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# PHASE TRANSFORMATIONS OF SILICA IN VEIN QUARTZ OF THE TULAKUL DEPOSIT

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## Abstract

The results of the study of vein quartz from the Tulakul deposit, which are a potential source of high-purity quartz raw materials, are presented. A brief description of the most promising deposits of vein quartz is given. Thermal studies of vein quartz of the Tulakul birthplace have been carried out. Stability temperatures and phase transition temperatures are established.

**KEYWORDS:** Vein quartz; quartz concentrate; silicon oxide; gas-liquid inclusions; α and β quartz; tridymite; cristobalite; quartz glass.

## INTRODUCTION

The Republic of Uzbekistan is rich in huge reserves of natural mineral resources capable of meeting the needs of the silicate industry. In connection with the construction of new and expansion of existing factories for the production of glass products, the development of technology for the development and enrichment of new promising deposits of quartz sands, quartzites and vein quartz in order to obtain glass products for household, construction, technical and other purposes on their basis becomes especially relevant [1-3].

In addition, interest in the source of high-purity quartz raw materials has increased due to the development of the glass industry of the Republic of Uzbekistan [4]. Natural quartz raw materials are the main source of obtaining high-purity transparent quartz glass and crystal [5,6].

Traditionally, vein varieties of quartz of various geological and genetic types are used to produce high-purity glass products [7]. As a rule, veins have small reserves and are heterogeneous in chemical composition. Unlike other vein varieties of quartz, vein quartzes of the Tulakul deposit have high purity [8].

Due to the increasing demand for high-quality raw materials, as well as the depletion of existing reserves of traditional deposits of quartz raw materials, the lack of reliable geological data, the task of studying the discovery of new quartz rocks (quartzites, quartz sandstones, quartz sands, etc.) and studying the secondary resources of the country, the development and widespread use of innovative technologies for the production of in-demand, in particular silicate materials for various purposes based on mineral resources, using industrial waste of the Republic will contribute to the successful solution of problems of great national economic importance in strengthening the economy of Uzbekistan [9, 10].

The purpose of this work is to study phase transformations in Tulakul vein quartz, since the study of the characteristics of phase transitions is an important step in the development of the composition of quartz concentrate production. Changing the parameters of the crystal lattice, at the temperature of interphase transitions, active opening of gas-liquid inclusions occurs, as well as at the temperatures of phase transformations, difficult-to-dissolve compounds can form, which negatively affects the production of glass.

## THE EXPERIMENTAL PART

The object of the study in this work was the vein quartz of the Tulakul deposit - as a new quartz raw material for the production of both technical silicon and raw material for obtaining high-quality quartz glass. Samples of vein quartz of the Tulakul deposit are presented in pic. 1.

**Fig. 1. Samples of vein quartz from the Tulakul deposit.**

Vein quartz of the Tulakul deposit is milky white, light gray, fine-grained, to coarse-grained, forming radial-rayed crystals, 1.5-2.0 mm in size, with an average content of the main substance SiO2 of 99.3%.

Table 1 shows the results of chemical analysis of 3 samples of vein quartz from the Tulakul deposit.

**Table 1.**

| **Name of samples** | **The content of basic oxides (wt.%)** | | |
|---|---|---|---|
| **Sample 1** | from | to | average |
| $SiO_2$ | 99.20 | 99.80 | 99.50 |
| $Al_2O_3$ | 0.20 | 0.50 | 0.35 |
| $Fe_2O_3$ | 0.02 | 0.04 | 0.02 |
| **Sample 2** | | | |
| $SiO_2$ | 98.30 | 99.20 | 98.75 |
| $Al_2O_3$ | 0.10 | 0.40 | 0.25 |
| $Fe_2O_3$ | 0.01 | 0.03 | 0.015 |
| **Sample 3** | | | |

| | | | |
|---|---|---|---|
| $SiO_2$ | 99.30 | 99.80 | 99.55 |
| $Al_2O_3$ | 0.10 | 0.70 | 0.40 |
| $Fe_2O_3$ | 0.03 | 0.05 | 0.03 |

As can be seen from Table 1, the obtained results showed that Tulakul quartz complies with the requirements of the GOST 22551-2019 standard “Quartz sand, ground sandstone, quartzite and vein quartz for the glass industry” for the production of glass materials [11].

According to the rate of degeneration of quartz minerals, the density of vein quartz at all points of this deposit belongs to the group with slow degeneration, since the density of the samples after firing is in the range of 2710 - 1850 kg / m3.

To determine the temperatures of phase transitions of vein quartz and their kinetics, a muffle furnace with a maximum heating temperature of 1750 °C using a gas-air burner was used. The temperature was recorded with platinum thermocouples located on the back wall of the muffle and controlled with an optical pyrometer. X-ray phase analysis of vein quartz from the Tulakul deposit was carried out using D/tex in the angle range of 20 = 10–120 deg. at a rate of 1.0 deg/min. A glass cuvette was used as a substrate. The shooting mode was standard. The studied samples were quartz grits with a size of 174<x<450 μm and 450<x<800 μm, obtained by grinding in a quartzite mortar. The EVA program from the DIFRAC.SUITE software package [13] by Bruker was used to perform X-ray phase analysis. The study was conducted on a Shimadzu diffractometer with Cu-Ka1 radiation, Goebbel mirrors, V= 30 kV, I= 30 mA using the powder method.

The preparation of a sample of vein quartz for conducting experiments on converting the original quartz into cristobalite, as well as into a liquid state, was carried out according to the following scheme:

1. Washing a piece of vein quartz in water with subsequent visual inspection and drying in a drying cabinet at a temperature of 100±10 °C.

2. Crushing the pieces in a quartz mortar to a size of 6-7 mm.

3. Grinding in a quartz mortar from the Rechitsa Porcelain Factory to a fraction of 0.2-0.4 mm.

4. Calcination of quartz grits in a muffle furnace at temperatures of 575 °C (±15), 870 °C (±15), 1440 °C (±15), 1720 °C (±15), the holding time was 90 min.

5. X-ray phase analysis.

Fig 2. shows the results of X-ray phase analysis of the studied sample of vein quartz from the Tulakul deposit. International reference data [14, 15] were used in calculations and in identifying crystalline phases based on the X-ray diffraction pattern.

The X-ray diffraction pattern of the original quartz sand sample (Fig. 2) shows effects with interplanar distances characteristic of quartz (d = 0.427; 0.335; 0.246; 0.228; 0.224; 0.213; 0.198; 0.182; 0.167; 0.154; 0.138; 0.137 nm).

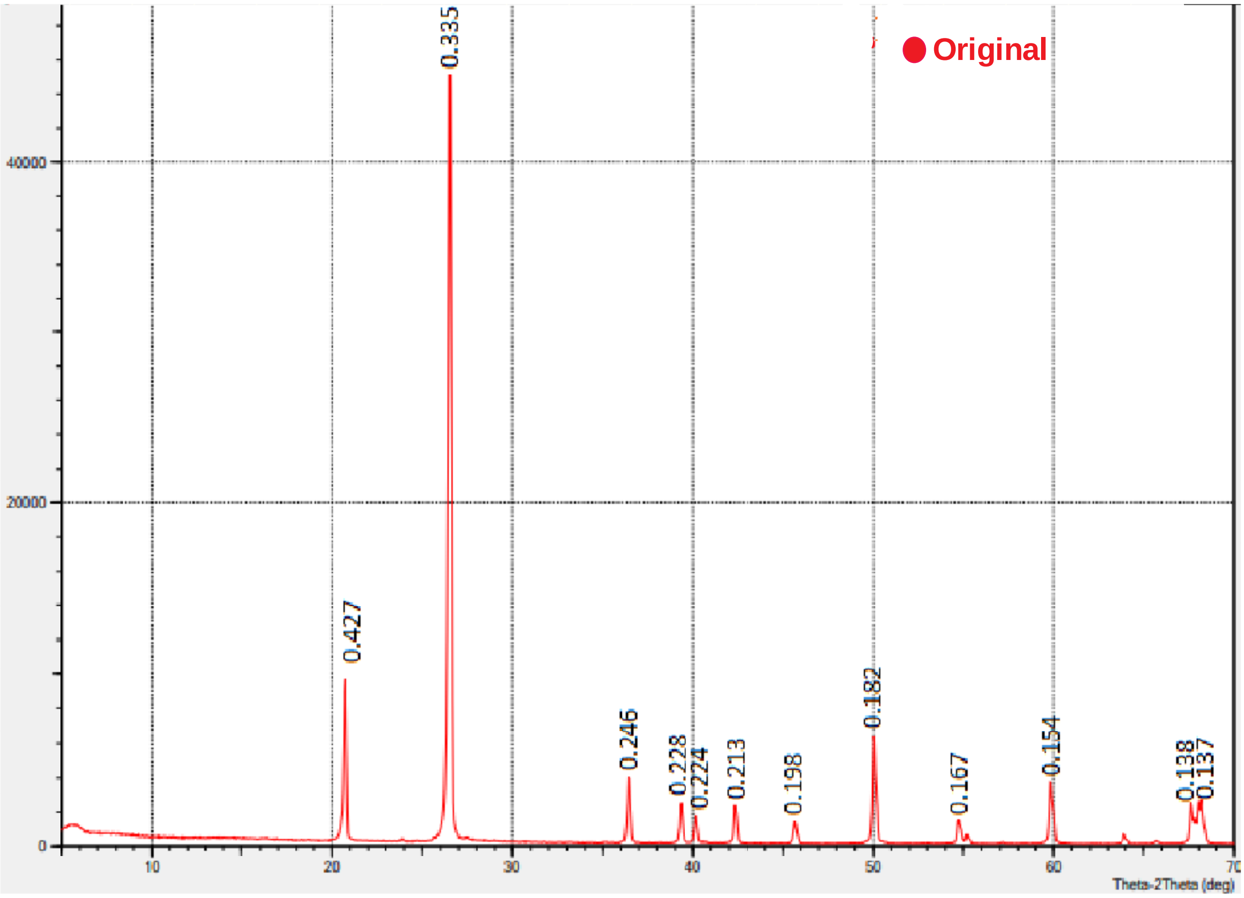

Fig. 2. X-ray diffraction pattern of the original sample of vein quartz.

The initial temperature of the study was 575 °C, since the α-Quartz phase can be recorded at this temperature. The experiment was conducted on fine-grained quartzite, the maximum holding time was 90 minutes at a temperature.

As a result of the experiment, the formation of the β-Quartz phase into the α-Quartz phase was 32.7%. The results of the phase transformations of fine-grained vein quartz at a temperature of 575 °C (±15) with a holding time of 90 minutes are presented in Fig. 3.

In the X-ray diffraction patterns of vein quartz samples fired at 575 °C (see Fig. 3), diffraction maxima characteristic of α-quartz are observed (d = 0.427; 0.335; 0.246; 0.228; 0.224; 0.213; 0.198; 0.182; 0.167; 0.154; 0.138; 0.137 nm).

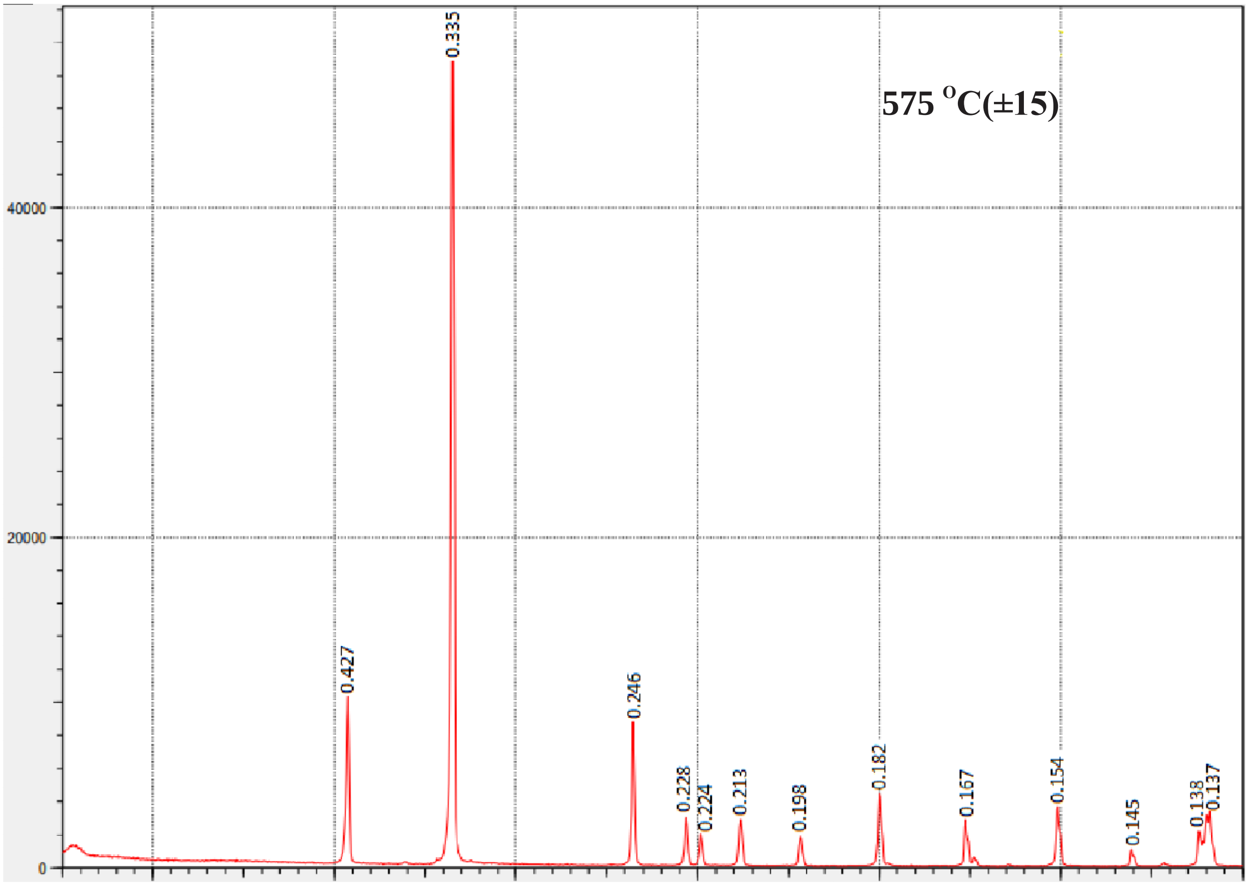

**Fig. 3. X-ray diffraction pattern of vein quartz fired at a temperature of 575 °C (±15).**

When fired at 870 °C with a holding time of 90 min, no decrease in the intensity of the diffraction maxima of α-quartz is observed, as evidenced by the appearance of characteristic effects corresponding to β-tridymite is not observed (d = 0.428; 0.336; 0.246; 0.228; 0.224; 0.213; 0.198; 0.182; 0.167; 0.154; 0.138;0.137 nm).

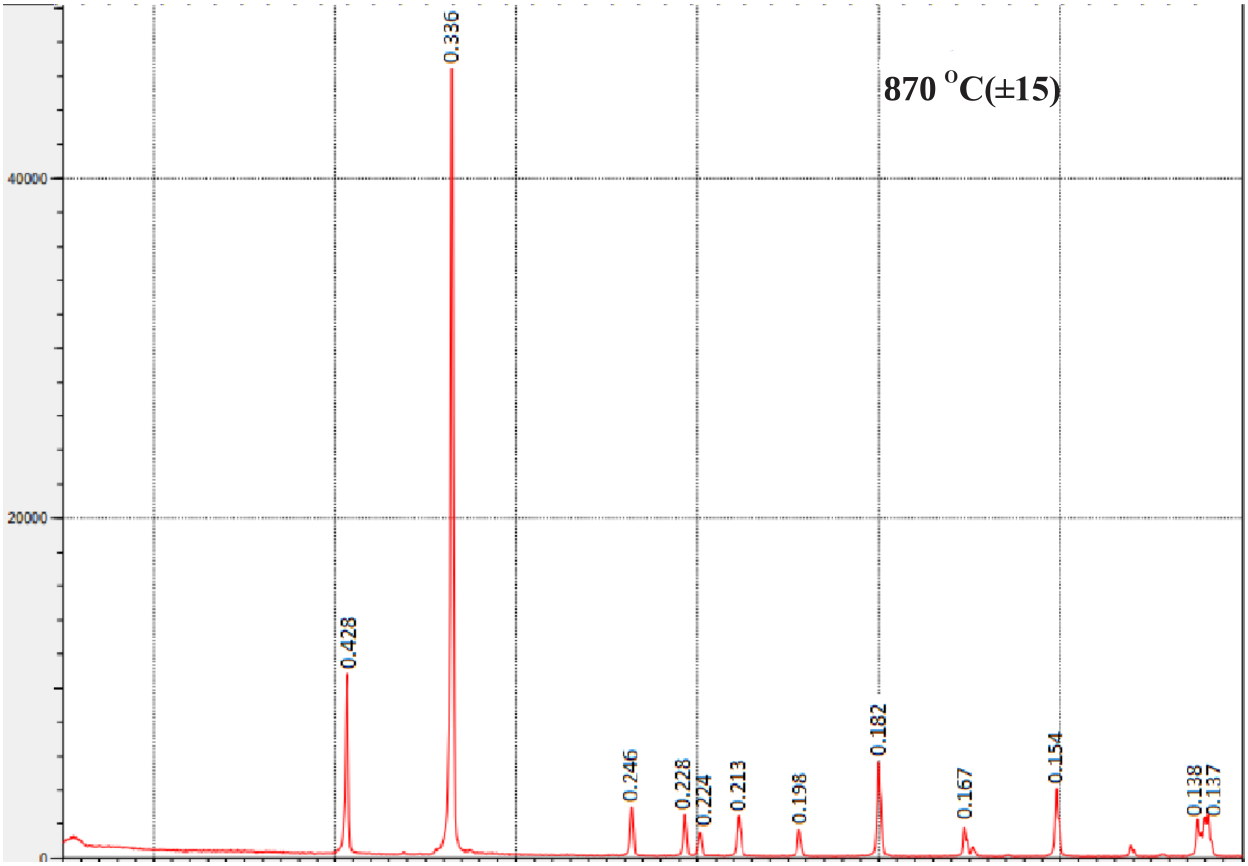

**Fig. 4. X-ray diffraction pattern of vein quartz fired at a temperature of 870 °C (±15).**

When quartz is fired at temperatures above 1470 °C, an effect with interplanar distance (d = 0.405; 0.335; 0.314; 0.284; 0.249; 0.247; 0.193; 0.187; 0.161 nm)appears on the X-ray diffraction patterns, indicating the formation of cristobalite.

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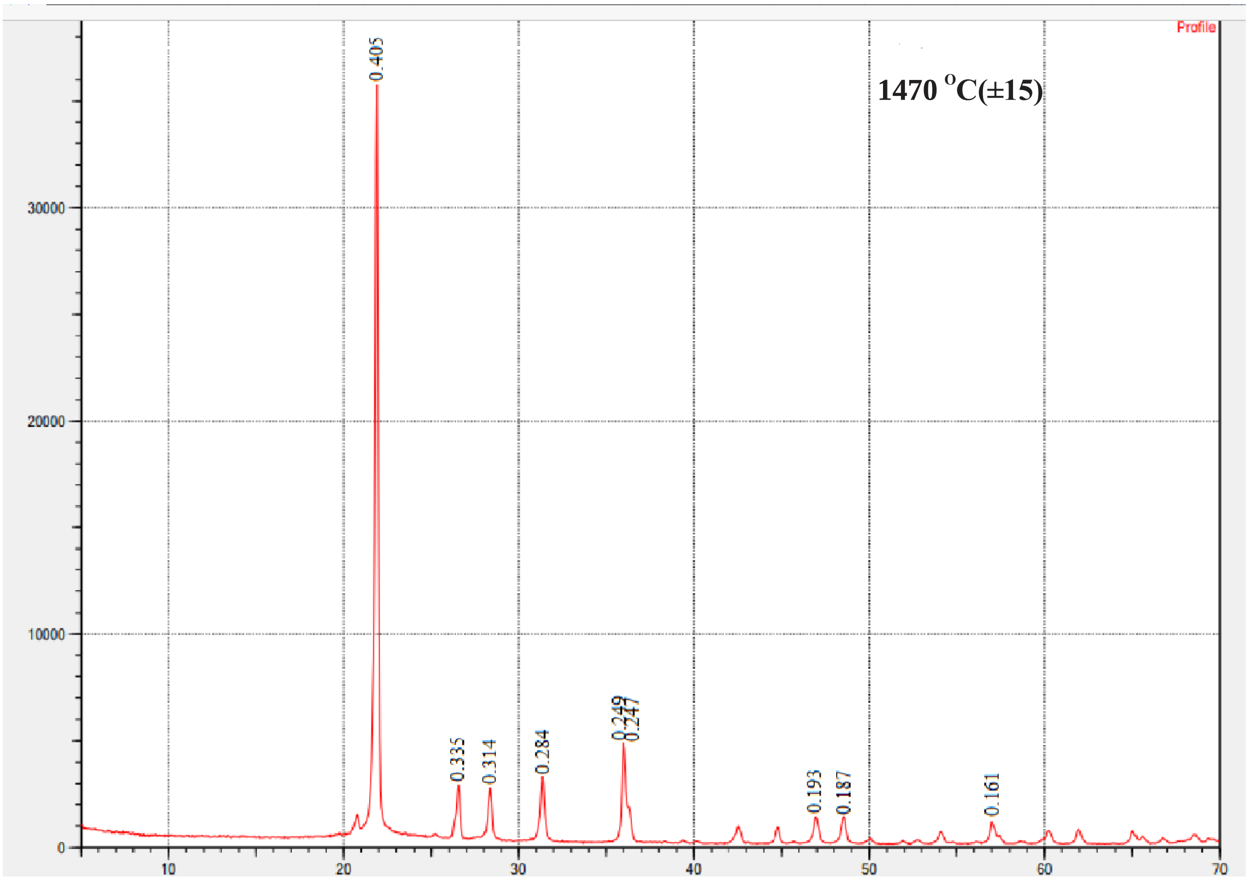


**Fig. 5. X-ray diffraction pattern of vein quartz fired at a temperature of 1470 °C (±15).**

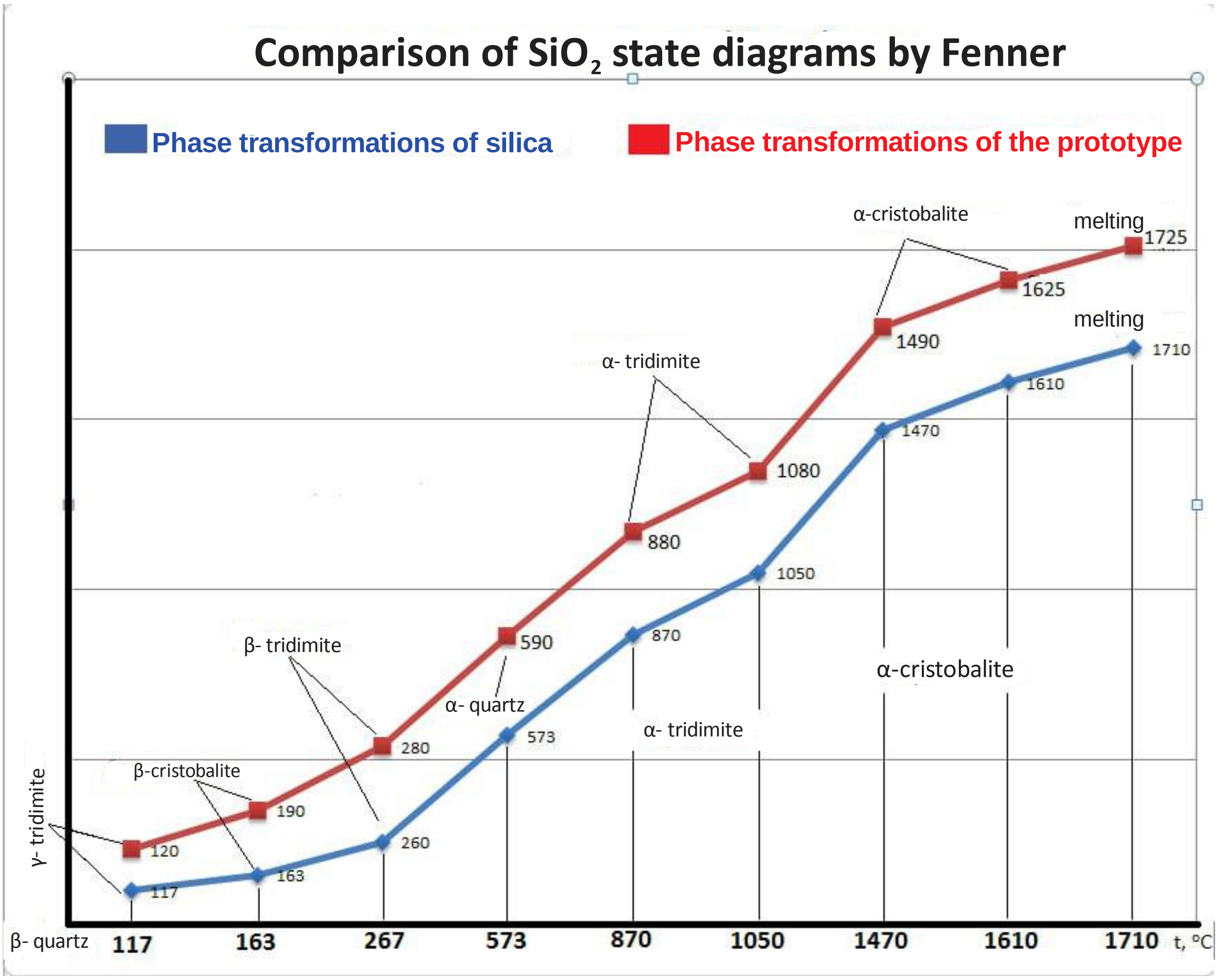
With an increase in temperature to 1720 °C, the diffraction maximum characterizing quartz gradually disappears, and therefore its melting begins.

**Table 2.**

**Changes and temperatures of silica transformation in vein quartz of the Tulakul deposit.**

| Modification | Transformation temperature (T$^{o}$C) | Volumetric effect at a given temperature, kg/m3 |
|---|---|---|
| $\beta$-quartz → $\alpha$- quartz | 590 -595 | 2,76 |
| $\alpha$- quartz → $\alpha$-tridimite | 880-1050 | 2,58 |
| $\alpha$-tridimite → $\alpha$- cristobalite | 1495-1610 | 1.92 |
| $\alpha$- cristobalite →melting | >1722 | |

**Fig. 6**



The main phase in the vein quartz of the Tulakul deposit is α-quartz, in the temperature range up to 1400 °C it retains its color and shape, at a temperature of 1470 °C and holding for 90 minutes. α-quartz passes into β-cristobalite, β-cristobalite retains its shape up to 1700 °C. Transition to the tridymite phase is not observed. The phase transition α quartz → cristobalite occurs slowly. The kinetics of the transition depends on the temperature and composition of the original material. Vein quartz of the Tulakul deposit most effectively passes into the cristobalite phase.

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