Classification of Raw Sources of Rare-Earth Elements in Kazakhstan

Madali Naymanbayev, Nina Lokhova and Zhazira Baltabekova

JSC "Center of Earth Sciences, Metallurgy and Ore Beneficiation", Almaty 050010, Kazakhstan

Received: February 21, 2013 / Accepted: March 27, 2013 / Published: May 25, 2013.

Abstract: The characteristics of the mineral composition of ores and valuable set of components: The technology of processing depending on the type of mineralization, the nature of the impregnation of ore minerals and their composition have been considered. There have been given technological schemes for processing concrete objects. The analysis of fitness fields for industrial development (degree of scrutiny, the effectiveness of developed enrichment and hydrometallurgy technology) has been provided.

Key words: Rare-earth-rare-metal deposits, technological research, enrichment, hydrometallurgy.

1. Introduction

World mining of rare earth metals has rapidly grown in the last 15 years and it has been increased for than twice.

One of the major problems of rare earth industry creation and development in Kazakhstan is raw material provision.

Kazakhstan disposes of significant deposits of rare earth elements (RARE EARTH ELEMENTS (REE) in the minefields of different in genetic type and complexity. However, on quality Kazakhstan ore deposits are significantly inferior to foreign one presented with high-tech rich ore deposits of rare earth itself [1]. In the ores of Kazakhstan complex deposits REE are available in low concentrations and being as supplementary associated components.

Ores are diverse, complicated in technological manner and processing them requires nonroutine solutions.

2. Results and Discussion

Description of rare-earth deposits and associated rare-earth metals deposits.

Analysis of outcomes of physical & chemical and technological researches maintained in studying a number of deposits containing rare earth elements, indicates that the following elements can be considered for potentially-industrial production of rare earth products with regard to complexity of their development [2]:

- Carbonatite deposits: containing zirconium, niobium, tantalum, scandium, rare earth elements, Krasnomayskoe deposit, in Akmola region, in which elements of the cerium group are 92%-93% in the amount of REE (37%-42% cerium, lanthanum 18%-20%, 15%-18%, neodymium 15%-18%);
- Albite granites containing: niobium, tantalum, zirconium, rare earth elements, Borsyksay deposit, in Aktobe region (the content of the sum of rare earth elements up to 0.19%, of which the yttrium group is up to 0.011%) and upper Espe;
- Stratified deposits: Vanadium deposits Balasauskandyk in South Kazakhstan region are the most attractive among them (the content of rare earth elements is 0.02%-0.053%) and Kurumsak in

Corresponding author: Madali Naymanbayev, PhD (Eng), research fields development of theoretical bases and creation of effective rational technologies of complex processing of polymetallic, titanite, magnesite and rare-earth raw materials with extraction of valuable components. E-mail: madali_2011@inbox.ru.

Kyzylorda region (REE content is 0.041%-0.092%).

Karatau phosphorus deposits: Sholaktau, Zhanatas, Aksay, Cox and Kokdzhon differs with industrial concentrations of rare earth elements. A content of the amount of rare earth elements varies from 614 to 1,088 g/t. Elements of yttrium group are dominating among the rare earth elements.

The content of the sum of the individual rare earth elements and rare earth elements are summarized below [3]:

- Zhanatas field: the average content of ΣREE 614 g/t; including yttrium 300 g/t; ytterbium 4.0 g/t; cerium 110 g/t; lanthanum 200 g/t.
- Aksai field: the average content of ΣREE 938 g/t, including yttrium 440 g/t, ytterbium 8 g/t, cerium 210 g/t, lanthanum 280 g/t.
- Sholaktau field: the average content of ΣREE 1,088 g/t; including yttrium 520 g/t; ytterbium 8.0 g/t; cerium 250 g/t; lanthanum 310 g/t.
- Kokdzhon field: the average content of ΣREE 630,5 g/t, including yttrium 312 g/t; ytterbium 5.5 g/t; cerium 138 g/t; lanthanum 175 g/t.
- Cox field: the average content of ΣREE 700 g/t, including yttrium 376 g/t; ytterbium 6.0 g/t; cerium 166 g/t; lanthanum 152 g/t.

Considering the unique Karatau phosphorus reserves and high content of rare earth elements, they should be considered one of the primary sources of rare earth elements in the country.

Uranium-bearing deposit Melovoe ($\text{Y}/\Sigma\text{REE} = 21.5\%$), located in Mangistau region, is also related to this group. In the 80s of the last century there were received yttrium and heavy lanthanides concentrates.

- Weathering crust (deposits Kundybay, Akbulak, Kostanai region). Rare earths and yttrium are located in the ion-sorption shape and form their own minerals.
- Titanium-zirconium placers containing rare earth metals in zircon, monazite and xenotime. The total content of rare earth metals in the Obukhov placer (Akmola region) in the minerals of the heavy fraction is 0.45%, and zircon from 0.1% to 1.9%.

Practical interest represent the upper Espe ($\text{Y}/\Sigma\text{RZM} = 11.7\%$), located in the Semipalatinsk region [4].

The field is represented by two stock formed outputs of alkali granites (big and small), the dimensions are 3 and 1.5 km². The granites are characterized by higher (2-10 times more than clark) concentrations of zirconium, niobium, tantalum, lithium, thorium, yttrium and rare earth metals.

Rare-metal and rare-earth-metal mineralization with industrial content of metals is concentrated in two types of ore, alkaline (albitized) mineralized granites and metasomatic reversed rocks (fenites).

The content of rare earth elements in mineralized granites is 0.1%-0.57%; an average of 0.25% and in fenites, 0.1%-0.64%; an average of 0.48%. Vein-shaped ore bodies and pegmatite of grand exit are most enriched with rare earth metals.

The main mineral containing rare earth metals, gagarinit, which contains 58.3% of REE stocks, 48.4% are concentrated in the pyrochlore and zircon. Yttrium and rare earth metals of the yttrium group are present mainly in Gagarinit, which is easily opened with acids. The main carrier of the cerium group, pyrochlore, also can be found bastnezit, monocyte, cerium gagarinit and fluorite. Dysprosium is concentrated in gadolinite, morit, ittrobastnezite, fergyusanite. Gadolinium and erbium is concentrated in xenotime and ittrosinhizite. Ytterbium, yttrium and erbium are the most common in Torit and feretories.

The deposit Upper Espe requires further exploration and further research on the enrichment of finely disseminated ores.

Of rare-earth deposits actually explored the most interesting ore occurrence is Kundybay ($\text{Y}/\Sigma\text{REE} = 33.4\%$), located in Kostanai region, it is associated with the Mesozoic weathering crust of ancient metamorphic rocks.

Weathering crust is zonal. Composition of the zones depends on the weathering level and is due to the ratio of relict and newly formed minerals. The

former include amphibole, mica, graphite, retile, ilmenite, sphene, titan magnetite, kulsonit; to the second: kaolin, limonite, gibbsite, goethite, hydro micas, rare earth elements.

Study of mineralogical characteristics of raw materials showed that Kundybayskoe ore occurrence represents a new genetic type of deposits of rare earth elements, which does not have analog in the world [5]. It is characterized by coupling with the crust of weathering of metamorphic rocks, previously unknown association of minerals of rare earth elements (Churchit, ittrorabdofanit, neodymium and ytterbium bastnezit), significantly yttrium composition, with uniquely high content of europium and other deficient lanthanide. A considerable part of the rare earth elements are situated in non removable by flotation and gravity methods forms of enrichment, probably in the structure of clay minerals.

Among the rare-earth deposits associated with weathering crusts the promising field is Akbulak ($Y/\Sigma REE = 34.4\%$) located in the Kostanai region [6].

The deposit is confined to linear weathering crusts developed along the southeast contact of the granite-gneisses from the Precambrian slates, within the rare-earth-rare-metal zone with the length 17 km, the width of 2-3 km. Crushed stone and clay-wood weathering crust are the productive ones. Mineralization can be traced throughout the section of the weathering crust. The depth of the roof of the ore deposit varies from 0.50 to 33.0 m, foot, from 4.0 to 64.5 m, average reservoir thickness, 13.2 m.

Linear strip ratio, assuming a development of the open method, varies from 0.0 (in the southern part) to 1.5 (in the central and northern parts of the deposit). The average content of yttrium oxide is 272 g/t (at carrying 100 g/t, the amount of oxides of rare earth elements is 790 g/t).

The main ore minerals are xenotime, rabdofanit, Churchit, bastnezit, tsirtolit. Perhaps some rare metal and rare earth elements are in ionic form and are associated with mica, clay minerals of the weathering

crust, as well as hydroxides of iron and manganese.

On material composition it is similar to the deposit Kundybay, and rare earth mineral rabdofanit is of larger size.

Besides of the group of rare earth elements installed on the field and can be simultaneously extracted: tin (50-100 g/t), silver (15.10 g/t), niobium (10.30 g/t), gallium (10.30 g/t), lithium (30-40 g/t).

Throughout the deposit were estimated reserves as per category C2, prospected resources R1, with a minimum capacity 4.0 m and cut-off grade of 100 g/m of yttrium oxide.

The deposit Akbulak requires resuming exploration work to refine the inventory and perform research to develop technologies for extraction of rare earth elements for industrial development of the field.

3. Engineering Researches

Based on the type of rare metals and rare earth mineralization, composition and structure of the ore various technological schemes are proposed, based on both the complex beneficiation and hydrometallurgical processing as well as on hydrometallurgical technologies directly, as shown in the example of few deposits.

Their main peculiarities are primary enrichment (after grinding to the optimal size corresponded to average grain size of rare metal minerals) with gravity methods using jigging machines, spiral separators and concentration tables, final processing of gravity concentrates using magnetic and electrical separation.

The staff of the Eastern Research Institute of Nonferrous Metals (ERINM) investigated the possibility of enrichment the ore deposits of Upper Espe to extract the pyrochlore, zircon, gagarinit, monazite, bastnasite to the products suitable for hydrometallurgical processing. It is recommended gravity scheme of material enrichment with fineness of $-0.044 + 0.2$ mm and $-0.0044 + 0.02$ mm [7].

It was proposed to complete the scheme on the cycle of obtaining complex concentrate. The resulting

complex concentrates contain masses.‰: Nb_2O_5 6.42-7.75; ZrO_2 17.0-28.1; $\Sigma\text{REE}_{\text{oxides}}$ 1.09-2.55. with the extraction of ore 40.9-43.4; 19.5-31.0 and 15.8-37.0, respectively to that.

Nabiev (Uzbekistan), Favorskaja (Kazakhstan) in 50-60 years were involved in technology of extraction of rare earth metals and yttrium at the processing of phosphate [8]. According to them 73.5%-80.0% of rare earth elements metals and yttrium transfers into solution during the decomposition of phosphate with 20% nitric acid at a stoichiometric ratio. The resulting solution was neutralized with ammonia in a mixture with air. On the content of rare earth elements in the sediment pH plays an important role. The yield of sediment and concentration of rare earth elements in it is inversely proportional to each other. In the sediment obtained at pH 2.0, contained 5.1% and at pH 0.4%-37.5% of the amount of oxides of rare earth elements. The optimal deposition was taken at pH 1.2. The proposed method was not implemented in production.

On superphosphate plants in Kazakhstan and Uzbekistan Karatau phosphorus ore are processed for fertilizer by sulfuric acid method, in which only 27% of rare-earth metals are dissolved, transfers into fertilizer and applied to land, and the remaining 73% fall in waste of production.

Technological studies of kundybayskie titanium-yttrium-rare earth ores were conducted in 1965-1998.

It was found that the natural minerals of rare earth elements are mainly represented with phosphates [9]:

- Churchite: is found only in the weathering crust. The content from trace to 5,700 g/t, noted with high content of europium;
- Xenotime: the content from traces to 244 g/t;
- Monazite: content from trace to 151 g/t;
- Rhabdophanite: content from trace to 19 g/t;
- Bastnasite: content from trace to 528 g/t, in some samples up to 2,440 g/t;
- Hydrophosphate REE: new water mineral that is

found only in the weathering crust, the contents from trace to 341, in some samples 5,747 g/t.

The most common is the churchite, its maximum concentration in some samples is 5.1%. However, the total content of rare earth elements in all found own minerals is only slightly (2-3 times) higher than clark values for the Earth's crust and constitutes 15%-25% of the total content of rare earth metals in the ore.

In the heavy (sand) fraction, the main carriers of the rare earth elements are their own minerals, primarily Churchite. In the light fraction of weathering crust rare earth elements are contained in adsorbed associated state, probably at the nodes and between nodes of the structural lattice of clay minerals in the form of individual ions and small aggregates, which are released during weathering of rock-forming minerals.

Very subtle germination and accumulation of rare earth metals in waste rock causes the difficulties of traditional methods of enrichment. Under the scheme, which provides granular concentration of ores and magnetic separation of crude concentrate, obtained a product containing 3% of rare-earth elements oxides, at the extraction of 13.9%. Flotation method obtained a concentrate containing 1.35% of rare-earth elements oxides, at the extraction of 12.6%.

In this regard, big prospects have ways of hydrometallurgical extraction of rare earth elements, based on de cation exchange or complete destruction of the lattice of minerals and the transference of rare earth elements into solution. The most effective appear to be relatively simple and economical method, developed by employees of Chemical and Metallurgical Institute (Karaganda city, Kazakhstan) under the guidance of Sharipov, et al. [7].

It consists in leaching raw ore with 18-20% of sulfuric acid solution, the separation of high-silicon sludge and the solution with decanting method, the sorption of rare-earth elements with cation KU-2-8 elution with the solution of 10%-20%, sulfuric acid solution and the allocation of 25% concentrate of rare earth elements in the form of the oxides. According to

calculations made by developers of ways of pounds cost 25% concentrate of REE was 45% of its market value (the price of that period).

Preliminary technological research of Akbulak ores, in two samples, showed total extraction of rare earth elements 62% (sulfuric acid leaching method) and 94% (using nitric acid), followed by processing of solutions with known methods to obtain individual rare earth elements.

4. Conclusions

Rare-earth elements occurring in rare-metal minerals mainly consist of calcium, niobium, tantalum, titanium, strontium, thorium, Uranus, fluorine, carbon and phosphor, including sodium and silicon in alkali massive.

Rare-earth minerals can be divided into two major groups: minerals with rare-earth minerals as the main/one of the main elements (monazite, xenotime, bastnaesite etc.), and minerals with rare-earth minerals as the associated elements, which partially replace the main elements (apatite, phosphorite, zirconium, Uranus, titanium etc.).

Summarized raw materials of all the above mentioned fields are significant and provide an opportunity to select objects according to their degree of preparedness and scrutiny, to create a production of rare earth concentrates and metals in Kazakhstan.

References

- [1] L.Z. Bykhovskii, S.D. Potanin, Geological and industrial types of rare earth deposits, Raw Minerals, Geological and Economic Series, Moscow: Publishing SIMS 28 (2009) 157.
- [2] A.A. Abdulin, H.A. Bespaev, E.S. Votsalevskij, Deposits of rare metals and rare earths in Kazakhstan, Almaty, 1998, p. 136.
- [3] A. Dzhurumbaev, V.N. Urich, Prospects for integrated processing of Karatau phosphate for fertilizers. Collection: Phosphates and alumina silicate based on mineral resources of Kazakhstan, Alma-Ata: Nauka (1984) 29-33.
- [4] E.I. Semenov, Mineralogy of Rare Earths, USSR Academy of Sciences, Moscow, 1963. p. 412.
- [5] A.A. Poceluev, L.P. Rihvalov, S.L. Nikolaev, On the complex nature of uranium ores and rare metal deposits of the North Kazakhstan ore province, in: Materials of the International Conference "Mineral Resources, a key factor in the integration of Kazakhstan into the global economy", Almaty, 1993, pp. 169-171.
- [6] N.L. Radenko, T.D. Koretskaya, On the prospects of the rare-earth mineralization in Kazakhstan, in: Materials of International Conference "Toporkovsk reading" Ore., 1999, pp. 187-195.
- [7] B.S. Uzhkenov, G.R. Bekzhanov, L.B. Ivanov, Rare metals and rare earths in Kazakhstan, Almaty, 2011, p. 277.
- [8] M.N. Nabiev, Nitric acid processing of phosphates, Tashkent, 1976, p. 367.
- [9] S.M. Ulasyuk, V.S. Kiseleva, The study of the material composition and technological characteristics of the rare-earth weathering crust, Process Evaluation of Mineral Resources (1981) 38-44.