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THERMO- AND SALT-RESISTANT DRILLING FLUIDS BASED ON
POLYMINERAL CLAYS OF UZBEKISTAN

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ABSTRACT

In conditions of high temperatures and pressures, reagents-stabilizers widely used in practice undergo chemical change and lose their stabilizing properties, as a result of which the stability and thixotropic functions of clay drilling muds deteriorate, their yield increases and the separation of the suspension occurs with the release of the dispersed phase. Therefore, it is considered promising to use polymineral clay compositions containing palygorskite, which do not require much chemical treatment.

I. INTRODUCTION

Currently, in the Bukhara-Khiva and Ustyurt regions of Uzbekistan, oil and gas wells are mainly drilled in saline formations, where for such purposes it is necessary to use drilling fluids, obtained mainly with the use of palygorskite clays (atapulgitite), which are rich in CaO. For the drilling of deep wells in difficult geological conditions, thermally and salt-resistant drilling muds, obtained using palygorskite clays and chemical reagents, are necessary.

The development of thermo- and salt-resistant drilling fluids can be carried out in two main directions, partially complementing each other;

- the creation of high-quality dispersed systems based on thermal and salt-resistant natural mineral raw materials;

- on the basis of thermo- and salt-resistant stabilizer reagents [1].

Of course, it is advisable to develop the first direction, as the most promising and cost-effective. Moreover, this does not exclude the possibility of work in the second direction, especially in the case of the use of flushing fluids when drilling in salt sediments alternating with clay

streams, where it is required to reduce the filtration of clay solutions to the minimum values. Of course, this can only be achieved through a combination of heat-resistant mineral raw materials and surfactants, i.e. by combining the two aforementioned directions. It is known that the use of even high-quality montmorillonites (bentonites) does not allow for efficient drilling in mineralized media without treatment with chemical reagents, which is many times higher than the costs of clay for drilling mud and often leads to the impossibility of their operation due to coagulation of the clay suspension with electrolytes. The use of palygorskite clays when drilling solid salt-bearing strata allows, in some cases, to dispense with expensive chemical reagents, which reduces the cost of drilling mud by a dozen times [2].

Long-term practice shows that conventional clay minerals, even during chemical processing, are not able to form disperse systems that are stable in the presence of electrolytes in the hydrothermal drilling mode. In this case, the use of palygorskite-containing drilling fluids allows further drilling of difficult and deep wells. Such solutions have low filtration and are suitable for drilling salt deposits interspersed with clay interlayers [3].

As can be seen, salt-resistant clay minerals do not significantly change the course of the deformation process in their dispersions when exposed to various electrolytes. Moreover, this is confirmed both with and without surfactant additives.

Today, special formulations have been developed abroad for the production of palygorskite-containing drilling fluids, which have low filtration and resistance to the action of high bottomhole temperatures and electrolytes. This once again confirms the need for the correct choice of local mineral raw materials for the preparation of drilling fluids used in difficult drilling conditions [4].

II. MATERIALS AND METHODS

The carbonate palygorskite (CP) of the Navbahor deposit (Navoi region) is an aqueous magnesium aluminum silicate with the ideal formula $R_5[Si_8O_2](OH)_2.(OH_2)_4, 4H_2O$. The crystal structure of this palygorskite, having a stratified structure, resembles the structure of an amphibole and has zeolite-like minerals of 6.4.3.7 Å in size. There are two types of water in them: the molecules are freely placed and bound to the electronegative surface of the tetrahedral bases, and molecules that are bonded to octahedral cations on the side walls of the channels. These molecules are removed from the latter at higher temperatures, as are water molecules from zeolites. The density of carbonate palygorskite (depending on the place of sampling) ranges from 2.3 to 2.5 g / cm³. By repeated chemical analyzes, it was found that in the carbonate palygorskite, the SiO₂: RO ratio varies between 2.1 and 2.5. (where RO is the content of MgO, FeO, Al₂O₃, Fe₂O₃ expressed in equivalents of the amount of MgO). For the carbonate palygorskite of the Navbahor field, the total exchange capacity is 20–30 mg-eq per 100 g of sample [5].

III. RESULTS AND DISCUSSIONS

Table 1 presents the results of thermal analysis of three types of clays from the Navbahor deposit. From table 1 it can be seen that the bentonites

(montmorillonites) of the Navbakhor deposit have differences in temperature with the observed endothermic effects, which shows the difference in their crystalline structure. In alkaline bentonite (AB), the first maximum is observed at 150-180°C, when the main amount of hygroscopic water is released;

Table 1.

The results of the analysis of endo- and exothermic effects by the methods of thermal analysis of bentonites and palygorskite Navbakhor field (NF)

Types of thermoeffect	Temperature, °C		
	bentonite NF		Carbonate palygorskite NF
	alkaline	alkaline earth	
Endothermic:			
-first maximum	150-180	160-190	-
-second maximum	550-600	600-620	-
- third maximum	720-760	740-790	-
Exothermic			
-first maximum	-	-	140-170
-second maximum	-	-	500-580
- third maximum	-	-	800-850

At 550-600°C, moisture is removed from the crystal lattice of the mineral of hydroxyl groups; at 720-760°C, residues of hydroxyl groups are removed with recrystallization of montmorillonite. When the type of bentonite changes from alkaline to alkaline-earth, approximately the same phenomenon is observed, with some difference in the temperatures of the maxima. In the study of the carbonate palygorskite of the Navbakhor field, unlike bentonites, three exothermic maxima are found associated with the removal of respectively adsorption-bound water, “zeolite” water from the channels of the crystal structure and OH groups, hydrated water to form a compressed form. Features of the crystal structure and chemical composition of carbonate palygorskite containing more than 16% of CaO have a significant role in obtaining thermal and salt-resistant drilling fluids. It should be noted that the carbonate palygorskite is characterized by relatively large dispersion than other types of clay.

All the above considered parameters of bentonites and carbonate palygorskite of the Navbakhor field determine their behavior during the formation of coagulation-thixotropic structures in the resulting drilling mud. The main indicator for determining the stability of clay suspensions when drilling wells in complicated geological conditions, especially in salt-bearing formations, is the cation exchange of the clays used. Given this, we have studied this indicator for all three types of clays of the Navbakhor deposit using standard methods [6].

The results are presented in table 2.

Table 2.

Values of cation exchange of clays of Navbakhor field

Type of clay	Exchange complex, mEq per 100 g of clay			
	Ca ²⁺	Mg ²⁺	Na ⁺	Total
Alkaline bentonite (AB)	56,4	7,9	1,1	65,4
Alkaline earth bentonite (AEB)	48,7	6,1	0,9	55,7

Carbonate palygorskite (CP)	-	prevails	-	27,8
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From the data of Table 2 it can be seen that the smallest value of cationic exchange belongs to the carbonate palygorskite of the Navbakhor field (27.8 mg eq per 100 g of clay), which is consistent with the salt tolerance of drilling fluids derived from it. Substitution of the carbonate palygorskite exchange complex with various ions slightly affects its hydrophilicity.

The physical essence in the salt tolerance of the suspension obtained on the basis of the carbonate palygorskite of the Navbakhor field is explained by its ability to form strong, “weakly vulnerable” in relation to the action of electrolyte-coagulators contacts [5,6]. As can be seen, the individual application of the clay of the Navbakhor field in the preparation of drilling fluids does not fully satisfy the modern requirements of the drilling geologists, which dictates the need to create effective polymineralized compositions based on them. In practice, “bentonite-kaolin”, “bentonite-palygorskite”, “bentonite-hydromica” clay mixtures for drilling wells in various conditions are used.

However, mixtures i.e. compositions of these types of clays of the Navbakhor field for obtaining drilling fluids have not been studied enough.

In order to fill this gap, we studied a number of compositions obtained on the basis of clays from the Navbakhor deposit and others [6].

The results are presented in Fig.1.

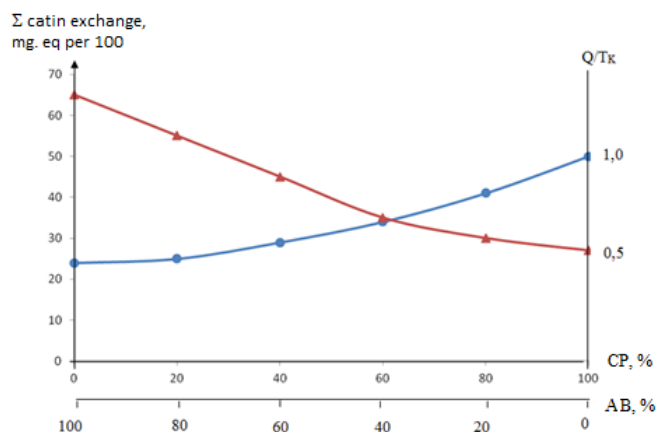


Fig. 1. Changes in the values of total cationic exchange (- ▲ -) and salt tolerance coefficient (- ● -) depending on the content of palygorskite and alkaline bentonite (AB) in the mud composition

In drilling muds obtained from the compositions of clay minerals, the relative decrease in the minimum concentration of the formation of a coagulation structure in all major mixtures is noteworthy. All these features of the formation of coagulation structures in solutions of polymineral clay compositions, determined by the possibility of the occurrence of certain types of contacts, the most effective in the conditions of the existence of suspensions, and their distribution in the volume of the system, i.e. the scheme for constructing the solution framework is a coagular confirmation of the advantage of carbonate palygorskite over other types of clays [7].

It is known that the salt tolerance of clay minerals, i.e. the stability of the coagulation structures of their water systems under cationic volume and the action of electrolytes is the most important property of the drilling fluid.

The results of an individual study of the carbonate palygorskite of the Navbakhor field and other clays in the preparation of salt-resistant drilling fluids showed that the creation of effective compositions based on them requires study in the form of clay suspensions.

We studied the changes in the values of total cationic exchange and the salt tolerance coefficient (Q/T) depending on the content of carbonate palygorskite and alkaline bentonite from the Navbakhor field in the composition of the mud. From Fig. 1, it can be seen that the greater the amount of heat of wetting Q of the suspension of the clay mineral in relation to the capacity, the cancellation of T_k , the more salt tolerant this mineral is.

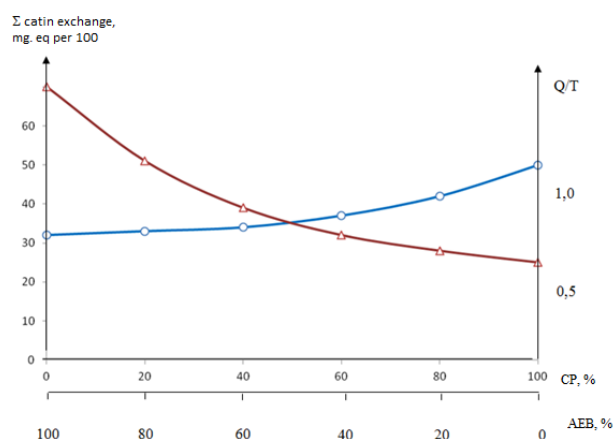


Fig.2. Changes in the values of total cation exchange ($-\Delta-$) and salt tolerance coefficient ($-\circ-$) depending on the content of carbonate palygorskite (CP) and alkaline earth bentonite (AEB) in the mud composition of the drilling mud.

From Fig. 2 it is seen that when replacing AB on AEB in the composition, the regularities are preserved only until the shift of the clay ratio to 50:50%.

As a comparative assessment of the salt tolerance of drilling fluids obtained from clay compositions, the stability coefficient (ε^1_0/C_{\min}), which is the ratio of the value of fast elastic deformation to the minimum suspension concentration, is more often used.

Based on this indicator, we investigated various clay compositions in the form of suspensions. The results are presented in Fig.3 and 4. At the same time, the energy indices (E/C) of salt tolerance of various compositions with the coefficients of their salt tolerance are compared.

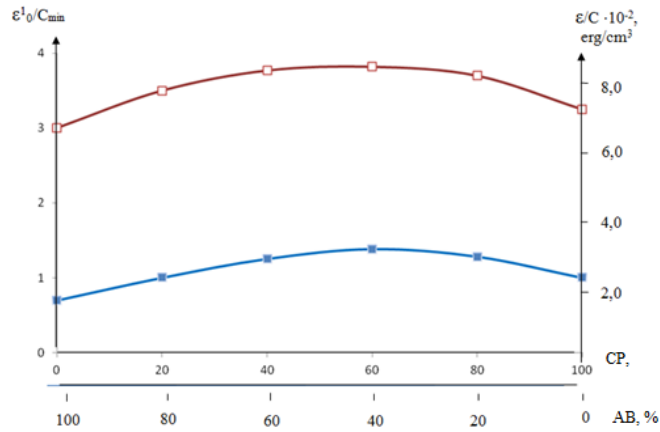


Fig.3. Changes in the values of ϵ^{10}/C_{min} (-■-) and specific binding energy (-□-) depending on the content of carbonate palygorskite (CP) and alkaline bentonite (AB) in the mud composition of the drilling mud.

The conclusion of the analysis of these curves (Fig. 1-4) is that the salt tolerance of drilling fluids can be increased by selecting an effective composition of clays including on the basis of clays Navbakhor field. Moreover, an increase in clay dispersity and the number of strong contacts leads to an increase in fast elastic deformations, a decrease in the minimum concentration of formation of a spatial network (C_{min}) and, consequently, to an increase in the salt tolerance coefficient and, in some cases, to a change in the structural-mechanical type of drilling mud.

Today in the drilling practice they use more hydromica clay, obtained from local quarries. These include the red clays of the Shorsuv deposit (Fergana region).

Of course, the individual use of such clays in obtaining drilling fluids is not advisable because there are low yields and unsatisfactory quality of the aqueous suspension obtained [8].

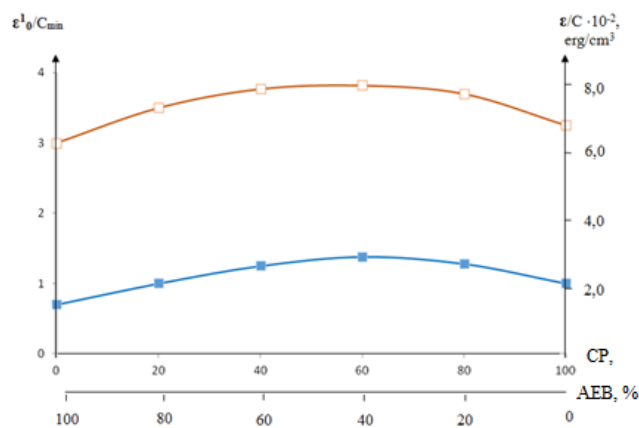


Fig.4. Changes in the values of ϵ^{10}/C_{min} (-◇-) and specific binding energy (-◇-) depending on the content of carbonate palygorskite (CP) and alkaline-earth bentonite (AEB) in the mud mud composition.

However, their combination with carbonate palygorskite, especially for increasing the salt tolerance of the resulting drilling mud, is of scientific and practical interest.

We, on the basis of carbonate palygorskite NF and hydromica clay “Shorsuv” were obtained drilling fluids of various qualities.

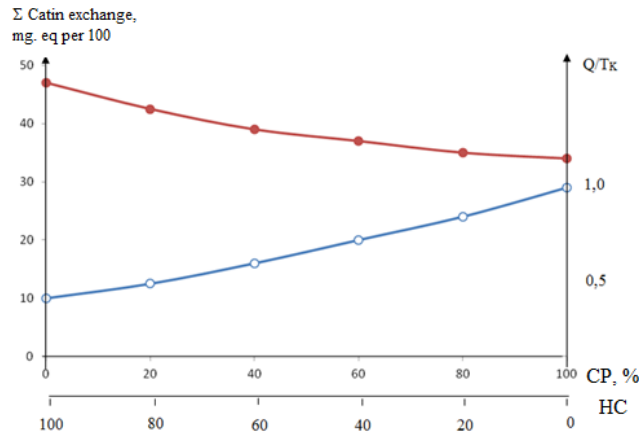


Fig.5. Changes in the values of total cation exchange (- o -) and salt tolerance coefficient (- ● -) depending on the content of carbonate palygorskite (CP) and hydromica clay (HC) in the mud composition.

Figures 5 and 6 show that, unlike compositions composed of carbonate palygorskite with alkaline bentonite or alkaline-earth bentonite, a mixture of carbonate palygorskite with hydromica clay gives more highly resistant drilling muds.

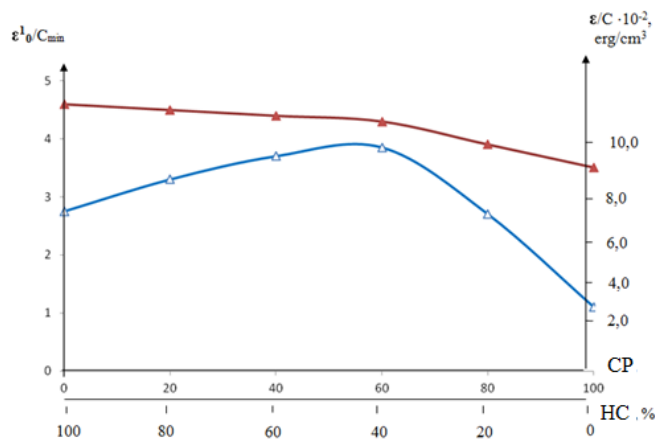


Fig.6. The change in ε10/Cmin (-Δ-) and specific bond energy (- ▲ -) depending on the content of carbonate palygorskite (CP) and hydromica clay (HC) in the composition of the drilling mud.

This can be explained by the fact that acicular crystals of carbonate palygorskite and rounded highly dispersed plates of hydromica clay form in the polymineral composition, compared with the corresponding individual clays, a much larger number of strong contacts. At the same time, between the crystals of carbonate palygorskite and aggregates-packages of hydrous micaceous clay, when they are introduced into the latter, compound-

inclusions are formed, which are much larger than the Van der Waals-London force [9-18].

From fig. 6 it can be seen that the specific binding energy of the palygorskite-hydromicaceous composition exceeds 9×10^{-2} erg/cm³ and the salt tolerance coefficient is 2.75. Of course, such a development of inclusion compounds in carbonate palygorskite compositions is possible with alkaline or alkaline-earth bentonites, where interpacket spaces due to significant imperfection of the structure are available for embedding palygorskite crystals into them.

IV. CONCLUSION

Thus, we can conclude that palygorskite-containing compositions of drilling fluids are highly resistant to the coagulant action of electrolytes. The salt tolerance of palygorskite clays is manifested in another 5% drilling mud. The presence of electrolytes in suspension contributes to a significant increase in the values of plastic strength, limiting statistical shear stress, and other structural-mechanical parameters. All this ultimately contributes to the hardening of the coagulation-thixotropic structure of the resulting drilling fluids.

In the composition "carbonate palygorskite-bentonite" compared with the solutions of the original minerals, a significant increase in the coefficient of stability of the coagulation structure is observed, which indicates a change in the process of structure formation. In addition, a more ordered structural grid is formed in this composition, in which the palygorskite particles are arranged in the most advantageous combinations for them. Their solutions are characterized by reduced elasticity, static plasticity and an increased period of true relaxation and the conventional modulus of deformation.

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