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# Quartz Concentrates Based on Compact Quartzite

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**Abstract**—This paper presents a study of a variety of quartz material from East Sayan: compact quartzite from the Oka–Urik block. We have investigated the texture and structure of quartz and mineral and fluid inclusions in it. It has been shown that the fluid inclusions are located mainly in the quartz grains and that the major salt component in the fluid inclusions is sodium. In the case of compact quartz, we have proposed a process for the preparation of extrapure quartz concentrates. A distinctive feature of the process is high-temperature precalcination of quartz grit prior to chemical enrichment, which makes it possible to open the fluid inclusions and remove sodium.

*Keywords:* quartz, quartzites, superquartzites, crystallization, quartz glass, silica ceramics, mineral inclusions, fluid inclusions

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## INTRODUCTION

Natural quartz raw materials are widely used in the preparation of high-purity and ultrapure quartz concentrates. The concentrates are then utilized to produce optical quartz glass for the visible and near-IR spectral regions and high-temperature silica ceramics for a great variety of applications. Traditionally, high-purity and ultrapure quartz concentrates are produced using clear quartz and vein quartz varieties of various geological and industrial types [1]. As a rule, vein-shaped quartz bodies have limited reserves and are very inhomogeneous. Moreover, in view of the growing need for high-quality quartz raw materials and the depletion of traditional quartz deposits, a strong need has emerged for a search for and assessment of other sources of extrapure quartz raw materials. One example of such a source of high-quality quartz raw materials is quartzites from East Sayan [2].

Research conducted at the Vinogradov Institute of Geochemistry, Siberian Branch, Russian Academy of Sciences, has shown that quartzites from East Sayan, studied in detail using those from the Bural-Sardyk deposit as an example, offer high homogeneity and purity [2–6]. Moreover, based on a high-purity variety of quartz raw materials from this deposit, named superquartzites [2], a KI optical quartz glass was produced [6].

The results presented in this report were obtained in a detailed study of compact quartzite taken in the southwestern part of the Oka–Urik block (Fig. 1) in the Gargan quartzite-bearing region. For comparison, we also present data for previously studied superquartzites [6, 7]. The Gargan quartzite-bearing area is located in the southeastern part of East Sayan, in the north sector of the Tuva–Mongolian Massif (Gargan block) [8]. The basement of the block has a sedimentary cover, whose base consists of Riphean (1.25 billion years) silica–carbonate sediments of the Irkut suite, which are rich in high-purity quartzites. The sedimentary cover deposits are interrupted by granitoid intrusions of the Sumsunur complex (790 million years) [8], which are situated to the southwest of the Oka–Urik block. Within this block, five ore shows were identified according to their spatial position and material composition (Fig. 1). The north area of this block, which is named the Bural-Sardyk deposit, is the best studied [2–7]. A detailed study of the chemical composition and fluid and mineral inclusions [5–7] allowed us to propose processes for obtaining high-purity quartz concentrates from superquartzites. Using vacuum compression melting, the concentrates were converted into KI optical quartz glass [6] in conformity with the Russian Federation State Standard GOST 15130-86 [9].

In the southwestern area, we took compact quartzite samples. Figure 2b shows a photograph of a typical quartzite sample. The results obtained for the compact quartzite are here compared to those for previously studied superquartzites [6, 7] (Fig. 2a).

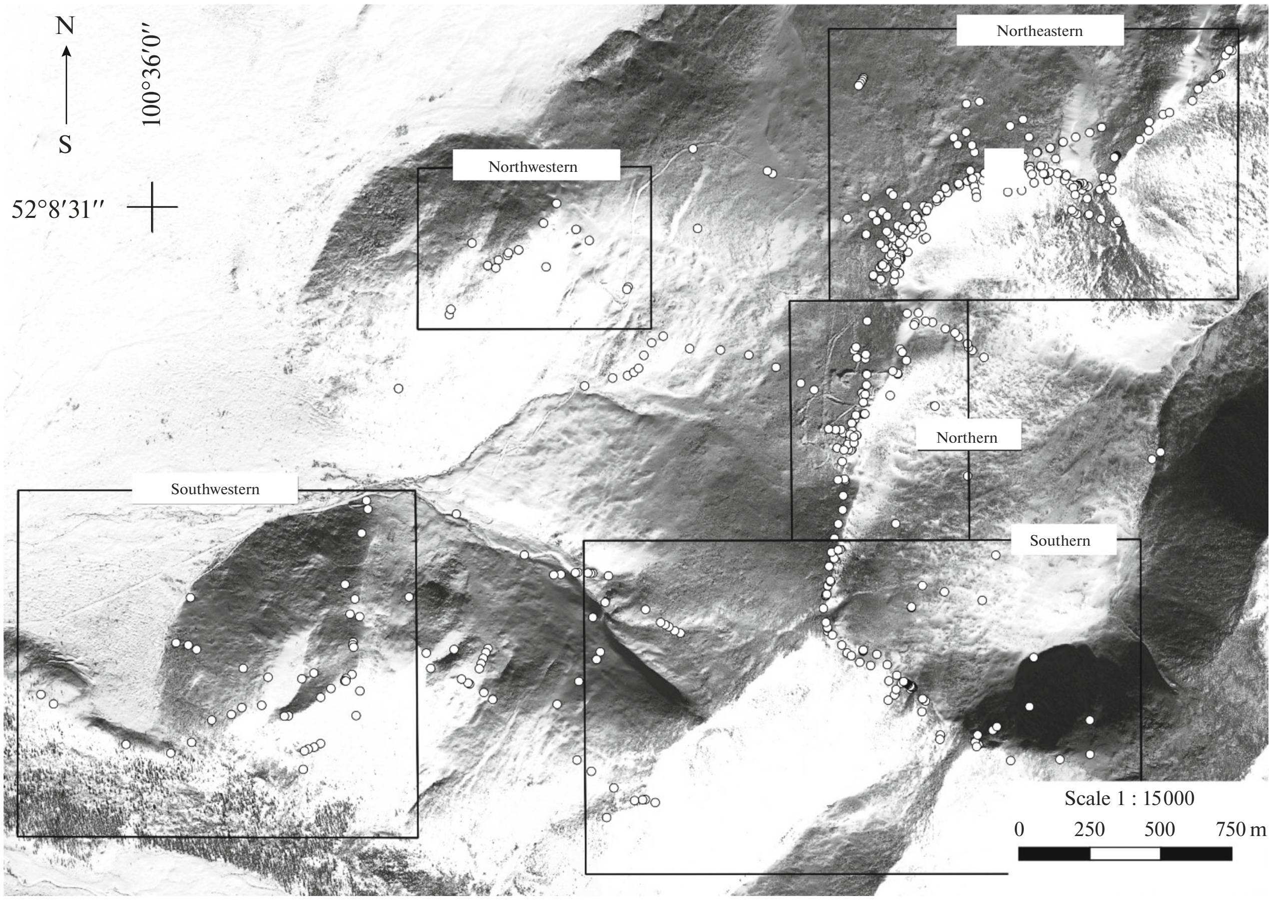

**Fig. 1.** Oka–Urik block of the East Sayan quartzite-bearing province.

## CHARACTERIZATION OF THE SAMPLES

High-purity quartzite varieties from the Bural-Sardyk deposit, previously named superquartzites [2] (Fig. 2a), have a monomineral quartz composition (99.9% of the rock).

Compact quartzites (Fig. 2b) have a massive texture. All of the aggregates the rock consists of are slightly elongated in the general stratification direction. The rock consists of quartz aggregates (99.9%) of various sizes: from a fine to coarse blastic texture. Subparallel orientation in the grains is weakly pronounced. Relicts of small quartz grains (about 25% of the rock) fill gaps between large and predominantly giant (>5 mm) quartz grain aggregates, which account for 75% of the rock. Accessory minerals have the form of separate sericite needles and flakes.

The quartz aggregates that make up the compact quartzite have high fluid saturation. Throughout the rock, there are strings of fluid inclusions (FIs) limited to cracks. The FI size in such strings is under 2 μm. In the large and giant blastic newly formed quartz aggregates, the FIs are predominantly tubular or columnar in shape. The FI in the fine and medium blastic relict quartz aggregates are larger and have more diverse shapes: tubular, elongated oval, irregular elongated, and complex shapes. Some of the FIs are well seen to contain a gas bubble. The FIs are situated mainly inside of quartz grains and, more rarely, in intergranular spaces. The ratio of two-phase and single-phase FIs is 60/40. The FIs range in size up to 40 μm.

The concentrations of the major volatile components were determined by thermal desorption mass spectrometry [10].[1] The results are presented in Table 1.

The compact quartzite differs drastically in the concentration of volatiles from the other samples. It contains large amounts of high-temperature forms of water and CO.

Table 2 indicates the weight fractions of impurities in the starting samples of quartz materials. The elemental composition of the impurities was determined by inductively coupled plasma mass spectrometry. The procedure was described in detail elsewhere [6]. The samples for analysis were prepared by thermal crushing and had the form of quartz grit ranging in particle

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[1] The evolution kinetics and composition of the volatiles were measured by V.A. Kreisberg (Department of Physical Chemistry, Faculty of Chemistry, Moscow State University).

size from 175 to 450 μm. The sample preparation procedure was described previously [6].

It is clear from analysis of the data in Table 2 that superquartzite and compact quartzite are similar in the sum of ten regulated impurity elements. At the same time, a distinctive feature of the compact quartzite is that it contains considerably more sodium than does superquartzite.

## RESULTS AND DISCUSSION

The chemical enrichment (CE) of the starting quartz grit was performed in a 20% HCl + 10% HF acid mixture at a solid : liquid ratio of 2 : 1. The quartz grit was then dried at a temperature of 120°C in a vacuum drying oven. The impurity concentrations in the quartz concentrates are indicated in Table 3.

It is seen from analysis of the data in Table 3 that superquartzite is easier to enrich. Comparison of Tables 2 and 3 indicates that, in the case of a standard enrichment procedure, the sodium concentration in the compact quartzite remains essentially unchanged. Given that this type of quartz material contains a large amount of high-temperature water and that the FIs are located predominantly inside of the quartz grains, it is reasonable to assume that most of the sodium is located in the FIs. Therefore, to remove sodium, the material should be calcined at high temperatures in order to open the FIs. To check this assumption, we performed the following procedures: the quartz grit of the compact quartzite was calcined in vacuum at a temperature of 1450°C for 3 h and then a standard CE procedure was carried out.

The impurity concentrations determined after these steps are listed in Table 4. It is seen from these data that calcination alone leads to a sharp drop in sodium concentration, whereas subsequent CE reduces the concentrations of all the other impurities and offers the possibility of obtaining highly enriched quartz concentrates with this type of material. To ensure a higher degree of enrichment of superquartz-

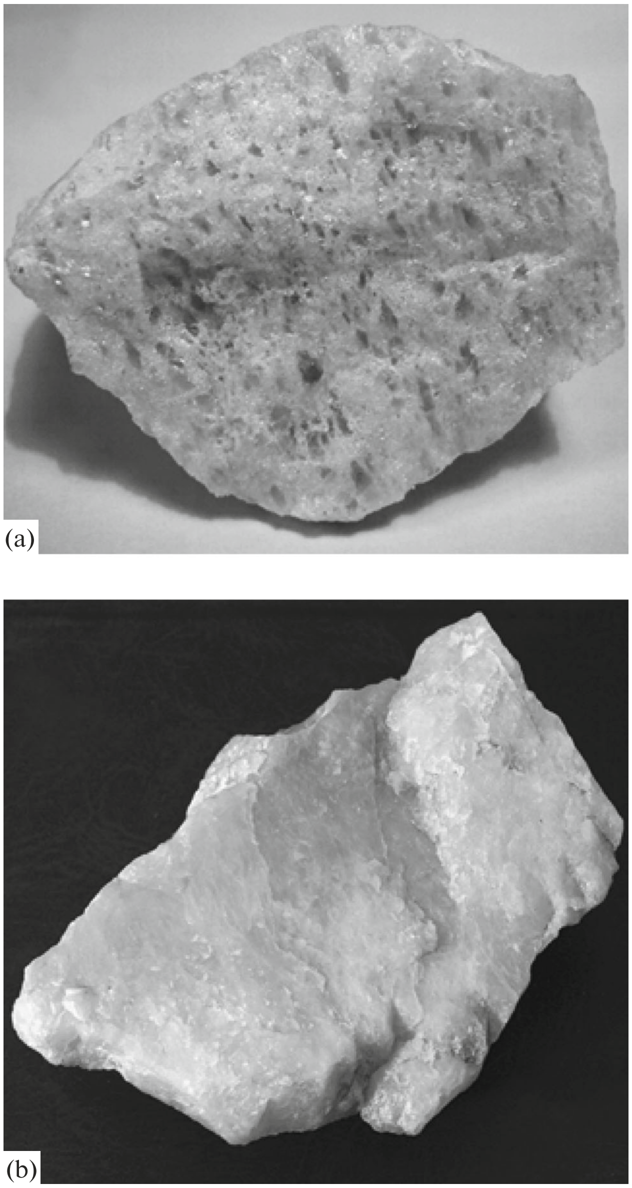

**Fig. 2.** Samples of quartz materials: (a) superquartzites, (b) compact quartzite.

**Table 1.** Concentrations of the major volatile components (ppm)

| Sample | $H_2O$ | | | $CO_2$ | CO | ΣC | $H_2$ | HCl | $H_2S$ | $SO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | ≤ 600°C | ≥ 600°C | Total | | | | | | | |
| Superquartzite | 58 | 66 | 123 | 2.4 | 9.4 | 7.9 | 0.2 | 1.9 | 0.8 | 0.2 |
| Compact quartzite | 177 | 285 | 462 | 8.1 | 19.9 | 16.3 | 0.1 | 0.8 | 0.02 | 0.48 |

**Table 2.** Weight fractions of impurities in the starting samples (ppm)

| Sample | Fe | Al | Ti | Ca | Mg | Cu | Mn | Na | K | Li | Σ10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Superquartzite | 6 | 27 | 1.7 | 0.8 | 1 | 0.17 | 0.02 | 3.5 | 6.3 | 0.13 | 46.6 |
| Compact quartzite | 4.9 | 10.4 | 0.3 | 7.3 | 0.9 | 0.2 | 0.1 | 19.3 | 6.2 | 0.3 | 50 |

**Table 3.** Weight fractions of impurities in the quartz concentrates after CE (ppm)

| Sample | Fe | Al | Ti | Ca | Mg | Cu | Mn | Na | K | Li | Σ10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Superquartzite | 0.9 | 4.5 | 0.8 | 0.7 | 0.2 | 0.14 | 0.005 | 2.5 | 0.5 | 0.12 | 10.4 |
| Compact quartzite | 0.7 | 7.3 | 0.4 | 5.6 | 0.4 | 0.2 | 0.07 | 20.9 | 3.6 | 0.4 | 40 |

**Table 4.** Weight fractions of impurities in the quartz concentrates after additional processing and CE (ppm)

| Sample | Fe | Al | Ti | Ca | Mg | Cu | Mn | Na | K | Li | Σ10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Superquartzite * | 0.6 | 3.9 | 0.6 | 0.7 | 0.2 | 0.03 | 0.002 | 2.5 | 0.5 | 0.1 | 9.1 |
| Compact quartzite ** | 8.9 | 9.9 | 0.3 | 2.9 | 0.8 | 0.18 | 0.07 | 1.7 | 1.7 | 0.4 | 27 |
| Compact quartzite *** | 6.9 | 5.3 | 0.2 | 2 | 0.5 | 0.11 | 0.05 | 1.1 | 0.9 | 0.4 | 17 |

* Double thermal crushing and CE in 20% HCl + 20% HF.

** The quartz grit of the compact quartzite was calcined in vacuum at a temperature of 1450°C for 3 h.

*** CE after calcination.

ite, we performed double thermal crushing in deionized water and CE in a 20% HCl = 20% HF acid mixture. The resultant concentrate corresponded to an ultrahigh enrichment level.

## CONCLUSIONS

The present results for two types of raw materials from East Sayan demonstrate that the types of mineral and fluid inclusions determine the parameters and scheme of processes for the preparation and enrichment of quartz concentrates. Based on compact quartzite, we have prepared highly enriched quartz concentrates and demonstrated the possibility of reaching an ultrahigh enrichment level using superquartzites.

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