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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ
«ХАЛЫҚ» ЖҚ

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»
ЧФ «Халық»

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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

ЧФ «ХАЛЫҚ»

В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением,
Благотворительный Фонд «Халык»!

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Satbayev University, Almaty, Kazakhstan.

E-mail: b.bektur@satbayev.university

RESEARCH OF GRAVITY CONCENTRATION OF THE GOLD PLACER OF EASTERN KAZAKHSTAN

Begalinov Abdrakhman — Doctor of Technical Sciences, Professor of «Mining» department, Satbayev University, Almaty, Kazakhstan
E-mail: begalinov_a@mail.ru, https://orcid.org/0000-0002-4793-6207;
Shautenov Mels — Candidate of Technical Sciences, Professor of «Metallurgy and Mineral Processing» department, Satbayev University, – Candidate of Technical Sciences, Professor of «Mining» department, Satbayev University, Almaty, Kazakhstan
E-mail: almen_t@mail.ru, https://orcid.org/0000-0001-9674-8598;
Bektur Bakytbek — PhD, Senior Lecture of «Mining» department, Satbayev University, Almaty, Kazakhstan
E-mail: bekturbek@bk.ru, https://orcid.org/0000-0003-0510-4995;
Sakhipova Karina — Master of Technical Sciences, Doctoral student of «Mining» department, Satbayev University, Almaty, Kazakhstan
E-mail: kakarinaa55@gmail.com, https://orcid.org/0000-0003-4941-1401.

Abstract. A representative sample to test the concentration characteristics was taken from the Central Takyr section of the Tuzbak formation pebbles of the Eocene and gravel-sand formations. The gold content in – 80 + 2 mm pebbles was 0.37 g/t, in – 2+0 mm sands, 1.41 g/t. A process chart for processing a representative sample and a chain of devices for its implementation were developed. The selected sample of gold-bearing sands was examined with regard to its concentration characteristics using the method of “passive” and “active” gravity in a SV-500 screw separator and a vibrating centrifugal bowl-type unit developed at KazNRTU after K.I. Satpayev (Peregudov et al., 2021). Based on the study of the mineral composition of gold-bearing pebbles and the forms of occurrence of the useful component in them, their concentration characteristics were examined. A process chart for concentration and an aggregate technological installation for processing mineral samples were developed. The content of finely dispersed gold in gold-containing products was checked on the basis of thermal activation in a developed thermal activator (Peregudov et al., 2015). Gravity concentration of various fractions of natural sand samples pre-processed in an autogenous mill was done using a developed chain of devices consisting of a vibrating screw separator and centrifugal devices. The research was conducted with regard to gold recovery from gravity concentration tailings based on environmentally safe thiosulfate leaching. The effect of using a complex leaching solution (5) was most pronounced when leaching the gravity concentration tailings. According to the results of analyzes of productive solutions and residual solid sediments (cakes), gold recovery during the leaching amounted to 92.75–93.75 %. The research results can be used to test samples of gold-bearing minerals with regard to their concentration characteristics using the gravity concentration method as well the hydrometallurgical method of processing concentrates.

Keywords: gold, placer, pebbles, sands, size class, autogenous mill, gravity enrichment, vibrating screw separator, centrifugal bowl-type unit, concentrate, tailings

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Satbayev University, Алматы, Қазақстан.

E-mail: b.bektur@satbayev.university

ШЫҒЫС ҚАЗАҚСТАНДАҒЫ ҚҰРАМЫНДА АЛТЫНЫ БАР ШАШЫРАНДЫ КЕНДЕРІНІҢ ГРАВИТАЦИЯЛЫҚ БАЙЫТЫЛУЫН ЗЕРТТЕУ

Бегалинов Әбдрахман — техника ғылымдарының докторы, «Тау-кен ісі» кафедрасының профессоры, Satbayev University, Алматы, Қазақстан
E-mail: begalinov_a@mail.ru, https://orcid.org/0000-0002-4793-6207
Шәутенов Мэлс — техника ғылымдарының кандидаты, «Металлургия және пайдалы қазбаларды байыту» кафедрасының просессоры, Satbayev University, Алматы, Қазақстан
E-mail: shautenov_m@mail.ru, https://orcid.org/0000-0002-0266-3882;
Әлменов Талғат — техника ғылымдарының кандидаты, «Тау-кен ісі» кафедрасының профессоры, Satbayev University, Алматы, Қазақстан
E-mail: almen_t@mail.ru, https://orcid.org/0000-0001-9674-8598;
Бектұр Бақытбек — PhD, «Тау-кен ісі» кафедрасының аға оқытушысы, Satbayev University, Алматы, Қазақстан
E-mail: bekturbek@bk.ru, https://orcid.org/0000-0003-0510-4995;
Сахипова Карина — техника ғылымдарының магистры, «Тау-кен ісі» кафедрасының докторанты, Satbayev University, Алматы, Қазақстан
E-mail: kakarinaa55@gmail.com, https://orcid.org/0000-0003-4941-1401.

Аннотация. Байытуға өкілдік сынаманы іріктеу эоценнің Тұзбақ формациясының қиыршық тастары мен қиыршық-құм түзілімдерінің орталық – Тақыр учаскесінен жүзеге асырылды. Ірілігі -80+2мм класты малтатастағы алтынның мөлшері 0,37 г/т, ірі класты құмдарда – 2+0 мм 1,41 г/т құрады, өкілдік сынаманы өңдеудің технологиялық сұлбасы және оны жүзеге асыру үшін аппараттар тізбегінің аппаратуралық сұлбасы жасалды. Құрамында алтыны бар құмдардың іріктелген сынамасы СВ – 500 бұрандалы сепараторында және Қ.И. Сәтбаев атындағы ҚазҰТЗУ-да әзірленген дірілді ортадан тепкіш табақшалы аппаратында «сылбыр» және «белсенді» гравитациялық әдісімен байыту зерттелді (Перегудов, 2021). Құрамында алтыны бар қиыршық тастардың минералды құрамын және олардағы пайдалы компоненттің түріне қарай зерттеу негізінде олардың байытылуына зерттеу жүргізілді. Байытудың технологиялық сұлбасы және минералдық-технологиялық сынамаларды өңдеу бойынша ірілендірілген технологиялық қондырғы әзірленді. Құрамында алтыны бар өнімдердегі жұқа дисперсті алтынның құрамын бақылау, жасалынған термоактиваторда – термоактивация негізінде жүзеге асырылды (Перегудов, 2015). Дірілді бұрандалы сепаратордан және ортадан тепкіш аппараттардан тұратын аппараттардың тізбегіндегі, құмды өздігінен ұнтақтау диірменінде алдын ала өңделген табиғи сынамаларды фракциялық гравитациялық байыту жүргізілді. Экологиялық қауіпсіз, тиосульфатты сілтілеу негізінде гравитациялық байыту қалдықтарынан алтынды бөліп алу бойынша зерттеулер жүргізілді. Комплексті сілтілеу ерітіндісін қолдану әсері, келесі көрсеткіштер негізінде – PH көрсеткіші 8,3–9,5 болғанда, гравитациялық байытудың қалдықтарын сілтілеу негізінде айқын көрінді. Өнімдік ерітінділер мен қалдықты қатты тұнба (кек) талдауларының нәтижелеріне сәйкес, сілтілеу кезінде алтынды айырып алу 92,75–93,75 % құрады. Зерттеу нәтижелері құрамында алтыны бар минералды шикізат сынамаларын гравитациялық байыту әдісімен өңдеу кезінде, сондай-ақ байыту өнімдерін гидрометаллургиялық әдісі негізінде өңдеуді қолданылуы мүмкін екендігі анықталынды.

Түйін сөздер: алтын, шашыранды кен, қиыршық тастар, құмдар, ірілік классы, өзін-өзі ұнтақтау диірмені, гравитациялық байыту, дірілді бұрандалы сепаратор, ортадан тепкіш аппарат, концентрат, қалдық

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Satbayev University, г.Алматы, Казахстан.

E-mail: b.bektur@satbayev.university

ИССЛЕДОВАНИЕ ГРАВИТАЦИОННОЙ ОБОГАТИМОСТИ ЗОЛОТОСОДЕРЖАЩЕЙ РОССЫПИ ВОСТОЧНОГО КАЗАХСТАНА

Бегалинов Абдрахман — доктор технических наук, профессор кафедры «Горное дело», Satbayev University, Алматы, Казахстан
E-mail: begalinov_a@mail.ru, https://orcid.org/0000-0002-4793-6207;
Шаутенов Мэлс — кандидат технических наук, профессор кафедры «Металлургии и обогащения полезных ископаемых», Satbayev University, Алматы, Казахстан
E-mail:shautenov_m@mail.ru, https://orcid.org/0000-0002-0266-3882;
Алменов Талгат — кандидат технических наук, профессор кафедры «Горное дело», Satbayev University, Алматы, Казахстан
E-mail: almen_t@mail.ru, https://orcid.org/0000-0001-9674-8598;
Бектур Бакытбек — PhD, старший преподаватель кафедры «Горное дело», Satbayev University, Алматы, Казахстан
E-mail: bekturbek@bk.ru, https://orcid.org/0000-0003-0510-4995;
Сахипова Карина — магистр технических наук, докторант кафедры «Горное дело», Satbayev University, Алматы, Казахстан
E-mail: kakarinaa55@gmail.com, https://orcid.org/0000-0003-4941-1401.

Аннотация. Отбор представительной пробы на обогатимость осуществлялся из Центрально-Такырского участка галечников Тузбакской свиты эоцена и гравийно-песчаных образований. Содержание золота в галечнике класса крупности – 80 + 2 мм составило 0,37 г/т, в песках класса крупности – 2+0 мм 1,41 г/т. Разработана технологическая схема обработки представительной пробы и аппаратурная схема цепи аппаратов для ее осуществления. Отобранная проба золотосодержащих песков исследовалась на обогатимость методом «пассивной» и «активной» гравитации в винтовом сепараторе СВ – 500 и виброцентробежном чащевом аппарате, разработанном в КазНИТУ им. К.И. Сатпаева (Перегудов, 2021). На основе изучения минерального состава золотосодержащих галечников и формах нахождения полезного компонента в них проведены исследование на их обогатимость. Разработана технологическая схема обогащения и укрупненная технологическая установка по обработке минералого-технологических проб. Контроль содержания тонкодисперсного золота в золотосодержащих продуктах осуществлялся на основе термоактивации в разработанном термоактиваторе (Перегудов, 2015). Проведено пофракционное гравитационное обогащение природных, предварительно обработанных в мельнице самоизмельчения песков пробы на разработанной цепи аппаратов, состоящей из вибровинтового сепаратора и центробежных аппаратов. Проведены исследования по извлечению золота из хвостов гравитационного обогащения на основе экологически безопасного тиосульфатного выщелачивания. Эффект применения комплексного выщелачивающего раствора состава – при pH 8,3 – 9,5, наиболее выражен1 о проявился при выщелачивании хвостов гравитационного обогащения. Согласно результатам анализов продуктивных растворов и остаточных твердых осадков (кеков), извлечение золота при выщелачивании составило 92,75–93,75 %. Результаты исследования могут применяться при обработке проб золотосодержащего минерального сырья на обогатимость гравитационным методом обогащения, а также на основе гидрометаллургического метода обработки продуктов обогащения.

Ключевые слова: золото, россыпь, галечники, пески, класс крупности, мельница самоизмельчения, гравитационное обогащение, вибровинтовой сепаратор, центробежный чащевый аппарат, концентрат, хвосты

Introduction

Currently, the main object for developing gold-containing minerals is primary gold ore deposits, while placers are practically not mined.

At the same time, over the history of mankind, at least 23,583 tons of gold have been extracted from placers (Polevanov et al., 1990; Tretyakov et al., 2009). According to N.T. Patyk-Kara and others, during the period of placer development (since the 1930s), about 5,450 tons have been mined in the gold-bearing regions of North-East Asia, in the Amur region – 700–800 tons, in the Urals — about 900 tons (Patyk-Kara et al., 1997). The analysis of the distribution of world gold production by type of deposits for 1998 shows that about 10 % (259 tons) was mined from placers (Yerofeev et al., 1969). In Russia, according to B.I. Benevalsky and others, up to 70 % of gold is mined from placers, while in Kazakhstan it is less than 1.4 % (Begalinov et al., 2005).

The reason for that is the geological exploration work being focused on the research and development of alluvial types of placers in modern valleys, the prospects of which are not great. Most of them have already been worked out. The further development of gold mining should be linked to the involvement of deep placers and the creation of new technologies for their extraction and processing (Meretukov et al., 2005).

Materials and methods

The mineralogical and technological studies included the following procedures: study of the granulometric and mineral composition of clastic material; gravity concentration of various fractions of natural sands pre-processed in the autogenous grinding mill; study of free native and bound gold in concentrates and their quantitative assessment, agitation tests to determine the values of thiosulfate leaching of gold from gravity concentration tailings using hydrometallurgical methods.

The work employed methods of chemical, mineralogical and granulometric analysis. Experimental studies of the concentration characteristics of a selected representative sample of gold-bearing sands of the Takyr-Kaldzhir site based on gravity concentration were done in the conditions of Limited Liability Company “Kazakhstan-Russian Research Center of Scientific and Technical Complexes” in Stepnogorsk, Akmola Region.

Concentration of various fractions of a representative sample was done on a developed aggregate technological installation for processing mineral samples. The mineralogical and technological studies included the following procedures: study of the granulometric and mineral composition of clastic material; gravity concentration of various fractions of natural sands pre-processed in the autogenous grinding mill; study of free native and bound gold in concentrates and their quantitative assessment.

Results and discussion

The studies were performed on a selected sample of gold-bearing sands of the Takyr-Kaldzhir pebble area. The sample mass was 215 kg, the gold content in the sample according to the nameplate was 352 mg/m^3.

The original sample was divided into two parts. One was studied using a material of natural size (granulometric, chemical, mineral composition) with concentration of various fractions of selected size classes. A standard set of technological parameters was obtained that made it possible to estimate the amount of free and bound native gold.

The other one was pre-treated in the autogenous mill with subsequent enrichment of the sand (-2+0 mm) fraction using the gravity process chart on the vibrating screw separator and the centrifugal bowl-type unit with the purpose of quantitative determination of free and bound native gold.

The granulometric composition was determined by means of manual wet screening and rubbing of fine-grained material on a screen. The screening was done on a round and square (5 mm and smaller) sizing screen. The liquid phase was preserved and — 0.044+0 mm solid particles were settled during 24 hours.

The sample material was screened into 11 size classes (mm): -40+20; -20+10; -10+5; -5+2; -2+1; -1+0.5; -0.5+0.25; -0.25+0.1; -0,1+0.074; -0.074+0.044 and -0.044+0.

Gravel and pebble classes (yield ranging from 10.5 to 17.61 %) were distributed quite evenly, while a significantly lower yield was in sandy classes with more or less even distribution (3–4 %).

The detrital material is semi-rounded and angular. As the grain size decreases, the degree of roundness also decreases. Coarse-grained material, pebbles and sand were screened on the 80mm, 40mm and 20mm screens and on the 5x5mm and 2x2mm sieves.

Coarse-grained (-80+2mm) class amounts to 47 %, about 20 % of 0.37 g/t gold is associated with it (Tables 1, 2). Fine detrital (-2+0 mm) class prevails, its yield is about 50 % (53.06 %) and it is associated with 81.13 % of all 1.41 g/t gold in the sample. The detrital material is rounded. Thus, the gross gold content in the studied sample is 0.92 g/t.

Table 1 – Distribution of pebbles and gravel-sand deposits in the studied sample

Name	Size class, mm	Yield		Au content, g/t	Au distribution, %
		kg	%		
Pebble	-80+2	38,39	47,27	0,37	19,02
Sands	-2+0	42,82	52,73	1,41	80,98
Original sample		81,21	100	0,92	100

* gold content in the pebble ground in a mill

Laboratory tests of concentration properties were conducted in line with a two-stage concentration process chart. At the first stage, natural material was subjected to concentration (by fractions). In the second, all materials were pre-treated in the autogenous grinding mill, followed by concentration of attrited sands (-2+0 mm).

The concentration was done at the aggregate technological installation shown in Figure 1.

Figure 1 – The aggregate technological installation for processing mineral samples.
1 – autogenous mill; 2 – screw separator; 3 – vibrating centrifugal bowl-type units.

In the developed autogenous grinding mill, natural pebbles (detrital material from the original sample of the studied material) are used as a grinding medium.

The novelty of the proposed technology for processing sample materials is the quantitative assessment of gold in all sample materials, from sand to boulder-pebble deposits.

The results of gravity concentration of natural material of gravel-sand class size are given in Table 2.

Table 2 shows that during the concentration of fractions, almost all finely dispersed gold is concentrated in the final tailings. Its total content in sands is 1.41 g/t, according to thermal activation data – 1.74 g/t, which is higher than the original values by approximately 23.40 %.

The developed process chart for processing samples is shown in Figure 2. The gravity concentration of sands rubbed from pebbles in the autogenous wet-grinding mill resulted in obtainment of gold-bearing sand and the following products: rubbed pebbles (+2 mm) – 79.60 kg; sands (-2+0 mm) – 126.40 kg; bulk gravity concentrate – 6.315 kg; final tailings –120.085 kg; the original sample weight was 199.68 kg.

Table 2 – The results of gravity concentration of natural material of gravel and sand sizes

Class size	Preparation products	Yield		Sample number	Au content, g/t	Au content, %
		Kg	%			
1	2	3	4	5	6	7
-5+2	Concentrate from the screw separator	0,19	2,43	3	0,88	3,77
	Tailings	7,65	97,57	2	0,52	96,23
	Original material	7,84	100	1	0,53	100
-2+1	Concentrate after re-cleaning on the screw separator	0,077	0,37	8	2,35	1,74
	Recleaning tailings after the screw separator	0,715	9,09	7	1,63	4,35
	Concentrate after the centrifugal unit	0,08	1,02	6	1,22	1,74
	Tailings	6,994	88,92	5	1,08	92,17
	Original material -2+1 mm	7,866	100	4	1,15	100
-0,1+0,5	Concentrate after re-cleaning on the screw separator	0,045	0,40	13	0,30	0,09
	Recleaning tailings after the screw separator	1,107	9,98	12	3,33	27,64
	Concentrate after the centrifugal unit	0,063	0,57	11	1,56	2,45
	Tailings	9,87	89,05	10	0,89	69,92
	Original material -1+0,5 mm	11,085	100	9	1,13	100
-0,5+0,25	Concentrate after re-cleaning on the screw separator	0,080	2,77	18	1,43	5,19
	Recleaning tailings after the screw separator	0,127	4,40	17	1,47	7,79
	Concentrate after the centrifugal unit	0,088	3,03	16	1,37	5,19
	Tailings	2,590	89,30	15	0,70	81,83
	Original material -0.5+0.25 mm	2,885	100	14	0,77	100

-0,25+0,1	Concentrate after re-cleaning on the screw separator	0,085	1,62	24	1,21	4,0
	Recleaning tailings after the screw separator	0,063	1,80	23	1,30	3,0
	Concentrate after the centrifugal unit	0,094	1,79	22	1,34	4,80
	Tailings	5,010	95,39	21	0,46	88,20
	Original material -0.25+0.1 mm	5,252	100	19	0,50	100
-0,1 +0,074	Concentrate after re-cleaning on the screw separator	0,103	1,24	29	2,68	2,16
	Recleaning tailings after the screw separator	0,503	6,06	28	2,18	8,62
	Concentrate after the centrifugal unit	0,95	1,14	27	1,40	1,04
	Tailings	7,60	91,56	26	1,48	93,18
	Original material -0.1 +0.074 mm	8,301	100	25	1,53	100
-0,074+0,044	Concentrate after re-cleaning on the screw separator	0,060	2,87	34	1,36	2,95
	Recleaning tailings after the screw separator	0,072	3,45	33	2,72	5,65
	Concentrate after the centrifugal unit	0,006	0,29	32	1,49	0,35
	Tailings	1,95	93,39	31	1,29	81,05
	Original material -0.074+0.044 mm	2,088	100	30	1,33	100
-0,044+0	Concentrate after re-cleaning on the screw separator	0,037	0,70	38	1,04	0,20
	Concentrate after the centrifugal unit	0,0013	0,24	37	1,05	0,11
	Tailings	5,26	99,26	36	3,47	99,69
	Original material -0.074+0.044 mm	5,36	100	35	3,45	-
Original material -5+0 mm		50,66	100	-	1,30	-
Class size -2+0 mm		42,88	100	-	1,41	-

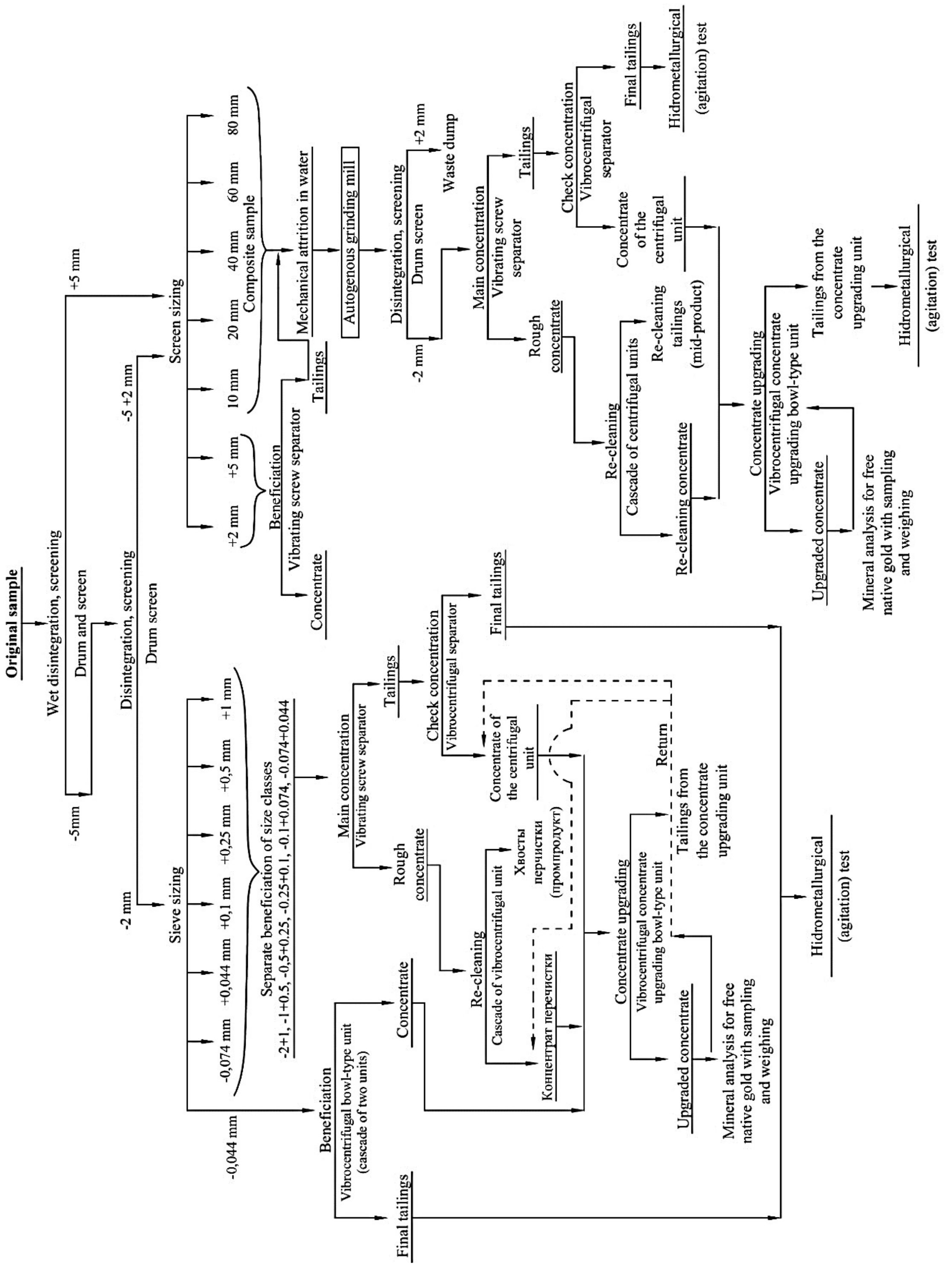


Figure 2 – The process chart for processing samples from the Takyr-Kaldzhir site.

The amount of finely dispersed gold was determined by thermal activation in the designed thermal activator. Thermal activation was done by means of red heating of a sample receptacle from the outside by burning coal (temperature 400–750–800˚C). The sample material was heated (450–1,000 degrees) inside the thermal activator in a hot gas medium without air access and disruption of continuity of the studied material. The organic mineral “crusts” of gold particles were destroyed, melted and enlarged. Volatile fractions were also captured in a thermal activator using a specially developed carbon-containing sorbent (Zakharov et al., 2004; Peregudov et al., 2022).

Moreover, the maximum content of nano-gold, to which we think its volatile fractions (i.e. sorbed) belong, is in clayey-sludge ~70 % (68.87 %) and fine-grained material (-0.1+0.074 mm) ~55 % (54. 61 %). In the rest materials it is within the range of 15–25 %.

Thus, using the thermal activation analysis it was possible to confirm not only the presence of finely dispersed gold, but also its content (1.74 g/t) in sands.

The yield of free gravitating native gold in preparation products is the following:

- Concentrate from the vibrating screw separator - 9.409 mg
- Concentrate from the vibrocentrifugal unit - 0.54 mg

Total in the sample - 9.949 mg

In terms of 1m^3 of sands - 99.65 mg/m^3

The results of gravity concentration of bound finely dispersed gold are presented in Table 3.

Table 3 – The results of gravity concentration of sands, a bulk sample ground in a mill

Preparation product	Yield		% of the sample	Gold content, g/t	Gold distribution, %
	Kg	%			
+2 (attrited pebble)	79,60	-	-	0,37	-
-2 mm	126,40	-	-		-
Concentrate after re-cleaning on the screw separator	0,04	0,03	46	2,74	0,06
Recleaning tailings after the screw separator	6,18	4,89	45	2,74	8,82
Concentrate after the centrifugal unit	0,09	0,08	44	8,76	0,46
Final tailings	120,09	95,0	43	1,45	90,66
Original sand	126,40	100	-	1,52	100

Finely dispersed gold is practically not gravitated (total recovery into the gravity concentrate was 8.84 %). The content of finely dispersed gold in the sample is 1.52 g/t. The amount of nano-gold (volatile fraction) is ~9 %. The gold content in the gravity concentrate is low and low-grade.

The research included a mineralogical description of free native gold in preparation products of all size classes, selection of -2+0.044 mm classes, weighing, and composition analysis.

During concentration of fractions, almost all finely dispersed gold was concentrated in the final tailings.

Finely dispersed gold is practically not gravitated (not concentrated). The total recovery into gravity concentrate was 8.84 %. The content of finely dispersed gold in the sample is 1.52 g/t. After thermal activation it increased to 1.90 g/t (by 25 %), the amount of nano-gold (volatile fraction) is ~ 9 %.

To capture finely dispersed gold from gravity concentration tailing it is proposed to use the hydrometallurgical method.

The content of free native gold in the entire sample is 327 mg/m^3, i.e. by an order less than finely dispersed gold content, but it is high-tech and is recovered by simple, cheapest gravity methods, therefore it is of practical interest.

Assessing of the feasibility of gold recovery from gravity tailings using hydrometallurgical methods (Plaksin et al., 1964).

To research the cyanide and thiosulfate leaching, three samples were presented: autogenous mills (sample No. 1), thermal activation (sample No. 2), thermal activation of the volatile fraction on a carbon-containing sorbent (sample No. 3).

Research on agitation leaching tests was done in the chemical analytical laboratory and the laboratory of physical methods of analysis of the Institute of Metallurgy and Beneficiation JSC. The samples were crushed to a particle size of 0.071 mm in a bead mill.

For agitation tests, 100 g sub-samples were taken from each sample to determine gold presence.

For chemical, X-ray fluorescence and X-ray phase analyzes, averaged and rubbed samples were taken from mineral samples. To determine the gold content in them, the following methods of analysis were used: atomic absorption and assay. Elemental composition was determined using X-ray fluorescence analysis method.

To determine the elements in the samples, an Axios "PaNalyical" (the Netherlands) combined X-ray fluorescence wavelength-dispersive spectrometer was used.

Qualitative and quantitative X-ray phase analysis was done using a D8ADVANCE diffractometer "Bruker Elemental Gmbh" (Germany).

Of industrial value is only gold the content of which, according to assay analysis, is (g/t): in sample No. 1–1.0; No. 2–1.2; No. 3–1.2.

According to the results of phase analysis, basically all samples are represented by quartz formations (more than 94.9 %), with fragments of calcite (1.6–2.5 %), microcline (1.4–1.5 %), albite (1.2 %). The results of the analysis of variance show that in the original sample of crushed ore the largest part is made up of the following size classes: sample 1 and sample 2 – 15–20 microns and 60–70 microns, respectively; sample 3, less than 10 microns.

The experimental results showed that to leach gold in sample 1, the optimal solution is to use a standard cyanide solution with a concentration of 1 g/l. Gold recovery during cyanidation of sample 1 was 92–93 %, which is 5–6 % higher than that of thiosulfate leaching. However, a repeated experiment on gold leaching from sample 1 showed that recovery was at approximately the same level of 81–84 %, both using cyanidation and a combination of sodium thiosulfate with ammonium sulfate. This factor demonstrates fairly high efficiency of this combined leaching solution as an alternative method of cyanide-free leaching of gold.

The effect of using the combined leaching solution ($Na_2S_2O_3$ – 50 g/l, $(NH_4)_2$ SO_4 – 25 g/l, Cu – 0.1 g/l at pH 8.3–9.5) was most pronounced when leaching samples 2 and 3. According to the results of analyzes of productive solutions and residual solid sediments (cakes), gold recovery during leaching of sample 2 was 92.75–93.75 %, and sample 3–89.58–91.67 %. These results also indicate the effectiveness of the previously described combination of reagents in a slightly alkaline medium as a leaching solution for gold-containing raw materials. They also prove that these experiments can be used for future development of cyanide-free hydrometallurgical technologies for gold production.

Conducting agitation leaching tests

Cyanidation tests were done using the agitator at a rotation speed of 40 rpm. The mass of samples 1, 2 and 3 in each series of experiments is 100 g.

This section contains the results of hydrometallurgical studies of original size (-0.071 + 0 mm) of samples No. 1, No. 2 and No. 3. Agitation leaching tests on each sample:

sample No. 1 agitation test with a 1.0 g/l NaCN concentration;
$Na_2S_2O_3$ – 50 g/l, $(NH_4)_2SO_4$ – 25 g/l, Cu - 0,1 g/l, pH – 8,3-9,5;
$Na_2S_2O_3$ – 30 g/l, $(NH_4)_2SO_4$ – 20 g/l, Cu - 0,1 g/l, pH – 8,3-9,6
sample No. 2 agitation test with a 1.0 g/l NaCN concentration;
$Na_2S_2O_3$ – 50 g/l, $(NH_4)_2SO_4$ – 25 g/l, Cu - 0,1 g/l, pH – 8,3-9,5;
$Na_2S_2O_3$ – 30 g/l, $(NH_4)_2SO_4$ – 20 g/l, Cu - 0,1 g/l, pH – 8,3-9,6
sample No. 3 agitation test with a 1.0 g/l NaCN concentration;
$Na_2S_2O_3$ – 50 g/l, $(NH_4)_2SO_4$ – 25 g/l, Cu - 0,1 g/l, pH – 8,3-9,5;
$Na_2S_2O_3$ – 30 g/l, $(NH_4)_2SO_4$ – 20 g/l, Cu - 0,1 g/l, pH – 8,3-9,6

Repetition of experiments for internal/external check (agitation leaching):
Cyanide leaching tests of all 3 samples with a concentration of 1 g/l;
Thiosulfate leaching tests in various options:

$(NH_4)_2S_2O_3$ – 50; $(NH_4)_2SO_3$ – 25; Cu – 0,1 at Ph = 8.3-9.5
$(NH_4)_2S_2O_3$ – 30; $(NH_4)_2SO_3$ – 20; Cu – 0,1 at Ph = 8.3-9.5

To study the technological properties of original samples 1, 2 and 3, cyanide and thiosulfate leaching tests were done using different concentrations and durations.

In order to increase the reliability of the results in each leaching mode, the experiments were repeated on three samples in the agitation mode.

The tests to study the effect of cyanide and thiosulfate concentration on gold recovery were done on materials of the following size: 92 % of -0.071 mm class. The samples for research were ground in a laboratory ball mill MSHL-1. It is designed for fine and wet grinding of samples of various raw materials. Drum rotation speed is 112 rpm. The diameter of the balls is 15–20 mm.

Leaching parameters identical for all tests are given in Table 4. Cyanidation was done in agitation mode. The laboratory test with stirrers is shown in Figure 3.

1 2 3 1 2 3 3 2 1

NaCN-1 g/l thiosulfate leaching 50/25 | NaCN-1 g/l | Thiosulfate leaching 30/20 NaCN-1 g/l

Figure 3 – The laboratory agitators for research on agitation leaching

Table 4 – Leaching mode of original samples

Parameter	Unit	Value
Cyanide concentration (NaCN)	g/l	1,0
Thiosulfate leaching ($Na_2S_2O_3$) $(NH_4)_2SO_4$) Cu	g/l	50 25 0,1
Thiosulfate leaching ($Na_2S_2O_3$) $(NH_4)_2SO_4$) Cu		30 20 0,1
Cyanidation duration	Hr	24
Pulp density during cyanidation	% of solid residue	30
pH	-	8.3-9.5
Solid to liquid ratio		1:3

The results of cyanidation and thiosulfate tests with different concentrations of original samples are given in Table 5.

Table 5 – Results of leaching samples 1, 2 and 3

Sample	Au initial, g/t	Leaching solution	V, ml	Au, mg/l		E Au, % for solution		For solid residue	
				8 hr	24 hr	8 hr	24 hr	Au cake, g/t	E Au, %
Original sample 1	1,0	NaCN - 1 g/l, pH – 10,5-11,0	230	0,27	0,4	62,10	92,00	0,07	93,00
	1,0	$Na_2S_2O_3$ - 50 g/l, $(NH_4)_2SO_4$ - 25 g/l, Cu - 0,1 g/l, pH - 8,3-9,5	230	0,26	0,37	59,80	85,10	0,13	87,00
	1,0	$Na_2S_2O_3$ - 30 g/l, $(NH_4)_2SO_4$ - 20 g/l, Cu - 0,1 g/l, pH - 8,3-9,6	230	0,24	0,36	55,20	82,80	0,16	84,00

Original sample 2	1,2	NaCN - 1 g/l, pH – 10,5-11,0	300	0,2	0,32	50,00	80,00	0,22	81,67
	1,2	$Na_2S_2O_3$ - 50 g/l, $(NH_4)_2SO_4$ - 25 g/l, Cu - 0,1 g/l, pH - 8,3-9,5	250	0,24	0,45	50,00	93,75	0,087	92,75
	1,2	$Na_2S_2O_3$ - 30 g/l, $(NH_4)_2SO_4$ - 20 g/l, Cu - 0,1 g/l, pH - 8,3-9,6	250	0,25	0,38	52,08	79,17	0,22	81,67
Original sample 3	1,2	NaCN - 1 g/l, pH – 10,5-11,0	200	0,33	0,5	55,00	83,33	0,15	87,5
	1,2	$Na_2S_2O_3$ - 50 g/l, $(NH_4)_2SO_4$ - 25 g/l, Cu - 0,1 g/l pH - 8,3-9,5	250	0,26	0,43	54,17	89,58	0,1	91,67
	1,2	$Na_2S_2O_3$ - 30 g/l, $(NH_4)_2SO_4$ - 20 g/l, Cu - 0,1 g/l, pH - 8,3-9,6	250	0,25	0,37	52,08	77,08	0,26	78,33

Table 6 – Repeating experiments with original samples 1, 2 and 3

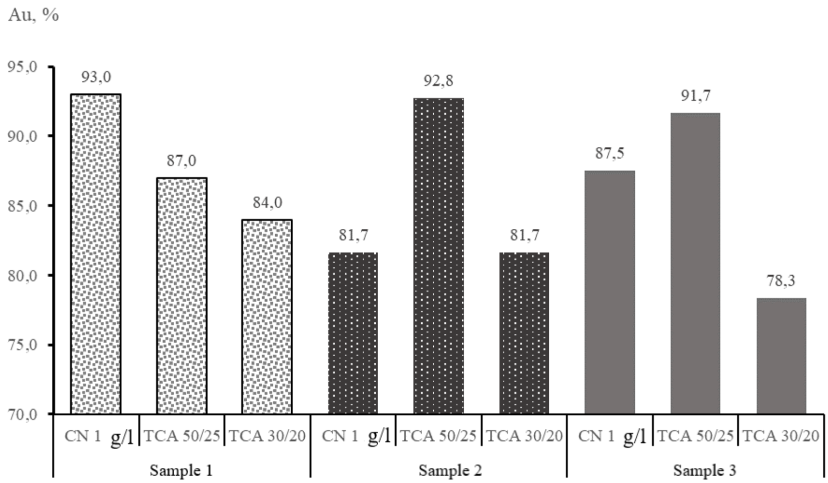
Sample	Au initial, g/t	Leaching solution	V, ml	Au, мg/l		E Au, % for solution		For solid residue	
				8 hr	24 hr	8 hr	24 hr	Au cake, g/t	E Au, %
Original sample 1	1,0	NaCN - 1 g/l, pH – 10,5-11,0	230	0,24	0,36	55,20	82,80	0,18	82,00
	1,0	$Na_2S_2O_3$ - 50 g/l, $(NH_4)_2SO_4$ - 25 g/l, Cu - 0,1 g/l, pH - 8,3-9,5	270	0,22	0,3	59,40	81,00	0,16	84,00

Original sample 2	1,2	NaCN - 1 g/l, pH – 10,5-11,0	300	0,2	0,33	50,00	82,50	0,19	84,17
	1,2	$Na_2S_2O_3$ - 50 g/l, $(NH_4)_2SO_4$ - 25 g/l, Cu - 0,1 g/l, pH - 8,3-9,5	280	0,25	0,36	58,33	84,00	0,16	86,67
	1,2	$Na_2S_2O_3$ - 30 g/l, $(NH_4)_2SO_4$ - 20 g/l, Cu - 0,1 g/l, pH - 8,3-9,6	290	0,15	0,35	36,25	84,58	0,15	87,50
Original sample 3	1,2	$Na_2S_2O_3$ - 50 g/l, $(NH_4)_2SO_4$ - 25 g/l, Cu - 0,1 g/l, pH - 8,3-9,5	270	0,25	0,37	56,25	83,25	0,14	88,33

The data in Tables 6 and 7 show that 92 % of the -0.071mm class of crushed samples significantly affects the performance of cyanide and thiosulfate leaching. The degree of gold recovery as a result of solid residue cyanidation for samples 1, 2 and 3 is 93.0 %, 81.67 %, 87.5 %, respectively; for thiosulfate leaching – 87.0 %, 92.75 %, 91.67 %, respectively.

In the subsequent repeated tests for cyanidation, 92 % of crushed samples with a particle size of -0.071 mm were used. Gold recovery in samples 1 and 2 is 82.0 % and 84.17 %, respectively; for thiosulfate leaching, gold recovery in samples 1, 2 and 3 is 84.0 %, 87.50 % and 88.33 % respectively.

Based on the data obtained, a histogram (Figure 4) was made showing gold recovery levels for each reagent.



TCA – thiosulfate leaching, CN – cyanidation

Figure 4 – Dynamics of leaching original samples 1, 2 and 3 with cyanide and using various options of thiosulfate leaching for solid cake

Gold precipitation from product solutions

To recover gold from cyanide solutions, the zinc precipitation method was used. Currently, this is a leading method in the practice of the gold mining. However, in recent years, the sorption method, based on the use of ion exchange resins and active carbons, has become increasingly widespread.

In the series of metal voltages in cyanide solutions, the potential of zinc (-1.26 V) is more negative than the potentials of gold (-0.54 V) and silver (-0.31 V).

Therefore, zinc metal easily displaces noble metals from cyanide solutions:

$$2\ Au\ (CN)_2^- + Zn = 2\ Au + Zn\ (CN)_4^{2-} \quad (1)$$

$$2Ag\ (CN)_2^- + Zn = 2Ag + Zn\ (CN)_4^{2-} \quad (2)$$

The equilibrium constant of reaction (1) is 1.0-1023, and that of reaction (2) is 1.4-1032. Therefore, in terms of thermodynamics, gold and silver can be precipitated almost completely. Along with the main reactions (1) and (2), there are significant side reactions during the cementation process. Being a strong reducing agent, zinc can reduce water molecules to release hydrogen gas:

$$2H_2O = H_2 + 2OH^- — 2e,\ \varphi_0 = -\ 0{,}83\ B \quad (3)$$

Precipitation of gold from cyanide solutions using the cementation method. After leaching samples 1, 2 and 3, from cyanide solutions, gold was precipitated using zinc dust (Figure 4, 5 a-d, Table 7).

a b c d

a – sample No. 1B (thiosulfate leaching 30/20); b – sample No. 3B (50/25);

c – sample No. 1B (NaCN-); d – sample No. 2B (thiosulfate leaching 50/25).

Figure 5 – Precipitation of product solutions with zinc dust

Conditions of the experiment

Consumption of zinc dust – 0.1 g/l. Precipitation time – 6 hours. For the precipitation experiment, solutions obtained during leaching of the samples were used:

1 – cyanide and thiosulfate 30 g/l; 2 – thiosulfate 50 g/l; 3 – thiosulfate 50 g/l. Precipitation was done with residual volumes of these solutions. The gold recovery was calculated based on gold assays before and after the precipitation.

Table 7 – The results of gold precipitation from product solutions onto zinc dust

Leaching solution	Before precipitation Au, мg/l	After precipitation Au, мg/l	Au precipitated, %
Sample 1 original, CN	0,4	0,0	100,0
Sample 1 – thiosulfate leaching 30/20	0,36	0,06	83,3
Sample 2 – thiosulfate leaching 50/25	0,45	0,05	88,9
Sample 3 – thiosulfate leaching 50/25	0,43	0,05	88,4

Since zinc dust oxidizes easily, there is always some amount of oxide in it. With large specific surface, such dust precipitates gold at high speed and level of completeness.

In production conditions, with a low gold content in the solution, the consumption of zinc dust is usually 15–25 g per 1 ton of solution. In rich solutions, it increases to 40–50 g per 1 ton of solution. The consumption of lead salts is approximately 10–30 % of the dust consumption. The degree of gold precipitation reaches 99.5–99.9 %; the concentration of gold in gold-free solutions does not exceed 0.02–0.03 g/m^3.

Gold precipitation using zinc dust results in cyanide sediments (sludge) with a very complex material composition.

The specified conditions of the process make it possible to recover 92.0 % of gold from sample No. 1 with an estimated gold content of 1.0 g/t and almost complete recovery using cyanide, and to produce cakes after leaching with a minimum gold content of 0.07 g/t. At thiosulfate leaching (50/25), gold recovery is 92.75 %.

Conclusion

Based on the study of the mineral composition of gold-bearing pebbles and the forms of occurrence of the useful component in them, their concentration characteristics were researched.

A representative sample was taken from the pebbles of the Takyr-Kaldzhir site. The concentration process chart and the aggregate technological installation for processing mineral samples were developed.

The content of finely dispersed gold in gold-containing products was checked by means of thermal activation in the designed thermal activator.

The content of free native gold in the entire sample is 327 mg/m^3, i.e. by an order less than finely dispersed gold content, but it is high-tech and is recovered by simple, cheapest gravity methods, therefore it is of practical interest.

Gravity concentration of various fractions of natural sand samples pre-processed in the autogenous mill was done using the developed chain of devices consisting of the vibrating screw separator and centrifugal devices.

Finely dispersed gold is practically not gravitated (cannot be concentrated). The total recovery into the gravity concentrate was 8.84 %. The content of finely dispersed gold in the sample is 1.52 g/t. After thermal activation it increased to 1.90 g/t (by 25 %). The amount of nano-gold (volatile fraction) is ~9 %.

The research was conducted with regard to gold recovery from gravity concentration tailings based on cyanide and thiosulfate leaching.

The effect of using the complex leaching solution ($Na_2S_2O_3$ - 50 g/l, $(NH_4)_2SO_4$ - 25 g/l, Cu - 0.1 g/l at pH 8.3–9.5) was most pronounced when leaching samples 2 and 3. According to the results of analyzes of productive solutions and residual solid sediments (cakes), gold recovery after leaching sample 2 amounted to 92.75–93.75 %; sample 3, 89.58–91.67 %.

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