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Role of mineralogical and technological evaluation in development of processing technologies for zeolite-containing rocks

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Abstract. The article presents a rational package of mineralogical and analytical research methods including a high-resolution optical microscopy, X-ray, morph metric, granulometric, thermal gravimetric and elemental analyses, magnetometry, IR spectroscopy and methods of toxicological, radioactive and hygienic assessing, which provides reliable mineralogical and technological evaluation of complex composition and structure of zeolite-containing minerals in Eastern Transbaikalia. The evaluation consists in defining chemical and mineral compositions of rocks, sizes and micro-concretion of grains, nature of micro-inclusions and distribution of elements.

1. Introduction

Natural zeolite is a new, unconventional and very promising kind of nonmetallic minerals. The use of zeolites in the industry and agriculture was started in the 1960s after discovery of deposits formed due to conversion of volcanic glass in USA, Japan and Italy. Currently more than 2000 deposits discovered in many countries of the world hold several tens of billions of tons of zeolite reserves, out of which USA, Japan and the CIS countries possess the reserves of 10–20 billion tons. By 2002 Russia had 14 deposits of zeolite-bearing rocks with the total in-place reserves of 649460 thousand tons (Category A+B+C1) and 798631 thousand tons (Category C2) located mostly (~ 74%) in the Transbaikal Region. These deposits occur in favorable geographic and economic conditions, and offer unbounded capabilities for mining and use of the inexpensive raw material in the industry, agriculture and ecology [1–3].

A series constraint for the wider range application of natural zeolites is insufficient and often nonuniform content in rocks (10–60%) because of genesis conditions. In the meanwhile, some technologies (dewatering of gases and nonaqueous fluids, refinery processing, catalysis and medicine), as the feedstock quality standards, the content of economic zeolite minerals (clinoptilolite, mordenite and chabasite) should be not less than 75–95%.

In this connection, it is of the current concern to develop processing technologies for zeolite-bearing rocks with regard to features of composition, texture and structure, morphology as well as physical, mechanical and chemical properties aiming to enhance potential of applicability of zeolites in science-driven sectors and to replace synthetic analogs [3, 4].

A framework of the uniform theoretical approach to zeolite-bearing rock processing is technological mineralogy with a package of modern tools for the integrated mineralogical and technological evaluation



helpful in selecting the most efficient ore pretreatment and concentration methods, and in prediction of zeolite behavior in technological processes using rational flow sheets.

2. Mineralogical and technological evaluation of zeolite-containing rocks

The proposed efficient package of mineralogical analysis methods includes high-resolution optical microscopy; X-ray, morpho metric, granulometric, thermal gravimetric and elemental analysis; magnetometry; IR spectroscopy; electron microscopy; Mossbauer effect study; toxicological, radioactive and hygienic assessing. This package of methods provided the reliable mineralogical and technological evaluation of very complex compositionally and structurally zeolite-bearing rocks of Eastern Transbaikalia, resulting in determination of chemical and mineralogical composition, grain size distribution, micro-structural concretion of grains, as well as the nature and distribution of micro-inclusions.

The tasks of the mineralogical support in creation of highly efficient circuits for zeolite-bearing rock processing are: determination of phase (mineral) composition of source feedstock and its structural characteristics (size of mineral grains and the natures of their concretion with other minerals); description of texture (mutual orientation of mineral aggregates); study of distribution of recoverable elements in rocks; estimation of mineral properties which have influence on the processing efficiency; mineralogical control of processes by means of express phase analysis of the processing products.

The analysis of such complex mineral objects as zeolite-bearing rocks needs modern mineralogical techniques. The development of processing technologies for low-grade zeolite-bearing rocks used a set of the mineralogical analysis methods that enable determination of all mineral phases, including highly dispersed, implementing diagnostics, defining distribution and interaction of mineral phases and estimating process properties of minerals.

The first-stage characterization of the texture and structure of zeolite-bearing rocks uses optical microscopy. The successive mineralogical studies aimed to determine all mineral components and phase composition, contents and properties of rock-forming minerals, nature of dissociation, types of mineral admixtures are carried out with the pre-milled and blended material sorted and fractionated with respect to density and magnetic properties.

Experience shows that conventional mineralogical research (optical–mineral and optical–petrographic) fail to ensure complete determination of mineral composition of rocks, with the diagnostics of all mineral phases and quantification of all contents. The reason is complex poly-mineral structure of rocks and the presence of finely dispersed aggregates. Accordingly, an optimal way out of the situation in integration of the optical-and-mineralogical methods with the X-ray, chemical, physicochemical and instrumental techniques of the phase composition determination, which allow reliable identification of all mineral phases and, then, analysis of variation in their quantitative ratios in the products of processing circuits.

It is impossible to study zeolite-bearing rocks without the electron microscopy analysis which detects surface fines by the direct observation of micro-relief, determines chemical compositions of minerals and informs on the surface distribution of elements.

For the express technological evaluation of zeolite-bearing rocks, examination of mineral distribution in rocks and dressing products, as well as the morphometry of mineral phases, the optical geometric image analysis with Video Master system was for the first time carried out.

The morphometric characteristics of zeolite-bearing rocks (phase/mineral compositions, texture and structure, dissemination sizes) were calculated in terms of geometric parameters of grains: area A (μm^2); length L (μm); width B (μ), perimeter P (μm), elongation $U = L/D$; shape factor $C = 4pA/P^2$.

Using the obtained optical geometric information, processability of zeolite-bearing rocks was estimated with the determination of: optimal pretreatment mode to ensure sufficient dissociation of mineral phases, ration process flow sheet and unavoidable process loss, which reduces amount of technological investigations while improving their efficiency.

Inasmuch as zeolite-bearing rocks contain iron either in the form of isomorphic admixture or mechanical micro-spots, Mossbauer effect spectroscopy was used to reveal features of rock composition and explain their magnetic properties.

In order to understand processes of deep conversion of zeolite-bearing rocks, it is important to know physical, physicochemical, mechanical, thermal and adsorption properties which mostly can be determined by the mineralogical techniques in accord with the regulatory documents of the Scientific Council for Mineralogical Research Methods. In particular, such physical characteristics as density, microhardness, specific magnetic susceptibility, ionic conductance, bulk weight, moisture content and strength were determined.

Within the adsorption properties analysis, the textural geometric parameters of zeolite-bearing rocks were measured (volumes and surface areas of pores per sizes grades).

The quality assessment of zeolite-bearing rocks involved the toxicological, radioactive and hygienic assessing. The efficiency of complexing of the mineralogical analysis methods is demonstrated in terms of zeolite deposits in Eastern Transbaikalia (Shivirtui, Kholin, Badin and Talan-Gozagor).

Based on the accomplished mineralogical and technological research of zeolite-bearing rocks in Eastern Transbaikalia, it is found that the main enclosing admixtures, including mineral phases of iron and silica, occur in concretions of zeolite and rock-forming minerals or as inclusions up to 5 μm in size. It is difficult to dissociate zeolite mineral because of their fine intergrowth and to recover selectively zeolites, and it is necessary to apply methods of directed dissociation (disintegration of minerals along the concretion boundaries. The similar physical properties of zeolites and basic associate minerals (montmorillonite, quartz, calcite, opal, calcedony, cristoballite, feldspar, etc.) call for the dissociation of minerals based on improvement of contrast characteristics of their process properties as well as using a set of purposeful physical and physicochemical effects.

3. Conclusions

1. The effective package of methods has been proposed for the reliable mineralogical and technological evaluation of very complex structurally and compositionally zeolite-bearing rocks in Eastern Transbaikalia, including chemical and mineral composition analysis, grain size distribution, microstructure of concretions of grains, nature of micro-inclusions and distribution of elements.
2. Based on the accomplished mineralogical and technological evaluation, the key characteristics of zeolite-bearing rocks of Eastern Transbaikalia, which govern selection of processing and concentration technologies toward maximum dissociation of minerals and removal of contamination admixtures (to 99%) as well as for the high-quality marketable production, have been determined.

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