PROSPECTS OF THE DNIESTER RIVER FLOODPLAIN TERRACES STRATA FOR GOLD MINERALIZATION

Despite long-term geological study of the Dnister River basin, we still have no clear evidences about gold-bearing potentiality of this area as well as origin of gold. The leading role of geological, geochemical and mineralogical criteria is proved for defining the prospects of substantial gold deposits finding within the Dnister river basin. Gold was found here in the crystalline basement and in this area as well as origin of gold. The leading role of geological, geochemical and mineralogical criteria is proved for defining the this river and its inflows recent alluvia.

The purpose of our researches is the study of VI and VII floodplain terraces alluvial deposits to clear these gold-bearing potential.

A brief description of the territory studied geological structure. Ancient Podolska fault zone of NW strike is the principal tectonic element that determines the structure of whole studied region. Width of this zone reaches 50 km, in contrast vertical movements are not exceed 50 m. Faults of this zone are indistinct on the surface and in the drillholes core. These faults appear as intensive fracture areas and minor thick mylonite sews of slip type in the sedimentary cover. Mylonites and cataclastic rocks are prevalent along with contacts of Bug's series metamorphic rocks and granitoids of Lower Proterozoic Berdychivsky complex. Older large faults are sublontitudinal Odessky (near Chervonoznamenka village) as well as NE zonez of Nemyrivsky fault (near Soroka town) and Perednnistrovskyy (in vicinity of Yampol town). All the faults were re-activated many times during the platform cover formation. More comprehensive structure of studied region appears after geophysical and remote sensing data interpretation.


Actuality. Gold-bearing potential of the Dnister River and its left inflows alluvium as well as the Dnister terrace complex is an object of great interest to study. Sedimentary rocks contain native gold here and they can be indicators of the ways of gold palaeotransportation into the Dnister alluvium during various stages of the river system neotectonic history.

Terraces complex study is always very important task during geomorphological and palaeogeographic research. River terraces are indicators of climate conditions changes and tectonic movements. Alluvial deposits terraces are the principal instrument for srtatigraphic correlation of distant continental deposits sections of different structural position and conditions of their formation. The latter can be reconstructed with the aid of deposits correlation.

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with prospection, particularly for gold (Arkhanhelskaia, 1983; Bratslavskiy et al., 1983; Velykanov et al., 1968; Nechaiev and Afanasieva, 1990; Latsun, 1997 and many other researchers). Generally geological studies revealed great prospect for various minerals within the Dniester Peri-Cratonic Belt.


V.Ya. Velykanov firstly found gold placer in the Dniester river bed as well along the Derla and Nemiya rivers (Mohyliv-Podisskyy concentrate halo) using panning and geochemical method (Velykanov et al., 1968). Gold content reaches 2.8 g/m³ in some samples (State geological map, 2007). M. Ianhycher also gave positive assessment of gold prospects for recent alluvium in the Mohyliv-Podilskyy area. He found association among gold, cinnabar and realgar in the heavy mineral concentrates. Thematic researches and searching for flint by Piyar et al. (1972) found gold in the alluvial deposits of II-III and V floodplain terraces.

V.K. Latsun (Latsun, 1997) found Naddniistryanskyy, Dereshivskyy and Rozdolivskyy gold occurrences in the Pliocene floodplain terraces deposits. R.M. Dovhan and V.M. Pavliuk (Dovhan et al., 2002; Pavliuk et al., 2008) gave great contribution to the gold-bearing study in the Dniester River basin mid-flow. They ascertained prospective plots for gold and described prospective geological formations units.

Prospects of Western Black Sea Area for gold were studied by Ye.F. Shnyukov in 1999, 2000 and O.O. Yushin in 1998–2005. Today this territory is considered as prospective for thin and dispersed gold. Prospects for gold of the Dniester River lower flow (from Rybnitsa town to the Dniester estuary) is not clear today.

Thus, studies in the region described reveal gold mineralization in the Pliocene-Quaternary alluvium of the river Dniester and its inflows along with significant distance – from Zalishchyky town to Mohyliv-Podilskyy town (Fig. 1). Two large prospective areas are ascertained – Melnitsa-Podilska and Mohyliv-Podilskaya. Inside these areas some plots are found, where native gold content in the Pliocene-Quaternary deposits is increased. Gold extent and its content in the alluvium grow from 13 mg/m³ to 32,1 mg/m³ in the meanders (Derevska, 2008).

Clastic gold in association with siver sulphosalts, galena, led tellurides and chalcopyrite is present in terrigenous deposits of Mohyliv series of Middle Dniester Vendian that overlays flood basalts or crystalline basement. More significant concentrations of native gold in association with galena, sphalerite, cinnabar and auripigment are found in the recent alluvium of the Dniester River and its inflows (Derevska, 2008).

Fig. 1. The schematic map of minerals and ores distribution in the Dniester river basin mid-flow (using Derevska, 2008):

1 – crystalline rocks of the Ukrainian shield; 2 – sedimentary deposits of the platform cover; 3 – the platform cover boundary; 4 – edge faults of the Podilska and Nemyrivska fault zones; 5 – flint beds distribution in the Upper Cretaceous deposits; 6 – phosphorites distribution in the Vendian and Cenomanian deposits; 7 – area of lead, zinc and barite (fluorite) occurrences in the Cambrian, Ordovician and Silurian deposits; 8 – barite-fluorite-base metal ore formation occurrences in the rocks of the crystalline basement and Vendian deposits; 9 – Grinchutske flint deposit; 10 – Zhvanskie phosphorite deposit; 11 – Bakhtynske fluorite deposit; 12 – maximum gold concentration in the Neogene-Quaternary alluvium of the Dniester River; 13 – the Velykokosnytskyy occurrence of bauxites; 14 – the Kotevskyy barite-base metal occurrence
Rocks of the Archean-Lower Proterozoic crystalline basement generally contain a carbonate amount of gold (75% samples content gold 3 mg/t and less). Detrital sediments of Riphean Soroksa suite are featured by increased gold content. The most stable content of gold show Riphean Kamianska suite basalts (up to 10 mg/t). Significant geochemical anomaly of gold is located between Rybnitsa and Kotovsk towns coinciding with the area of basalts extension. Here content of gold is up to 30 mg/t in all of the platform cover suites. Native gold of this plot show low content of silver (3.5–3.8%) and lead (0.05–0.15%) (Der evska, 2008).

Native gold is found in all geological units, from Proterozoic to the recent alluvial deposits within the Dniester Peri-Cratonic Belt, so the necessity of further prospecting is evident.

The problems that are still unsolved. Despite long-term geological study of the Dniester river basin (deep geological mapping, searching for mercury, diamonds, thematic researches for gold etc.), we still have no clear geological mapping, searching for mercury, diamonds, term geological study of the Dniester river basin (deep ravines and gulches. The main water artery of the region is Upland, which is deeply dissected by the river valleys, wide range of metallic and non-metallic minerals. Belt, so the necessity of further prospecting is evident.

Presentation of the main material. The territory of the Dniesterian depression has a complex geological and tectonic structure of the region with multiple neotectonic movements. This derives from complex geological and tectonic structure of the region with multiple neotectonic movements.

The explored territory is located within the Podolian Upland, which is deeply dissected by the river valleys, ravines and gulches. The main water artery of the region is the Dniester river, which forms a canyon-shaped valley. Together with its inflows, this river interposes into the rocks to a depth of 200 m. The inflow of the different age alluvial deposits can be explained by the complicated geological structure and a considerable length of the area.

The overall picture of exploration maturity of these territories is presented in the table of the prospective zones for the gold search (Table). The results of studies indicate the gold-bearing material distribution heterogeneity due to the different tectonic structure and the lithology of deposits.

It is worth pointing out that the main gold-bearing areas are confined to the territories of the Vendian terrigene deposits and the Upper Pliocene terraces of the Dniester River extension. In addition to the basic data on promising areas, information is also provided on test methods and concentration of gold in samples. According to the gold spectral analysis of the bottom sediments of the Dniester basin rivers, 17 gold haloes were found (Nechaiev and Afanasieva, 1990).

According to the given data, it can be asserted that the prospect of the Dniester basin mid-flow in search of industrial occurrences of gold is also related to the geochemical and mineralogical features: 1) the presence of gold with different typomorphic features in the alluvium of the Dniester and its inflows, which points to the diverse sources with distinct genesis and age; 2) the presence of associated minerals (realgar, auripigment, cinnabar, galena, sphalerite), which are unstable in exogenous conditions and cannot be transported over long distances, which indicates points to the local sources of indigenous gold or its interjacent collectors; 3) the presence of geochemical anomalies of gold and its indicator elements both in the crystalline rocks of the basement and sedimentary cover.

The gold-bearing of the Pliocene-Quaternary deposits in the Dniester basin mid-flow is related to the Pliocene (VI-IX floodplain terraces) and the Quaternary (I-V floodplain terraces) terrace complexes of the Dniester river and the modern alluvium of the Dniester river and its inflows.

<table>
<thead>
<tr>
<th>№</th>
<th>Name of location</th>
<th>Location</th>
<th>Host rocks</th>
<th>Au content, g/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Derlivskyy occurrence</td>
<td>The lower part of the Derlo river, Karpivka village</td>
<td>1. Alluvium of the river channel, Vendian terrigene deposits</td>
<td>0,1–0,2 to 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Argilites and silstones of the Lomozivsky layers</td>
<td>0,175</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3. Yampilsky sandstone</td>
<td>0,01–0,07</td>
</tr>
<tr>
<td>2</td>
<td>Liadova river basin</td>
<td>Liadova and Derlo rivers basins</td>
<td>1. Alluvium of the river channel, Vendian terrigene deposits</td>
<td>0,005–0,5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Conglomerates, multicolor breccia</td>
<td>Up to 0,175</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 Grushhynska suite deposits</td>
<td>0,005–0,1</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>4. Light gray feldspar-quartz sandstone of the Olchavediv Beds</td>
<td>0,001–0,04</td>
</tr>
<tr>
<td>3</td>
<td>Nemiyska area</td>
<td>Lower flow of the river Nemiiia, villages Nemiiia and Ozarynts</td>
<td>Crystalline rocks, sedimentary deposits of the Vendian</td>
<td>0,01–0,05</td>
</tr>
<tr>
<td>4</td>
<td>Derezhivsky occurrence</td>
<td>Upper flow of the river Zhvan, Derezhova village</td>
<td>Alluvium of river channel, Vendian terrigene deposits</td>
<td>0,005–0,1</td>
</tr>
<tr>
<td>5</td>
<td>Naddni nianskiy occurrence</td>
<td>Lower flow of the river Materka, near Naddni nianskiye village</td>
<td>Terrigene deposits of the Pliocene terraces, Vendian rocks, crystalline rocks</td>
<td>0,05–0,2</td>
</tr>
<tr>
<td>6</td>
<td>Karaietsky occurrence</td>
<td>Lower flow of the river Karaiets, toward the South from Perekoryntsi village</td>
<td>Alluvium of river channel</td>
<td>0,01–0,02</td>
</tr>
<tr>
<td>7</td>
<td>Mohyliv-Podilsky region</td>
<td>Middle flow of the Dniester river</td>
<td>1. In basalts</td>
<td>0,005–0,007</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. In chaledony-like light gray pebble from the Cretaceous deluvium</td>
<td>0,3</td>
</tr>
</tbody>
</table>

The ancient Pliocene terraces of the Dniester are represented by the formations of the river bed (sandy lithotypes) and floodplain (clay lithotypes) facies and are distributed on the watersheds of Nichlava-Zbruch rivers (VI–VII terraces), in the interfluve of Studenytsa-Zhvan and Liadova rivers, Derlo river (VI–IX terraces) (Dovhan et al., 2002; State geological, 2007; Tomenyuk, 2012). In the bottom of the terrace deposits lie pebble-beds and boulders. Pebbles are represented mainly by sandstones, flint, limestone, quartz, jasper flint, and chaledony. Below we present the
description of alluvial deposits of the Dniester terraces on the basis of data collected. Sands are from fine to coarse-grained, argillaceous, horizontally – and crossbedded, brownish-yellow, yellow-gray, sometimes contain layers and lenses of clay and pebbles in the size of 1–10 cm. The sands are overlapped by floodplain clays, which are aleuritic, dense, viscous, brownish-gray, red-brown, brown. The thickness of the Pliocene terraces is different: VI terrace – up to 10,0 m, VII terrace – up to 30 m. Alluvial deposits of the V terrace are represented by pebbles (well-rounded pebbles of sandstones, siltstones, limestones, and flint); inequigranular sands, horizontally- and crossbedded, gray, brownish-yellow, red-brown with pebbles, gravel, and, occasionally, clay lenses. The average thickness of deposits is 13 m.

Alluvial deposits of the IV floodplain terrace are represented by inequigranular sands, horizontally- and crossbedded, grey, yellowish-gray, with rare clay lenses and pebbles with sand aggregate (well-rounded pebbles of sandstones, limestones, and flints in the size of 5-10 cm) and sandy loams.

Alluvial deposits of the III floodplain terrace are represented by pebbles (well and slightly rounded pebbles of Silurian limestones and Cretaceous flints up to 5 cm in size); inequigranular sands, horizontally- and crossbedded, gray, heavily ferruginized, with the inclusion of fine pebbles, with clay lenses and sandy loams. The thickness of deposits is up to 10 m.

Alluvial deposits of the II floodplain terrace are represented by pebbles with grains of sandstones, siltstones, limestones, dolomites, sometimes flints, with layers and lenses of sand; inequigranular sands with gravel and pebbles; loams with layers and lenses of fine-grained quartz sand with pebbles. The thickness of deposits is up to 10 m.

Alluvial deposits of the I floodplain terrace are represented by pebbles (grains of limestones, dolomites, flints); fine to medium-grained sands, gray, sometimes ochred, with rare inclusions of pebbles and slightly rounded debris of limestones, dolomites and flints; loams yellow-brown, with a rare pebble and slightly rounded fragments of sandstones, limestones, flints, as well as sand and clay lenses. The thickness of sediments is up to 20 m.

Alluvial deposits of the Dniester and its inflows are represented by poorly sorted boulder-pebble and sand-clay slightly ferruginized deposits with humus. The thickness of deposits in the Dniester is up to 20 m.

The formation of the terraces of the Dniester river valley (according to A. Bogutsky, A. Yatsyshym) occurs due to the periodic repetition of tectonic movements. They are subject to cyclic physical-geographical changes.

Analysis of the materials regarding the lithologic and mineralogical composition of the floodplain terraces, typomorphic features of native gold allows us to assert that paleogeographic conditions and source areas of clastic material have been changed during development of the Dniester river valley at various tectonic-geomorphological stages.

It is noteworthy that the main gold-bearing areas are confined to the territories of the Vendian terrigene deposits extension and the Upper Pliocene terraces of the Dniester River.

Recent years, the use of natural building materials has become more intense. So-called “Carpathian pebble” of two oldest terraced levels – the VI and the VII terraces of the Dniester river valley – is actively mined (legally and illegally). This led to the formation of deep and branched quarries near Novosilky, Goligrady, Kulakivtsi, Synkiv, Isakivtsi, Tsviklivtsi villages. Mining works opened new outcrops, the study of which may serve as a basis for the continuation of the prospecting and evaluation works on placer gold.

To study the gold content, lithologic, mineralogical and geochemical features of the terrace deposits, we chose the strata in the Dniester middle flow, where the sixth terrace outcrop. The corresponding territory is clearly traced by an intermittent band from the village Novosilky (high left bank of the Seret river) to the village Tsviklivtsi (the left bank of the Dniester river). There are shallow excavations (up to 3 m) near the village Goligrady on the left steep high bank of the Seret River, in which the alluvial deposits of the sixth terrace outcrop. They are represented by the interlayers of pebble material and light sand with red-yellow to dark brown lenses. There are sandy deposits with well-rounded inequigranular, mostly light-gray "Carpathian" pebbles (often with traces of "desert tan") at the base of the excavation.

Near village Kulakivtsi (left side of the road to the village Synkiv), gravel-pebble construction material excavations reveal the outcrop of the sixth terrace of the Dniester (Fig. 2). The geological section is represented by a thick layer of pebble material with lenses or layers of light-gray sand. There are white and red spots at the top of the profile. Alluvial deposits are covered with a layer of gray-yellow sand with rare inclusions of pebbles and gravel (up to 25 cm), and higher in the profile river deposits are covered with loams (up to 15 cm). Above is a 10-centimeter layer of podzolized soil. The quarry with steep walls covers an area of about 3 hectares, has a depth of up to 3 m, is partially covered with garbage, overgrown with shrubs and weeds. Currently, the object is abandoned and not recultivated. Samples weighing about 80 kg were collected here for granulometric, heavy minerals concentrate and geochemical analyses.
Alluvial deposits from the Dniester river were also studied near the village Isakivtsi between two inflows of the Dniester river – Zbruch and Zhvanchyk. Here, due to the extraction of gravel, a geological section of about 20 m height is revealed. In the base of this section there are dense conglomerates, which are cemented with clay material and contain fauna fossils. The well and slightly rounded fragments in the size from 2–5 to 10 cm are represented by flints, jasperoids, argillites, sandstones, coal shales, etc., as well as the remnants of Sarmatian shells. Above is the layer of coarse-grained, light, striped sand with layers of sand formations of brown color (IV–V terraces of the Dniester). Above, the strata of so-called "Carpathian" pebbles is determined, the deposits of which belong to the sixth terrace of the Dniester River. In the upper part of the profile, sedimentary deposits are brownish-red due to high iron content. Samples of about 60 kg total weight were taken for further research.

Analytical study of the sedimentary rocks was carried out in the laboratories of Kyiv and Kryvyi Rig.

Lithologic-mineralogic sampling with alluvium enrichment was held on in the laboratory of the Center for problems of marine geology, geoeconomy and sedimentary ore formation of the NAS of Ukraine, Kryvyi Rig (analyst V. Ivanchenko). Polymineral sedimentary deposits of the Dniester mid-flow VI, V and IV floodplain terraces have high content of heavy minerals, such as almandine, ilmenite, zircon, monazite, iron oxides etc. So, this deposit was enriched with the method of multistage dry separation with subsequent withdrawal of several concentrates. These contain gold that appears as thin and dispersed gold (about 90 % of its total amount). Minor amount of mineralogical-geochemical studies was based on mineral composition of gravel-pebble, sandy and clay-carbonaceous material from Pliocene terraces and their basement. Analysis of clay-carbonaceous material of the Lower Sarmatian deposits basal level shows presence in the fine fraction of garnet, zircon, monazite, native gold and copper, apatite, pyrite, iron globules (Fig. 3).

Perspective directions of research. Our field and analytical studies, analysis of geological reports and scientific publications made it possible to distinguish the main ways of further geological work, mainly within the VI–IV terraces of the middle Dniester:

1. Study of alluvial formations of the Dniester river basin and its terrace complex will clarify their material composition, find out the extent of gold-bearing, and define a change in the disintegration areas in time.

2. Geological-mineragenetic mapping of the Dniester left inflows of using the heavy minerals concentrates analysis.

3. Lithochemical and geochemical searches of gold mineralization after anomalies and elements dispersion halos, as well as the definition of general principles of gold
distribution for distinguishing prospective sites within the research territory.

4. Hydrochemical searches for hydrochemical anomalies of native and mineral type in alluvial and saline environments within the territory of the research; the secondary dispersion haloes to find out the general features of native gold that will clarify their material composition, define the extent of the features, and give a possibility to allocate prospective areas and forecast sites rich in native gold.

5. Study of typomorphic features of native gold using modern analytics for defining its ore-formational affiliation and mineral type.

The beginning of this research was started by the authors of this paper.

Outlined directions of further research allow focusing on specific search tasks.

Conclusions. Completed own field and analytical studies, analysis of geological reports and scientific publications in the context of studies of alluvium gold deposits, the results of previous research works, allowed to make the following conclusions.

1. Mid-flow Dniester area is the most comprehensive area for gold bearing within whole Dniester river basin. This area is a potentially gold-bearing region that is most suitable for detailed exploration work. It is the terrain of the territory consisting of the area of the geological and tectonic development, paleogeographic conditions for the distribution of gold-bearing and potentially gold-bearing sedimentary deposits, lithological rocks composition, conducive for concentration of gold (osn, sedimentary and hydrogen), as well as with the processes of eometamorphism and hydrothermal activity (due to the renewal of tectonic fault zones).

2. The main areas of further exploration and evaluation works are: a detailed study of the alluvial formations of the Dniester and its terrace complex (mainly VI–IV terraces), which will clarify their material composition, define the extent of gold-bearing and a change in the denudation areas in time; lithgeochemical searches after primary and secondary dispersion haloes to find out the general principles of the distribution of gold content; selection of perspective sites within the territory of the research; the study of typomorphic features of native gold from alluvial and terrace deposits using modern analytics for defining its ore-formational affiliation and mineral type.

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ПЕРСПЕКТИВЫ ВИКЛАДІВ НАЗАПЛЯВНИХ ТЕРАС ДІНСТРА НА ЗОЛОТО МІНЕРАЛІЗАЦІЮ

У межах басейну річки Дністер на найвищою щодо золотоносності нні є території середніх течій. Незважаючи на привале геологічне вивчення, одночасно вирішує питання золотоносності території прикорінних дінестрових долин здійснює стверджувати, що в протяжному розрізі річкової долини Дністру на різних географічних етапах її розвитку змінювалися палеогеографічні обставини, що вплинули на формування пліоцен-четвертинних відкладів Середнього Придністров'я (північні - ЗУ-IX надзапливні тераси) та четвертинних (І-V науки надзапливні тераси) терасовими комплексами річки Дністер, сучасним алювієм Дністра й його приток. Продовження досліджень стверджують, що в межах Середнього Придністров'я самородне золото виявлено в усіх географічних утвореннях, починаючи з прошарку і закінчили сучасними алювіальними відкладами, що дозволяє на обставини подальших пошукових робіт для визначення корінних джерел золота.

Здійснені польові, аналітичні дослідження та збір опублікованих даних дозволили виокремити основні напрями подальших пошукових робіт. Серед них головним елементом розгляду є деякі особливості, що дозволяє встановити зміни реконструкції складу золота відкладів за межами територій сучасних наукових відкладів.

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Ключові слова: золото, басейн Дністра, надзапливні тераси.