low-weight modal size classes and the gravel size component plays a significant role. At lower reaches of the Vilyui River (386 km along the river channel), the alluvium is depleted in the coarse-clastic material because of the predominance of sandy sediments in

Table 1. Results of the grain size analysis of samples from different horizons of the channel shoal facies of auriferous sediments in the Vilyui River

Grain size class, mm	Yield of size classes (wt %) in the CB facies horizons					
	916 km along the channel			386 km along the channel		
	upper	middle	lower	upper	middle	lower
+100	10.3	–	–	–	–	–
80–100	55.9	6.9	1.2	2.2	–	–
40–80	16.4	36.2	9.6	6.7	2.2	3.8
20–40	1.8	14.5	6.6	25.5	15.5	17.9
10–20	1.2	4.3	9.3	20.0	20.0	20.4
5–10	0.4	1.1	3.3	4.1	4.4	7.5
–5	14.0	37.0	70.0	41.5	57.9	50.4

(–) Clastic material of the given size class is absent.

the provenance. This segment of the channel lacks conditions needed for the mature grain size distribution in the coarse-clastic sediments. Their bulk content varies little across the sedimentary sequence, and the weight fraction of their modal size class is insignificant. Nevertheless, as in the previous case, clasts at the CB facies top are represented by the coarser size class. It should be mentioned that alluvium in the estuarine segment of the river is even more depleted in the coarse-clastic material. Here, gold particles are often concentrated at the sandy sequence top marked by a minor content of gravel and pebbles.

Analysis of the composition of clasts in different horizons (Table 1) also suggests that the degree of sedimentary differentiation is a function of time for a specified site of CB facies accumulation, resulting in the deposition of more and more sorted sediments. Such peculiarity is also typical of the superimposed sedimentary cycles in the facies section.

In sediments of the El'ga River flowing in the mountain zone (Indigirka River basin), discrimination of the coarse-clastic component of auriferous horizons is markedly weaker because of a low degree of hydrodynamic sorting of clasts in the channel. In this case, in order to decipher structural indicators of gold concentration in the river sediment based on the study of its coarse-clastic component, we should accomplish a fractional grain size analysis of alluvium samples with the determination of statistical parameters of the distribution of clastic particles (Osovetskii et al., 1980). High concentration of gold particles at the top of the CB facies alluvium in a mountain region suggests the presence of clasts of the boulder size (more than 100 cm). Such clasts were, however, omitted in the grain size analysis because of a relatively small volume of the alluvium samples.

Grain Size Distribution Profile of the Fine-Clastic Component of Alluvium

The fine-clastic (size class <1.0 mm) alluvium is a mixture of particles with different rates of precipitation in water. As is known, they are marked by content variation across the alluvium section and retention of the trend of their gradual diminution toward the top of the CB facies and the top of its sedimentary rhythms. Our results of the study of alluvium sections in the gold concentration zone demonstrated retention of this trend of clastic particle distribution. Table 2 presents size classes of small clastic particles in the coarse-clastic alluvium samples from the plain and mountain regions. The table also shows contents of the gravel size clasts (as the adjacent size class) and gold particles. These data suggest that the Au-rich river sediments at the CB facies top in both mountain and plain regions are characterized by increase of small clastic particles (size less than 1.0 mm) that are most mobile in the water flow. This fact indirectly suggests the fluvial transport of SF gold particles together with the fine-clastic material and their joint participation in the sedimentary process. Grain size determination was carried out for small particles (0.1–1.0 mm) that dominate in weight and occur in all horizons of the CB facies. Figure 3 shows the typical plots of sandy particle distribution in different grain size classes of the auriferous alluvium from the plain and mountain regions. Contrast differentiation of the modal size class of grains indicates that they are better sorted in the Au-rich sediments. Moreover, the most contrast structural variation in the sandy component of alluvium is manifested in its depocenters within the plain region. Here, its sorting degree is also reflected in the content of the fine-clastic component. This is demonstrated in the figure as bar chart reflecting the total weight content of its size classes: the value of this parameter is almost two times different in alluvium samples from the plain because of gold concentration. Therefore, we can draw the following conclusion: the high-water channel in this area is most favorable for the differentiation of fine-clastic material; each size class of this material is deposited in a certain segment of the channel bar; and its upper edge is covered by particles of the smallest size class. On the contrary, the low degree of particle differentiation in the river flow of a mountain region is reflected in almost equal con-

Table 2. Variation in the content of size classes of clastic particles in the coarse-clastic alluvium of the channel bar alluvium within the mountain (El'ga River) and plain (Vilyui River) areas in the gold particle concentration zone

Sampling site	Size classes (mm)			Au content
	1.0–10.0	0.1–1.0	–0.1	
El'ga River (lower reaches)	40.0 / 50.0	52.4 / 47.5	7.6 / 2.5	10x / x
Vilyui River (lower reaches)	25.0 / 50.0	73.2 / 44.0	1.8 / 1.0	10x / x

The numeral shows the content (wt %) of size classes in the upper facies horizon; the denominator, in the lower horizon. (x) Au content approximately 100 mg/m^3.

tents of the fine-clastic component in different horizons of the CB facies alluvium. Nevertheless, this region is also marked by refinement of the sorting of sandy grains upward the sedimentary sequence. For example, the modal size of sandy particles is often obscure in the lower horizons of the CB facies. As shown in the figure, this size embraces several coarse size classes. In the upper horizons, the modal particle size is more distinct and usually corresponds to the fine sand class. It should be noted that variation in the sorting of sandy grains is accompanied by gradual variation in the content of gold particles from the lower horizon of the CB facies to the upper horizon. For example, the content in sediments of the Chara River (plain region) varies from n mg to 33.1 g of gold particles per 1 m^3 of washed out rock. This parameter is an order of magnitude lower in the channel bars of the El'ga River.

Contingence of Size Classes of the Clastic Material

The joint analysis of the grain size composition of coarse and small clasts in the CB facies alluvium provides insight into the relationship between their different size classes due to different contents of gold particles. It is noteworthy that the previous generalization of grain size profile of the highly sorted alluvium revealed stable correlation (contingence) between the contents of separate size fractions in the coarse- and fine-clastic components: their modal sizes are contiguous (Lunev, 1967). We established that such grain size composition of river sediments is characteristic of the

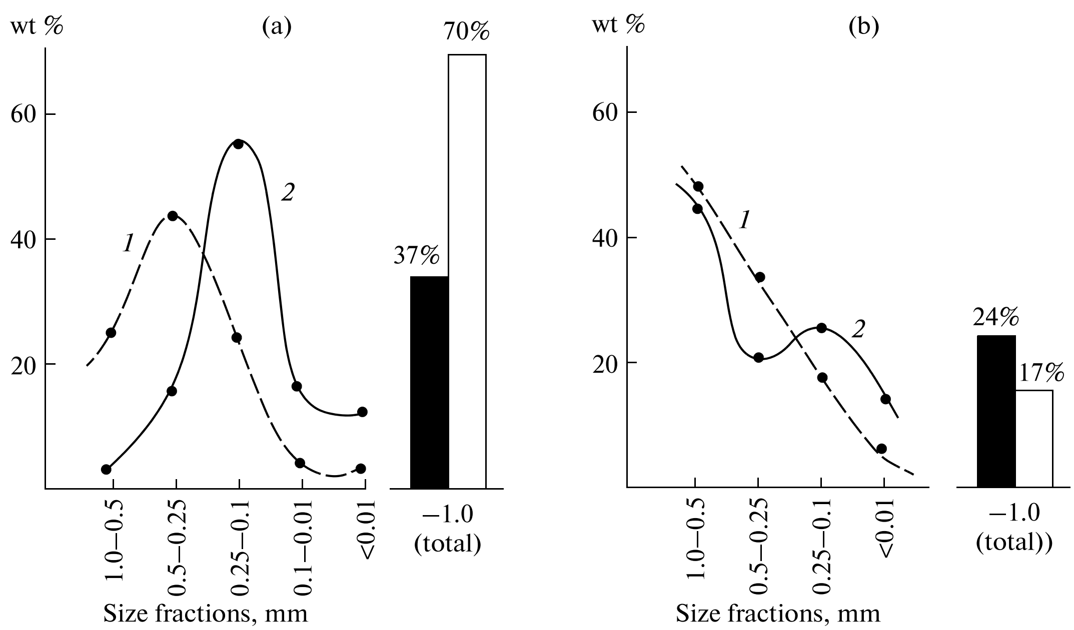


Fig. 3. Size class distribution of fine-clastic particles in the CB facies alluvium samples from the boulder–pebble horizon in the plain and mountain areas. (a) Plots of particle distribution in the alluvium in the plain area (middle reaches of the Vilyui River, left bank, 916 km along the channel); (b) plots of particle distribution in alluvium of the mountain area (lower reaches of the El'ga River, right bank, estuary of the Shirokii Creek). (*1*) Au-rich sediments; (*2*) Au-poor sediments.

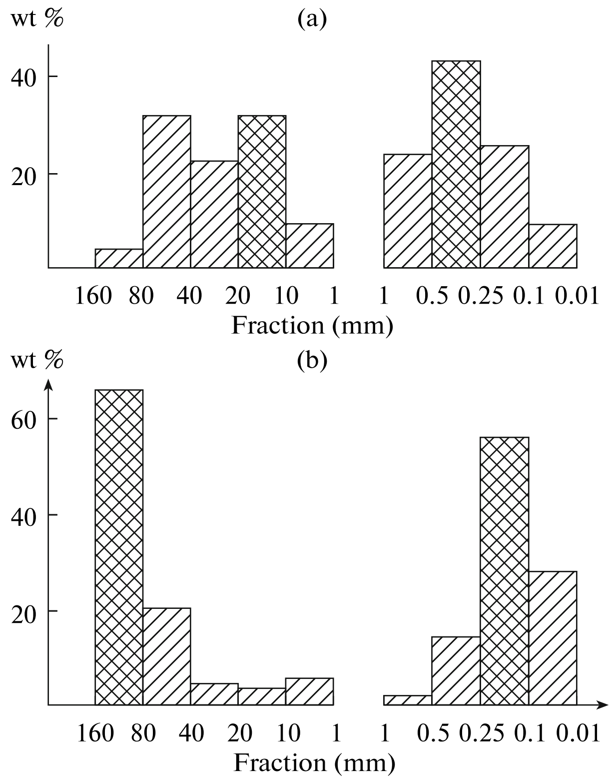


Fig. 4. Contingency of modal size classes of the coarse- and fine-clastic particles in the recent CB facies alluvium with different Au contents (middle reaches of the Vilyui River, left bank, 915 km along the channel).

(a) Alluvium with low Au content; (b) alluvium with high Au content.

channel bar facies beyond the gold concentration zone marked, as indicated above, by the normal superposition of lithological beds. At a sharp river bend, the CB facies alluvium section is characterized by distortion of such conjugation between size fractions of clastic material. For example, modal classes of both distribution types are conjugated in the lower horizons, thus reminding the typical structure of differentiated sediments in the normal alluvium section. On the contrary, the modal classes are most discrete (if the deficiency of coarse clasts in the alluvium is taken into consideration) in the upper horizons with the highest Au concentration.

In the mountain region, the contingence of size fractions is not so explicit in the river sediments because of a weaker expression of their modal size class. In contrast, this structural feature is prominent even during the macroscopic examination of river sediments. Figure 4 shows the comparison of size classes of the clastic material in the most contrast (in terms of gold concentration) horizons of the modern channel bar facies in the Vilyui River valley (middle reaches). It is evident that the modal sizes of small and coarse clastic particles are conjugated in sediments with low gold concentration. On the contrary, modal classes of clasts of the boulder–pebble and sand dimensions are represented by end members of the size series in the Au-rich placer sediments. As mentioned above, such unusual association of size fractions of clastic material reflects specific constraints of sedimentation at the sharp river bend during high water. We believe that clasts of the coarse and small fractions are sorted according to different principles. For example, small clastic particles are sorted during sedimentation according to the hydraulic dimension, and the sequence of their superimposition in the CB facies fits the normal alluvium structure. Sorting of coarse clasts in the channel is governed by the area of their front cross-section facing the water flow force. Such differentiation of particles with respect to resisting forces during the transport with the solid runoff was proposed in the theory of debris formation (Velikanov, 1948). These processes lead to the formation of heterogeneous (in terms of sorting mechanism) river sediments with very specific grain size compositions.

MINERALOGICAL FEATURES OF ALLUVIUM

It is known that the mineral assemblage in aureoles is formed according to the principle of hydraulic equivalency; i.e., grains of approximately equal hydraulic size (velocity drop) are concentrated in the sediment. Hydraulic size, as a function of many properties of mineral particles, depends, in particular, from the flatness of their shape. The measurement results (Blinov and Maltsev, 1983) demonstrated that equant grains of ore minerals settle down at the same rate as flattened gold particles, which are highly characteristic of ore deposits. Therefore, hydrodynamic sorting of clastic material in the channel promotes the formation of auriferous horizons enriched in heavy minerals. Such “mineralogical segregation” of alluvium in gold concentration zones depends to a great extent on the degree of its differentiation. As mentioned above, the latter parameter changes with increasing growth of the alluvium section.

Table 3 presents our data on the content of heavy mineral fraction in different horizons of the CB facies with concentrations of gold particles. It is shown that sediments with a high concentration of gold particles contain abundant heavy minerals. We can only repeat once more that such sediments are always confined to the facies top and to the top of sedimentary cycles within the facies. In the Au-depleted sediments, the heavy fraction content is approximately equal in all horizons of the facies, suggesting that the concentration of SF gold particles is related to the sedimentary differentiation of mineral matter. Degree of differentiation changes with accumulation of the sedimentary sequence. Table 3 shows that the mineralogical segregation of alluvium with high gold concentration is also reflected in its petrophysical characteristics, an indicator of magnetic susceptibility (MS). This indicator was used for sorting the alluvium sections destined for

Table 3. Parameters of the heavy mineral fraction in different horizons of the CB facies auriferous alluvium in the Vilyui River valley (384 km along the river channel, right bank)

Parameters	Horizons			
	lower		upper	
Au content, g/m	1.0236	0.012	1.509	0.020
Content of the heavy fraction, %	5.4	3.5	12.8	4.3
Magnetic susceptibility (10^{-5} SI units)	90	6	250	25

The content of heavy fraction in the size class less than 1.0 mm.

gold sampling and lithological study. It should be emphasized that we took into consideration only relative variations of the indicator (MS) within the exposed facies horizon. The value of this indicator depends on the mineral composition and disintegration degree of clastic material delivered to the riverbed. For example, the MS value is as much as $n \times 10^{-2}$ SI units in auriferous alluvium samples taken at lower reaches of the Chara River (Lena region plateau), and does not exceed $10n \times 10^{-5}$ SI units in sediments of the El'ga River (Indigirka River basin). Values of this indicator are also reflected in the content and composition of the heavy fraction of auriferous alluvium. For example, sediments of the Chara River include abundant magnetite-rich fraction (up to 15% of the fine-clastic component). Consequently, the highest values of MS were recorded in the auriferous sediment here. On the contrary, the auriferous alluvium in the El'ga River valley is characterized by very low content of the heavy fraction (up to 1.4%), in which the Fe-bearing mineral components are mainly represented by biotite and iron hydroxides. The MS values measured in the alluvium samples of this area turned out to be three orders of magnitude lower. Values of this indicator are closely linked with the contrast of its variations due to gold concentration in the alluvium. For instance, the values change by one order of magnitude in sediments of the Chara River and they are of nearly similar order in sediments of the El'ga River.

Contrast of the mineralogical segregation of alluvium in the SF gold concentration zone also depends on the disintegration degree of clastic material transported to the riverbed from walls of the river valley. This is also supported by the results of magnetic susceptibility measurements. For example, sampling of alluvium at the Uchur River (Aldan River tributary) estuary in the ore-bearing rock erosion area revealed a zone enriched in SF gold particles containing magnetite intergrowths with the rock. The aggregates are poorly differentiated in the river flow, resulting in a sufficiently high but monotonous magnetic susceptibility ($100n \times 10^{-5}$ SI units) in the alluvium with different degrees of gold concentration. In the Aldan River valley, the MS value in alluvium shows a distinct correlation with gold concentration.

On the contrary, high disintegration degree of clastic material transported to the riverbed creates favorable conditions for the contrast mineralogical segregation of the auriferous CB facies alluvium even with a very low content of heavy fraction minerals. For example, we carried out petrophysical measurements in alluvium of the sandy section on the left floodplain at lower reaches of the Vilyui River (Chybylda River estuary) and revealed thin (*n* cm) layers with a high concentration of fine (0.1–0.05 mm) gold particles. Fixation of this gold concentration zone by panning became possible due to specification of sampling intervals in the mine working section based on the results of fractional measurements of magnetic susceptibility: the content of gold particles(less than 0.1 mm) was 18 g/m^3 in one sandy loam layer 2 cm thick. At the same time, the MS value was only $10n \times 10^{-5}$ SI units.

STRUCTURE OF THE SEDIMENTARY SEQUENCE OF ALLUVIUM

The above mentioned lithological indicators of alluvium in the SF gold concentration zone indicate stagewise development of sedimentary process in this region. The placer area shows a combination of geological (auriferous source rock) and hydrological (rock erosion, removal of mineral grains, and their concentration) factors. Based on experimental data, N.I. Makkaveev (1955) defined that the velocity field structure of water flow at the channel curvature is highly heterogeneous, asymmetric contrast (in terms of equal velocity lines) and most intense (in terms of kinetic energy of flow). Such setting of alluvium deposition is also essentially reflected on the alluvium sequence structure at the level of gold particle concentration, as shown in Fig. 5. Its left part shows a principle geomorphological scheme reflecting the orientation of relief change and floodplain structure due to transformation of the river flow structure (Chernov, 1983). The right part reflects the correlation recorded by M.I. L'vovich (1938) between the level of gold particle concentration in

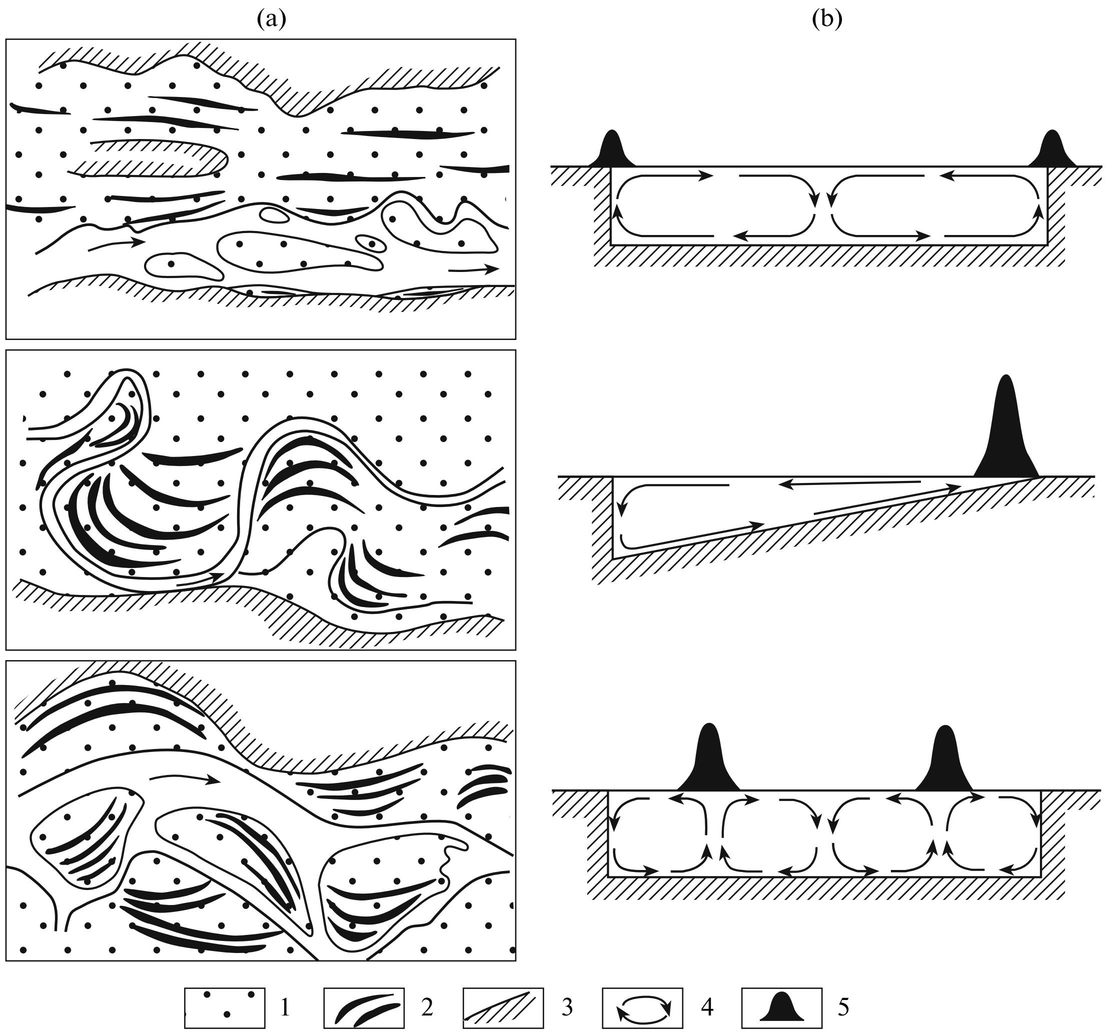


Fig. 5. Relationship between morphology of the river floodplain massif, level of gold particle concentration in alluvium, and structure of the channel flow. (a) Morphological types of floodplain (from the top to bottom): parallel-ruffed, segmental-ruffed; (c) segmental-insular. Based on (Chernov, 1983). (b) Character of circulating currents of river water and level of gold particle concentration in recent alluvium in different sectors of the river channel (from the top to bottom): rectilinear, curved as a single meander, and braided. Based on (L'vovich, 1937). (1) Floodplain; (2) levees; (3) valley slope; (4) direction of circulating currents of water; (5) sectors and level of gold particle concentration.

alluvium and the pattern of channel currents in the Sutar River valley (Amur River basin). Comparison of fragments of this segment suggests the following conclusions.

In rectilinear segments of the river flow (see upper fragments of the figure), the spiral water flow is weakly manifested and often divided by islets into separate currents. These processes lead to the formation of a floodplain sequence with low, parallel-ruffed morphology that reflects the structure of the alluvium sequence as a group of isolated rectilinear sedimentary lodes. Therefore, this region can accommodate isolated gold concentration areas in floodplain sediments that cannot be combined into a single placer deposit.

In the channel curvature segment (see middle fragments of the figure), water flow has a united and spiral structure, which provides large-scale coastal erosion and accumulation, resulting in a great volume of gold particle concentration (reserve). The quality of clastic material differentiation is enough for a high concentration level of components. This area is marked by the formation of floodplain with a segmental-ruffed surface, which reflects the alluvium sequence structure as a group of aggradational segments, resulting in the coupling of the frontal (most enriched in gold particles) segments of aggradational segments. Their unification into a single body can produce a large placer deposit.

The river channel is divided into separate branches at the valley widening (see lower fragments of the figure), resulting in distortion of the united structure of water flow and appearance of numerous small spiral water currents that promote the erosion and accumulation of sediments in the riverbed. This area is usually

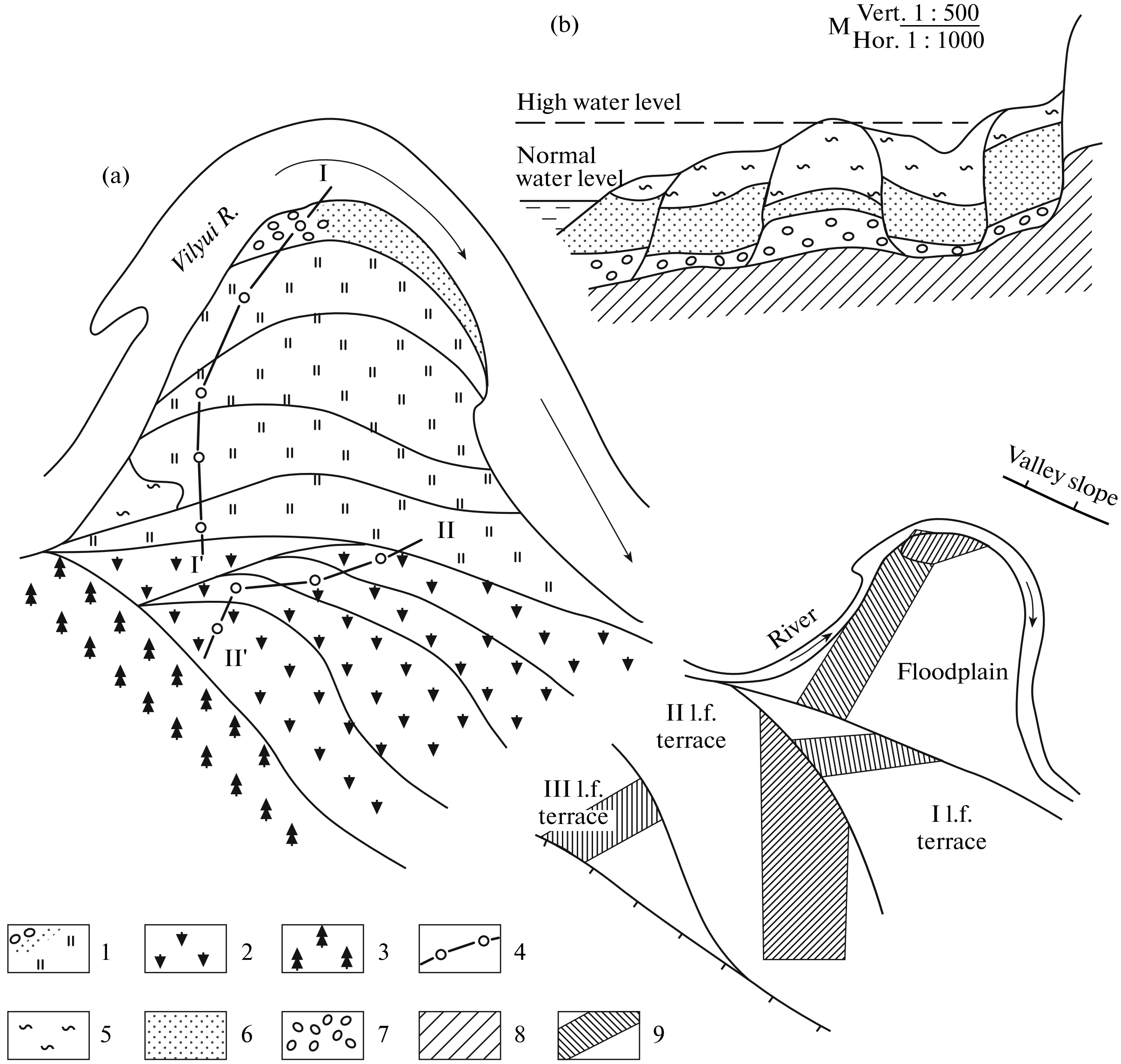


Fig. 6. Conditional geomorphological situation and schematic structure of alluvium at placers of small and fine gold particles (based on parameters of accumulative formations in the Vilyui River valley, middle reaches). (a) Geomorphological scheme of river floodplain massifs and adjacent terraces; (b) schematic structure of floodplain alluvium; (c) possible version of relationship between different age placers combining the head sectors of alluvial segments. (1) Floodplain; (2, 3) different age terraces; (4) exploration mining profiles; (5–7) composition of river sediments: (5) clay-rich, (6) sandy, (7) boulder–pebble; (8) river valley bed; (9) inferred boundaries of placers.

marked by the lowest content of gold particles in the CB facies alluvium. The alluvium sequence thus formed has an "insular" surface that reflects the structure as isolated accumulation centers. Here, we can predict a mosaic placer deposit with low contents of the useful component.

Thus, the meandering segment of river channel is marked by an alluvium sequence as a pile of large aggradational segments, each hosting placer concentration of SF gold particles. Upon unification into a single body within the floodplain or terrace, they make up a placer deposit oriented across the river valley in concordance with the conjugation of alluvial segments. For example, the length of such body in the Vilyui River valley (lower course) is approximately 1.5 km, and gold reserve therein reaches severs tons, and the average content in "placer bed" is 247.0–310.0 mg/m^3. From this point of view, the concentration of gold particles in the present-day channel bar represents the formation of one placer lode. It widens in response to coastal erosion, and its thickness is limited by stackings of the floodplain alluvium.

Figure 6 shows a conditional geomorphological situation in the SF gold concentration area of the river valley. Different fragments of the figure show the following cases: (a) conjugation of aggradational segments of alluvium on the floodplains; (b) their composition; and (c) possible character of the combination of river valley and placer lodes hosted in different age alluvium massifs. It should be noted that the inevitable (in real conditions) relative displacement of gold concentration zones within the adjacent alluvial segments should be reflected in the curvilinear lines of exploration mine workings.

CONCLUSIONS

The SF gold particles are accumulated in the differentiated alluvium together with particles of the host sediments, and their distribution inherits the structure of the sedimentary sequence. Concentration of particles is a result of the hydrodynamic sorting of clastic material in the river channel at its curvature. The resulting sedimentary sequence has a specific structure and composition. Therefore, the lithological approach can be applied for modeling the placer lode therein, and we can propose a new formulation of the placer body that takes into consideration concepts of regularities in the formation and structure of alluvial sequences (Shantser, 1951). Placer of SF gold particles in the differentiated alluvium (placer of the “spit” genetic type) is understood as a multilayer SF gold concentration, which is confined to the channel bar facies in the sedimentary sequence of river floodplains and terraces. It stretches across the river valley and includes the frontal aggradational segments with the highest concentration of component. It should be noted that the proposed definition of placer body is applicable for defining the alluvium-hosted accumulations of any mineral grains having the hydraulic dimension of SF gold particles.

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