Perspectives to process old gold-bearing tailings at Kumtor gold ore concentrator, Kyrgyz Republic

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Abstract. Research findings on old tailings at Kumtor gold deposit are presented. The data on the chemical, phase, grain-size analysis of flotation tailings and cyanidation cakes are reported. Heap leaching process is described. Economic advantages of promising processing of mining wastes by the integrated conventional and innovative technologies in view to support metal production from accumulated mining and concentrator wastes in Kyrgyz Republic are demonstrated.

1. Introduction
High-altitude gold deposit Kumtor explored by Soviet geologists in 1989 in Kyrgyz Republic is a unique gold deposit which initial proved gold reserves amounted to 731 t of gold. The development of this-kind mineral deposit was repeatedly postponed because of mining complexity under permafrost conditions. However in 1992 the government of Kyrgyz Republic entered into the contract with Kyrgyzaltyn state corporation and Cameco Corporation, Canada. The contract granted exclusive rights to Cameco Corp. to develop Kumtor deposit. Within the terms of the contract Kumtor Gold Co. was founded. The company promoters were Kyrgyzaltyn Corp. on behalf of Kyrgyz Republic government and Cameco Corporation on behalf of Canada with 1/3 : 2/3 capital interest, respectively.

In 1997 the commercial exploitation of the deposit was launched. The average production rate amounted to 17 t of gold/year (550 thousand oz.), and up to 2 t of silver/year (65 thousand oz.). In 2003 the Kumtor restructuring agreement signed between the government of Kyrgyz Republic and Cameco Corporation involved rescission of the Contract dated by 1992 and foundation of a new joint stock company, registered as Centerra Gold Inc. in Toronto, Canada. Above 120 Mt of gold-bearing ore of average grade within 4 g per 1 t of ore (480 t of gold) was processed at the gold ore concentrator for 21 year operation of the gold mine. More than 360 t of marketable gold were produced. The low requirement for the run-of-mine ore grade, inefficient techniques for ore processing, the valuable content in concentrator tailings, as a rule, appreciably exceeded the admissible level (Table 1). Preliminarily calculated metallurgical balance of Kumtor tailing dumps indicates the content of more than 100 t of gold, 160 t of silver, more than 4000 t of copper.

The poor prospected vein gold reserves, scaling down of geological prospecting activity, deficit of promising areas in the open acreage give grounds to re-estimate the rating of non-traditional mineral resources and to assess commercial value of gold-bearing wastes at Kyrgyzstan gold mines. The advance in mineral processing enables to consider such mineral mining and processing wastes as large man-made (techno-genic) mineral deposits. In foreign countries the gold-bearing waste materials are
involved into re-processing. Thus in Republic of South Africa the annual gold recovery rate from waste materials amounts to 3–5 t [4]. In Kyrgyz Republic Makmal, Tereksai and other operating and idle mines afford the promising potential for additional gold recovery from wastes. Specific legislation concerning the utilization of techno-genic objects, lack of information on actual ore loss in the course of exploitation of currently-idle mines, poor geological and technical documentation make impossible the prompt involvement of “ready-made” techno-genic deposits into production. Investment attractiveness of techno-genic mineral foundations is enhanced by their location in developed industrial regions in the vicinity of operating ore preparation plants, provided that dumps are on the daylight surface, as in this case the material mass is disintegrated and low expenditure are demanded to involve waste material into production.

Table 1. Chemical composition of the pulp discharged from Kumtor gold ore concentrator.

| Year     | 2008   | 2009   | 2010   | 2011   |
|----------|--------|--------|--------|--------|
|          | Au     | Ag     | Cu     | Au     | Ag     | Cu     | Au     | Ag     | Cu     |
| January  | 0.37   | 0.73   | 20.30  | 0.29   | 1.13   | 26.32  | 0.93   | 1.21   | 26.08  |
| February | 0.36   | 0.97   | 22.23  | 0.24   | 1.11   | 29.99  | 0.84   | 1.27   | 21.36  |
| March    | 0.58   | 1.40   | 17.98  | 0.47   | 0.97   | 35.03  | 0.63   | 1.06   | 18.57  |
| April    | 0.42   | 1.02   | 17.84  | 0.55   | 1.10   | 32.17  | 0.41   | 1.03   | 18.88  |
| May      | 0.59   | 1.41   | 31.70  | 0.40   | 1.01   | 23.52  | 0.45   | 1.02   | 17.98  |
| June     | 0.58   | 1.10   | 30.44  | 0.49   | 0.94   | 25.70  | 0.44   | 1.12   | 21.91  |
| July     | 0.46   | 1.13   | 24.41  | 0.78   | 1.51   | 28.39  | 0.28   | 1.08   | 21.56  |
| August   | 0.52   | 0.96   | 40.48  | 0.67   | 1.36   | 46.77  | 0.25   | 0.90   | 23.23  |
| September| 0.75   | 1.23   | 60.82  | 0.38   | 1.03   | 41.19  | 0.26   | 0.87   | 25.91  |
| October  | 0.76   | 1.09   | 44.15  | 0.32   | 2.07   | 26.78  | 0.30   | 1.09   | 26.40  |
| November | 0.74   | 1.22   | 25.70  | 0.94   | 1.51   | 37.58  | 0.78   | 1.27   | 28.60  |
| December | 0.56   | 1.13   | 21.19  | 1.19   | 1.79   | 41.58  | 1.85   | 2.78   | 51.51  |

Table 2. Chemical composition of Kumtor tailing specimens.

| Parameter   | Tailings | Abundance in host rock |
|-------------|----------|-----------------------|
| Ag, mg/l    | 410      | 0.04–0.3              |
| Al, %       | 7.83     | 8.32                  |
| As, mg/l    | 8.9      | 1–13                  |
| Sb, mg/l    | 4.1      | 1.5                   |
| Ba, mg/l    | 42       | 425                   |
| Ca, %       | 5.86     | 4.15                  |
| Cd, mg/l    | 0.15     | 0.03–0.3              |
| Co, mg/l    | 24.1     | 25                    |
| Cr, mg/l    | 80       | 100                   |
| Cu, mg/l    | 28       | 4–87                  |
| Fe, %       | 6.28     | 5.63                  |
| K, %        | 4.3      | 2.09                  |
| Mg, %       | 1.45     | 2.33                  |
| Mn, %       | 1.8      | <0.15                 |
| Mo, mg/l    | 5.79     | 1.5                   |
| Na, %       | 1.16     | 2.36                  |
| Hg, mg/l    | 0.023    | 0.09                  |
| Ni, mg/l    | 56.6     | 2–130                 |
| Pb, mg/l    | 30.2     | 6–20                  |
| Zn, mg/l    | 72       | 16–105                |
In 2009 Alex Stuart laboratory, Kumtor Gold, performed chemical analysis of tailings of gold ore concentrator (Table 2). The pulp was sampled at different points of the tailing beach, the dressing capacity of the dump material was studied. Geological specific features of techno-genic foundations depend on origin and composition of gold-bearing material subjected to first techno-genic and later to hypergenic effects (low temperature, pressure, oxidation, etc.). At present the attempts are made to substantiate the process for gold recovery from old tailings of beach-type dumps by drainage of a tailing massif and division it into non-productive horizons, including poor-grade tailings in the top section of the techno-genic mass and productive horizons at the base of techno-genic mass with higher gold content. Thus, hypergenic transformation of tailings under influence of acid aggressive sulfate-calcic medium at the techno-genic water-bearing formation leads to redistribution of gold from a disseminated state to horizons specified by enriched precious metal content of 1–10 g/t, applicable for commercial processing. The establishment of boundaries of a hypergenically modified productive horizons, removal of tailings from non-productive horizons and further processing of modified tailings at productive horizons are efficiently realized by applying the heap leaching process [1]. It is reasonable to emphasize that at present there is a number of scientifically substantiated innovative structures for a leaching module in the permafrost zone. The advantages of heap leaching process run as follows: low total and specific capital expenditures, low maintenance costs, lack of energy- and material-intensive operations, high labour performance, few personal.

2. Increasing the efficiency of gold mining

The present research work aims at improving efficiency of Kyrgyzstan gold deposit development at the expense of integrated conventional and innovative processes for metal production from accumulated mining wastes and ore processing at the final stages of mineral deposit exploitation (2, 3, 5).

The mineralogical analysis is executed by counting in monomineral gold fractions. Gold is lost in flotation tailings because gold remains associated with nonmetal minerals. Non-floatable gold in flotation tailings occurs as intergrowths with nonmetal minerals mostly with carbonates (Table 3, 4).

Table 3. Granulometric characteristic of flotation tailings, cakes of cyanidation of flotation tailings and concentrates.

| Size class, \( \mu m \) | Yield of granulometric classes, % |
|------------------------|----------------------------------|
|                        | Flotation tailings | Cyanidation cakes |
|                        | Flotation tailings | Cyanidation cake |
|                        | Concentrate       | Concentrate       |
| +150                   | 21.47             | 23.72             |
| 53–150                 | 27.72             | 29.88             |
| 25–53                  | 15.03             | 14.38             |
| 5–25                   | 20.16             | 13.25             |
| −5                     | 15.62             | 18.77             |

Table 4. Gold content in mineral different-density fractions, g/cm\(^3\).

| Fraction size, \( \mu m \) | Flotation tailings | Cakes of cyanidation of flotation tailings | Cakes of cyanidation of concentrate |
|-----------------------------|-------------------|------------------------------------------|-----------------------------------|
| 2.68–3.10                   | 2.68–3.10         | 2.68–3.10                                |
| +150                        | 0.65              | 0.49                                     |
| 53–150                      | 0.51              | 0.24                                     |
| 25–53                       | 0.50              | 0.15                                     |
| 5–25                        | 0.28              | 0.11                                     |
| −5                          | —                 | 0.17                                     |
| 2.68–3.10                   | 0.51              | 0.42                                     |
| 2.68–3.10                   | 0.15              | 0.67                                     |
| < 2.68                      | 0.17              | 0.96                                     |
| < 2.68                      | 0.17              | 0.48                                     |
| < 2.68                      | 0.17              | 1.42                                     |
The gold loss in flotation tailings is attributed by poor opening of finely disseminated gold and calaverite in host rocks, while gold is lost in cakes of cyanidation of the concentrate because of insufficient opening of gold-bearing minerals among pyrite and their incomplete dissolution (Figure 1). The loss of gold and calaverite inclusions in pyrite is 40.3%; the ore specimen ground to 77% of 25 µm, gold and calaverite grains of 7 µm in size remain confined within pyrite (Figure 2). Grinding down to less than 10 µm guarantees opening of all the gold inclusions within 3 µm size range. Grinding down to 10 µm the expectant gold content in cyanidation cakes can be about 1.5 g/t, assuming that gold loss in adsorption of gold by slimes is eliminated. The experimental data on are close to gold content (1.4 g/t), obtained in the product of intensive cyanidation. In this case the low gold leaching (0.84 g/t) is explained by finely dispersed gold content in the pyrite structure and gold-bearing mineral inclusions of less than 3 µm in pyrite.

Figure 1. Relationship of opening degree of gold (1) and calaverite (2) in pyrite versus their grain size.

Figure 2. Inclusions of (a) virgin gold and (b) calaverite in pyrite.

The investigation into phase composition of gold in tailings of the gold ore concentrator revealed the following reasons for gold loss.

- Gold loss in flotation tailings:
  — insufficient opening of gold and calaverite due to their fine dissemination in host rocks is responsible for 65% of total loss values; the average 12 µm inclusions contain gold mainly associated with carbonates (37%);
— loss in slime size class of 5 µm (15%);
— unfloatable free gold and calaverite (10%).

• Gold loss in cakes of cyanidation of the concentrate:
  — gold-bearing minerals of 1–7 µm in size, confined within pyrite (40.3 gold loss);
  — insoluble gold and calaverite, free and in intergrowths (28%);
  — finely dispersed gold and calaverite of less than 1 µm in size (18%);
  — adsorption of gold by carbon substance under applied process (15%).

• Gold loss in cakes of cyanidation of flotation tailings:
  — insufficient liberation of virgin gold and calaverite from gangue (65%);
  — due to adsorption by carbon substance (24.6%).

3. Conclusions
It is scientifically justified that the processing of techno-genic gold-bearing mineral materials can provide the production cost of 1 ounce of gold 1.5–2 times lower as compared to that in conventional technologies, moreover, the acting laws afford appreciable preferences (The Tax Code of Kyrgyz Republic, article 300. point 3), the zero tax on mineral resource utilization is granted.

It is verified by computations that innovative techniques for additional recovery of precious metals from technogenic waste materials enable to expend operation life of active mines by 15–20 years, along with concurrent solution to economic, mineral resources, ecological and social problems of the region and the state as a whole.

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