MINERAL RESOURCES

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THE MORPHOLOGY AND COMPOSITION OF LIBERIA PLACER GOLD

(Reviewed by the editorial board member V. Zagnitko)

Due to civil war in Liberia, which lasted from 1989 to 2003, the geological study of the country was suspended, and became possible only after its end. That is why today, Liberia has no specific geological zoning of the gold-bearing regions. The morphology of gold of Liberia is examined very poorly, and Soviet literature paid no attention to studying this issue.

This article is devoted to the study of morphological forms of gold from different regions of the Republic of Liberia.The main objectives of the morphological analysis are to distinguish the main morphological types of gold of the country and their origin and to identify possible ways of placer formation. For achieving more accurate results, roentgenospectrographic and roentgen-fluorescent analyses were carried out. The comparative analysis of the morphological features and the fineness of gold was held in eight regions: Kolahum, Magua, Konia and Zeya in the northern part of the country, Solo and Eastern in its southern part, Soso in the western part, and Timbo in the central part of Liberia.

Different types of the gold under study were distinguished according to their morphological features which may indicate their genesis. Well-flattening of grains indicates either a large distance of the transportation of the material, or the fact that the gold has been reworked from nearby local paleoplacers. In the case of the Magua area, considering a large variety of shapes, sizes and the mineral composition of the gold grains, its gold can be of two genetic types: 1) paleoplacer gold, the closest analogue of which is Tarkva deposit in Ghana; 2) indigenous gold, related to ferruginous quartzites, where laterite crusts of weathering are developed.

As a result of the roentgenospectrographic (electron microprobe) analysis of gold from different regions, it was found that all of the analysed grains have gold content close to 100%. Due to the results of the analysis, we can affirm that all the samples, except of the sample number 142 are of typical metallic composition of gold, which represent the geochemical features of this element. Sample number 142 is distinguished by its anomalous silver content, which reaches 16.7%.

Introduction. The Republic of Liberia stretches for 500 miles along the Atlantic Ocean. The relief of the country is midlands covered with forests and a swampy tropical coast. The coastal lowland plain is slightly dissected and swampy here and there. In the hinterland, the plain rises up to 400-600 m and turns into Leone-Liberian Upland. There are also many wide but short rivers (the Mano, the Loffa, and the St.Paul). The climate is tropical, hot, and humid.

The geology of Liberia is determined by its location on two large geological structures:

- early Precambrian Leone-Liberian massif (the Leo-Man shield), which occupies most of the country;
- late Precambrian mobile belt Rockelides, separated from the massif by a large thrust and located along the coast.

Among Archean granite-gneisses of the Leone-Liberian massif, the residues of greenstone belts are preserved. They are metasedimentary and metavolcanic formations such as quartz-mica and quartz-mica-graphite shales, ferruginous quartzites, amphibolites and itabirites (Nimba and Simandu series).

Early Proterozoic metamorphic formation (Birrim series) is composed of shales, quartzites, metaeffusives of mafic, intermediate, and more rarely felsic composition, manganeseferous phyllites, gondites, transected by Eburnean granites. More recent formations involve Permian-Triassic and Jurassic trappean sills and dikes, and small kimberlite bodies. Laterites and alluvial deposits are of the Quaternary age.

The territory of the country was greatly influenced by the periods of tectonic-magmatic activation that accompanied the formation of the West African craton:

- Cratonization stage (3,5 – 2,6 Ga)
- Before Eburnean stage 2,5 – 2,3 (Ga)
- Eburnean stage 2,2 – 1,8 (Ga)
- Meso-Cenozoic stage 300 – 50 (Ma)

Exactly during the Eburnean stage, the accumulation of gold-bearing conglomerates of Tarkwa series (Ghana) took place, and the main gold-quartz and gold-sulfide deposits of this craton were formed. Besides, a significant impact on the geological structure of Liberia was made by the Phanerozoic epochs of tectono-magmatic activation associated with the formation of the Atlantic. This activation facilitated the formation of a large number of Mesozoic and Cenozoic dykes.

Natural and geographical conditions and the geological structure of Liberia define the main directions of industry development, which is poorly developed and has basically raw-product orientation. Among mineral resources, the country is rich only in high-quality iron ores in explored

reserves of which Liberia takes one of the first places in Africa. They are usually associated with ferruginous quartzites of supracrustal Archean complexes (Bea Mountain, Wologisi). In the country, there are also deposits of manganese, barite, gold, diamonds, and cyanite. Liberian diamonds are mined from alluvial and eluvial placers. Most of the gold deposits of Liberia are also related to alluvial deposits; however, in the east of the country, auriferous quartz lodes were found too.

State of the problem. During the period of civil war in Liberia, which lasted from 1989 to 2003, the geological study of the country was suspended, and became possible only after its end. That is why today Liberia has no specific geological zoning of the gold-bearing regions. Its production is mostly carried out by manual methods.

The morphology of gold of Liberia is examined very poorly. Soviet literature paid no attention to studying this issue; although, there are some sources which represent general characteristic of the gold mining sector in Liberia [3].

Setting of the problem. The main objectives of morphological analysis are to distinguish the main morphological types of gold of the country and their origin and to identify possible ways of placer formation. For achieving more accurate results, roentgenospectrographic and roentgenfluorescent analyses were carried out.

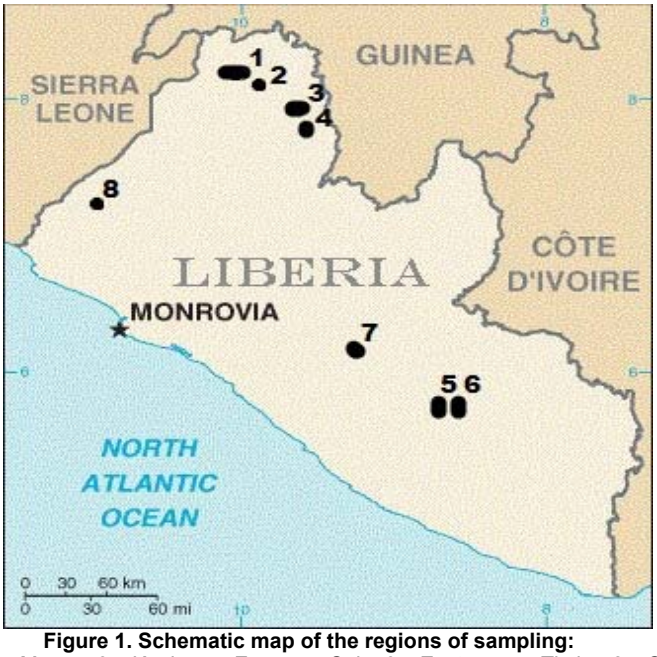

Figure 1. Schematic map of the regions of sampling:
1 – Kolahun, 2 – Magua, 3 – Konia, 4 – Zeya, 5 – Solo, 6 – Eastern, 7 – Timbo, 8 – Soso Camp

Morphological analysis of gold. The comparative analysis of the morphological features and the fineness of gold was held in eight regions: Kolahum, Magua, Konia and Zeya in the northern part of the country, Solo and Eastern in its southern part, Soso in the western part, and Timbo in the central part of Liberia (Figure 1).

The Kolahun area (775 km^2) is situated in the northwestern part of the Republic of Liberia. The geological structure of the area is predominated by Archaean granites and gneiss-granites (geochronological dating is 2580-2770 million years) with their significant feature of granite-gneiss cupolas. They are transected by diabase dykes, mainly of sublatitudinal, more rarely of submeridian and north-west directions, that reflects the features of fault tectonics of the area. Among faultings, submeridional and north-east shear zones as well as sublatitudinal fault systems and disjoining structures (fracture systems) are prevailing.

Gold grains from Kolahun samples are characterised by a round flat shape, indicating an intense mechanical wear. The grains have glitter and golden yellow colour, which may indicate a high fineness of gold. There are only two available samples with signs of gold from this region, one in each, that's why their exact origin is difficult to determine (Table 1).

The perspective area of Magua is located in the southeast framing of the Kolahun area. The flat part of the territory is composed of Archean leucocratic gneisses, including lens-shaped amphibolite bodies and quartz-muscovite shales. The mountainous part of the area is predominately composed of quartz-muscovite and quartz-amphibole shales, up to phyllites, which contain horizons and lenses of quartz conglomerates.

Table 1

General table of linear characteristics of gold samples by areas

Area	Number of samples with gold	Number of gold grains in the area	Measured results								
			length (μm)			width (μm)			elongation		
			min	max	av.	min	max	av.	min	max	av.
Kolahun	2	2	272	340	306	170	272	221	1,25	1,6	1,43
Magua	17	314	68	1598	359	34	884	230	1	5	1,61
Konia	2	19	204	1054	478	136	578	311	1,08	2,58	1,55
Zeya	3	104	136	1190	449	102	1190	279	1	3,78	1,66
Solo	9	464	102	1394	341	68	918	207	1	8	1,71
Timbo	5	324	102	2040	428	34	1224	268	1	4,67	1,66
Soso Camp	4	213	68	884	274	34	510	181	1	5	1,63
Total	42	1440	68	2040	364	34	1224	228	1	8	1,66

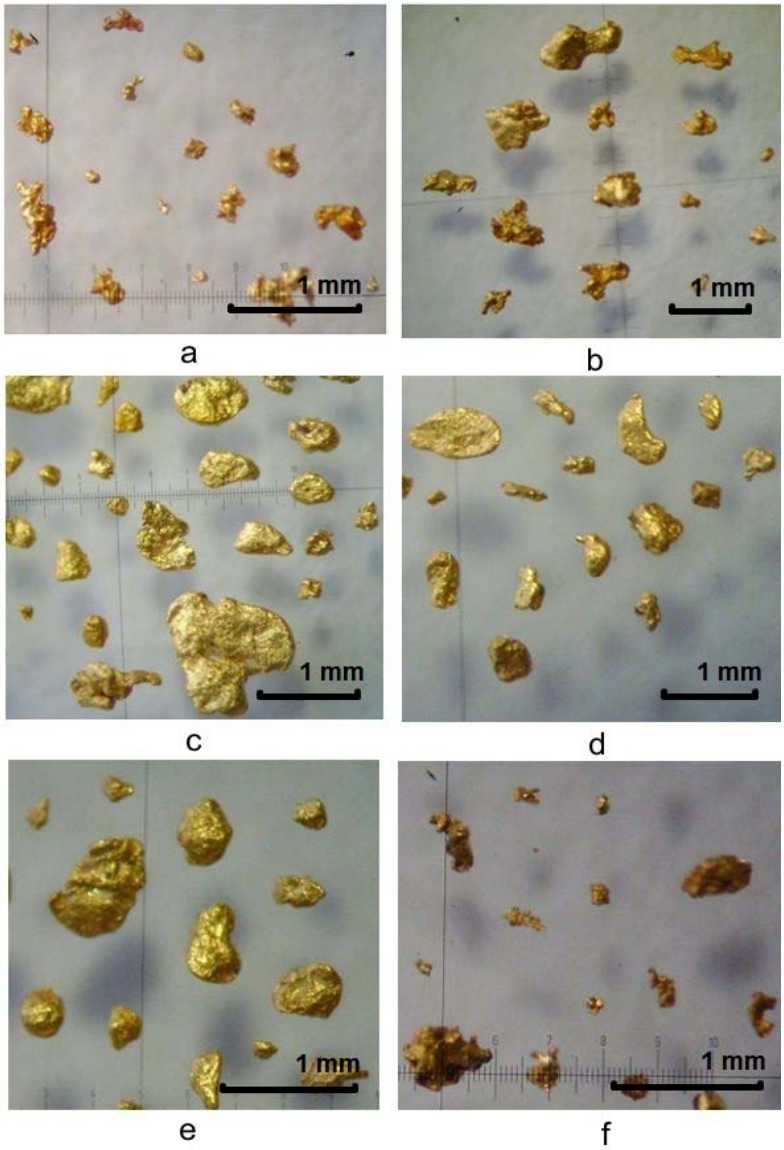

Figure 2. Photo of gold grains from different regions of Liberia:
a – Magua, b – Konia, c – Zeya, d – Solo, e – Timbo, f – Soso Camp

The gold from the region of Magua is characterized by the presence of irregular in shape and discoid grains; they have a smooth or commonly folded surface, usually with incurved protrusions and traces of mechanical wearing. The colour of grains is generally golden yellow, and the shine is bright. Extremely interesting is the sample number 142, which contains gold grains of two various types of morphology which may have different origin (Figure 2, a). The first, well-flattened type of grains, most likely was transported in a fluvial environment, and the second type, with a rough surface and various protrusions, was formed in situ from a nearby primary source.

The perspective area of Konia is located in the north-western part of Liberia. The region is composed of monotonous granites and gneisses. In a dump of developments and in deluvium, light grey and grey banded migmatites prevail; also there occur fragments of quartz, dark-green-grey amphibolites, and crystal slates.

The gold from the region of Konia is irregular in shape with a commonly folded surface and smoothed grain outlines (Figure 2, b). The colour of grains is golden yellow with a bright shine, which also indicates a high fineness. The linear dimensions of gold grains from this region are above average taken in all regions of research.

The area of Zeya is located in the river basin of the same name, 10 km to the south of Konia's frame, so it has a similar geological structure. Gold grains from this region usually have a commonly folded discoid and leaf shape (Figure 2, c). Their shape indicates that the distance of transportation was not very long, which suggests the presence of indigenous sources close to the alluvial placers. The grains are golden yellow. Compared to the gold of the Magua area, it is characterized by a wide variety of shapes and sizes and, in particular, by the presence of large fractions of grains that highly exceed the size of the gold of the Magua area.

The Solo (902 km^2) and Eastern (803 km^2) areas are located in the south-eastern part of the Republic of Liberia. Geologically, the area is located in the block, composed of Paleoproterozoic sediments, comparable with a series of West African Birrim, favourable for gold mineralization. These deposits occur in the north-western part of the Solo area, where they create a block of 36 x 8 km, extended to the north-east. There are complexes of the rocks favourable for gold mineralization, such as shales, including black shales, and geological structures, namely a combination of fault structures of north-east and north-west directions. The rest of the territory mostly consists of gneisses intersected by diorite intrusions. Also, in the central part of the Eastern area,

there is a number of amphibolite bodies elongated in a north-east direction.

In the samples from these regions, there are both irregular in shape and spherical grains with smoothed grain outlines and a smooth surface (Figure 2, d). The colour of grains is generally golden yellow, which may indicate a high fineness of gold. The linear dimensions of gold grains from the Solo and Eastern regions are below average taken in all regions of research (274 versus 296 microns).

The area of Timbo is located in the central part of Liberia in the Timbo river basin. In the samples from this region, there are irregular in shape and discoid grains with a commonly folded surface (Figure 2, e). The grains are golden yellow, the linear dimensions of them are above average taken in all regions of research (348 versus 296 microns).

The perspective area of Soso Camp is located in the western part of the Republic of Liberia, near the eponymous village. Gold is already mined there by intensive artisanal workings in the crust of weathering. The crusts of weathering are developed along the series of alternation of leucocratic and melanocratic gneisses with blocks of more acidic rocks, possibly granites. In the crust of weathering, there are also impregnations of amphibolite shales sized up to 5-6 m, along which the manganese oxides and fragments of quartz deposits are being developed.

The gold grains from the Soso Camp area are commonly irregular in shape with folded outlines; they also tend to be smaller in size (Figure 2, f). All this indicates that the gold has been transported from not far away, in other words, it was formed in situ during the formation of the crust of weathering on the basement rocks. The colour of gold grains has a brown tint, which may indicate the presence of admixtures of other metals and a low fineness of gold.

Roentgenospectrographic analysis. As a result of the roentgenospectrographic (electron microprobe) analysis of gold from different regions, it was found that all of the analysed grains have gold content close to 100%. In other words, all gold samples have high levels of gold fineness. The only exception is the grain from sample number 142, which was collected near the village of Kpadamey (the Magua area). It has a high silver content, about 45%. After this analysis, it was decided to conduct an additional roentgenospectrographic analysis of three more gold grains from this region. One was selected from number 139, also taken from the alluvial-diluvial placers near the village of Kpadamey. Morphologically, it is highly flattened. The electron microprobe analysis showed the presence of a significant admixture of silver, about 10%. The other two gold grains were taken from the same sample number 142. However, unlike the previous case, there have been selected the instances of a well-flattened type. According to the microprobe analysis, they both are almost 100% composed of gold, with no meaningful content of silver.

It confirms a guess that was made after the morphological analysis: a well-flattened type of grains was transported from remote regions or reworked from local paleoplacers, while the other type of grains with elongations in several ways and protrusions was formed in situ.

Roentgen-fluorescent analysis. Six samples were given to the laboratory to conduct the research (Table 2).

Table 2

The results of the roentgen-fluorescent analysis

Area	Sample №	Ag (%)	Cu (%)	Zn (%)	Au (%)	Total (%)
Magua	32	3,27	1,08	0,22	95,42	100,00
Magua	142	16,70	15,68	3,87	63,75	100,00
Konia	204-1	1,74	3,31	0,56	94,40	100,00
Zeya	121	2,15	0,43	0,09	97,32	100,00
Solo	1004	2,39	0,20	0,06	97,34	100,00
Soso Camp	77	1,98	2,42	0,06	95,53	100,00

Due to the results of the analysis, we can affirm that all the samples, except of the sample number 142 are of typical metallic composition of gold, which represent the geochemical features of this element. Anomalous silver content was observed in sample number 142; it is up to 16.7%. This outcome confirms the results of the electron microprobe studies and the morphological analysis in the following way: taking into consideration the fact that in the sample there are gold grains with a high and low fineness (based on the electron microprobe analysis), and also knowing that the vast majority of gold grains are of low fineness (based on morphological analysis), we can therefore state the fact that the obtained silver content is just the result of the mixture of gold grains with different fineness.

An interesting result of this analysis is also an abnormally high content of zinc in the sample number 142. The presence of zinc may be associated with some rock-forming minerals, from which this gold placer was formed. To confirm this hypothesis, there has to be carried out a detailed study of the bedrock of this region which could produce the placer gold of the Magua area.

Conclusions. As a result of the research, there can be presented a range of morphological features of the gold under study which may indicate its genesis. Well-flattening of grains indicates either a large distance of the transportation of the material, or the fact that the gold has been reworked from nearby local paleoplacers. In the case of the Magua area, considering a large variety of shapes, sizes and the mineral composition of the gold grains, its gold can be of two genetic types: 1) paleoplacer gold, the closest analogue of which is Tarkva deposit in Ghana; 2) indigenous gold, related to ferruginous quartzites, where laterite crusts of weathering are developed.

The Zeya area is related to the south-eastern part of the belt of rocks which are similar in composition to those associated with Magua mineralization. They are shales, quartzites, amphibolites, and ferruginous quartzites. Considering a relative similarity in morphological characteristics of the gold grains and the proximity of their geographical location, the gold of the Kohalun area may have the same genesis as the Magua gold. The gold from the Konia region is not well-flattened and has a commonly folded surface; it may indicate that the distance of its transportation was very short.

At the Solo area, as a result of geological studies, there were found the complexes of the rocks favourable for gold mineralization. They are shales, including black shales and geological structures, namely a combination of fault structures of north-east and north-west directions. Most likely, the auriferity of the Solo area is associated with these conditions.

The gold grains from the Timbo area are mainly irregular in shape with a commonly folded surface. This may indicate a relatively short distance of transportation. It is likely that the gold placers are associated with alluvial-diluvial sediments of small streams or granitoids' crusts of weathering.

The gold from the Soso Camp area, according to the morphological analysis and geological studies, could be accumulated during the formation of the crust of weathering on the basement rocks, among which their felsic varieties were prevailing.

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МОРФОЛОГІЯ ТА СКЛАД ЗОЛОТА РОЗСИПНИХ РОДОВИЩ ЛІБЕРІЇ

У зв'язку з періодом громадянської війни, яка тривала в Ліберії з 1989 по 2003 рік, геологічне вивчення країни було призупинене, і стало можливим тільки після її закінчення. Саме тому до сьогодні територія Ліберії не має чіткого геологічного районування золотоносних регіонів. Морфологія золота Ліберії вивчена дуже слабко. У вітчизняній літературі вивченню цього питання увага не приділялась.

Стаття присвячена дослідженню морфологічних форм золота з різних регіонів республіки Ліберія. Основними цілями проведеного морфологічного аналізу було виділення основних морфологічних типів золота країни та їх генезису, а також визначення можливих шляхів формування розсипів. Для досягнення більш точних результатів було також проведено мікрозондовий та рентгенофлуоресцентний аналізи. Порівняльний аналіз морфологічних особливостей та пробності золота проводився по восьми регіонам досліджень: Колахун, Магуа, Конія та Зея в північній частині, Соло і Східна – в південній частині, західній (Сосо) і центральній (Тімбо) частинах Ліберії.

Різне за типом золото, що досліджувалось, було класифіковане за його морфологічними особливостями, що могли також вказувати на його генезис. Добра окатаність зерен вказує або на значну відстань переносу матеріалу, або на те, що золото було перевідкладене із палеорозсипищ. У випадку регіону Магуа, враховуючи велику різноманітність форм, розмірів та речовинного складу золотин, дане золото може мати два генетичні типи: 1) палеорозсипне, найближчим аналогом якого є родовище Тарква в Гані; 2) корінне, приурочене до залізистих кварцитів, на яких розвиваються латеритні кори вивітрювання.

В результаті проведеного рентгеноспектрального (мікрозондового) аналізу золотин з різних регіонів було визначено, що всі аналізовані зерна мають у своєму складі вміст золота близький до 100%. За результатами проведеного аналізу можна засвідчити, що усі проби, окрім проби №142 мають типовий металічний склад золота, який характерний для геохімічних особливостей даного елементу. У пробі №142 відмічається аномальний вміст срібла, який становить аж 16,7%.

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МОРФОЛОГИЯ И СОСТАВ ЗОЛОТА РОССЫПНЫХ МЕСТОРОЖДЕНИЙ ЛИБЕРИИ

В связи с периодом гражданской войны, которая длилась в Либерии с 1989 по 2003 год, геологическое изучение страны было приостановлено, и стало возможным только после её окончания. Именно поэтому до сих пор территория Либерии не имеет четкого геологического районирования золотоносных регионов. Морфология золота Либерии изучена очень слабо. В отечественной литературе изучению этого вопроса внимание не уделялось.

Статья посвящена изучению морфологических форм золота из разных регионов республики Либерия. Основными целями проведённого морфологического анализа было выделение основных морфологических типов золота страны и их генезиса, а также определение возможных путей формирования россыпей. Для достижения более точных результатов было также проведено микрозондовый и рентгенофлуоресцентный анализы. Сравнительный анализ морфологических особенностей, а также пробности золота был проведён по восьми регионам исследований: Колахун, Магуа, Кония и Зея в северной части, Соло и Восточная – в южной части, западной (Сосо) и центральной (Тимбо) частях Либерии.

Разное по типу золото, что исследовалось, было классифицировано по его морфологическим особенностям, что могли также указывать на его генезис. Большая степень окатанности зёрен указывает или на значительное расстояние переноса материала, или на то, что золото было переотложено из палеороссыпей. В случае региона Магуа, учитывая большое разнообразие форм, размеров и вещественного состава золотин, это золото может иметь два генетические типы: 1) палеороссыпное, ближайшим аналогом которого является месторождение Тарква в Гане; 2) коренное, приуроченное к железистым кварцитам, на которых развиваются латеритные коры выветривания.

В результате проведённого рентгеноспектрального (микрозондового) анализа золотин с разных регионов было определено, что все рассматриваемые зёрна имеют в своём составе содержание золота близкое к 100%. По результатам проведённого анализа можно говорить, что все пробы, кроме пробы №142 имеют типичный металлический состав золота, который характерен для геохимических особенностей данного элемента. В пробе №142 отмечается аномальное содержание серебра, которое составляет вплоть до 16,7%.