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Research paper

Changes of energy potential on clay particle surfaces at high pressures

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A R T I C L E I N F O

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A B S T R A C T

Bentonite and kaolin were treated by high pressure (to 2200 MPa). Using the XRD parameters (full width at half maximum, integrated intensity, interplanar distance, diffraction angle 2θ of reflection maximum), a significant pressure effect on the crystallite size of main clay minerals (montmorillonite and kaolinite) was established. The crystallite size is closely related to the energy activity of the clay particles. The boundaries with a pressure of 125 and 750 MPa were identified, which divide the measurements into three classes. Each class has its own regularities for changing parameters. Mathematical models for predicting changes in energy activity of clay particles have been developed.

1. Introduction

Clays are a natural material whose particle surface is energetically active. Due to this property, clays are widely used in industry as sorbents (Ilić et al., 2016; Seredin et al., 2017b).

To increase the sorption capacity of clays, two groups of technologies are used. The first group combines technologies that increase the specific surface area of clay rocks by mechanical treatment (Dellisanti and Valdre, 2008; Hrachova et al., 2007; Osipov and Sokolov, 2013; Sanchez-Soto, 2009). The second group includes technologies aimed at increasing the energy activity (potential) of the surfaces of clay particles (Puskaryova, 2000; Sapronova et al., 2015).

Alabarse et al. (2011) established that the montmorillonite structure was stable under high pressure and did not present significant structural changes up to 8 GPa. On the contrary, the results of studies on the mechanical treatment of clays by pressure (Mauricio-Iglesias et al., 2011) have shown that the physicochemical properties of clays have changed significantly under pressure. Therefore, the treatment of clays with high pressure is a new technology, allowing to form the given physicochemical properties of clays, and consequently, clay soils.

In previous work we found that during treating of the bentonite and kaolin up to 125 MPa the specific surface of the clays is reduced in 1.5–2 times, and with a further increase in pressure up to 2200 MPa, the specific surface of the clays changes insignificantly (Seredin et al., 2017a).

Studies on the change in the mass of adsorbed water in clay soils at pressures to 2200 MPa (Seredin et al., 2017b) have shown that in kaolin, as the pressure increases, the loss of bound water mass decreases, and in bentonite, on the contrary, increases.

In this article we intend to obtain a more complete picture of the change in the energy activity of clay minerals when they are processed at a pressure of up to 2200 MPa by means of XRD parameters.

2. Experimental

The materials for the study are bentonite from Perm region (Lobanovo) and kaolin from Chelyabinsk region.

2.1. High-pressure treatment

Fraction of < 0.01 mm was extracted from the raw clay material using sedimentation procedure. The extracted material was exposed to compression with shear under pressure of 2200 MPa using the specially designed and produced device under the procedure described in the research paper (Seredin et al., 2017b). Specially prepared samples were used for next researches.

2.2. X-ray diffraction

X-ray diffraction analysis of the samples was carried out using powder diffractometer D2 Phaser with Ni-filtered CuKα (λ = 1.54060 Å) radiation and linear detector (LYNXEYE).

The sample presented in the form of sealed pressed "pellets" was abraded with alcohol in agate mortar. Then the sample was put into a cuvette and a diffraction pattern survey was made under the following conditions: divergent slit was 0.2 mm, Soller slits were 2.5° each,

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Table 1
Mineral composition of clays (wt%).

Pressure, P, MPa	Bentonite						
	Quartz	Albite	Potash feldspar	Calcite	Clay minerals	Montmoril-lonite	Kaolinite
0	11.4	6.7	–	3.3	78.6	75.0[a]	3.6
1000	15.3	10.3	–	3.7	70.8		
1500	14.7	9.3	–	3.4	72.7		
2000	13.5	6.9	–	2.0	77.6		
	Kaolin						
0	7.6	–	0.1	–	94.3	15.6	76.7
1000	21.8	–	0.7	–	77.5		
1500	23.0	–	0.3	–	76.7		
2000	25.4	–	0.6	–	74.0		

[a] The relative content of clay minerals was calculated only for initial samples. For the pressure-treated samples, only the total content of clay minerals was calculated.

counting time was 1.0 s with step scan size 0.02°. At the first stage of the studies the survey was carried out at the angle range from 5 to 70°2θ, at the second stage – from 4.5 to 15° 2θ. The reduced range allows to reveal the most intensive basal reflections of clay minerals, particularly 14 Å for montmorillonite, and 7.15 Å for kaolinite. Each sample was scanned three times after the cuvette refilling.

Minerals contents were calculated by integral intensities of the most intensive reflections with corundum coefficients.

The measuring of the basal reflection parameters of XRD patterns was produced with program Diffrac.Eva.

The experimental data were processed using the programs Statistica and MS Excel and with recommendations (Gorbunov et al., 1952).

3. Results and discussion

3.1. The studying of pressure effect on changes of clay mineral content

3.1.1. Bentonite

According to the XRD data, the initial sample of bentonite has montmorillonite as the main component (75.0%) and kaolinite (3.6%) as the second clay mineral (Table 1, Fig. 1). In addition, it contains quartz (11.4%), albite (6.7%) and calcite (3.3%).

Analysis of montmorillonite content has shown changes in clay in the course of their compression. It has demonstrated that building-up of pressure to 1000 MPa leads to increase of quartz, albite and calcite content in clay. Besides, clay minerals content has reduced from 78.6% to 70.8%. As pressure rises to 2000 MPa, inversion is observed. The contents of quartz, albite and calcite have been reduced and the total content of clay minerals, on the contrary, has been increased.

3.1.2. Kaolin

Initial samples of kaolin reveal domination of kaolinite (76.7%) and quartz (7.6%). In addition to kaolinite there is also montmorillonite (15.6%) in a clay minerals group. Among other minerals only potash feldspars (0.1%) are presented (Table 1, Fig. 2).

The analysis of minerals content changing has demonstrated that as pressure rising quartz and potash feldspars contents have been increased naturally and clay minerals, on the contrary, have been reduced. The revealed regularity is observed in bentonite as well, where both quartz and albite contents are increased. It is probably caused by crumbling of quartz and albite micrograins from clay aggregates.

Thereby, it has been experimentally found that with rising pressure clay minerals content has been reduced and the other components have been differently changed.

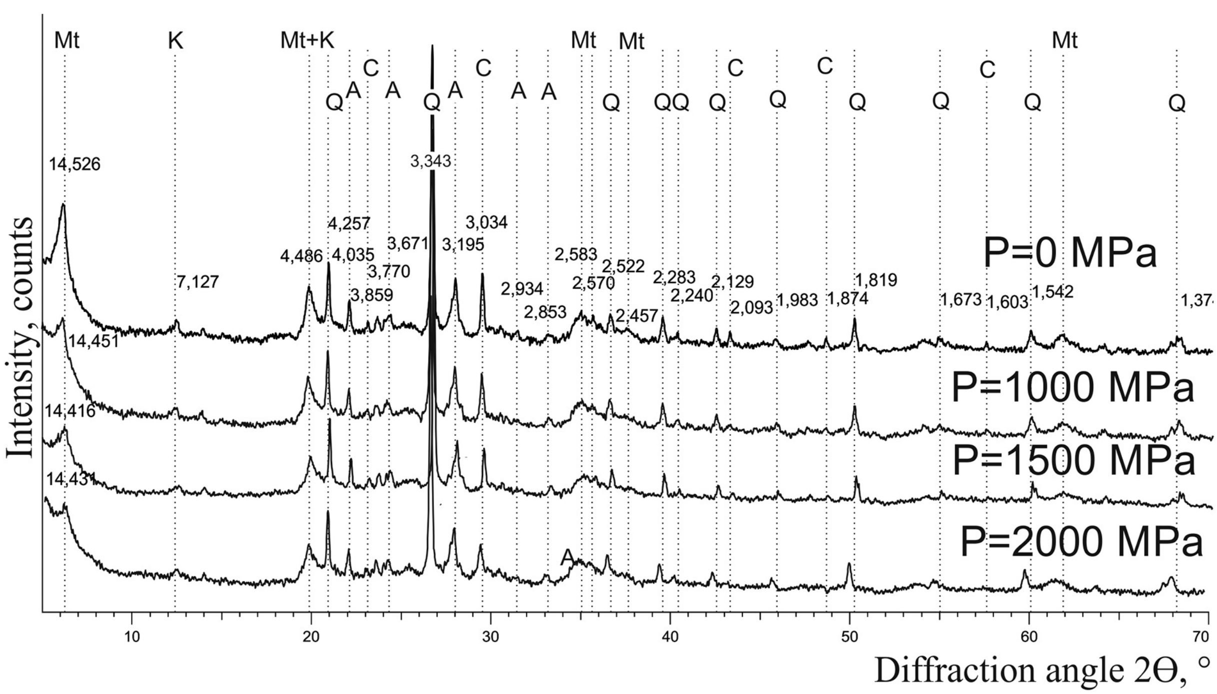

Fig. 1. XRD patterns of bentonite: initial and effected by pressure. Mt. – montmorillonite, K – kaolinite, Q – quartz, A – albite, C - calcite.