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Physical-Chemical Research and Characteristics of Vermiculite of the Tebinbulak Deposit

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ABSTRACT: The paper presents the results of physical and chemical studies of vermiculite from the Tebinbulak field. A comprehensive analysis of the mineral and chemical composition of the samples was carried out using X-ray phase analysis (XRD) and thermal analysis (DTA, TGA). Vermiculite of the deposit was found to be characterized by a typical layered structure of hydromica, a high content of magnesium and iron, as well as a significant ability for interlayer exchange and dehydration upon heating. The processes of dehydration and swelling of vermiculite during heating were studied, as well as the effect of heat treatment on its physicochemical properties, temperature intervals of phase transformations and the degree of swelling of the material. The obtained data confirm the high sorption capacity and heat resistance of vermiculite, which determines the prospects for its use in construction, ecology and industry for cleaning media, thermal insulation and as a catalyst carrier, also as raw materials for producing complex fertilizers. The fractional composition of vermiculite was also determined, a large amount of vermiculite isolation falls on a fraction with a mesh size of 1,00 and amounts to 46,37%.

KEY WORDS: Karakalpakstan, Tebinbulak, agricultural ore, vermiculite, swelling, agriculture, physicochemical analysis, monofraction.

I. INTRODUCTION

Vermiculite is a mineral from the widespread group of aluminosilicates, isolated under the name of hydroslude. The ability of vermiculite to swell upon heating with a 20-30-fold increase in volume and the formation of a light loose mass with high thermal and sound insulation properties is of practical interest. In addition, swollen vermiculite, due to its lightness (density 0,07-0,2 t/m^2), low thermal conductivity, fire resistance, inertness, good adsorption and ion exchange properties, is used in construction (thermal insulation fire-resistant materials, insulation fillers, aggregate in concrete, cement), as a sorbent for purifying oils, oil, gasoline, wastewater. It is also widely used in agriculture (a mineral fertilizer filler that improves soil structure, gas exchange, and hydroponics substrate). It is used to purify environments from a number of toxic organic compounds (benzene, toluene, and others) [1]. Vermiculite is increasingly being introduced into modern practice for various purposes: growing vegetable, ornamental, and forest crops, producing green vitamin feeds, creating lawn carpet coverings, including for the reclamation of disturbed and dusty areas [2]. Vermiculite is also used for livestock and chicken feed [3-7], which increases egg production by 1,2-3,2%, reduces the cost of mixed feed, decreases egg wallpaper by 43,8-44,9%, and improves the use of nitrogen, calcium, and phosphorus.
The use of vermiculite as a component of bitumen compositions and mastics for road construction allows for improving the characteristics of these materials [8]. Vermiculite boards have become popular due to their

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properties, including relatively high fire safety. This is especially relevant in connection with the constant tightening of fire safety requirements, especially in places with large crowds of people, such as supermarkets, medical institutions, schools, etc., [9].

The first mention of vermiculite in Uzbekistan dates back to 1940, when Ya.S. Vysnevskiy discovered it in the pyroksenites of Sultanuizdag. Later, X.M. Abdullayev also noted the presence of a vermiculite vein in Langar. Vermiculite was also recorded as worm-like formations in the pizolite tuffs of Zambarak. According to A. F. Sviridenko, vermiculite, together with biotite, accounts for 34,7% of the total pyroksenite mass in Sultanuizdag. It occurs in the form of grains with sizes of 1,6-1,7 mm and under a microscope is characterized by a pronounced pleochroism from yellowish-brown to practically colorless. The refractive index (Nm) is 1,619.

When heated, the vermiculite from Sultanuizdag significantly increases in volume. Vermiculite from Langar forms a vein that cuts through the granate-pyroxene skarn and its accumulations. This mineral has a finely scaled or radial-radial structure, and is brown, light brown, and greenish in color. Under the influence of heating, it also swells significantly and acquires a golden color [10].

II. RELATED WORK

Scientists around the world investigated the physicochemical properties and characteristics of vermiculite. Analysis of the presented studies shows that the physicochemical properties of vermiculite significantly depend on the conditions of its treatment and modification. The paper [11] revealed that thermal, hydrothermal, mechanochemical and microwave treatments change the structure and texture of the mineral in different ways: the interlayer distance decreases, porosity and specific surface area increase, which is confirmed by data from XRD, TGA/DTG and BET analysis. The study [12] showed that when creating composites based on vermiculite and poly (acrylate-acrylamide) copolymers, it is possible to significantly improve the water-regulating and sorption characteristics of the material, which expands its application in climate control systems. Works [13-14] confirm the effectiveness of chemical and mechanochemical activation of vermiculite, in particular with the use of acidic reagents and phosphates, leading to an increase in specific surface and adsorption capacity. The study [15] additionally showed the potential of vermiculite as an effective sorbent of radionuclides (for example, strontium) due to the developed porous structure and ion-exchange properties. Together, these results indicate that a change in the physicochemical characteristics of vermiculite due to various methods of modification makes it possible to purposefully regulate its sorption, structural and functional properties for use in ecology, construction and materials science.

III. RESEARCH OBJECTS AND METHODS

Uzbekistan has large reserves of vermiculite mineral. Vermiculite produced by the Tebinbulak field, located in the North-West end of the Sultanuvais mountains, 16 km from the village of Karatau and 8 km from the Karauzyak railway station in the Republic of Karakalpakstan, was chosen for the study. The total amount of reserves of vermiculite rock of the Tebinbulak field is 1332620 tons. The main consumers of expanded vermiculite products are thermal centers, glass, porcelain, cement plants, agriculture, paints and varnishes, construction organizations [16].

IV. RESEARCH MATERIAL AND METHODOLOGY

X-ray diffraction analysis was carried out on an XRD-6100 diffractometer (Shimadzu, Japan). Qualitative and quantitative identification of sample phases was performed using MATCH! software. ® Phase identification from Powder Diffraction (Crystal Impact, GbR, Bonn, Germany, 2015) [17-18].

Thermal analysis of Karakalpakstan vermiculite was carried out on a DTG-60 device, Shimadzu, with a K-type thermocouple (Low RG Silver) with porcelain crucibles. Results processing and computer graphics were carried out using the Shimadzu LabSolutions TA Start Window software package [19].

V. RESEARCH RESULTS

The melting point of the investigated samples is within the range 1360-1385^{o}C. At the temperature 1400^{o}C A melt is formed, which solidifies as a matte black glass. Empty rock minerals are predominantly represented by olivine, pyroxene, calcite, magnetite, apatite, iron hydroxides, and others.

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As can be seen from Table 1, a large amount of vermiculite secretion occurs for a fraction with a sieve cell size of 1,00 and is 46,37%. Further, the fractional composition during vermiculite swelling was determined from the natural fractional composition, the results of which are presented in Table. 2.

Table 1
Fractional composition of natural vermiculite of the Tebinbulak deposit

№ Sieve	Fraction, mm	Content in %
1	3,0	3,64
2	2,0	5,98
3	1,0	46,37
4	0,5	27,89
5	0,25	11,15
6	0,16	3,35
7	≥0,16	1,62

Average vermiculite content in ores is 30-35%. The characteristics and chemical composition of the swollen vermiculite and vermiculite ore of the Tebinbulak deposit in Karakalpakstan are presented in Table. 3-4.

Table 2
Content of fractional composition of swollen vermiculite

№ Sieve	Swelling fraction mm	Content in %
1	3,0	16,92
2	2,0	19,74
3	1,0	16,62
4	0,5	15,89
5	0,25	13,10
6	0,16	14,46
7	≥0,16	3,25

Table 3
Characteristic of swollen vermiculite

Parameters	Density	Melting temperature	Toxicity	Acidity
Measurements	kg, m^2	^0C	-	pH
Mineral	2410-2720	-	Not toxic	7,0
Swollen vermiculitis	65-312	1340-1380	Not toxic	7,0

Table 4
Chemical composition of vermiculites of the Tebinbulak deposits of Karakalpakstan

Samples Tebinbulak deposit	Component content, weight. %	Samples from the Tebinbulak deposit	Component content, weight. %
SiO_2	44,3	MnO	0,09
Al_2O_3	18,9	Fe_2O_3	13,2
MgO	11,2	NiO	0,03
K_2O	8,04	ZnO	0,01
CaO	1,12	Rb_2O	0,02
TiO_2	2,11	SO_3	0,16
V_2O_5	0,16	SrO	0,01
Cr_2O_3	0,02	ppp	0,42
∑ %			99,79

Further, a thermal analysis of the Karakalpak vermiculite was carried out on a device DTG-60, Shimadzu, with a K-type thermocouple (Low RG Silver) with porcelain crucibles. All measurements were carried out in an inert nitrogen atmosphere with an argon flow rate of 80 ml/min. The temperature range was 25-900°C, and the heating rate was 10°C/min. The measurement system was calibrated with the standard substance - In (indium). Processing

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of the results and computer graphics was carried out using a software package Shimadzu LabSolutions TA Start Window **[19].** The results are presented in Figure 2.

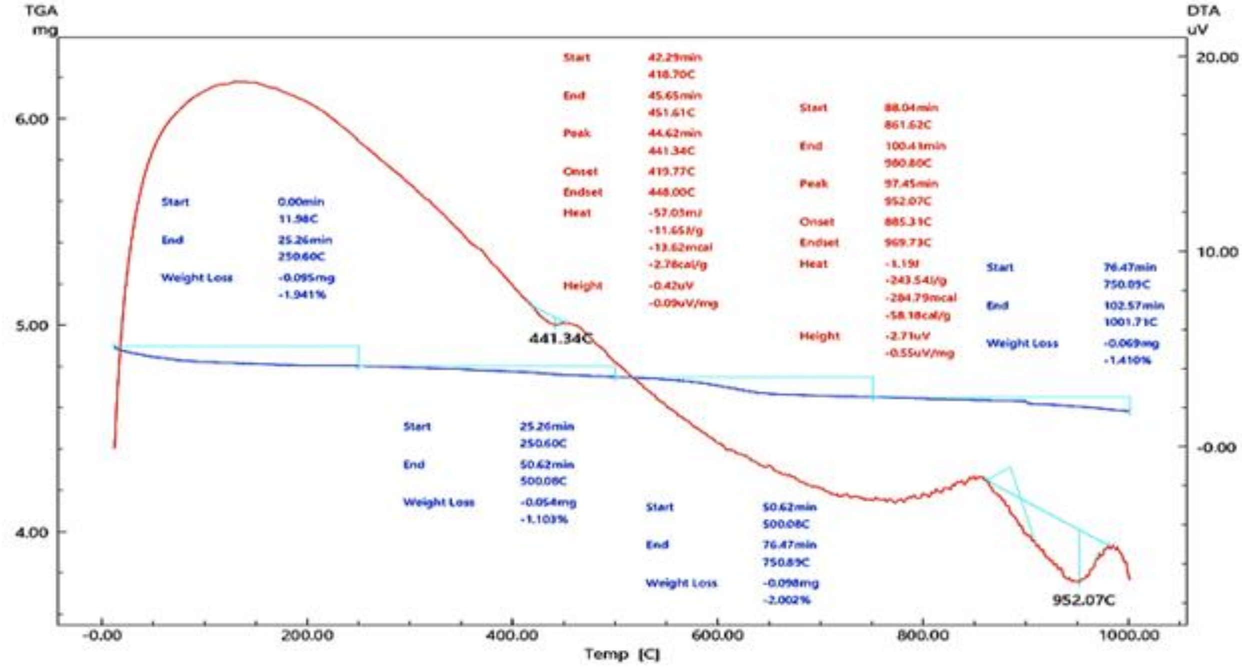

Fig. 2. TG-DSK vermiculite of the Tebinbulak deposit

The first endoeffect on the curve of crushed vermiculite appears in the range of 418,70-448,00°C, due to the release of chemically bound molecular (interpacket water) and is noted at 441,34°C. Further, the crushed sample is characterized by an endo-effect with a maximum at 952,07°C, apparently due to the oxidation of iron Fe^{2+} to Fe^{3+} present in the impurity mineral, which is associated with the peculiarities of the metamorphism of the original micaceous minerals present in the vermiculite raw material.

The next endothermic effect at 861,62-969,73°C for vermiculite is due, in everyone's opinion, to the release of hydroxyl water, which leads to the disintegration of the vermiculite crystal lattice and the crystallization of enstatite. This endo-effect for selected vermiculite aggregates is recorded at 952,07°C, where the structure of the mineral is already destroyed and completely swells.

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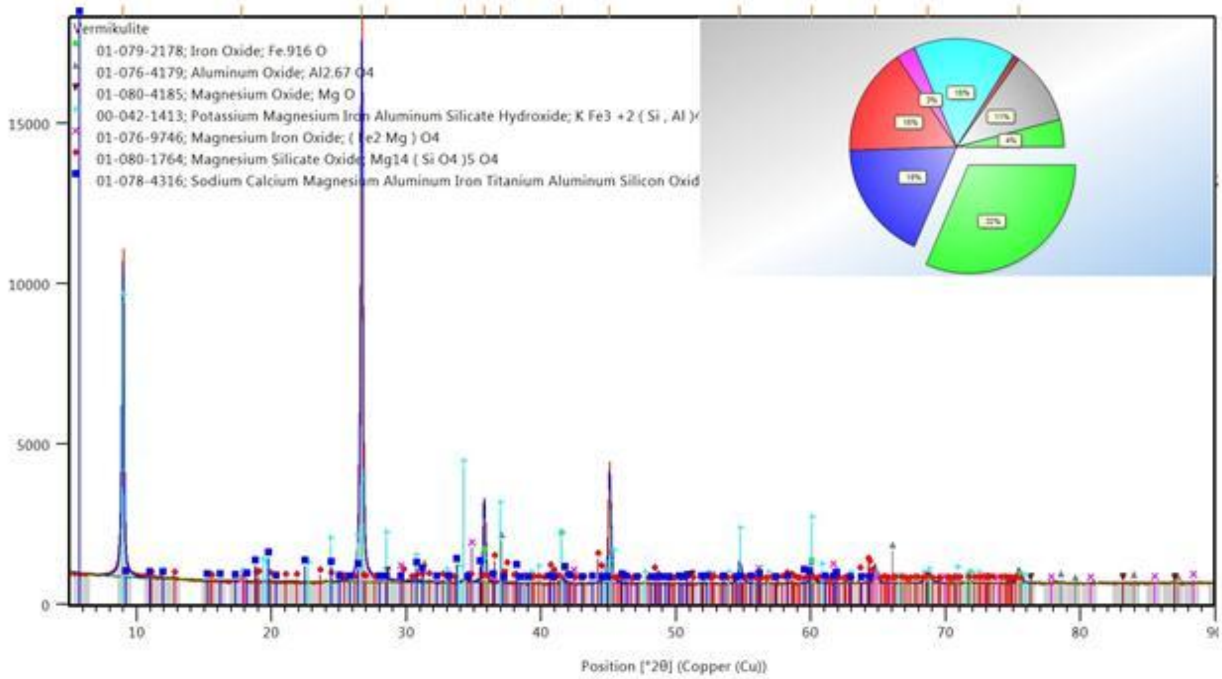

Fig. 3. X-ray phase analysis of vermiculite

Data in Fig. 3 show that the vermiculite composition exhibits the following peaks of the diffraction band of the oxides of iron, aluminum, titanium, magnesium, silicon, potassium, sodium, and calcium.

VI. CONCLUSION AND FUTURE WORK

The physical and mechanical characteristics and chemical composition of vermiculite from the Tebinbulak deposits are presented. Methods are described for determining the chemical composition and commercial quality, as well as for conducting physical and chemical studies of vermiculites. For this purpose, radiographic and thermal research methods were carried out using modern instruments.

The sieve and mineralogical compositions were determined, and the physicochemical properties of the original and expanded vermiculite of the Tebinbulak deposit in Karakalpakstan were studied.

It has been established that the fractional composition of natural vermiculite from the Tebinbulak deposit is predominantly in the 3 mm fraction; the vermiculite content of the total mass of ore in some samples reaches 3%. In the +0.5+1 mm fraction, the vermiculite content is at least 27.89% and reaches up to 46.37%.

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