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# NEWS
# OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES

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## MARCH – APRIL 2026

THE JOURNAL WAS FOUNDED IN 1940

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*The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.*

*The journal is also included in the Emerging Sources Citation Index (ESCI) of the Web of Science platform (Clarivate Analytics, since 2018).*

*Indexing in ESCI confirms the journal's compliance with international standards of scientific peer review and editorial ethics and is considered by Clarivate Analytics as part of the evaluation process for potential inclusion in the Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (AHCI).*

*Indexing in Scopus and Web of Science ensures high international visibility of publications, promotes citation growth, and reflects the editorial board's commitment to publishing relevant, original, and scientifically significant research in the fields of geology and technical sciences.*

*«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.*

*Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.*

*ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылымды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.*

*Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.*

*Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.*

*Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).*

*Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).*

*Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.*

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# APPLICATION OF THE X-RAY RADIOMETRIC METHOD TO IMPROVE THE OPERATIONAL QUALITY CONTROL OF COPPER ORES DURING GEOLOGICAL TESTING

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**Abstract.** *Relevance.* The traditional sampling of copper ores is characterized by high labor intensity, long technological process and relatively low representativeness, as a result, chemical analysis takes a relatively small amount of material of about 50 grams (Industry standard, 2005; Instruction on Internal, 1982).

*Purpose.* Improvement of the existing system of standard testing of copper ores in the direction of reducing financial costs, labor intensity, increasing efficiency and accuracy of obtaining representative information on copper content from core sampling data.

The quality control of ores during their extraction is carried out by core testing. Due to the fact that the sampling methods used at enterprises include operations for sampling, delivery to the laboratory, processing, and analysis of samples, they are time-consuming, expensive, and unsuitable as a means of obtaining information for operational impacts on the technological process. *Methods.* From these positions, significant prospects are opened by the advent of X–ray radiometric sampling (hereinafter referred to as RRR), which allows us to proceed to the rapid determination of the components of interest without sampling, directly in the conditions of natural occurrence of rocks and ores. It makes it possible to reduce the duration of testing to several minutes or seconds, significantly reduce the cost of work while increasing the amount of information to the required completeness.

*Results and conclusions.* The results obtained indicate the possibility of core testing by X-ray fluorescence of copper in crushed representative samples of class -1 mm. A more representative sampling of the core itself (its rounded and flat surfaces of the sawn core) makes it possible to quickly separate the ore and rock intervals.

**Keywords:** X-ray radiometric testing, standard testing method, representativeness

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# ГЕОЛОГИЯЛЫҚ СЫНАУ КЕЗІНДЕ МЫС КЕНДЕРІНІҢ САПАСЫН ЖЕДЕЛ БАҚЫЛАУДЫ ЖЕТІЛДІРУ ҮШІН РЕНТГЕН РАДИОМЕТРИЯЛЫҚ ӘДІСТІ ҚОЛДАНУ

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**Аннотация.** *Өзектілігі.* Дәстүрлі мыс кендерін сынау әдістері, әдетте, жоғары еңбек сыйымдылығымен, технологиялық операциялардың ұзақтығымен және тиімділік деңгейінің салыстырмалы түрде төмен болуымен ерекшеленеді. Бұл, ең алдымен, химиялық талдауға пайдаланылатын материал көлемінің аздығымен түсіндіріледі – орта есеппен шамамен 50 грамм ғана (Industry standard, 2005; Instruction on Internal, 1982).

*Мақсаты.* Мыс кендерін стандартты сынау жүйесін жетілдіру өндірістік шығындарды қысқартуға, еңбек ресурстарына түсетін жүктемені азайтуға, талдау жеделдігін арттыруға, сондай-ақ керндік материалдар бойынша мыс мөлшерін анықтау дәлдігін жоғарылатуға бағытталады.

Кен өндіру процесінде шикізат сапасын бақылау негізінен базалық сынау арқылы жүзеге асырылады. Алайда өндірістік кәсіпорындарда қолданылатын сынау тәсілдері сынама іріктеу, оны зертханаға тасымалдау, алдын ала өңдеу және талдау кезеңдерін қамтитындықтан, олар көп еңбекті қажет етеді, экономикалық тұрғыдан шығынды және технологиялық процесті жедел басқару үшін жеткілікті жылдам ақпарат бермейді. *Әдістер.* Осы тұрғыдан рентген-радиометриялық сынау (бұдан әрі – РРО) әдісін қолдану айтарлықтай мүмкіндіктер ұсынады. Бұл тәсіл тау жыныстары мен кендерді табиғи жату жағдайында, қосымша сынама алмастан-ақ, мақсатты компоненттердің құрамын жедел анықтауға мүмкіндік береді. Соның нәтижесінде талдау уақыты бірнеше минутқа, тіпті секундтарға дейін қысқарып, алынатын деректер көлемі қажетті деңгейде сақтала отырып, зерттеу құны бірнеше есеге төмендейді.

*Нәтижелер мен қорытындылар.* Зерттеу нәтижелері −1 мм класына дейін ұсақталған репрезентативті үлгілерде мыстың құрамын рентгендік флуоресценция әдісімен анықтауға негізделген базалық сынауды жүргізудің тиімділігін көрсетті. Сонымен қатар кернның өзінен, атап айтқанда оның кесілген бөлігінің тегістелген және дөңгелектенген беттерінен алынған неғұрлым репрезентативті сынамалар кен мен жанасушы тау жыныстарының шекарасын жедел ажыратуға мүмкіндік береді.

**Түйін сөздер:** рентгендік радиометриялық сынау, стандартты сынау әдісі, репрезентативтілігі

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# ПРИМЕНЕНИЕ РЕНТГЕНОРАДИОМЕТРИЧЕСКОГО МЕТОДА ДЛЯ СОВЕРШЕНСТВОАНИЯ ОПЕРАТИВНОГО КОНТРОЛЯ КАЧЕСТВА МЕДНЫХ РУД ПРИ ГЕОЛОГИЧЕСКОМ ОПРОБОВАНИИ

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**Аннотация.** *Актуальность.* Традиционное опробование медных руд характеризуется высокой трудоёмкостью, длительностью технологического процесса и сравнительно низкой представительностью, поскольку на химический анализ направляется ограниченное количество материала (около 50 г) (Industry Standard, 2005; Instruction on Internal, 1982). *Цель исследования* - совершенствование существующей системы стандартного опробования медных руд в направлении снижения финансовых затрат и трудоёмкости, повышения оперативности и точности получения представительной информации о содержании меди по данным кернового опробования. Контроль качества руд при добыче традиционно осуществляется методом кернового опробования. Однако используемые на предприятиях методы включают этапы отбора, транспортировки, подготовки и лабораторного анализа проб, что делает их трудоёмкими, дорогостоящими и малопригодными для оперативного управления технологическими процессами. *Методы.* В этой связи значительные перспективы представляет применение рентгенорадиометрического опробования (РРО), позволяющего проводить экспрессное определение содержания элементов без отбора проб непосредственно в условиях естественного залегания горных пород и руд. Данный метод обеспечивает сокращение времени анализа до нескольких минут или секунд, значительное снижение стоимости работ и увеличение объёма получаемой информации до необходимого уровня полноты. *Результаты и выводы.* Полученные результаты свидетельствуют о возможности эффективного кернового опробования с использованием рентгенофлуоресцентного анализа меди в измельчённых представительных пробах класса –1 мм. Установлено, что более представительное опробование непосредственно по керну (включая округлые и плоские поверхности распиленного керна) позволяет оперативно выделять рудные и пустые интервалы, что повышает эффективность геолого-технологического контроля и обеспечивает более точную оценку содержания меди.

**Ключевые слова:** рентгенорадиометрическое опробование, стандартный способ опробования, представительность

**Introduction.** The standard core sampling method includes the following steps:

– core description by its visual description by geologist;
– core sawing along its axis in two halves;
– sampling of one half of the core for further testing, the second half is stored;
– ragging of core samples to a fraction class - 1 mm;
– abrasion of samples to the fraction of analytical powder class - 0.074 mm;
– chemical analysis.

**Literature Review.** For small to medium capacity plants under operation and uner deigning, pre-concentration is an effective solution to compensate for the decrease in valuable component content. For polymetallic ores it is advisable to use X-ray fluorescence separation, which allows for taking into account the content of several valuable components in the screened knobs (Efremova et al., 2017).

The mining industry includes production branches engaged in exploration of mineral deposits, their extraction from the subsoil and concentration. At all stages of the technological process of extraction of mineral resources (MR) from the subsoil, starting from prospecting and exploration of deposits, there is a sequential concentration of the valuable component (VC) in the marketable product, and each stage is characterized by its losses of MR (Marchevskaya, 2001).

To reduce ore dilution at the stage of mining operations, process selection of ore can be applied by batch excavation of blocks according to the grade plan defining the boundaries of the external overburden, mineralized mass and ore zone, which, in turn, can be divided into two sub-zones according to their total gold balance content, for example: poor and rich zones. Economic profitability of processing of poor in gold content ore can be achieved due to the introduction of low-cost technology of preliminary ore concentration by the method of lump separation based on the X-ray radiometric method (Zabolotskiy and Nerushchenko, 2021).

A preliminary trade-off study of various concentration scenarios has shown that the optimal approach consists in maximizing tungsten recovery in a rough concentrate containing tungsten in an amount that, according to the practice of Chinese concentrate producers, allows for its cost-efficient processing by the flotation method (0.18-0.2% WO3). The research was aimed at determining a method allowing for maximizing the extraction of tungsten in the concentrated product of the above composition. Calculations have shown that in order to obtain the required concentrate from ore with the initial content of 0.12-0.15 % WO3, the tungsten content in the separation tailings should be at the level of 0.02-0.035 % WO3. In the course of research, it was found out that due to natural features of the ore being studied (chemical and mineral composition, textural and structural characteristics), the best results were obtained using X-ray absorption technology (Kulmukhamedov and Ligay, 2023).

The totality of methodological and hardware developments ensured the status of X-ray radiometric testing (XRT) as the main tool for geological monitoring of exploration and mining operations. According to the results of XRT in the ores of the deposits, new elements were revealed (Yefimenko et al., 2014).

The existing standard method of coal testing involves labor-intensive operations: collection of point (primary) samples from the tested batch, crushing of the combined sample, averaging, grinding and direct thermal gravimetric analysis of analytical samples (~0.1 mm) for ash content. At each stage of standard testing, an error can occur due to the heterogeneity of coals (Starchik and Pak, 1985).

The closest in technical essence and achieved result method is the method consisting in recording the element and gamma radiation scattered by the substance along with X-ray fluorescence radiation, while concentration of the identified element is estimated by the value of the spectral ratio, that is ratio of the intensity of X-ray fluorescence of the element to the intensity of scattered gamma radiation (Leman, 1978).

X-ray imaging is a low-cost and powerful technology that is widely used in medical diagnostics and non-destructive industrial inspection. Ability of X-rays to penetrate the body represents a major advancement for non-invasive imaging of its internal structure (Zhu et al., 2019).

Problems related to the influence of artifacts on the quality of assessing the internal structure of control objects in X-ray computer tomography continue to be one of the most important areas of research (Xiangyu Ou, 2021; Sarkar, 2019; Dremel, 2017; Stolfi, 2018; Hsieh, 2015).

**Materials and Basic Methods.** Disadvantages of the Standard Testing Method Core Documentation.

At many deposits, known ore-free intervals are rejected during core description to save further core sawing and laboratory analytical studies. However, the visual approach often results in a loss of quality characterization of the core. Therefore, there is a loss of ultimate content. An example is presented below.

Example. The geological structure of the Zhaissan ore field is formed by granitoids of the Kurday-Chatyrkul complex, which belong to the Upper Ordovic.

The deposit is composed of the following rock types: granodiorites, biotite granites and biotite corniferous granites.

Granodiorites compose the northern and northeastern parts of the deposit. The rest of the deposit is composed of biotite granites.

Contacts of granodiorites with granites are intrusive and rather uneven. Granites often go far into granodiorites in the form of bays, and rest in them in the form of separate bunches.

In the south-eastern part of the deposit in the contact zone of granites and granodiorites, minor bodies of biotite corniferous granites with unclear contacts and gradual transitions into them are developed. There is an opinion that biotite corniferous granites are endocontact margins of the granodiorites as a result of differentiation of intrusive granitic magma into granodiorites (Avdeev, 2018).

Granites and granodiorites are intersected by dikes of aplite-like fine-grained granites, pegmatoid granites, microdiorites, diorite and diabase porphyrites, quartz-carbonate and quartz-magnetite veins.

Dikes of aplite-like and pegmatoidal fine-grained granites mainly gravitate to the near-contact zone of granodiorites and biotite corniferous granites. These dikes occur less frequently in biotite granites.

Dikes of microdiorites and diabase porphyrites are common in both granites and granodiorites (Zablyudsky et al., 2016).

– copper cutoff grade for the deposit - 0.80%

– minimum thickness of the ore body included in the mineral resource volumetrics polygon - 1.0 m

– maximum thickness of substandard ores and waste layers included in the contour of the ore body - 3.0 m

Figure 1 - PHOTO of core UH-ZSN-95-25 in the interval of sample 20025

As can be seen from Figure 1, the core is ore-free visually and according to the geologist's description, but according to the LAI data. According to the standard sampling method, well UH-ZSN-95-25-20026 should be ore-free, since the final sampling intervals should be ore-bearing with intermediate rocks tacked on.

Table 1 – Testing of Well UH-ZSN-95-25

| No. | Samples | Interval | | Cu, % |
|---|---|---|---|---|
| | | from | to | (0.0005-10) |
| 1 | UH-ZSN-95-25-20001 | blank | | 0.017 |
| 2 | UH-ZSN-95-25-20002 | 41 | 41.7 | 0.209 |
| 3 | UH-ZSN-95-25-20003 | 41.7 | 42.4 | 0.082 |
| 4 | UH-ZSN-95-25-20004 | 42.4 | 43 | 0.152 |
| 5 | UH-ZSN-95-25-20005 | 43 | 44 | 0.404 |
| 6 | UH-ZSN-95-25-20006 | 44 | 45 | 0.220 |
| 7 | UH-ZSN-95-25-20007 | 45 | 46 | 0.527 |
| 8 | UH-ZSN-95-25-20008 | 46 | 47 | 1.17 |
| 9 | UH-ZSN-95-25-20009 | 47 | 48 | 0.202 |
| 10 | UH-ZSN-95-25-20010 | 48 | 48.6 | 0.732 |
| 11 | UH-ZSN-95-25-20011 | 48.6 | 49.3 | 2.91 |
| 12 | UH-ZSN-95-25-20012 | 49.3 | 50.3 | 1.45 |
| 13 | UH-ZSN-95-25-20013 | field duplicate | | 0.700 |
| 14 | UH-ZSN-95-25-20014 | pulp duplicate | | 1.44 |
| 15 | UH-ZSN-95-25-20015 | grinding duplicate | | 1.49 |
| 16 | UH-ZSN-95-25-20016 | CRM | | 0.441 |
| 17 | UH-ZSN-95-25-20017 | 50.3 | 51.3 | 1.08 |
| 18 | UH-ZSN-95-25-20018 | 51.3 | 52.3 | 2.38 |
| 19 | UH-ZSN-95-25-20019 | 52.3 | 53 | 0.281 |
| 20 | UH-ZSN-95-25-20020 | 53 | 54 | 0.793 |
| 21 | UH-ZSN-95-25-20021 | 54 | 55 | 0.242 |
| 22 | UH-ZSN-95-25-20022 | 55 | 56 | 0.150 |
| 23 | UH-ZSN-95-25-20023 | 56 | 57 | 0.505 |
| 24 | UH-ZSN-95-25-20024 | 57 | 58 | 0.455 |
| 25 | UH-ZSN-95-25-20025 | 58 | 59 | 0.876 |
| 26 | UH-ZSN-95-25-20026 | 59 | 60 | 0.962 |

Core Sawing Operations. According to the traditional method, the core is sawn along its axis in half, with one half of the core sampled for further testing and the other half retained for storage.

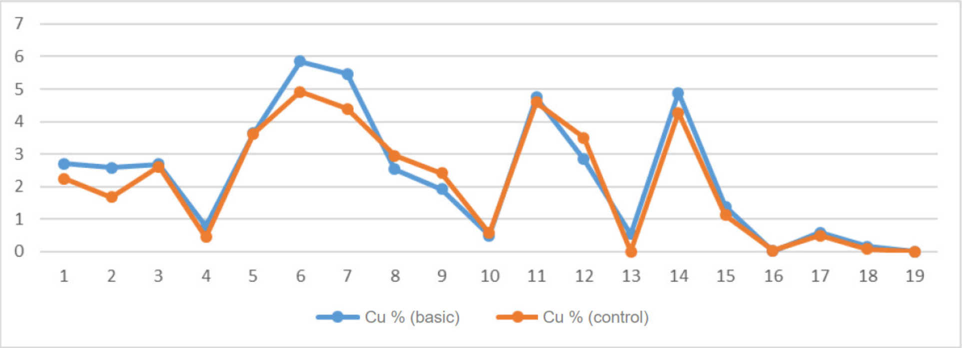


Figure 2 - Diagram of Comparing Two Core Halves

As can be seen from Figure 2 the heterogeneity of minerals occurrence is clearly visible, the two halves of the core are not always identical in terms of copper content.

Sample Preparation and Chemical Analysis

– Ragging of core samples to a fraction class - 1 mm;
– Abrasion of samples to the fraction of analytical powder class - 0.074 mm;
– Chemical analysis.

Table 2 - Sample Weight at Different Stages of Testing

| Stage No. | State | Sample Weight |
|---|---|---|
| 1 | full core | 5.0 kg |
| 2 | sawn core | 2.5 kg |
| 3 | crushed fraction | 1.2 kg |
| 4 | abrasion | 0.3 kg |
| 5 | chemical analysis | 0.05 kg |

As shown in Table 2, the core sample originally weighed 5.0 kg, but was crushed to below 50 grams for chemical analysis. Consequently, the loss of sample representativeness is estimated to be at least 100 times.

The accuracy and precision of X-ray radiometric testing is usually assessed by comparing its data with the results of standard testing, the final step of which is most often chemical analysis for copper content. In this approach, the results of a standard testing are usually taken as true. Therefore, the researchers' actions are aimed at minimizing random discrepancies between the X-ray radiometric method and chemical analysis data, while taking into account tolerances adopted by the relevant standards. However, these tolerances only apply to the final stage of testing, i.e. at the stage of abrasion to analytical powder.

Labor intensity is reduced by eliminating a number of standard testing operations (crushing, grinding, reduction and abrasion of samples to analytical size) (Pak Yu. and Pak D., 2016).

It should be noted that the chain from the traditional testing method was used to ensure integrity of the research for the purpose of finding an optimal method.

The same copper ores of the Zhaissan deposit from the area belonging to Kazakhmys Corporation LLP were subjected to X-ray radiometric testing: in the amount of 5 linear meters or 5 core samples. XRT was conducted at 4 stages of sample preparation (rounded core, sawn core material, crushed fraction up to grade - 1 mm, analytical powder fraction of the grade - 0.074 mm). At the sample preparation stages of the rounded and sawn core, for each 1-meter core sample, 13 measurements were taken and averaged, according to the crushed fractions: class -1 mm - 10 measurements, class -0.074 - 5 measurements (see the below) (Pak et al., 2024).

An Niton analog X-ray radiometric testing instrument was used for the experiment. However, this does not change the essence of the test method itself, as the rapid analysis methodology can be applied to other devices of this type (Pak et al., 2025).

**Results and Discussion.** For the purpose of verifying the accuracy of the measurements, the instrument was calibrated using the certified VIMS reference standards in the form of analytical powder of the fraction class - 0.074 mm, and ore types of the same deposit were used. For stable operation, the instrument was calibrated using the reference standards before each measurement at the different stages of sample preparation.

Table 3 - Comparison of XRT and Chemical Analysis of the Reference Standards

| *Name* | **XRT, %** | chemical analysis, % | deviation |
|---|---|---|---|
| *VIMS 33620* | **0.444** | 0.433 | -0.011 |
| *VIMS 33920* | **3.065** | 3.08 | 0.015 |

Figure 3 - Geological Core for XRT

As Table 3 shows, the deviations are extremely minimal, the XRT confirms the chemical analysis data.

Full core**.** The wells were drilled using the core drilling method with coring. Drilling with diameter NQ 75.3 mm, core diameter of 47.6 mm (Figure 1). XRT was performed on the rounded portion from two core planes with the intervals of 7 cm along the axis, and the data were averaged using 13 measurements.

Within the interval of 67 and 70 m. Ore zone. Quartz-magnetite-chalcopyrite vein. The host rock is granite up to the depth of 70.0m. Chalcopyrite is developed in the form of nests, which are 1x2.5 cm in size, vein-like spots. Chalcopyrite for the entire interval is approximately 10-12% of the total core volume. Fracturing is weak.

*XRT for the Core*

Table 4- Comparison of Averaged XRT Data of Rounded Core of Both Planes

| **UH-ZSN-93-25** | **XRT, %** | | | | |
|---|---|---|---|---|---|
| | **int 65-66 m** | **int 66-67 m** | **int 67-68 m** | **int 68-69 m** | **int 69-70 m** |
| region-1 | 0.165 | 0.019 | 3.464 | 2.93 | 0.333 |
| region-2 | 0.205 | 0.019 | 1.913 | 2.883 | 0.338 |
| average | 0.185 | 0.019 | 2.689 | 2.907 | 0.336 |

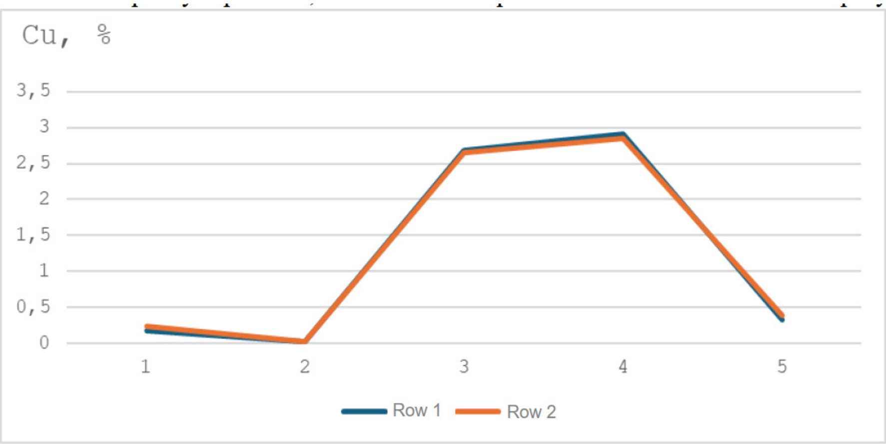
Based on the data in Table 4, in the interval of 67-68 m, there is a nonuniformity in the natural occurrence of the Cu ore element, which affects the final average value for the interval. At the same time, the other intervals have similar results.

Sawn core. The core was sawn by a stone cutting machine into 2 halves along its axis, one half was packed in a sample bag and sent to the laboratory for sample preparation and chemical analysis, and the second half of the core was placed in a core box for storage. In this case, the flat surfaces of both core halves were pre-exposed to XRT at 7 cm intervals, multi-point measurements per 1 meter were also averaged.

Table 5 – Comparison of Averaged XRT Data of the Sawn Core by Their Flat Sides

| **UH-ZSN-93-25** | **XRT, %** | | | | |
|---|---|---|---|---|---|
| | **int 65-66 m** | **int 66-67 m** | **int 67-68 m** | **int 68-69 m** | **int 69-70 m** |
| saw-1 | 0.278 | 0.029 | 1.929 | 2.678 | 0.369 |
| saw-2 | 0.185 | 0.022 | 3.369 | 3.024 | 0.419 |
| *average* | *0.232* | *0.026* | *2.649* | *2.851* | *0.394* |

Based on the data in Table 5, and in the interval of 67-68 m, there is a nonuniformity in the natural occurrence of the Cu ore element, which affects the final average value for the interval. At the same time, the other intervals again have similar results.



Row 1 – rounded core, Row 2 – sawn core,
1 - int 65-66 m, 2 - int 66-67 m, 3 - int 67-68 m, 4 - int 68-69 m, 5 - int 69-70 m
Figure 5 – XRT for Cu. Comparison of the Rounded and Sawn Core

As Figure 5 shows, the sensitivity of the core to copper is within the limits for both the rounded core and the sawn core, the results are identical.

Crushed fraction and analytical powder. The sample was prepared by KazGidroMed LLP. Sample was processed using drying, crushing to the grade fraction of 1 mm, quartering and abrasion of core samples to an analytical powder of grade of 0.074 mm.

XRT measurements were made using the crushed fraction (Table 6) and the analytical powder (Table 7). The crushed fraction was evenly scattered into a tray with the dimensions of 15*20 cm, and about 1 cm thick, and the analytical powder was scattered into a tray of 15 cm diameter, also about 1 cm thick, as shown in Figure 6.

Figure 6 - Crushed Fraction (Left) and Analytical Powder (Right) for XRT

Table 6 - XRT of Crushed Fraction of the Class of 1 mm

| **Measurement No.** | **XRT, %** | | | | |
|---|---|---|---|---|---|
| | **int 65-66 m** | **int 66-67 m** | **int 67-68 m** | **int 68-69 m** | **int 69-70 m** |
| average | 0.294 | 0.034 | 2.433 | 1.892 | 0.631 |

The spread of XRD data for the crushed fraction is characterized by natural nonuniformity of rock occurrence.

Table 7 - XRT of Analytical Powder with Fraction Class of 0.074 mm

| **Measurement No.** | **XRT, %** | | | | |
|---|---|---|---|---|---|
| | **int 65-66 m** | **int 66-67 m** | **int 67-68 m** | **int 68-69 m** | **int 69-70 m** |
| average | 0.301 | 0.042 | 2.284 | 2.014 | 0.591 |

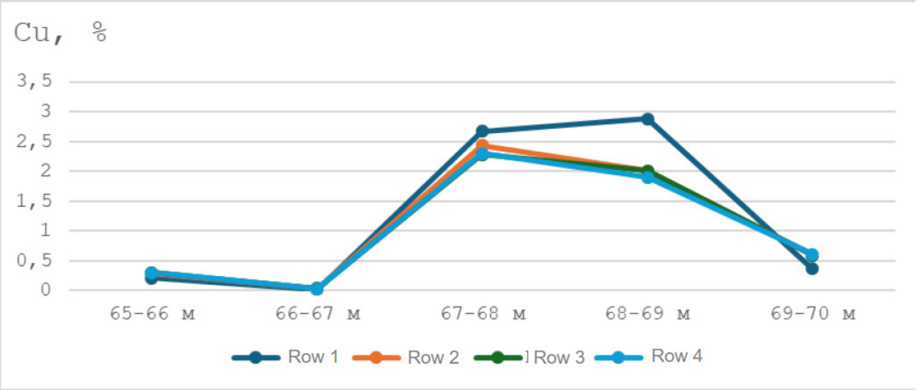
The data from Tables 6 and 7 show that the XRT produce similar results for both the analytical powder and crushed fraction samples, despite some natural nonuniformity in the larger grade fraction of 1 mm compared to the grade fraction of 0.074 mm.

Chemical analysis. All samples in the form of analytical powder with fraction of 0.074 mm were analyzed in the same chemical laboratory of KazGidroMed LLP by the semi-quantitative ICP-OES method for Cu (Table 8).

Table 8 – Chemical Analysis of the Analytical Powder of Class of 0.074 mm

| No. | Interval | chemical analysis - Cu, % |
|---|---|---|
| 1 | 65-66 m | 0.307 |
| 2 | 66-67 m | 0.033 |
| 3 | 67-68 m | 2.30 |
| 4 | 68-69 m | 1.90 |
| 5 | 69-70 m | 0.607 |

The problems of ensuring the required precision and accuracy of the standard methods of testing are especially relevant in connection with the intensive development of instrumental nuclear geophysical methods of quality control for various raw materials. For the purpose of defining correctness of the X-ray radiometric testing data, *the XRT and chemical analysis data were compared* (Figure 7).



Row 1 – XRT core, Row 2 – XRT - 1mm, Row 3 – XRT - 0.074 mm, Row 4 - chemical analysis.
Figure 7 – Comparison of XRT and Chemical Analysis for Cu

Figure 7 shows the results of the XRT study for the 5 core intervals and chemical analysis. The data indicate satisfactory convergence.

**Conclusion.** To increase the accuracy of quantitative determinations of Cu contents, it is necessary to switch to denser calibration standards by pressing analytical powder, and obtain a statistically reliable dependence of the correction factor for various classes of Cu content in the ore.

In cases of uneven distribution of productive mineralization, a higher representativeness of the RPO has been established in comparison with the standard method of core sampling by chemical analysis.

Even with the results achieved, the high efficiency of the RPO allows us to recommend it as the main method for ore quality control during the development of deposits. Representative core sampling using the X-ray radiometric method (rounded and sawn flat surfaces) makes it possible to confidently separate ore and rock intervals.

Studies have shown that, due to its efficiency and sufficient representativeness, X-ray radiometric testing can be recommended not only during the development of deposits, but also in laboratory conditions for determining the copper content in samples of class -1 mm.

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