ГОДИШНИК НА МИННО-ГЕОЛОЖКИЯ УНИВЕРСИТЕТ “СВ. ИВАН РИЛСКИ”, Том 50, Св. I, Геология и геофизика, 2007
ANNUAL OF THE UNIVERSITY OF MINING AND GEOLOGY “ST. IVAN RILSKI”, Vol. 50, Part I, Geology and Geophysics, 2007

GEOLOGY, CHEMISTRY COMPOSITION AND PREPARED BENTONITE AND ACTIVATED BENTONITE CLAY FROM DEPOSITS ”PROPAST – DOBROVOLETS”, KARDJALI APPLICABILITY IN DRILLING OPERATION

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ABSTRACT. This paper presents a review of geology, chemistry composition and prepared bentonite clay applicability for drilling operation (horizontal direction drilling). Research focused on recommended and application of the bentonote clay from deposits Propast – Dobrovolets, Kardjali, Bulgaria for drilling mud prepared and laboratory analyses API 13A (Spec. 13A) and OCMA Grade Bentonite. In laboratory research activators additives – soda ash and polymers for best bentonite mud properties: yield of bentonite slurry, rheologycal properties and filtrate loss.

ГЕОЛОГИЯ, ХИМИЧЕН СЪСТАВ И ПРИЛОЖЕНИЕ НА БЕНТОНИТОВИТЕ ГЛИНИ ОТ НАХОДИЩЕ “ПРОПАСТ – ДОБРОВОЛЕЦ”, КЪРДЖАЛИ ЗА СОНДАЖНИ ЦЕЛИ

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РЕЗЮМЕ. В настоящата статия са разгледани геологията, химичният състав и приложението на бентонитови глини за сондажни цели, в частност хоризонтално – насочено сондиране в градски условия. Изследването е фокусирано върху оценка приложимостта на бентонитовите глини от находище Пропаст – Доброволец, Карджалийско, за сондажни цели – приготвяне на промивни течности и лабораторен анализ съгласно стандарти API 13A (Spec. 13A) и OCMA Grade Bentonite. В лабораторни условия е изследвано и влиянието на активатори – калцинирана сода и полимери за подобряване качествата на бентонитовите суспензии: добив на суспензия, реологични параметри и филтрационни свойства.

Introduction

The term *bentonite* is used for commercially-mined sodium montmorillonite (which is a form of smectite) that is used as an additive for drilling mud. *Geologically, bentonite is a bed of altered volcanic ash.* One of the biggest deposits of this volcanic ash occurred over 60 million years ago in areas of North America now known as the Blacks Hills of Wyoming and South Dakota, and the Big Horn Mountains of Wyoming. Bentonite clay mined in Wyoming actually comes from this volcanically deposited bentonite bed. Bentonite clay mined in other areas of the world may be from other types of geological deposits. Because of their small particle sizes, clays and clay minerals are analyzed with special techniques such as x-ray diffraction, infrared absorption and electron microscopy. Cation Exchange Capacity (CEC), water adsorption and surface area are some of the properties of clay minerals that are often determined in order to better characterize clay minerals as well as to minimize drilling problem.

Bentonite is plastic clay generated frequently from the alteration of volcanic ash, consisting predominantly of clay minerals, usually montmorillonite. Depending on the nature of their genesis, bentonites contain a variety of accessory minerals in addition to montmorillonite. These minerals may include quartz, feldspar, calcite and gypsum. The presence of these minerals could impact the industrial value of the deposit, reducing or increasing its value depending on the application.

Bentonite is clay containing not less than 70% of montmorillonite. Montmorillonite is superfine flaky aluminosilicate, where due to lattice nestehiometrical cations exchange surplus negative charge appears and compensates cation-exchange located in interlayer area. High waterproofing is conditioned on this. In case of water tempering, water penetrates in interlayer area of montmorillonite, hydrates its surface and cation-exchange, so that provides swelling of the mineral. Bentonite forms firm viscous suspension with thixotropic properties during further water dilution. Montmorillonite has high cation-exchange and adsorption properties.

Bentonite presents strong colloidal properties and its volume increases several times when coming into contact with water, creating a gelatinous and viscous fluid. The special properties of bentonite (hydration, swelling, water absorption, viscosity, thixotropy) make it a valuable material for a wide range of uses and applications.

Owing to these properties bentonite has found wide application as viscous gelling agent and filtration diminishing agent in drilling muds production for well drilling and boring.

Geological setting

The Propast - Dobrovoletz bentonite deposit is discovered in 1960. Its operation starts in 1963. The bentonite form the Propast - Dobrovoletz deposit is of hydrothermal - metasomatic type. They are related to Oligocene volcanogenic – sedimentary complex witch belongs to the first intermediate pyroclastic horizon [2]. The deposit is located eastern of Kurdjali town. The bentonite clays are formed in hydrothermal alteration of volcanic tuffs. They alternate by not altered tuffs in some areas in or around the deposit. The bentonite clays are covered by the products of the second acid lava - pyroclastic horizon. The clays are green, grey - greenish and yellow - greenish. They contain apatite, biotite, plagioclase, etc [2]. The main mineral is montmorilonite (Na - montmorilonite type). The caolinite is in minor amounts.

Some applications of bentonite:
- Bentonite in civil engineering applications is traditionally used as a thixotropic, support and lubricant agent in diaphragm walls and foundations, in tunnelling, in horizontal directional drilling (HDD) and pipe jacking. Bentonite, due to its viscosity and plasticity, is also used in Portland cement and mortars.
- Drilling: Another conventional use of bentonite is as a mud constituent for oil - and water - well drilling. Its role is mainly to seal the borehole walls, to remove drill cuttings and to lubricate the cutting head.

Bentonite has the best technical properties if montmorillonite contains exchanged sodium cations. The deposits of natural betonite are located in Kardjali region, Southern Bulgaria. In Bulgaria the most well known are the deposits with 30—60% montmorillonite content, called bentonite by mistake. Practically, all Bulgarian bentonite is calcium — magnesium. Consumer properties of such bentonite, containing not less than 70% of montmorillonite, after soda ash and polymers activation might approach to natural-sodium bentonite.

Mined bentonite clay is activated with soda ash due to the consumer needs. The main consumers for such bentonite are ore mining and processing enterprises using bentonite as a binding agent in iron ore pellets.
Soda ash and polymers activated bentonite clay fits with special technical specifications and has the following quality characteristics:

Technical specifications

- Montmorillonite content, not less 75 %
- Swelling index, not less 14 ml/g
- Moisture mass fraction, not more 21 %
- Effective viscosity, not less 30 cP

For the purpose of increasing bentonite consumer properties, as binding agent for iron ore pellets we work up and produce bentopolymer compositions. They are considered to be soda ash activated bentonite with special polymer content.

Horizontal-Directional Drilling (HDD) overview

Trenchless Technologies, known in the whole world as NO-DIG, are the variant of performance the job of underground building without opening-out ground. Trenchless Technology makes possible to perform more than 90% of job under ground that excludes:
1. Necessity of restoration of pavement;
2. Service lines damage;
3. Congestion of main traffic arteries;
4. Breach of the habitual tempo of life;
5. Annihilation of green planting;
6. Demolition of beautification features;
7. Surface excavation, etc.

Trenchless Technologies are economically more profitable (2.5-3 times) in comparison with the traditional method. The explanation of it is the economy of means, that were spent on the development of trenches, restoration of pavement, etc. while using the open method of pipe laying. In addition, Trenchless Technologies shorten the time of performance of the work and reduce the number of staff, considerably raise the level of works safety (absence of trenches and machinery on the line of laying), and also they don't harm the environment.

There are four traditional methods of trenchless pipe driving: *horizontal drilling; piercing; punching; pipe replacement* [1, 3]

Horizontal-Directional Drilling (HDD) is a great alternative to traditional trench technology and allows to us to simply pass under both natural and artificial obstacles (rivers, dams, roads, railway embankments) leaving them untouched [1, 5].
To conduct a simple comparison between the estimated costs of HDD and the costs of the trench technology would be misleading. It is true that during the building both costs and work time are saved considerably, yet the main saving of this method lies in future prospects. In a comparative analysis of the two pipelines building's methods, it is easy to see the superiority of the HDD-Technology.

There are three stages in the laying of a pipeline:
- Drilling of the pilot drill;
- A consecutive widening of the drill;
- A pipeline's tightening.

From *CONVENTIONAL HDD PROCESS* the three-stage operation of HDD involves drilling a pilot hole, reaming and pipe installation (see Fig. 1) [5]

The pilot hole is drilled via the projected trajectory. Using provides the highest speed of drilling various types of pilot bore. The hole is widened on a stage-by-stage process. The diameter of the widened hole is by 20-25% more than pipeline's diameter. The pipeline joint is fastened to the drilling column and the reamer, and is pulled through the hole by the drill rig.

At all the drilling stages drilling fluid is used. This purifies and stabilizes the hole, minimizing the friction losses and cools off the drilling tool. The basic component of the drilling fluid is the fresh water, and bentonite, which is used for viscosity and additives for special application.

Bentonite is an ecologically clean material, because of its natural origin (clay). In addition to HDD-technology for drilling fluids (mud), it used for the construction of ponds and dams, tunneling and all.

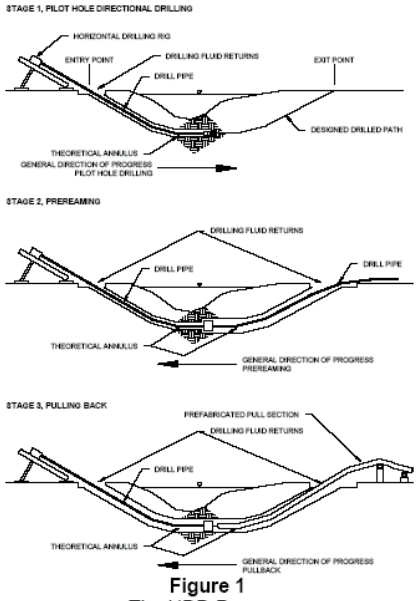

Figure 1
The HDD Process

Fig. 1. The three-stage operation of HDD process

Drilling fluid is used for a number of tasks in the HDD process including [3, 4, 5]:
- Cooling and lubricating the drill stem, mud motor and bit;
- Providing hydraulic power to the mud motor this in turn converts hydraulic power to mechanical power;
- Carrying cuttings out of the bore hole;
- Stabilizing the bore hole during the drilling process;
- Sealing fractures in the formation.

Drilling fluid is usually a mixture of freshwater and bentonite. Bentonite is naturally occurring clay that is extremely hydrophilic (i. e., has high swelling characteristics). Certain polymers may also be used that enhance the drilling fluid benefits.

A drilling fluid design plan should be established before the start of the project. This plan should also be modified, when warranted, throughout the project to ensure the drilling fluid is fulfilling its function.

The contractors' drilling execution plan should identify the equipment to be maintained onsite to check drilling fluid properties. Alterations to the mix should be made, when warranted, to stay within the proposed boundaries in the drilling fluid management plan.

A mud handling system should be onsite to ensure drilling fluid parameters are within the set standards.

Technical approach (materials and methods). Test procedures and results

A laboratory experimental program has been undertaken to develop a better quantitative understanding of the performance of bentonite, activate soda ash and polymers bentonite clays based drilling fluid for Horizontal-Directional Drilling (HDD).

The Department of Economics Geology, Geochemistry laboratory and Drilling, Oil and Gas Production, *laboratory Drilling fluids and cement slurry* at the University of Mining and Geology "St. Ivan Rilsky" – Sofia has development a series of laboratory experiments to quantify bentonite from deposits "Propast – Dobrovolets", Kardjali district and drilling fluids performance.

Specific and standard laboratory test and experiments included standard API RP 13A Sample: section 4 BENTONITE, section 5 NONTREAD BENTONITE and section 6 OCMA Grade Bentonite [6] and API RP 13B [7].

Bentonite clays mining at these deposits contain from 30% to 60% montmorillonite, with exchange interaction containing calcium and magnesium cations. Moisture bentonite is activated by soda ash, that means that calcium and magnesium cations are replaced by sodium cations, and activated with polymers. After that bentonite properties are near to natural sodium bentonite properties.

Chemical composition of moisture bentonite clay are presented in the following table 1.

Table 1
Chemical composition of representative samples (major elements)

Chemical compound, oxides wt. %	Sample # 1 – Yellow granular	Sample # 3 – Gray-Green granular	Sample # 5 – trade mark for drilling muds
SiO_2	64.53	60.59	57
TiO_2	0.69	0.82	n.a.
Al_2O_3	13.56	14.65	15
Fe_2O_3	3.81	4.39	5
MnO	0.09	0.09	n.a.
MgO	2.85	3.34	4
CaO	6.47	5.07	6
Na_2O	0.24	0.68	3
K_2O	0.83	1.09	1
P_2O_5	0.17	0.22	n.a.
SO_3	<0.03	<0.03	n.a.
BaO	0.40	0.10	n.a.
SrO	0.02	0.01	n.a.
LOI	8.99	8.66	7

Bentonite powders #1, #3 and #5 follow the requirements of specifications API 13A and section 6 OCMA grate bentonite. The suspension properties are shown in Table 2.

From table 2 can be seen that the bentonite clays and the tested suspensions – sample # 3 (with a few exceptions) and # 5 have technological parameters according to the regulations of the standard API RP 13A which indicates the high colloidals and and adsorption properties. Sample # 1 doesn't comply with requirements and the standards for bentonite clays that are aimed to be used for drilling.

Bentonite powders are produced from soda ash activated bentonite clay and meet the requirements of the technical standards - bentonite powders for the drilling muds. The properties are presented in Table 3.

Table 2
Specifications suspension properties - Standard API 13A Specification for drilling fluids materials

Requirements - Physical	Specifications suspension properties			
	Standard API 13A Specification for drilling fluids materials	Sample # 1 - Yellow granular	Sample # 3 - Gray - Green granular	Sample # 5 – bentonite for drilling mud "S & B Industrial Minerals" /old "Bentonit", Kardjali/
Suspension properties Viscometer Fann 35 SA dial reading at 600 r/min	Minimum 30	27	39	40
Filter Volume	Maximum 16.0 cm^3/30 min	23.5	16.5	15.0
Yield point/plastic viscosity ratio – YP/PV	Maximum 6	7	7	5
Residue of diameter grater then 0.075 mm	Maximum mass fraction 2.5 wt. %	8.5	6.5	2.3
Moisture	Maximum mass fraction 13.0 wt. %	21.5	15.3	10

Table 3
Property of bentonite slurry sample

The main specifications	Unit	Property of bentonite slurry		
		Sample # 1	Sample # 3	Sample # 5
Solution yield, viscosity 20 cP.	m^3/t	12.2	15.1	18
Moisture mass fraction	%	22	15	10

The experience of industrial use bentonite on deposits a "Propast – Dobrovolets", enterprises in 2006 had shown that bentonite produced by "S & B Industrial Minerals", Kardjali of the highest quality for drilling fluids production, due to the mud yield, surpassing all the other bentonite products. High colloidity and high ability to disperse in water, in combine with domestic or import polymer reagents let to increase the quality of drilling fluids, improve washover of horizontal directional drilling boreholes; give 20-30 % reduction of polymer reagents consumption.

We project and design in laboratory *"Drilling fluids and cement slurry"* high quality bentonite suspension activated by soda ash and special polymer additives for rapid development of draw-in construction of underground communications by horizontal directional drilling method. The quality characteristics of bentonite suspension for drilling fluids intended for horizontal directional drilling boreholes are presented in the Table 4. All laboratory tests made and included standard API RP 13B.

Design activated bentonite suspension (Sample #5 – 3% bentonite for drilling mud; 0.1 soda ash Na_2CO_3 and 0.75% Na-polymer) for drilling fluids used in directional drilling have high technological properties:
- high reological properties of the suspension;
- low sand content;
- short time of dispersion;
- forms a tight, thin filter cake in unstable formations;
- mixes quickly;
- high yield of suspension;
- eliminates clay and shale swelling, bit balling and sticking problems.

Table 4
Characteristics and properties of Bentonite suspension for drilling mud's

Properties	Unit	Product concentration and specifications suspension properties		
		Sample # 5a 3% bentonite 0.1% Na_2CO_3 0.75% polymer	Sample # 3 - Gray - Green Granular Non acivated	Sample # 5 – bentonite for drilling mud "S & B Industrial Minerals" /old "Bentonit", Kardjali/
Specific gravity, SG	Kg/L	1.035	1.05	1.04
Marsh viscosity	Sec/L	40	36	38
Rheology - Viscometer Fann 35 SA dial reading at 600 r/min 300 r/min 200 r/min 100 r/min 6 r/min 3 r/min	Dial reading	 46 35 30 24 11 9	 22 17 14 11 6 4	 32 25 22 18 10 8
Filter Volume API (100PSI @ 20 ˚C)	cm^3/30min	12.5	18	15.0
Filter cake	mm	1.0	2.5	1.5
Plastic viscosity, PV	cP	11	5	7
Yield point, YP	$Lb/100ft^2$	24	12	18
Gel 1min/10min	$Lb/100ft^2$	11/15	4/8	10/14
pH		9.0-10.0	8.5-9.0	9.5-10.0

Sand contend	% vol.	< 0.5	2.0	< 0.5
Free water dreg after 24 hours	ml	0.1	2.5	1.0
Yield of suspension	m^3/t	22	15.1	18

The comparative analysis of the technological parameters of the prepared drilling muds, particularly in the yield of suspensions, show that it's imperative to activate bentonite clay with soda ash and with polymers if it's necessary.

Bentonite provides polymer-clay drilling fluids creating with technical requirements for horizontal direction borehole washover in sand-clay rocks that makes possible to receive 1.03-1.04 kg/L suspension density, 35-42 sec/L Marsh funnel viscosity and pH=9.5-10.5 in normal drilling condition that presents high bentonite colloidity and high dispersion ability in water. For best results water acidity is needed to be regulated with soda ash or ammonia soda to the 8.5–9.0 pH level.

Conclusion and final remarks

Taking in account performed laboratory tests we could conclude:

- Bentonite powders Sample # 5 and granular Sample # 3 follow the requirements of specifications API 13A OCMA grate bentonite;
- In laboratory condition design and testing high quality bentonite suspension activated by soda ash and special Na-polymer additives for horizontal direction drilling;
- Bentonite powders for drilling fluids used in directional drilling have high technological properties: high reological properties of the suspension, low sand content, short time of dispersion and high yield of bentonite slurry.

Recommended for publication by the Department of Geology and Prospecting of Mineral Deposits, Faculty of Geology and Prospecting

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