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Utilization Aspects of Pegmatite Feldspar and Quartz Sand in Ceramics

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ABSTRACT
This article presents the results of the physico-chemical analysis of Pitov feldspar in the Nurota district of the Navoi region, Republic of Uzbekistan. Particularly, the study focuses on investigating the thermal phase changes of feldspar at high temperatures, which holds significant practical importance in producing various ceramic composite materials. These data are considered valuable for the production of fine ceramic materials.

KEYWORDS: *pegmatite, qurtz, anortite, diffraction, leytcite, IR spectr.*

Pegmatite feldspar and quartz sand cones. In the cone area, eight types of feldspar and feldspar-quartz zones were identified, which together form the total area of the cone. Microcline comprises 50.0-85.0% and is considered the main compositional part. The thickness of the cone in the central part reaches 30.0 m, in some places - 7.0 m, on average - 16.0 m. Pegmatite feldspar-quartz concentrates meet the requirements of GOST 7030-67, have good sintering properties, and can be used as a raw material for fine ceramics. Under specified conditions, the calculated content of useful feldspar is 68.5%, microcline is 18.2%, and impurities (xenolites and others) - 13.3%. The volumetric mass of feldspar and microcline is 2.5 t/m3: 68.5% is feldspar, and 18.2% is microcline. The estimated reserves of pegmatite feldspar-quartz raw material in category C2 amount to 375.0 million tons, including 256.8 million tons of quartz and 68.2 million tons of microcline. When heated at high temperatures, quartz in pegmatites is classified by its high reactivity [1; -351b.].

In the study of kaolin-feldspar-quartz systems, the influence of the particle size of quartz and feldspar particles on the sintering and bending strength is studied. Initially, the average particle sizes of quartz and feldspar powders in cone cones are in the range of 1.2-8 μm and 1.2-4 μm, respectively. Quartz, feldspar, and kaolin were mixed in a ratio of 30:31:29, and samples were fired at temperatures of 1100-1350°C. The strength of sintering was determined with a decrease in the particle size of quartz and feldspar, and at a pressure of 176 MPa, the maximum strength was obtained for particles with an average size of 1.2 μm [2; 131-140b.].

To produce glassy phases in the composition of feldspar and quartz in the presence of alkali components, the formation of crystallization of cristobalite and tridymite is considered [3; b.62-71]. Large quantities of quartz-containing ceramic products not only differ in good transparency and smoothness but also have similar mechanical strength to traditional masses [4; 61-65b.].

Chamotte masses based on sericite-pyrophyllite have high mechanical strength and porosity. Sericite-pyrophyllites show a positive effect in reducing wear and tear and deformation due to fatigue. Also, the presence of quartz in the usual composition of clay strengthens the mechanical strength due to the interaction of quartz with the mullite phase, but it reduces the thermal expansion coefficient [5; 871-876b.]. The amount of mullite-like phase in the clay composition reaches 60%. The role of clay in the process of its formation is especially significant. The characteristics of the properties of products, especially clay crucibles and insulators, are determined by the structure of the mullite-like phase [6; 403-412b.].

Due to the low content of impurities, the most valuable of pegmatite feldspars for the ceramic industry are: potassium and sodium feldspars. They are characterized by low impurity content in the form of dust, so they are used in the production of ceramic masses. Because of the different compositions of feldspar, their effect on the sintering time varies. When sodium feldspar is sintered at 1410°C, it has a lower fusion viscosity compared to potassium feldspar, contributing to strong deformation during its fusion [14].

Therefore, potassium and sodium feldspars are added to ceramic raw materials. Increasing the content of CaO in feldspar reduces the transparency of the glaze, i.e., the translucency of the glaze decreases in the upper layer of the ceramic body [15; 16-17b.].

In the synthesis of ceramic materials, one of the promising areas is the use of natural lithium-containing alumino-silicate minerals as an initial component: spodumene, lepidolite, petalite, amblygonite, eucryptite, and lithium orthoclase. Abdel A.A. synthesized high-strength ceramic materials based on spodumene concentrate. In particular, the introduction of spodumene into ceramic compositions leads to a significant decrease in firing temperature (1250°C), an increase in plasticity and transparency when compared with fired clays, and a decrease in the thermal expansion coefficient (TKChK) [16].

Scientific studies [17; 293-300b., 18; 282-283b.] used feldspar rock as a ceramic raw material. The combination of pegmatite and feldspar, along with partly kaolin, was found to be possible in order to expand the resource base of raw materials for the ceramic industry. The addition of feldspar to clay masses for complex use of feldspar pegmatite allows for an increase in the melting range, improvement of plasticity, reduction of porosity, and an increase in the mechanical strength of fired products.

According to literary sources [22], at the chinni plant in the Primorsky Territory, feldspar was replaced by rhyolite in the composition of raw materials (50-60%) with rhyolite, (30-35%) quartz, and (5-12%) kaolinite. Due to the dispersed state of quartz in rhyolite, it is classified as a material that, in the structure, is prone to the formation of cristobalite-tridymite under conditions favorable for this process.

In conclusion, the article presents the utilization aspects of pegmatite feldspar and quartz sand in ceramics. The study highlights the composition, properties, and potential applications of these materials in the production of ceramic products.

Researchers [23; -383b.] have studied the influence of the ratios of potassium and sodium oxides on the mechanical properties and microstructure development during the evolution of phases in Chinese clay formations. In this study, a combination of sodium and potassium feldspar, along with nepheline syenite, was utilized as fluxing agents. Six different compositions of fluxing agents were employed. The study suggests that the influence of fluxing agents on the development of mullite, where crystalline phases such as cristobalite and tridymite may form due to the effect of melting agents in the composition. Evaluation of the evolution phases involved assessing the dissolution of fluxes, the kinetic aspects of quartz dissolution, and the formation of cristobalite and tridymite during the cooling process, utilizing X-ray diffraction.

A crucial aspect of Pitov pegmatite feldspar is its high potassium module, i.e., the ratio of K2O:Na2O ranging from 7.1 to 7.5, primarily derived from potassium feldspar. It meets the requirements of GOST 7030-75 with PshK 0.15-3 and PSh 0.20-3 indicators. According to GOST standards, the content of K2O and Na2O in feldspar should be at least 12%, with their ratio being no less than 3. In the case of Pitov pegmatite feldspar, these indicators are 16% and a ratio of 6.5, respectively. The quantity of fluxing oxides complies with quality standards. The half-quantitative elemental spectral analysis of the Pitov pegmatite feldspar sample is presented in Table 1, and their distribution in the diagram is illustrated in Figure 1.

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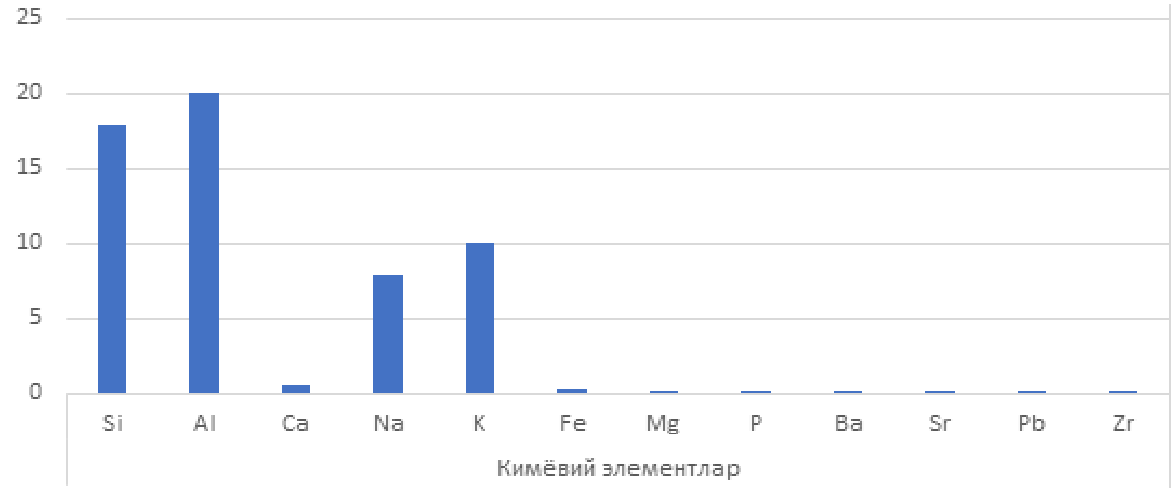
Half-Quantitative Elemental Spectral Analysis Results of the Pitov Pegmatite Feldspar Sample

Table 1

Percentage of chemical elements, %											
Si	Al	Ca	Na	K	Fe	Mg	P	Ba	Sr	Pb	Zr
18	20	0,5	8	10	0,3	0,06	0,06	0,1	0,02	0,06	0,02

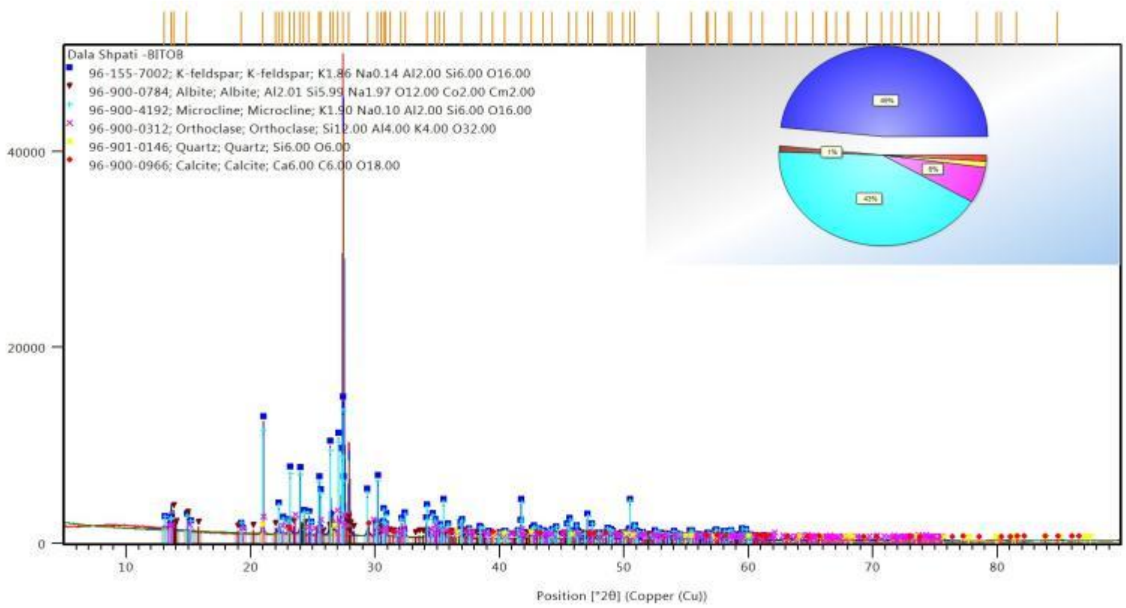


1-Image. Diagram of the half-quantitative elemental spectral analysis of the Pitov pegmatite feldspar sample

According to the results of the half-quantitative elemental spectral analysis, elements Si, Al, K, Na, Ca, Fe predominate. In terms of oxide composition, it consists of SiO2-38.57%, Al2O3-37.78%, Na2O-10.78%, K2O-12.05%, Fe2O3-0.43%. From this, it can be inferred that Pitov pegmatite feldspar is considered a unique ceramic raw material for high-potassium modulus fine ceramic materials.

According to Figures 2 and 3, when comparing Pitov pegmatite feldspar and Langar leucogranite, it can be observed that the Pitov pegmatite feldspar has a high content of potassium feldspar. The structure of Pitov pegmatite feldspar, confirmed by X-ray and IQ spectroscopic results, belongs to the potassium type (KAlSi3O8).

2-Image. X-ray diffraction pattern of the Pitov pegmatite feldspar sample.



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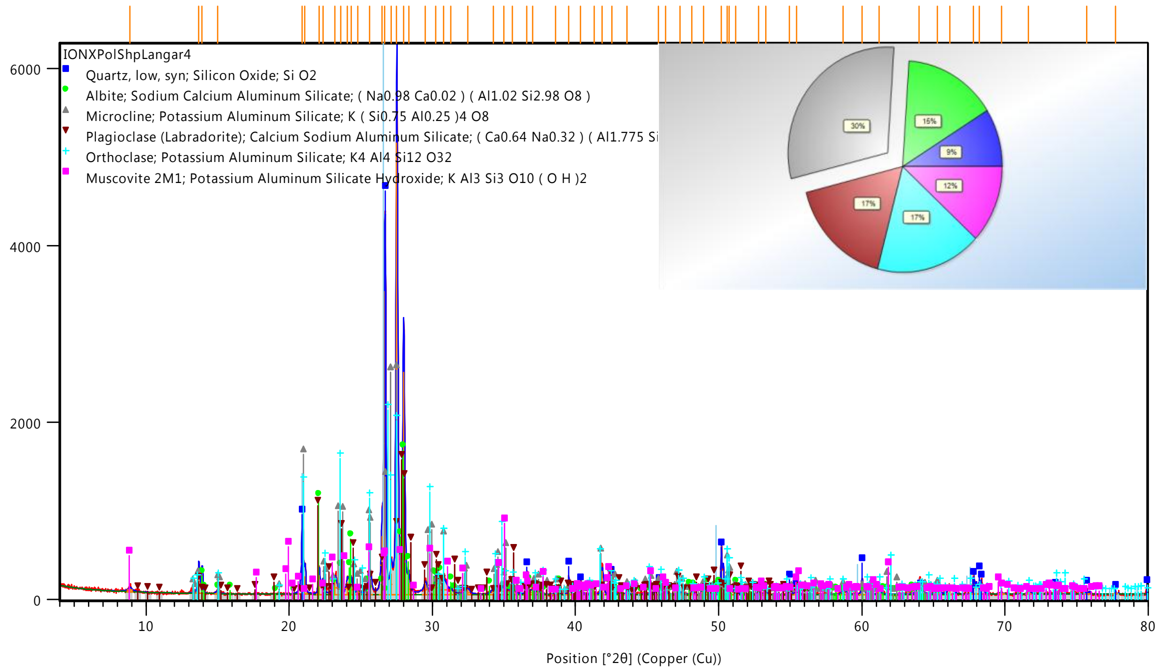
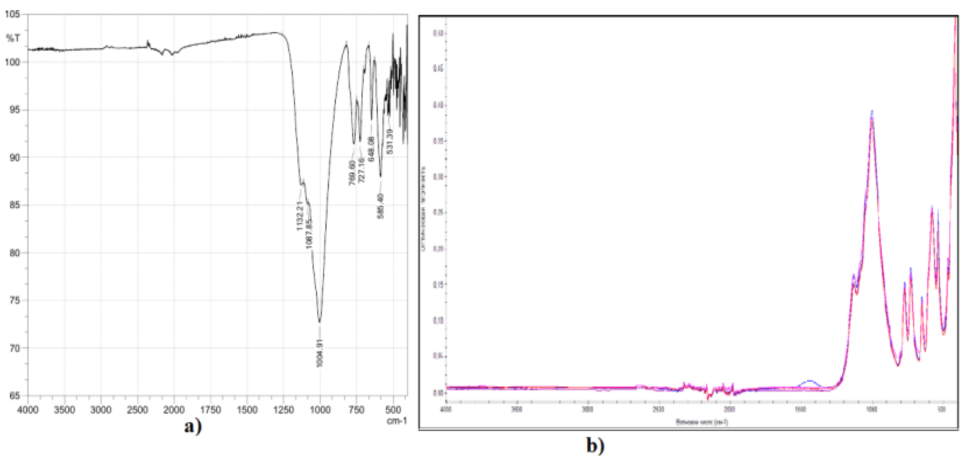


3-Image. X-ray diffraction pattern of the sample of Langar leucocratic granite

The slightly elevated content of quartz, plagioclase, and albite in the composition of Langar leucocratic granite indicates a negative effect on the production of fine ceramic products.

During the examination, the utilization lines of Langar leucocratic granite and Pitov pegmatite at 1140, 1055, 1015, 775, 730, 650, 615, 590, 535, 465, 430 cm-1 and the wavelengths of 0.426, 0.404, 0.387, 0.374, 0.361, 0.351, 0.339, 0.326, 0.305, 0.297, 0.290, 0.281, 0.264, 0.259, 0.254, 0.244, 0.234, 0.216, 0.199 nm were identified. In the experiment, the distinctive features of the X-ray phase analysis were found to be consistent with the high-intensity presence of aluminum silicate KAlSi3O8. According to the IQ spectra, it was determined that the complex from the comprehensive survey corresponds to the KAlSi3O8 monoclinic modification [24; 220b]. According to the information, orthoclases have only one zone of proximity to 769 cm-1 in the IQ spectrum in the diffusional region, while in the microcline, in the triclinic form, two small utilization zones are present at 769 and 773 cm-1. The IQ spectrum of the Pitov pegmatite at 730 and 775 cm-1 has an average intensity with two overlapping utilization paths, suggesting the possibility of transitioning to the KAlSi3O8 structure in a triclinic form related to them.



4- Image. a) Langar leucocratic granite and b) Pitov pegmatite samples sintered at 900, 1100, and 1200 °C and their IR spectra

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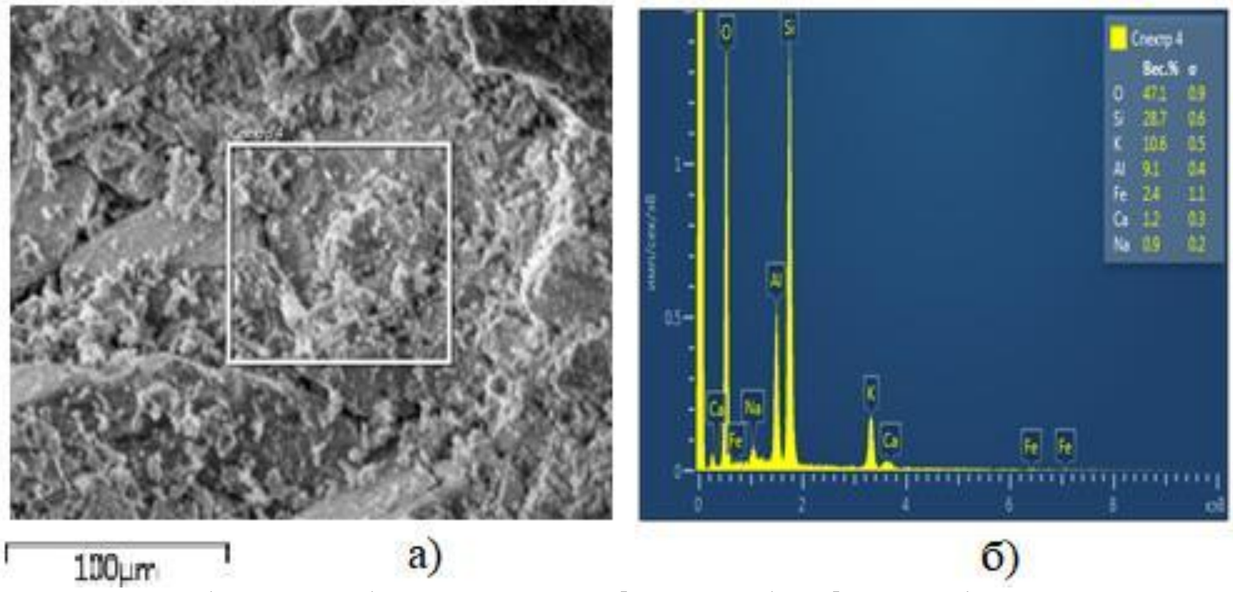
The presence of microcline modifications with a weak maximum utilization at 1015 and 1055 cm-1 is shown in the doublet spectrum. The classification of utilization in these spectra in this field requires identification of strong utilization paths related to the KAlSiO8 – adularia in the monoclinic form at lower temperatures, with a strong utilization path merging with orthoclase at 1042 cm-1. In the analyzed Pitov pegmatite, two different forms are observed in small amounts. Scanning electron microscope data are presented in Table 3.13.



5- Image. Pitov pegmatite appearance under a scanning electron microscope

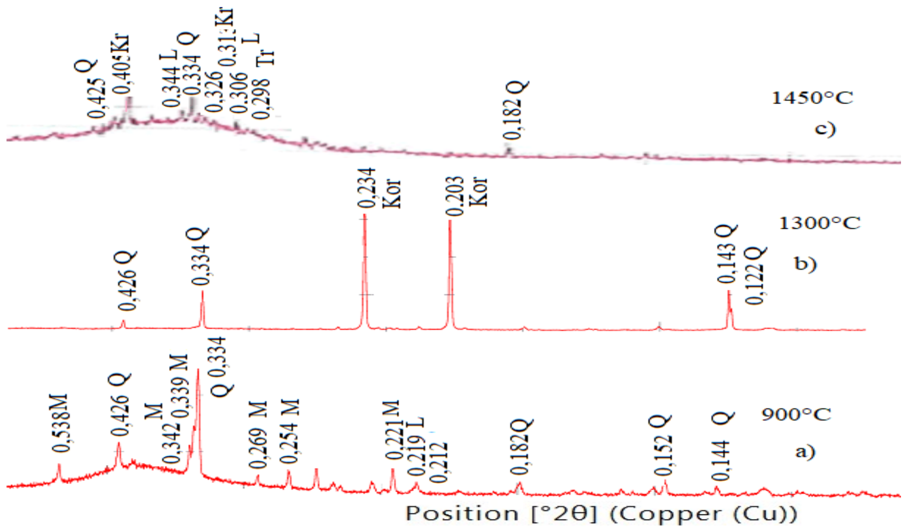
a) Sample appearance under the microscope; b) Elemental analysis of the sample

Table 2. Scanning electron microscope data

Scanning electron microscope data					
Element	weight%	Sigmaweight%	Element	weight%	Sigma weight%
O	47.08	0.90	K	10.64	0.52
Na	1.87	0.18	Ca	2.19	0.34
Al	9.08	0.35	Fe	0.45	1.06
Si	28.69	0.64	SUM:	100.00	

According to scanning electron microscope data, the mass fraction of K2O in the specified area of the Pitov granite sample constitutes 12.82%.

In the investigated Pitov granite samples, the indices of light reflectance in the visible spectrum, represented by the colors red, green, and blue, are 1.528, -1.514, and -0.014, respectively. At the second (polishing) polishing temperature, Pitov granite, enriched with nepheline, exhibits a leucite mineral appearance in the cold glass. The refractive index of the modal constituents in the glass appearance, according to petrographic analysis data, corresponds to 1.490.



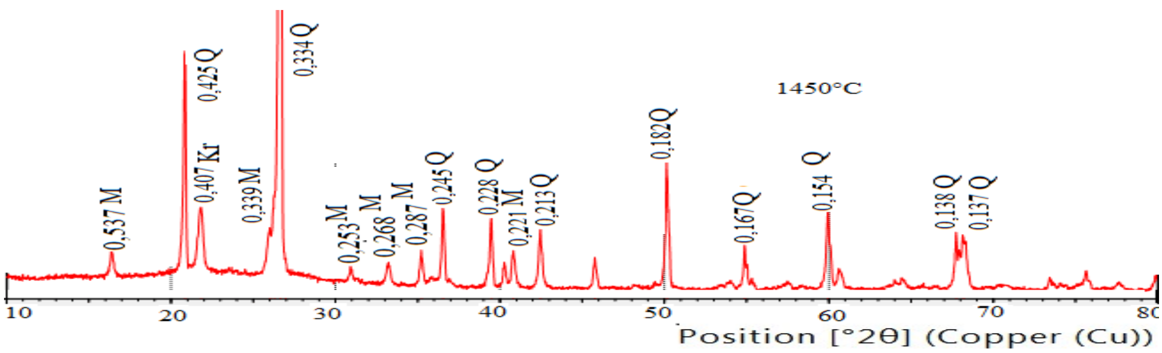
6-Image. X-rayograms of Pitov granite samples fired at high temperatures

From the X-rayograms of Pitov granite fired at high temperatures, it can be observed that the minerals associated with granite are not clearly distinguished at a certain temperature. This is because the composition of the granite is mainly related to potassium and sodium feldspars, and even at a temperature as high as 900ºC, it does not show diffraction lines due to the transition to an amorphous state. In samples fired at 900ºC, a low-intensity, mullite crystal formation can be observed. As the temperature rises to 1450ºC, the disappearance of mullite and quartz crystals in the sample is noted, and almost no diffraction lines are visible due to the transition to a completely amorphous glass phase.

3rd Table Chemical composition of the used ceramics

Raw materials	Percentage of oxides, %										
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	SO_3	k.y	Summa
Altintag kaolin	51,12	0,15	33,83	0,8	0,56	0,49	0,47	1,32	0,21	12,02	100,00
Kakayoz quartz sand	98,06	0,02	0,1	0,02	0,1	0,26	0,27	0,13	0,24	1,26	100,00
Pitov basin feldspar	65,14	0,03	18,12	0,22	0,2	0,39	2,75	13,10	0,01	0,03	99,99

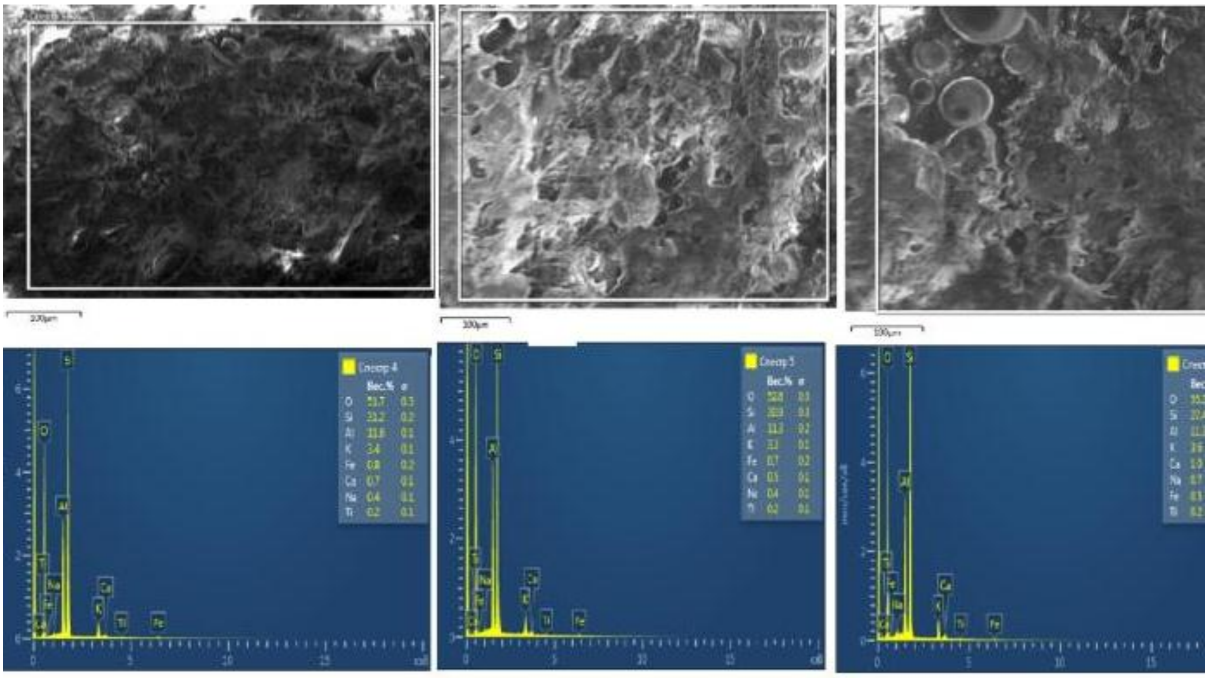
The synthesis process of ceramic samples obtained from experimental materials was studied based on the continuous sintering method, and the results of water absorption, bulk density, and shrinkage upon firing were determined. The research also included an analysis of the results based on X-ray phase analysis.



7-Image. The mineralogical composition effect of 10% content of feldspar in the ceramic sample

The physicochemical reactions occurring during the firing of ceramic materials and their influence on the synthesis of ceramics were studied using differential thermal analysis methods, and firing was carried out simultaneously at different temperatures.

In the composition consisting of 50% kaolin, 40% quartz, and 10% feldspar, even at temperatures up to 1450ºC, the diffraction lines of mullite and β-quartz are clearly visible due to the significant amount of quartz. A small amount of feldspar also ensures a symmetrical ordered appearance in the crystal structure of the ceramic mass (Image 7).



a) b) c)

8-Image. 1150ºC fired sample with 50% feldspar; 30% Altintag kaolin; 20% - The SEM (Scanning Electron Microscope) image (x500) and elemental analysis of the sample of ChM with a composition of kakayoz quartz

8- s) - In the s)-image, relatively large-sized quartz crystals on the melted surface are demonstrated. The mullitization process for the mixture in MChM begins at 1250°C, resulting in distinct donor mullite crystals. The majority of quartz particles in the ceramic mass composition can be observed (Image 8, a). The formation of quartz shards and residual kaolinite (Image 8, s) indicates the main phase of glassy material production with the melting point of feldspar (1100-1200°C). Analyzing the specimens fired at 1150°C provides insights into the initiation of the cooling phase of the synthesis. The shapes of feldspar-like grains differ from each other. The change in the amount of mullite produced in the glass phase with a certain amount of mullite in the glass phase was observed.

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