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STUDY OF THE COMPOSITION OF THE LOCAL JERDANAK MINERAL SHALE RAW MATERIAL

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Abstract: This study investigates the mineralogical and chemical composition of shale raw material obtained from the Jerdanak deposit in the Sherabad district of Uzbekistan for its potential use in refractory brick production. The shale samples were crushed, sieved, and thermally treated to evaluate their physical and structural transformations. Analytical techniques such as FTIR spectroscopy and X-ray fluorescence (XRF) were applied to determine the presence of silicate, alumina, and oxide phases. The main components identified include SiO_2 (49.16%), Al_2O_3 (32.36%), and K_2O (11.96%), which correspond to quartz, feldspar, and mica/illite minerals. Minor elements such as Fe, Ti, Mn, and Ca were also detected. The results indicate that the Jerdanak shale possesses a composition suitable for use as an additive in aluminosilicate-based refractory materials, potentially enhancing their thermal stability and mechanical performance.

Keywords: Jerdanak shale; refractory materials; aluminosilicate; FTIR analysis; X-ray fluorescence; mineral composition; high-temperature ceramics.

Introduction. The role of refractory materials in industry is incomparable, and their main task is to maintain structural strength in high-temperature environments and provide long-term service in aggressive conditions [1–3]. Metallurgical furnaces, chemical reactors, power generation facilities, cement and ceramic industries cannot function without refractory bricks. Therefore, the issue of optimizing their composition, production technology and properties is at the center of scientific research [4]. Aluminosilicate refractories are the most common type, containing up to 40–80% Al_2O_3 and SiO_2 [5]. Their thermomechanical properties depend mainly on the amount of mullite phase ($3Al_2O_3 \cdot 2SiO_2$), which is formed at high temperatures. The unique crystal lattice of mullite gives it high strength, low thermal expansion and resistance to thermal shock [6–

7]. Therefore, increasing the mullite phase is a particular focus in the development of refractory materials.

The literature presents various ways to produce mullite: by roasting kaolin, adding bauxite and feldspar, and also shows that it is possible to increase economic efficiency by using industrial waste [8–10]. In kaolin-based bricks, mullite and cordierite phases are formed together as a result of high-temperature sintering, which increases the mechanical strength and thermal stability of the material [11]. In recent years, there have been studies on the improvement of the microstructure of refractory bricks by adding nanomaterials (e.g., nano-Al_2O_3, nano-SiO_2) [12]. It has also been noted that modified sol-gel methods, high-pressure heat treatment, and plasma sintering technologies are effective in increasing the strength and durability of the material [13–14]. Analysis methods are also becoming more modern. For example, phase changes are monitored using X-ray diffraction (XRD), and microstructural features are determined using SEM/EDS [15].

Differential thermal analysis (DTA) and thermogravimetric analysis (TGA) are used to analyze the dehydration and phase transformation processes of raw materials [16]. The results of such in-depth analyses allow us to determine the optimal firing temperature and composition of the refractory materials being developed.

The issue of thermal shock resistance is also important. In some studies, aluminosilicate bricks were evaluated for their ability to withstand multiple “heating-cooling” cycles, and it was found that an increase in the mullite content and a decrease in the porosity level had a positive effect [17–18]. At the same time, the issue of increasing the corrosion resistance of such materials in high-temperature chemically aggressive environments (for example, when in contact with slag in metallurgy) is also relevant [19].

In general, the literature review shows that, despite the high performance of aluminosilicate-based refractory materials, new structural additives, innovative technologies, and microstructural optimization are necessary to increase their mechanical strength, thermal shock resistance, and chemical resistance [20–21].

2. Preparation of raw materials.

The purpose of the study is to use samples of shale layered silicate mineral obtained from the Zherdanak deposit in the Sherabad district, located in the south of Uzbekistan, as an addition to the traditional raw materials for refractory bricks. Slates have a layered structure and are easily broken. This silicate mineral contains several minerals such as muscovite, quartz, staurolite, and albite.

We start by grinding the raw material. The shale pieces were placed in a ball mill and ground to a particle size of 0.3 mm. Then they were passed through a 0.160 mm sieve.

The sample was pressed by adding 18% of its mass of water and made into capsules. The prepared capsules were dried at room temperature for one hour. After that, the capsules were dried in a drying oven at 200℃ for 20 minutes. The dried samples were baked in a kiln at 1350℃ for 4 hours. After baking, the sample was cooled in a desiccator and weighed on an analytical balance.

The studied raw material slate samples were ground in a mortar to check their melting point. They were passed through a sieve with a mesh size of 0.160 mm. Water was added in an amount of 18% of the sample mass and pressed. During the pressing process, it was poured into a pyramidal mold. It was brought to the pyramidal shape and dried. The dried sample was placed in a special furnace for checking the melting point. The temperature was gradually increased. When the furnace reached a temperature of 1450 °C, the melting point of the sample was checked.

3. Analysis of the results. The composition and physicochemical structure of samples prepared on the basis of layered silicate of the Zherdanak shale, which is planned to be used as an additive to raw materials, were studied.

3.1. Infrared spectroscopy analysis of the sample was carried out and the following conclusions were drawn:

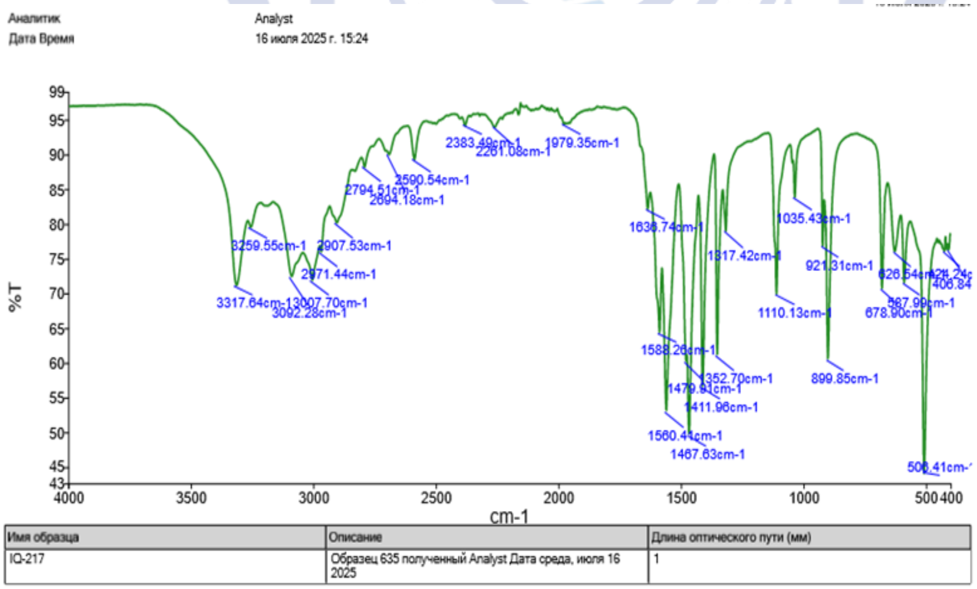

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Figure 1. Infrared spectroscopy analysis of a sample of additional raw material shale

The given FTIR spectrum was obtained for a sample of silicate-coated shale. The following is an analysis of only the inorganic parts of the spectrum (oxides and mineral phases).

Key observations:

1000–1110 cm^{-1} (1110, 1035 cm^{-1}) – Peaks related to Si–O–Si asymmetric bonds are observed. These peaks indicate the presence of silica (SiO_2) and silicate minerals (quartz, phyllosilicates). 920–900 cm^{-1} (922, 899 cm^{-1}) – Tetrahedral vibrations of the silicate layer or the possibility of the presence of carbonate ($CaCO_3$) ions. In the regions of 680–570 cm^{-1} and 500–450 cm^{-1} (678, 508–500 cm^{-1}) – We observe deformation vibrations related to Si–O–Si and vibrations related to metal–oxygen (Fe–O, Al–O,) bonds. These peaks indicate the presence of iron, aluminum oxides. The vibrations in the region of 1638 cm^{-1} can be attributed to the vibrations of the H–O–H bond of adsorbed or structural water. These peaks indicate the presence of moisture or hydroxyl groups in the studied sample. 3317–3259 cm^{-1} – Broad peaks indicate vibrations of structural OH groups (phyllosilicates such as kaolinite, chlorite) or adsorbed water. 1400–1500 cm^{-1} and ~875 cm^{-1} – May correspond to vibrations of carbonate ions (CO_3^{2-}). There is a possibility of the presence of $CaCO_3$.

As a result of the analysis of the inorganic part of the IR spectrum, it can be concluded that the following phases were detected in the sample:

1. Silicate minerals (SiO_2 as the main component).
2. Aluminum oxide phases (Al_2O_3) and phyllosilicates.
3. Iron oxides (Fe_2O_3/FeO) or iron silicates.
4. Carbonates ($CaCO_3$) may be present.
5. Structural/adsorbed water and OH groups.

3.2. X-ray fluorescent analysis of a shale sample used as an additive to refractory brick raw materials was conducted.

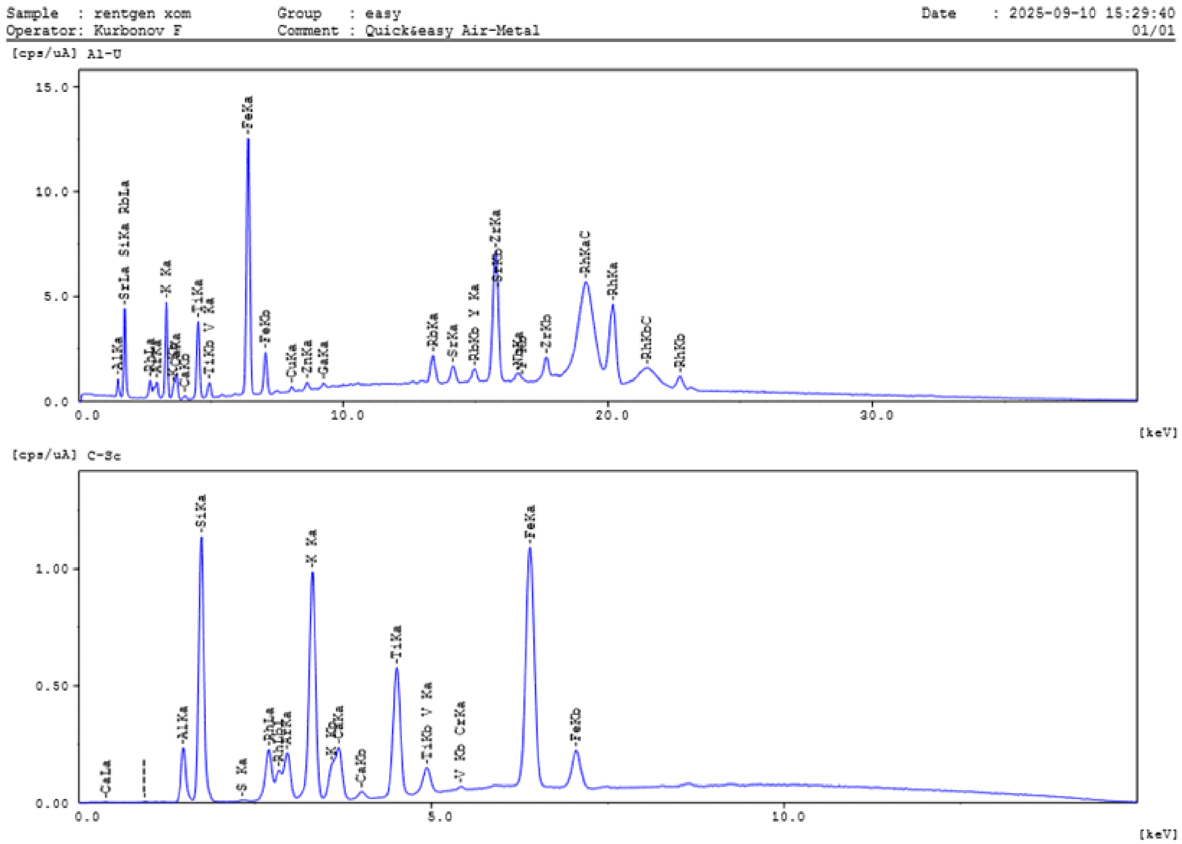

Figure 1. Infrared spectroscopy analysis of additional raw material shale sample

Results are given in elemental percentages (wt%). Main components: Si (57.82%), Al (21.55%), K (12.49%). These correspond to silicate material (quartz + feldspar). Fe, Ca, Ti are present as additional elements (around 2–3%). Zr, Rb, Sr, Mn, Y, Cu, Ga, Nb, Zn are noted in small amounts.

3. Element → Oxide conversion:

Element	Element wt%	Oksid	Oksid wt% (normallashtirilgan)
Al	21.545	Al_2O_3	32.36
Ca	2.486	CaO	1.38
Cu	0.022	CuO	0.01

Fe	2.772	Fe_2O_3	3.15
Ga	0.021	Ga_2O_3	0.02
K	12.493	K_2O	11.96
Mn	0.034	MnO	0.02
Nb	0.019	Nb_2O_5	0.02
Rb	0.089	Rb_2O	0.08
Si	57.820	SiO_2	49.16
Sr	0.044	SrO	0.02
Ti	2.256	TiO_2	1.50
V	0.099	V_2O_5	0.14
Y	0.034	Y_2O_3	0.03
Zn	0.016	ZnO	0.01
Zr	0.252	ZrO_2	0.14

The sample consists of high silica (SiO_2) and potassium-rich aluminosilicate (Al_2O_3 + K_2O), which is compatible with minerals such as quartz, feldspar and mica/illite and can be used as a raw material in the production of ceramics, glass and aluminosilicate materials. Traces of Fe, Ti, Mn, Cu and Zn can affect the color and optical properties. It is likely that zircon and Nb, Y accessory minerals are mixed. The following table lists the mass fractions of the elements, spectral lines and their corresponding standard X-ray energies (eV) determined using the EDX-8100 spectrometer for the X-ray sample X-ray 2.

Element (simvoli)	Massaviy ulushi (%)	Spektral chiziq	Energiya (eV)
Kremniy (Si)	57.820	Kα	1739.98

Alyuminiy (Al)	21.545	Kα	1486.70
Kaliy (K)	12.493	Kα	3313.8
Temir (Fe)	2.772	Kα	6403.84
Kalsiy (Ca)	2.486	Kα	3691.68
Titan (Ti)	2.256	Kα	4510.84
Sirkoniy (Zr)	0.252	Kα	15775.1
Vanadiy (V)	0.099	Kα	4952.20
Rubidiy (Rb)	0.089	Kα	13395.3
Stronsiy (Sr)	0.044	Kα	14165.0
Marganets (Mn)	0.034	Kα	5898.75
Ittriy (Y)	0.034	Kα	14958.4
Mis (Cu)	0.022	Kα	8047.78
Galliy (Ga)	0.021	Kα	9251.74
Niobiy (Nb)	0.019	Kα	16615.1
Rux (Zn)	0.016	Kα	8638.86

Source: X-ray Data Booklet (LBL–NIST).

Conclusion

The shale raw material obtained from the Jerdanak deposit was found to contain a high proportion of silicon dioxide (SiO_2) and aluminum oxide (Al_2O_3), confirming its suitability as an aluminosilicate raw component. FTIR and X-ray fluorescence (XRF) analyses verified the presence of quartz, feldspar, mica, and iron oxide phases within the samples. These mineral components contribute to improving the thermal stability and mechanical strength of refractory materials. Therefore, Jerdanak shale can be considered a promising and economically advantageous local raw material for the production of high-quality aluminosilicate-based refractory bricks.

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