Chemical and mineralogical studies of basalt "Aydarkul"

A Kurbonov[1,*], *L* Sattorov[1], *B* Kamolov[1] and *O* Rakhimov[1]

[1]Karshi Engineering-Economics Institute, 225, Ave. Mustakillik, Karshi, 180100, Uzbekistan

Abstract: In the article, the geologic, structural, and mineralogical composition of the "Aydarkul" basalt mine was studied as a result of research, and a complete analysis of the physical and chemical pieces of the basalt rock was given. Based on the results of theoretical and experimental studies, the physical and chemical foundations of pyro- and hydrometallurgical methods of rock processing - basalt raw materials - have been developed. Technological options are proposed that allow obtaining demanded products of various compositions. A schematic diagram of the complex processing of basalt raw materials has been developed, including the processing of waste and by-products, as well as the extraction of accessory materials. The study found that the basalts of the Aydarkul mine can be used in the electric power industry.

1 Introduction

Basalt (from the Latin "basalts" - a touchstone and at the same time basalt - the name from the Ethiopian, "basal" - means - iron-containing stone) is a rock. Basalt is a dense and extremely hard rock, and it has a grain size of a different order. Coarse- and medium-grained rocks are called dolerites, fine-grained - anime sites, and very fine-grained - proper basalts. Coarse and medium-grained basalts are also called diabase.

The following classification of basalts has been established [1-2]:

- By composition-oceanic (alkaline) and continental (olivine). Oceanic basalts differ from continental ones in their lower content of SiO_2 and higher content of Na_2O, K_2O, and MgO.
- By structure - cyanotype, paleotype.
- According to the geological conditions of formation - geosynclinal, platform.
- By mineralogical composition – metabasalts, oceanides, leucobasalts.
- In terms of textural and structural composition - full-crystalline, fine-grained, intermediate.

In this regard, the experience of foreign countries shows that basalts are a unique and promising resource base for Uzbekistan. Therefore, chemical and mineralogical studies of basalts are of practical interest, the results of which make it possible to correct the

* Corresponding author: bobur160189@mail.ru

diversified use of basalts in our country. Currently, the known raw material reserve of basalts in our country is more than 1 billion tons, which can be involved in the production turnover to organize the production of products for various purposes. This will turn this gift of nature into a unique raw material for the construction of houses, bridges, and fortifications [3-4]. To do this, it is necessary to study a number of characteristics and material indicators of basalt rock. Therefore, this article's materials are devoted to studying the mineralogical and chemical properties of this rock, in the example of basalts from the “Aydarkul” deposit. As a result from the “Aydarkul” deposits, the following indicators were identified related to their mineralogical composition.

2 Materials and methods

To determine and elucidate the mineralogical properties of basalts from the “Aydarkul” deposits, a semi-quantitative analysis of the “Aydarkul” rock was carried out.

Basalts of the “Aydarkul” deposit are rare and finely porphyritic rock with aphyric, allotriomorphic granular structure. It consists of an approximately equal amount of completely irregular grains of plagioclase and pyroxene, which, in optical properties, is close to diopside - augite C:Ng=36-43˚. The size of plagioclase grains does not exceed 0.01 mm in the groundmass and 0.5÷0.7 mm in very rare porphyroblasts. The appearance of the crystals is elongated, with an indistinct faceting, forming sinuous jagged, gulf-like boundaries. The crystals are twisted, forming felt-like structures together with the same xeromorphic augite grains, the grain size of which in the groundmass is somewhat smaller than that of plagioclase laths. The content of the anorthite component cannot be determined due to the curvature of the polysynthetic twins. According to the width of the twins, these are plagioclases of the Labradorite composition, possibly descending to andesine and rising to bytownite in places.

Augite crystals are more isometric than elongated plagioclase grains. They form small tabular crystals, most of which do not exceed rock. But some places in the rock can be occupied by larger crystals of augite, which form fine porphyry segregations up to 0.5÷0.7 mm in size.

There are cases of the formation of such porphyritic secretions of glomeroblasts, consisting of 3÷5 individuals. The sizes of glomeroblasts can reach 1.0÷1.5 mm. In them, the augite has a clear prismatic cleavage, rare sections that have 2 systems of cleavage cracks intersecting almost at a right angle (≈ 87).

The high relief, a rather high refractive index compared to adjoining plagioclase crystals, rather bright light yellow-brown interference colors, together with a large extinction angle, which ranges from 36÷43°, allow us to consider the composition of pyroxene as a transitional difference from diopside to augite. In crossed nicols, due to interference coloring, it is easily diagnosed. In addition to these two mineral phases, the rock contains about 30% of the volume of glassy matter of microgranular and implication structure.

The described rock apparently underwent a flow of erupted magma along the slope of the volcano. This is evidenced by the banded distribution of a glassy substance oriented in one direction. The wrapping of individual crystals of augite and plagioclase with glass creates a pattern of the ocillary structure of the groundmass. The dark gray and almost black color of the glassy substance indicates its complex structure.

The twisting of plagioclase crystals and the felt-like orientation of the groundmass crystals may indicate the formation of the rock under conditions of lava movement. This breed also has a certain number of pores. The pores here are oriented along the flow direction or bands that differ from each other in the ratio of glass and crystalline phases.

Some bands contain more glasses than bands whose structure is dominated by crystalline grains.

Everywhere the pores are oblong, their length, corresponding to the direction of banding, reaches 2.0 mm, with a width of 2–3 times less than the length of the pores. Sometimes the pores are mutually communicated by narrow thread-like cracks. Almost all large pores here are hollow, filled with Canadian balsam. However, in some parts of the rock, there are smaller, relatively isometric pores filled with chalcedonic quartz. Together with quartz, they contain pseudo-rocks of non-aggregated amorphous chlorite in very small segregations, the development of which occurs in which minerals it is difficult to determine. Such finely porphyritic aphyric basalts located north of the North Nurata Mountains were studied by L.V. Shpotova and V.N. Ushakov. They consider them to be the product of the outpouring of basalts from the Beltau-Kuraminskaya structural-formational zone.

Our joint general analysis of the chemical composition of basalts in the Central Research Laboratory of the Joint Stock Company Navoi Mining and Metallurgical Company (JSC *NMMC*). 15 samples were selected for chemical analysis.

3 Results

The results of the study of all samples are presented in table 1.

The study of the chemical structure of basalts from the Aydarkul and Asmansai deposits was carried out under laboratory conditions. The aim was to determine the content of oxides: silicon, aluminum, titanium, calcium, iron, magnesium, potassium, sodium, total sulfur, and sulfate sulfur by chemical analysis, taking into account moisture and weight loss on ignition.

Table 1. The chemical structure of the "Aydarkul" deposit.

No	SiO_2	TiO_2	Al_2O_3	CaO	MgO	FeO	Fe_2O_3	K_2O	Na_2O	MnO_2	P_2O_5	H_2O	Other	
													Content< 1%	slimes
1	49.7	1.9	9.05	9.67	3.8	5.6	3.4	0.11	4.23	0.05	0.08	1.01	3.1	8.3
2	50.3	2.5	11.2	7.8	2.8	4.9	4.0	0.11	3.3	0.09	0.05	1.1	2.9	8.6
3	52.9	2.1	10.2	10.8	2.65	5.9	3.9	0.14	4.3	0.01	0.02	1.09	1.11	4.88
4	47.7	1.98	7.2	8.89	2.75	4.6	3.87	0.11	2.3	0.05	0.08	1.04	8.17	11.26
5	57.1	1.9	9.67	11.18	2.53	5.6	3.9	0.14	3.11	0.16	0.05	1.02	0.87	2.77
6	56.8	1.77	10.9	7.95	2.69	6.9	3.87	0.1	4.13	0.033	0.02	1.03	0.73	3.07
7	55.9	2.5	8.27	10.45	3.44	6.55	3.9	0.17	4.53	0.05	0.01	1.01	0.53	2.69
8	54.44	2.44	9.43	9.9	2.81	6.6	4.9	0.14	3.31	0.001	0.02	1.01	0.71	4.19
9	53.9	1.79	7.2	9.87	3.0	4.6	2.9	0.14	3.3	0.03	0.08	1.1	2.12	9.97
10	47.7	2.2	11.1	10.12	3.2	4.65	2.3.0	0.13	3.13	0.06	0.04	0.98	6.63	10.06
11	53.21	2.27	8.28	9.76	3.4	4.6	2.9	0.15	2.86	0.16	0.06	1.05	5.71	5.59
12	54.4	1.9	11.2	6.8	3.0	4.66	2.97	0.15	2.89	0.11	0.05	1.07	4.16	6.45
13	52.9	2.45	9.07	7.89	3.5	5.6	3.0	0.21	3.53	0.15	0.02	1.07	7.7	10.94
14	43.71	1.91	10.07	10.28	3.1	4.76	2.9	0.13	3.23	0.18	0.06	1.03	4.11	5.05
15	51.9	2.2	10.72	9.7	2.9	5.3	3.4	0.14	3.34	0.19	0.03	1.02	5.64	4.6
$\sum$	52.1	2.1	9.5	9.4	3.0	5.3	3.4	0.13	3.4	0.08	0.04	1.04	3.81	6.56

Based on the results of the studies, data were obtained characterizing the chemical composition of the basalts of the "Aydarkul" deposit. The results of the analysis showed that in the composition of the basalts of the "Aydarkul" deposit, the content of silicon oxide in some samples reaches up to 62.9%, against 47.0÷53% in other basalt deposits of the world and Uzbekistan.

Magnesium oxides 5% versus 10%, calcium 15% versus 3%, sodium oxides 3,6% versus 3% iron 12% versus 15%, etc.

It should be noted that the melting temperature of the basalt deposits “Aydarkul” and “Asmansai” differ from each other by approximately 100÷200°C. In the chemical compound of the “Aydarkul” deposit, the content of SiO_2 is in the range of 58.7÷62.9 %, in the basalts of “Asmansai” it is in the range of 45.7÷53.3%.

It is known that non-organic compounds in rocks can experience structural changes as a result of external influences, which can affect the properties of the contents of the compounds in the rocks of chemical elements and are further set by the performance parameters. In this case, a special place was given to spectral analysis. As you know, spectral analysis allows you to detect the number of chemical elements in the rocks and the state of the structural features of the basalt rock.

It was experimentally revealed that the “Aydarkul” basalt consists of 24 chemical elements. The main rock-forming elements are magnesium, sodium, silicon, iron, aluminum, calcium, and other chemical elements, the number of which reaches up to 43, making up an insignificant amount in the rock. IR spectrometry was carried out with a Nicolet 6700 spectrometer (USA).

On figure 1. IR spectrometry images of a sample of basalts from the “Aydarkul” deposit are presented. It has been established that basalts consist of three silicate compounds, which are: olives, pyroxenes, and plagioclases, which consist mainly of metal-containing oxides.

Thus, it was found that the bond of oxygen with metal elements leads to the formation of the corresponding oxides. In such an integral structure, the silicon-oxygen bond plays an important role, since the main part of basalt consists of SiO_2 oxide.

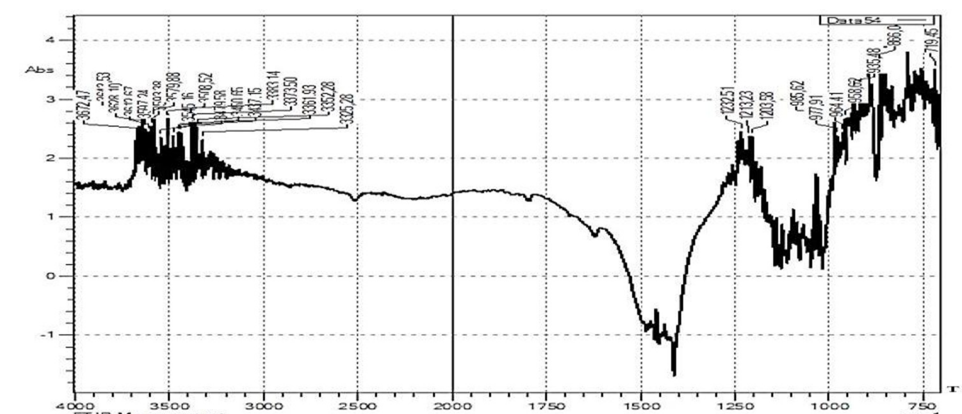

Figure 1. IR spectra of basalts from the “Aydarkul” deposit.

The results of the experimental study show that absorption bands are noticeable in the IR spectra. Such bands can be especially seen in the region of 756÷800 sm^{-1} related to the deformation vibration of the Ms - OCO group disappearing after heat treatment (900 °C), which is confirmed by the decomposition of (-CO3) carbonates.

Absorption bands in the region of 1000 sm-1 are seen in a wide spectrum related to the group ν(CO)Pr (-OH) ν (-SiO). The absorption bands in the region of 1639, and 1620 sm^{-1} belong to the deformation vibrations δ (H_2O), which become short in intensity in the spectra after processing. In the region of 3400 and 3600 sm^{-1}, the absorption band corresponds to the OH groups of water and mineral acid residues such as $[CO_4]^{2-}$, $[SiO_4]^{2-}$ and $[-Al(OH)_4]^-$. In general, the obtained data of the IR spectrum confirm that during the heat treatment of the basalt rocks “Aydakul” experience a change in the mineralogical composition.

Based on the results of the study on the derivatogram, the samples were subjected to heat treatment at temperatures up to 100°C. The manifestations of the endothermic effect of the thermolysis process, which appear at a temperature of 80÷240°C, have been studied. They show the decomposition of clay impurities or the removal of hygroscopic water contained in the rocks. Later, at a temperature of 520°C, the effects weaken and an increase by an insignificant amount of mass is observed, which corresponds to the interconversion of the basalt component.

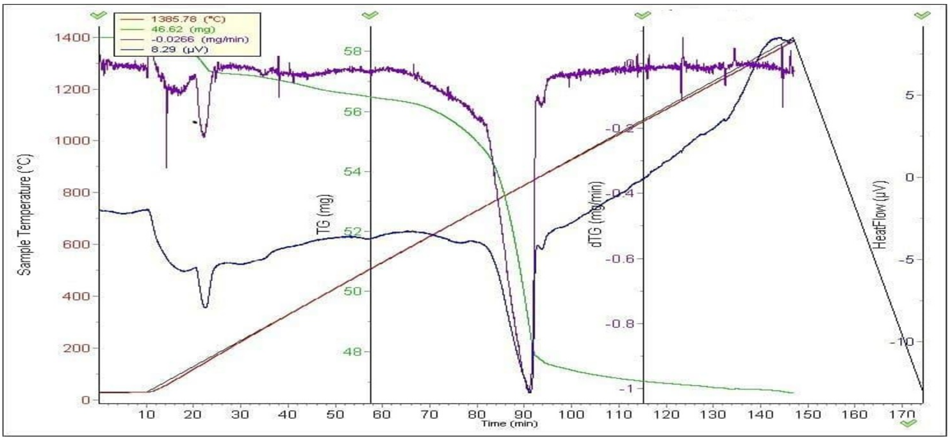

Figure 2. Derivatogram of the results of thermal treatment of Aydarkul basalt samples.

4 Discussions

The structure and glassy form of crystalline fibers, as well as their properties, are closely related to the cooling rate of the basalt melt. Therefore, the temperature of the melt after exiting the die is maintained by additional heated air. When the basalt melt is cooled, in accordance with the rapid increase in viscosity and decrease in temperature, the thermal motion of the particles is frozen.

Table 2. Experimental data of derivatogram results.

No.	Temperature, ℃	Lost weight, mg	Lost mass, %	mg/min	The amount of nergy consumed (µV·s/mg)
1	50	0.09	0.167	0.009	0
2	100	0.52	0.89	0.083	6.91
3	200	1.19	2.02	0.214	3.89
4	300	1.36	2.31	0.223	3.99
5	400	1.73	2.93	0.262	4.13
6	500	1.97	3.35	0.282	4.97
7	600	2.21	3.75	0.284	6.70
8	700	3.04	5.15	0.309	4.32
9	800	6.13	10.34	1.317	5.32
10	820	7.76	13.17	1.359	5.36
11	850	10.5	17.86	1.408	3.35
12	900	10.9	18.59	1.917	4.36

13	1000	11.3	19.16	0.915	3.98
14	1050	11.4	19.35	0.915	5.36
15	1100	11.5	19.49	0.835	4.36
16	1200	15.3	22.3	0.635	3.35
17	1300	18.3	23.8	0.536	4.35

Physical methods for the study of inorganic components of basalt fiber. Derivatographic analysis makes it possible to conduct studies under similar or identical conditions, and this, in turn, makes it possible to obtain comparative data on the reactivity of calcium, lithium, sodium, and potassium carbonates when interacting with iron oxide, depending on the ratio of the mixture components and the conditions for conducting experiments on basalt inorganic constituents. In mixtures of alkali metal carbonates with iron oxide, initially, regardless of the ratio of components, meta ferrite is formed, which exists in a certain temperature range as the only compound. Derivatograms of the samples were taken on a synchronous thermogravimetric derivatograph LabSysEvo (Setaram, France) up to 1400°C, finely ground sample weight 150÷200 mg, sample heating rate 10 deg/min. The weight loss when the test sample is heated to 1400°C is 20.61%. A further increase in temperature is accompanied by the burning out of organic substances, and dehydration of impurity minerals [10-11].

Table 3. The results of the study of X-ray analysis of a sample of basalt from the “Aydarkul” deposit.

Elements	Content, %
Si	41.944
Al	8.627
Fe	5.593
K	3.818
Ca	1.906
Ti	1.557
S	0.255
Mn	0.180
Sr	0.045
Rb	0.028
Cu	0.023
Zn	0.022

5 Conclusions

The results of the conducted studies show that the basalts of the “Aydarkul” deposit are quite suitable for the production of modern refractory heat-insulating materials of a new generation.

As a result of the conducted research, it was found that the basalts of the “Aydarkul” mine are very suitable for the production of modern refractory heat insulating materials of the new generation.

According to TSh-64-15562057-03:2002, the investigated basalts are environmentally friendly, have positive physical and mechanical ratings, are resistant to acid and alkaline environments, and also have low thermal conductivity coefficients. In addition, they have a wide range of applications compared to other similar materials.

These properties of basalts from the “Aydarkul” deposits determined the urgency of the problem of further development and creation of highly efficient heat-insulating materials and products for various industries.

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