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SPECIFICITIES OF GEOLOGICAL SAMPLING METHODS IN ALLUVIAL DEPOSITS

Vladan Kašić¹, Slavica Mihajlović¹, Nataša Đorđević², Srdan Matijašević¹, Ana Radosavljević-Mihajlović¹

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Abstract: Sampling alluvial deposits is important in geological exploration, providing data for understanding sediment composition, stratigraphy, and resource potential. The study including testing alluvial wells, conducting examinations during shallow shaft mining operations, and assessing deposits through floating dredgers. Across all methods, the key requirement is proper sampling and ensuring a sufficient quantity of material. Analyses of the collected samples, supported by calculations, reveal both the concentration of valuable minerals within the deposit and the spatial consistency of their distribution. In drilling testing methods, it is essential to precisely measure the volume of the drilled rock column and to determine the concentration of the useful component in the material recovered through washing. During mining operations, the sample comprises all material removed while deepening the shaft by 0.5 or 1.0 m. Sampling of floating dredger is conducted during exploitation measurements as the dredger advances along the transverse profile from one end of the deposit to the other. The horizontal spacing between sampling points is typically 5 m. Samples are taken first at the greatest digging depth and then at every meter of sediment. Due to their mobility and precision, floating excavators are particularly suited for operations in remote or inaccessible regions.

Keywords: testing, alluvial deposits, boreholes, mining operations, floating dredger orts

1 INTRODUCTION

Geological exploration worldwide has involved continuous improvements to existing methods, the development of new testing approaches, and the introduction of sustainable

¹ Institute for Technology of Nuclear and Other Mineral Raw Materials, Franchet d'Esperey 86, Belgrade, Serbia

² Institute of General and Physical Chemistry, 12 Studentski Trg, 11000 Belgrade, Serbia

E-mails: v.kasic@itnms.ac.rs, ORCID: <https://orcid.org/0000-0002-4430-567X>;
s.mihajlovic@itnms.ac.rs, ORCID: <https://orcid.org/0000-0003-0904-3878>;
natasa.djordjevic@iofh.bg.ac.rs, ORCID: <https://orcid.org/0000-0002-2353-6751>;
s.matijasevic@itnms.ac.rs, ORCID: <https://orcid.org/0000-0002-3897-8085>;
a.radosavljevic@itnms.ac.rs, ORCID: <https://orcid.org/0000-0002-9194-161X>

technologies that enhance efficiency. Achievements in the field of geological sciences have contributed to the creation of scientifically grounded methods for investigating mineral resources, including those derived from alluvial deposits. In circumstances where useful minerals are present, it is essential to develop new methodological approaches both for the assessment of mineral reserves and for determining the content of valuable components. This enables a clear understanding of the prerequisites directly linked to decisions on initiating exploitation. Indeed, no mining activity can commence without prior quantitative mapping of the mineral content within the deposit. At the same time, evaluations of the quality of primary and associated minerals are conducted. Such practices contribute to the rational use of natural resources and the protection of areas within potential exploitation zones. Altogether, these considerations highlight the importance of geological activities in generating data that define the spatial regularity of mineral occurrence within the Earth's crust and the requirements of mining procedures, thereby ensuring rational resource utilization and the economic viability of deposit development (Malanchuk et al., 2024; Zuo, 2020; Zeng et al., 2020; Rysbekov et al., 2020).

A mandatory and inherent activity before the exploitation of alluvial deposits is the sampling of unconsolidated material, most commonly sand, gravel, clay, or other alluvial sediments. Following this, the content of valuable minerals (e.g., gold, platinum) is determined to assess the economic feasibility of opening the deposit. Since these are alluvial deposits, the processes of sampling and investigation differ from those applied to solid rock formations. It is particularly important to emphasize the necessity of collecting large quantities of material, as useful components occur in fine grains that are typically present throughout the deposit (Dominy, 2014; Balaram and Subramanyam, 2022). This so-called 'volumetric testing' is a prerequisite for subsequent stages, namely the exploitation of the alluvial deposit. Washing the samples with water follows, intending to separate heavy minerals from lighter sand and silt. The content of the valuable element is presented in grams or milligrams per cubic meter of material (mg/m^3 or g/m^3). The results obtained serve as indicators of the profitability of exploiting a given metal from the alluvium (Mathioudakis et al., 2023a; Mathioudakis et al., 2023b; Bettenay and Ross, 2026; Vakanjac, 1992).

2 BOREHOLE SAMPLING IN ALLUVIAL DEPOSITS

Proper sampling of alluvial sediments and the results of preliminary analyses of collected samples significantly impact decisions on the exploitation of valuable components and their profitability. Depending on when and how the alluvial deposits were formed, they differ in grain size, composition, layer thickness, orientation, and other characteristics. Accordingly, different sampling and testing techniques have been applied over time, which have become increasingly advanced (Ghorbani et al., 2023; Awal et al., 2019; Khomsin et al., 2021).

For the exploration of alluvial deposits containing precious and rare metals at shallow depths (up to 20 m), sets for manual impact rotary drilling are most commonly used. However, for deposits at depths of 20 to 50 m and beyond, mechanical rope driven impact drilling equipment is applied. In the method of testing (sampling) alluvial deposits by drilling, the most important aspect is the precise measurement of the volume of the drilled rock column. Equally important is the determination of the content of the valuable component in the material obtained by washing the drilled rock, expressed in units of mass (kg, g, mg) per cubic meter of rock (sand) (Karpov and Petreev, 2021; Oparin et al., 2022).

The accuracy of determining the initial volume of the extracted rock (sand) during drilling is influenced by several factors:

1. Rock disintegration: As the borehole penetrates the formation, the rocks pass into a loose state, which affects the increase in their volume. The degree of disintegration varies depending on the composition and physical condition of the rocks.
2. Loss in suspension: A portion of the rock extracted with a scoop (including flap scoops) is lost in the water suspension, with the percentage of loss depending on the amount of clay particles.
3. Displacement by chisel drilling: During chisel drilling, part of the rock is displaced outside the cased space, reducing the initial volume of rock that enters the casing column.
4. Hydrogeological conditions: In formations with higher water content (lower permeability), high groundwater levels, and insufficiently vigorous forcing of the casing column, significant inflow of rock into the casing may occur, along with the washing out of clay particles beneath the shoe of the casing column.

To ensure the most accurate sampling results during drilling, the shoe of the casing column must remain ahead of the drilling tool at all times. This is achieved through continuous or frequent forcing of the casing column.

During the normal course of drilling and testing, tools such as scoops or flap scoops are used to extract a column of sand from the casing. When rocks are loosened with a chisel and during the use of scoops, gold and other heavy minerals tend to sink into the lower parts of the borehole. To reduce the amount of gold that 'settles' during drilling of a gold bearing layer, 1–2 liters of clay solution are added at each casing stage. The addition of clay must be taken into account and included as a correction factor when determining the volume.

Samples are collected at regular drilling intervals, most often every 0.5 m. When drilling overburden rocks that are known to represent barren material, only control point samples are taken after each meter. The bedrock of the deposit (from bed + rock), usually composed of alluvial parent rocks, is also sampled, as it often contains significant

amounts of metals. When the bedrock is soft, the core must be carefully examined to determine whether it represents a weathered crust or alluvium. Occasionally, clayey rich 'false' bedrock may cover sand layers rich in metal.

During manual drilling of boreholes with diameters of 117 and 165 mm, accurate recording of the initial volume for samples is achieved by measuring the depth of the borehole before and after using the scoop. The difference in depth provides the actual height of the extracted rock column. In certain cases, the actual volume of rock extracted from the borehole is determined using a specific construction: a vertical pipe of defined height and diameter (the diameter must be such that the area of the inner circular cross-section equals 100 cm²). The pipe is fixed to a wooden tripod with an inclined steel chute. The sand sample from the scoop is poured into the chute, flows into the pipe, is compacted, and then measured. The height of the rock column in the pipe is multiplied by 100 to obtain the volume in cm³. For measuring the actual volume of rocks extracted during mechanical impact drilling with casing columns of 165 and 210 mm, a horizontal trough with a measuring box is used. The box has a precisely defined cross-section and height, and is graduated along its height. Material from the scoop is poured into the measuring box, and the height of the deposited material is read. Based on the known cross-section of the box and the measured height, the volume of the deposited material is determined.

When investigating gold bearing alluvial deposits by drilling, graphite grease is used for lubricating the threads of drilling (cased) pipes and rods. Standard greases are avoided because they penetrate the sand and cause 'gold flotation' during the washing process. In such cases, instead of remaining at the bottom, gold floats to the surface, resulting in the loss of a certain amount of this precious metal (Sillitoe and Hedenquist, 2010; Hedenquist, 2000; Robert et al., 2007; Kašić, 1995). The material obtained from washing the sample is dried, measured, and labeled according to the sampling location. The content of the valuable mineral in the alluvium (*S*), expressed in kilograms, grams, or milligrams per cubic meter of rock or sand, is calculated according to Formula 1:

$$S = \frac{M}{Z} \quad (1)$$

where: *M*-mass of the obtained mineral sample, (g); *Z*-volume of the sample, (m³).

It should be emphasized that there are two methods for calculating the content of valuable minerals in alluvial deposits: 1. Based on the theoretical volume of the sample and 2. Based on the actual volume of the sample.

In the calculation method based on theoretical volume, it is assumed that the entire rock mass pressed by the shoe of the casing column enters the column and is extracted by the drilling tool. Therefore, the rock volume is taken as the volume of a cylinder, expressed according to the following formula:

$$Z = \frac{\pi \cdot p^2}{4} \cdot d \quad (2)$$

Where: d -length of the coated column, (m); P -external diameter of the shoe of the coated columns, (mm).

In this case, the formula for determining the content of useful minerals takes the following form:

$$S = \frac{M}{Z} \cdot 1000000 = \frac{M}{d} \cdot \frac{4 \cdot 1000000}{\pi \cdot P^2} = \frac{M}{d} = k \quad (3)$$

Where:

1000000-multiplier for the transition from the cross-section expressed in mm² to m²;

k -constant coefficient.

However, the volume of rock that in practice reaches the lining columns of a smaller diameter can be significantly different from the theoretical volume. Therefore, the theoretical method can only be applied to boreholes that are drilled with large diameter drills (eg Nevjan drill with a diameter of 530 mm).

When drilling with smaller diameters of 117 and 165 mm, the volume of the samples is determined according to the inner diameter of the pipe and the difference in the height of the column before and after filling the drill. The loosening of rock pillars in the cladding columns is not considered. The metal or valuable mineral content is calculated according to the formula:

$$S = \frac{M \cdot 4 \cdot 1000000}{\pi \cdot P^2 \cdot V} \quad (4)$$

Where: V -height of the column that is pulled out (difference in height before and after working with the pusher), (m).

At P-93 mm, the constant coefficient is:

$$k = \frac{4 \cdot 1000000}{\pi \cdot 93^2} \quad (5)$$

For percussive drilling with a rope of 165 and 210 mm diameter (whereas the inner diameters of the working casing columns are 145 and 195 mm) the value of the coefficient k is 65 and 33, respectively. All calculations are performed using special tables. Calculations must be absolutely accurate. Otherwise, the values of the content of the useful component in the sediment, which were obtained by calculation, can be significantly higher than the actual content. Potential errors can occur if the recovered

gold from the well is spread over a deposit volume corresponding to the inside diameter of the casing columns (mill shoes) instead of, as is correct, to the outside diameter. Likewise, an increase in the content and reserves of gold in the deposit can occur due to improper drilling technology, when the drilling equipment is ahead of the casing column cutter. In this case, material may seep into the well from the side (so-called "excess" material). Also, to the enrichment of the lower parts of the layer with gold due to the loose walls of the well that are not covered with a casing column and through which the gold falls on the bedrock itself. In that case, the bedrock shows a high gold content, which is not confirmed later during mining.

When coarse gold is encountered in a sample, the question arises regarding the threshold mass of nuggets to be included in reserve calculations. For each large alluvial deposit, or for a group of deposits of the same type, the threshold mass of nuggets is determined based on experimental data. Therefore, all metal obtained from the borehole is measured and subjected to sieve analysis. Based on the results, the class is identified from which the total mass of metal increases only slightly; the number of gold grains in that class is determined, as well as the average mass of a single grain in milligrams. This value is taken as the threshold mass for gold of normal grain size. The difference between the mass of nuggets and the mass of gold grains substituted for them in the calculation is accounted for in the estimation of total gold reserves in the alluvial deposit by introducing a correction coefficient, the value of which is always greater than one (Dominy and Annels, 2001a; Dominy and Hunt, 2001b; Dominy et al., 2006; Dominy, Xie and Platten, 2008).

3 TESTING DURING MINING WORKS

Sampling of materials and formation of samples during mining operations in shallow shafts is very specific. A sample is taken from the entire excavated alluvial material whose mass corresponds to a layer of material with a vertical thickness of 0.5 or 1.0 m. That is, practically, all the material taken when deepening the shaft by 0.5 or 1.0 m. Sample washing is carried out immediately, or at the latest 3-5 days after the sample is formed. If the sample remains for a longer time, it may lose its representativeness, especially if it is washed away by atmospheric precipitation or due to the rise of the water level in the riverbed.

The washing of the sand sample is carried out in a washing basin which is placed in the water approximately at the center of the investigation plot. The washing basin is a rectangular groove or structure, 2.5–3.0 m long and 0.7 m wide, made of thick boards and set at a slight slope (7–15°). The upper part consists of a square wooden box fitted with a horizontal grid with openings of 6–7 mm. To retain sand and water, a wooden frame made of four planks inclined toward the grid is placed above it. The inclined bottom of the washer serves as the working surface ("canvas") on which the sand is washed. Sand for rinsing is manually placed on the grid and mixed while receiving a jet

of water from either a pump or gravity flow. The washed gravel fragments are removed from the grid and deposited in a designated area, while sand and clay pass through the grid openings and are carried away by the water along the wash surface. To capture schlich (German: "schlich" - a concentrate of heavy metals obtained by washing rock material) and gold particles, the work surface of the washer is covered with a material that retains schlich. It can be cloth (fabric made from wool or coarse cloth made from goat or camel hair). The material is attached with transversely placed wooden slats 1-2 cm thick. Under the washboard, in the part where the tailings are separated, a box is placed to control the separation of the sludge. Productivity of the washing machine when washing sand, in average conditions, is 1.5 to 4.0 m³ during a shift that lasts 8 hours.

After rinsing the sample, the so-called "crying out" is performed. With a small amount of water, the movable frame, the cloth, the surface of the washing machine and the entire slide, which is lowered into the bucket or the sample placed under the lower end of the washing machine are carefully washed (rinsed). A pan is a traditional wooden or metal pan used to separate gold from river sediment. In a bucket or a sample (with the addition of mercury in the presence of fine gold), the metal is separated from the slag. After drying, the cuttings are sampled (weight 50-100 g), packed and submitted for mineralogical analysis. The amalgam is heated to release the mercury. The obtained gold is measured and stored in a special cardboard box (capsule). Gold content in sand in g/m³ is determined by dividing the mass of washed metal in g by the volume of the sample in m³ (Boukari et al., 2025; Mathioudakis et al., 2023a).

The content of minerals in the sands is determined as follows: after drying, the slag from the washboard is measured, and its content in the sediment is determined, expressed as kg/m³ of washed sands. The magnetic fraction (magnetite) is separated from the slag with the help of a magnet, while pieces larger than 2 mm are separated by hand. All the separated classes are measured individually. The class smaller than 2 mm, is scattered on the glass, on the underside of which a white paper with a centimeter grid has been glued. A typical test strip, 10-12 cm long, is separated from the schist, preferably "one grain" in width, and the interesting mineral is separated with a needle. It is preferable to use a binocular magnifier. The ratio of the length of the parallel strip of the same mineral to the total length of the initial strip gives the approximate content of the useful mineral in percentage by volume. By introducing the specific mass into the calculation, volume percentages are converted into mass. The total mass of pure useful mineral in all grades, divided by the volume of the sample, gives its content in sands. During the exploitation of alluvium by underground mining works, excavation testing is of decisive importance, since the entire work in the pit depends on the results of the testing. Based on the test results, excavation work is interrupted or extended, and the thickness of the layer with the balance ore and the height of the excavation are determined. Bad or improperly organized testing entails improper exploitation of sediments, with all the consequences that result (Skrzypkowski et al., 2022; Lu et al., 2024).

Sampling in the metal-bearing layer should be done with a wide vertical channel, in the direction from the floor to the roof of the section. The channel sample is divided according to the height of the channel into three or four parts to take sectional samples. The first sample is taken covering 0.2 m of the substrate, while larger fragments of primary rocks are discarded. The sample material is poured into the trough to measure its exact volume. The troughs are made of boards or sheet metal, the volume is 25500 cm³, which corresponds to the volume of 0.02 m³ of massif sediment (compact rock). Before filling the trough, a badge with a number is placed on the bottom, which is recorded in the geologist's field log. The vertical channel above the first sample is divided into three unequal parts for taking sectional samples. The bottom sample is taken starting from the deposit base up to a height of 0.4-0.5 m. The middle sample covers the middle of the column with a section length of 1.2-1.4 m. The last upper sample with a length of 0.3-0.4 m reflects the metal content in the upper part of the column next to the roof itself. Dividing the sampling column by height into unequal parts excludes the possibility of enriching the upper and lower samples at the expense of the richer middle sample. In the case of the presence of pebbles, their primary content on the surface of the ore is determined macroscopically and based on the geological sketch of the column. Troughs filled with samples are sent for washing, usually on a smaller washboard. The metal content of the sample (g/m³) is calculated by multiplying the mass of the mineral by 50, because the bed volume represents 1/50th of a cubic meter. The average metal content on the ore is calculated as a weighted average value proportional to the length of the channel of individual samples. The metal content in the substrate (base, bedrock) is not taken into account during the calculation, because during normal exploitation, there must be no metal in the substrate test. Coarse grains of gold are a common occurrence in the underground mining of many deposits, which is why they are taken into account when calculating the average metal content of the ore, as well as the average content for the entire deposit.

4 SAMPLING OF FLOATING DREDGE

Proper testing of floating dredges has great practical importance. Based on testing, the average content of useful metal (minerals) in a cubic meter of excavated rock is determined, the contours of the excavation polygon (the balanced part of the deposit) are determined, and the purity of the bedrock or deposit base is controlled. The contour of the dredging polygon is drawn on the measurement plan based on the graphical interpolation of the marginal (minimum economic) metal content determined by testing shallow wells or wells. However, there are cases when the actual contour of the balanced part of the deposit was wider than the design contour determined based on the exploration. Namely, when determining the limit of dredging, one should be guided not only by the project polygon, but also by the results of testing in the process of working of the excavator. Sampling the dredging soil vertically can show the following: the existence of clay layers in deposits with increased metal content above them (the so-

called "false bedrock"), and confirm the complete capture of the bedrock during dredging. The testing of soil in the column of sediment on floating dredgers in operation has the following characteristics:

- a) excavating section and sediment beds are underwater and are not available for direct observation;
- b) samples should be taken from the dredger buckets that are moving during the operation of the floating dredger;
- c) Quick regulation of the sampling site is necessary due to the constant movement of the excavator along the excavation section.

The simplest method of testing the soil during dredging is a test sample. The washer takes the sample from the buckets moving in the trough and, knowing its volume, washes it on the deck of the floating dredge. Such testing is not complex, but it does not reflect the quantitative distribution of the metal content on the ore and does not provide the exact coordinates of the sampling site for its application on the test plan. In order to ensure more accurate mapping of the sample locations on the sample plan, in the field, and on the plan, a square grid with sides of 5m² and at the appropriate scale on the plan is set up. According to this grid, the exact position of the field in the plan at the time of sampling is determined. The vertical position of the sample taken on the transverse profile of the sediment is determined based on the angle of inclination, that is, the depth of the bucket carrier. The sample is washed on a special washboard placed on a floating dredge.

The testing is done on the day of measurement of exploitation works for a ten days or for a month, when the excavator moves along the cross-section, from one end of the deposit to the other. The distance between the tests in the plan, according to the horizontal line, is normally 5 m. Sampling should start from the greatest depth of digging. Then, when the frame is gradually raised, one sample is taken from each meter of deposit thickness. Special attention should be paid to testing the boundaries of the excavation site. Along the lines of the measurement survey and along the borders of the polygons, mean arithmetic contents are applied, calculated from a series of individual samples in each vertical section. During dredging, the method of mass sediment testing is also applied, where the volume obtained between two washes is measured. The entire mass of metal obtained by washing that amount of sand is divided by that value. The intermediate contents obtained in this way are applied to the plan of the excavation site. The application of the presented testing methods on floating dredgers enables the reduction of losses of useful metal (minerals) as well as the constant control of floating dredger operations. Also, these systems incorporate advanced technology for extracting gold particles with minimal environmental concerns. The mobility and precise operation of floating dredgers enable their application in remote and hard-to-reach places (Roshchupkin, 1975; Delgado, 2023).

5 CONCLUSION

In order to obtain representative samples, proper sampling and testing of alluvial deposits requires special techniques and compliance with rules during the execution of all geological activities. When choosing a sampling technique, it is necessary to take into account the heterogeneity of the sampling material and large variations in the size of the useful mineral particles. One of the applied methods is the testing of vertical boreholes, which provides a large volume sample from all layers of deposits. For drilling at shallower depths (up to 20 m), manual percussive-rotary drilling rigs are used, while for greater depths (20 to 50 m and more), mechanical rigs with percussive drilling with rope are used. In this method, the most important thing is the accurate measurement of the volume of the column of rock being drilled and the determination of the content of the useful component in the material obtained by washing the drilled rock, expressed in mass units (kg, g, mg) per 1 m³ of rock (sand). When performing mining works in shallow shafts, sampling of materials and formation of samples is very specific. From the entire excavated alluvial material, a sample is taken whose mass corresponds to a layer of material with a vertical thickness of 0.5 or 1.0 m. This is all the material taken when deepening the shaft by 0.5 or 1.0 m. Sample washing is carried out immediately, or at the latest 3-5 days after the sample is formed. Floating dredges are widely used due to their many advantages, which provide practical and sustainable solutions for sediment management, resource exploitation, and environmental protection. The mobility and precise operation of floating excavators enable their use in remote and hard-to-reach places. The testing is done on the day of measurement recording of exploitation works for a decade or for a month, when moving the excavator along the cross profile, from one end of the deposit to the other. The distance between the tests in the plan, according to the horizontal line, is normally 5 m. Sampling should start from the greatest depth of digging. Then, when the frame is gradually raised, one sample is taken from each meter of deposit thickness. Special attention should be paid to testing the limits of the excavation site

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