The Method of Assessment Mineral and Raw Capacity of Fields Kaolinic Ores of Russia

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Abstract. To carry out an effective policy of rational use and development of kaolin mineral resource base, to solve strategic and operational tasks in the field of subsoil use of these raw materials, it is necessary to provide the subsoil fund government with economic and analytical materials in the mode of current time and forecast. The basic element of these materials is the economic assessment of the mineral and raw material potential of kaolin ores based on analyzing the market conjuncture for mineral raw materials, taking into account the determination of their mineral and raw material potential. The article discusses the natural types of kaolin, the main industrial types of kaolin deposits, analyzes the prospects for industrial development of kaolin ore deposits, the main indicators of kaolin production, the parameters of estimated conditions for eluvial kaolin deposits (exploration and appraisal stage), industrial classification of technological types of kaolin raw in Russia. In conclusion, proposed measures to improve the efficiency of using the mineral potential of kaolin ores are proposed.

1. Introduction
Kaolin-raw is an earthy mass, the rock destruction product containing feldspar and mica granites, granodiorites, gabbros, granite gneisses, mica schists, arcosian sandstones. Kaolin occurs during the decomposition of rocks rich in feldspar, which are kaolinized. The decomposition of rocks that form kaolin occurs in nature during weathering, as well as under the influence of hydrothermal processes

Kaolin has a white color (it is possible to have greenish, yellowish or grayish shades). Mohs's hardness is 1.0. Specific weight is 2.6 g/cm³. Kaolin is greasy to the touch; highly hygroscopic; when it is dried it sticks to the tongue; it is inert with respect to alkaline and acidic solutions (it decomposes when it is heated with H₂SO₄); it has low toxicity, maximum permissible one time concentration (MPC) when the content of free silica is 2-10% is 4 mg/m³; it is fireproof. Kaolin forms a plastic mass with water (plastic varieties); it smells like clay when it is wet; it has high mechanical strength in the dry state; it has a white color of burnt shard.

2. Relevance
Among the currently available methods for calculating the value of the mineral and raw-materials potential (MRMP) in the depths, the following should be considered as the most reasonable.
L.V. Gromov and K.P. Kavun and others [7,8,10,11,14,18,21] suggested that while calculating MRMP it is necessary to take into account the resources of the existing system for categorizing mineral reserves \((A + B + C1 + C2)\). At the same time, it was proposed to consider the forecast mineral reserves separately as a reserve of the region mineral and raw material potential (MRMP), which would be realized at carrying out further geological exploration.

V.P. Vasilenko, V.A. Aliskerov, M.N. Denisov and others [15] considered the following options for calculating the value of the mineral and raw-materials potential:

- **MRMP** as the gross potential value of all minerals in the subsoil, taking into account the value of all explored and evaluated subsoil use objects (deposits) of the categories \(A + B + C1 + C2\), as well as the value of the estimated resources in the depths, which have the categories \(P1 + P2 + P3\) excluding losses during production, enrichment and redistribution. This variant reflects not so much the value of MRMP, as the mineral saturation of the territory, which can be used mainly to assess the viability of high-order mineragenic and oil-and-gas bearing structures.

- **MRMP** as the value of a part of minerals extracted from the subsoil, recorded in proven, previously estimated reserves and forecast resources of subsoil use objects (deposits), taking into account losses in the extraction, enrichment and redistribution. This option deliberately significantly overestimates the value of MRMP, since the forecast resources of various categories of confidence are equal to proven reserves.

- **MRMP** as the value of active explored and estimated reserves extracted from the depths (categories \(A + B + C1 + C2\)), and the estimated resources of the objects of subsurface use (deposits). The latter are reduced to the conditional category \(C2\) by means of confirmation coefficients (transfer of resources), which are derived statistically on the basis of a retrospective analysis of the search work results in the region. This version of the calculations has certain difficulties associated with the reliability of allocating the active part of the reserves, as well as defining the reduction (to forecast resources) coefficients.

A.Ya. Kats, S.A. Kimelman, N.K. Nikitina, and others [1-3, 6, 9, 12, 17, 21] propose to calculate the value of the total mineral and raw material potential, which includes the cost estimate of balance reserves (categories \(A + B + C1 + C2\)) and forecast resources of subsoil use objects (deposits and forecast areas) of various prospect degree. At the same time, the forecast resources of categories \(P1\), \(P2\), and \(P3\) should be preliminarily brought to reserves (reserve reliability) of categories \(C2\) by applying appropriate coefficients.

3. **Formulating the problem**

The issues of comprehensive studying the mineral potential of kaolin ores, reproducing the mineral resource base of kaolin deposits from the system approach viewpoint, the efficiency of the mineral complex in the subsoil use process, taking into account the specifics of this raw material, are not well understood and require their scientific justification.

4. **Theoretical part**

By origin, kaolins are divided into primary (autochthonous) and secondary (allochthonous). Eluvial, hydrothermal-metasomatic and re-modified bauxites are attributed to the primary, clay-like sedimentary kaolins and kaolin-containing sands are attributed to the secondary. Eluvial kaolins, which are products of weathering acidic and medium-sized feldspar-containing rocks (granitoids, gneisses, arkose sands), and sedimentary, formed during the redeposition in a calm water environment of kaolinite mobilized during erosion of the weathering kaolin, gained the greatest industrial importance.

Hydrothermal-metasomatic kaolins and kaolin-containing sands have a sharply subordinate significance, although in a number of countries which do not have eluvial and sedimentary kaolin resources, they serve as a source of raw materials for kaolin products (Mexico, Japan, Bulgaria, Romania, etc.).

Mineral field belongs to the first and second groups judging by the complexity of the geological
structure.

The reserves (million tons) of kaolin deposits are divided into rather large that contain more than 50, large that contain 50-20, medium that contain 20-5, small that contain less than 5.

Depending on the content (or absence) of specific mineral components in kaolin raw materials, its main natural types are distinguished: high-alumina kaolins, normal or proper kaolins and alkaline-containing ("alkaline") kaolins, each of which is in turn divided into subtypes and varieties.

The overwhelming majority of the mined kaolin is subjected to enrichment, with the help of which harmful impurities containing iron, titanium and sulfur are removed. At the same time selecting a number of products containing minerals of quartz, mica light, potassium feldspar are produced, each of which can be used in industry. The choice of the technological enrichment scheme is determined based on the properties of the minerals that make up the kaolin raw, and the associated components, taking into account the consumers' requirements to the quality of the enriched kaolin concentrate and by-products.

The main methods of enriching kaolin raw materials are gravity methods, which are used in wet and dry enrichment. Both individual grades of kaolin feedstock and mixtures of various grades in specified proportions are enriched. Before enrichment, the raw material is subjected to disintegration and homogenization, for which crushers, impact mills and other equipment are used.

At enrichment plants in Ukraine, Russia, and Kazakhstan, kaolin enrichment in hydrocyclones is traditionally carried out in the class of ~56 microns. Most of the foreign enterprises use multicyclones, which allow obtaining products with a particle size less than 20 microns. The finest kaolin products used mainly for paper coating (chalking) are obtained in centrifuges, the discharge of which contains 99.5% of particles which have sizes less than 10 microns and 75% of particles which have sizes less than 2 microns.

Abroad, all large-scale shipment of enriched kaolin to consumers is carried out in the form of a thick suspension in barrels or tanks, which eliminates the energy-intensive drying process.

Regardless of the enrichment schemes, the most important task of enrichment is preventing technological contamination of the resulting concentrates (especially iron).

The main indicators of enriching various technological types of kaolin ores are given in Table 1.

Table 1. The main indicators of enriching various technological types of kaolin ores in Russia.

| Indicator | Eluvial kaolins | Kaolinite sands |
|-----------|-----------------|-----------------|
|           | Wet enrichment  | Dry enrichment  | Wet enrichment |
| Mass fraction in the total processing volume (for the Russian Federation),% | 20 | 65 | 15 |
| Firmness Protodeakonov | 2-4 | 2-4 | 1-3 |
| The content of kaolinite,% in raw in concentrate | 49 | 43 | 32 |
| in tails | 99,6 | 94,4 | 99,3 |
| Concentrate yield, % | 4,0 | 8,0 | 1,5 |
| Extract to concentrate, % | 37 | 34,5 | 16,5 |
| Secondary concentrates Quartz Quartz, quartz-feldspar Quartz-feldspar |
| Concentrate moisture,% | 20 | 20 | 20 |
| Enrichment efficiency | 65,0 | 68,0 | 54,0 |
| E= ε (β - α)/(β min - α), % | | | |
Part of enriched kaolin in order to give it new or improved consumer properties is sent for additional processing. The types of such processing are the following: - refining that is cleaning from impurities; delaminating that is splitting of larger lamellar particles of kaolinite into thinner ones; - calcination that is calcining in order to obtain a dehydroxylated substance; - modification that is treatment with chemical reagents to change the surface properties of kaolinite in the desired direction.

Refining processes are of particular importance. They allow removing from the enriched kaolin part of the iron and titanium oxides present in it and thereby increasing its whiteness both in the dry state and after the calcination. To achieve this, two methods are mainly used: chemical bleaching under the influence of recovering acidic medium and high-gradient electromagnetic separation. The first method reduces the content of predominantly iron, the second removes more effectively the fine minerals of titanium and the iron associated with it. In the United States and Japan, the increase in whiteness is carried out in stages: the first is the electromagnetic separation of the suspension, the second is the chemical bleaching of the product. In contrast to European practice in the USA and for the purpose of kaolin purification, in addition, methods of froth flotation and selective flocculation are used.

Increasing the whiteness of these methods requires additional costs, which is economically justified only to obtain products that have high demand, despite the relatively high cost.

In the process of kaolin enrichment kaolin and quartz concentrates are obtained. At enriching alkaline kaolin and quartz-feldspar-kaolin sands, additional feldspar concentrate is extracted.

Quartz concentrate can be used as a raw material for the glass and building industries, as well as in manufacturing ceramic products (including porcelain and faience), abrasives (including silicon carbide).

Feldspar concentrate is used in producing ceramics and, in particular, electroceramics.

The commercial product for the ceramic, electrical and chemical industries contains at least 30% of \( \text{Al}_2\text{O}_3 \), the quality of the fillers is regulated according to whiteness, size and particle shape. Harmful impurities in the kaolin product (excluding fillers) are \( \text{Fe}_2\text{O}_3, \text{TiO}_2, \text{CaO}, \text{SO}_3, \text{MgO}, \text{CuO}, \text{MnO} \).

5. Results of experimental studies

The valuation of the mineral and raw-material potential (hereinafter referred to as the mineral and raw-material potential) is carried out both for a separate field and for a group of fields, ore regions, etc.

To calculate it, formula 1 is used:

\[
\text{MRMP} = ( Q_{\text{res.}} + Q_{\text{for.}} \times K_{\text{conf.}} )^F
\]  

where \( Q_{\text{res.}} \) are mineral reserves in the subsoil given in units of measurement adopted in the State balance of reserves (categories A + B + C1 + C2); \( Q_{\text{for.}} \) are forecast resources of solid minerals (categories P1 + P2 + P3) or prospective hydrocarbon resources (category D), common minerals and groundwater in volumes that can be realized in relatively limited time (up to 50 years); \( K_{\text{conf.}} \) is the confirmability coefficient of the forecast resources; \( P \) is the world market price of a unit of final commodity products.

As a result, a forecast table was constructed for extracting, producing and consuming commodity kaolin (Table 2).
Table 2. Forecast of extracting, producing and consuming commodity kaolin.

| Indicators          | Unit of measurement | World                  |          |          |          |
|---------------------|---------------------|------------------------|----------|----------|----------|
|                     |                     | 2005       | 2017      | 2020 (forecast) |
| Extraction (MRMP)   | mil. tons (mill.    | 67         | 72 (936)  | 75       |
| Production          | rubl.) million tons | 45         | 48        | 50       |
| Extraction (MRMP)   | mil. tons (mill.    | 0,9        | 1,3 (16,9)| 2,0      |
| Production *        | rubl.) million tons | 0,5 (0,1)  | 0,7 (0,2) | 1,0 (0,4)|
| Consumption *       | million tons        | 0,8 (0,3)  | 1,0 (0,4) | 1,4 (0,7)|
| Central Federal District | Consumption *                         | 0,3 (0,2)  | 0,5-0,6 (0,3) | 0,6-0,7 (0,4) |

Note: * - total production and consumption of commodity kaolin (production and consumption of enriched kaolin)

The mineral and raw-material potential of kaolin deposits is also calculated for man-made (technogenic) deposits which are the demanded mineral raw materials contained in mining waste.

6. Conclusions

Summing up, the following should be noted:

1. The market situation of kaolin is favorable for the production development. Consumption forecast and prices for commodity kaolin have a positive trend.
2. The most competitive fields of the Near Abroad and Russia are Proshyanskoye and Glukhovetskoe (Ukraine), Alekseevskoe and Soyuznoe (Kazakhstan), Zhuravlini Log, Kyshtymskoye, Nevyansko and Tuganskoye (Russia).
3. Commercial products of Russian manufacturers are inferior to foreign ones. The reasons are poor quality of raw materials and backward enrichment technology.
4. The main Russian consumers of commodity kaolin are concentrated in the Central, North-West and Urals Federal Districts, which predetermines the expediency of developing and exploring their own MRMPs.

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Acknowledgments
This work was supported by a grant from the President of the Russian Federation to young scientists (MK-1522.2018.5).