The composition and activation aspects of El-Fayoum clays for using as a drilling fluid

Medhat S.El-Mahllawy[1]*, Aly M.Sharara[1], Mahmoud M.Hassaan[2], Abdeen M.Abdel Haleem[1]
[1]Housing and Building National Research Center, P.O. Box 1770, Cairo, (EGYPT)
[2]Al-Azhar Univ., Faculty of Science, Nasser city, Cairo, (EGYPT)
E-mail: medhatt225@yahoo.com

ABSTRACT

The local consumption and the high importation cost of the imported bentonite to Egypt lead to find local substitute solutions for economical aspects. Hence, this paper presents composition and activation capability of clays collected from claystone quarries in Kom Oshim area at El-Fayoum province, Egypt for the application as a drilling fluid (water-based mud). It is an attempt to minimize the importation cost of the imported bentonite to Egypt by a local solution and maximize the usage of the studied clay sediments. The physical, chemical, thermal and mineralogical characteristics of five Egyptian clay samples were studied. The rheological properties of the prepared slurries from these samples and their activation characterization during studying the influence of NaOH and POLYPAC-R polymer as activators were investigated. It was found that the non-activated samples can't be used as a drilling mud but it could be after the activation process where some significant changes in the rheological properties were observed. The experimental results revealed that the activated fitted samples may express as medium grade bentonitic clay and this type of clays can be used as a drilling fluid for shallow depth wells.

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KEYWORDS

Clay;
Bentonite;
Rheological properties;
Drilling fluid;
NaOH;
POLYPAC-R;
El-Fayoum.

INTRODUCTION

The name bentonite is given to a particular type of clay that was first noted in about 1980 in Upper Cretaceous tuff near Fort Benton in the region Wyoming of USA. The main constituent, which is the determinant factor in the clay's properties, is the clay mineral montmorillonite. This in turn, derives its name from a deposit at Montmorillon, south France. Montmorillonite is a layered silicate mineral that belongs to smectite group of clay minerals. The crystals of montmorillonite consist of three layers: an aluminum octahedron sheet sandwiched between silicon tetrahedron sheets. In montmorillonite, some of the Al ions may be substituted by magnesium ions, resulting a negative charge on the two large surfaces of montmorillonite platelets. This negative charge is neutralized by interlayer cations, such as, Na^+, K^+, Ca^{2+}, which separates adjacent layers of platelets. This structure makes montmorillonite chemically stable. In industry, montmorillonite is generally clas-

sified as sodium (Na) or calcium (Ca) types, depending on which exchangeable cation is dominant on montmorillonite surface.

Bentonite often contains more than 80% montmorillonite. It has a wide range of industrial applications, such as bleaching earth, cat litter, foundry, construction and civil engineering but it is widely used in oil drilling fields as a mud additive for viscosity and filtration control. Bentonite swells considerably when exposed to water, making it ideal for protecting formations from invasion by drilling fluids. Sodium bentonite meets drilling-mud and civil engineering specifications due to its excellent colloidal and rheological properties[1].

On the other hand, Egypt imports annually huge amounts of bentonite for oil well drilling and other industrial purposes. Normally bentonite deposits are exploited by surface quarrying. Bentonitic clays have been found in Egypt with promising reserves mainly in sex regions according to previous studies[2]. The major problems facing the utilization of the Egyptian clays are their low concentration of smectite, high level of impurities and inconsistent composition. Also, the response of the Egyptian clays to Na-exchange is poor and their hydration, plastic and rheological properties are inferior to those of commercial bentonites[3].

Furthermore, most Egyptian clays without beneficiation are unsuitable for the majority of industrial applications[4,5]. The activation process could be carried out by addition of the common salts and polymers[6-8].

The present paper deals with the characterization and upgrading of the clay in Kom Oshim area at El-Fayoum province, Egypt for the application as a drilling fluid (water-based mud). It is an attempt to minimize the cost of the imported bentonite to Egypt by a local solution and to maximize its profiting in a useful application.

GEOLOGY

The samples used in this study were taken from claystone quarries located at Kom Oshim area, El-Fayoum province, Egypt. These samples belong to Qasr El-Sagha Formation of the Upper Eocene age[9]. The studied quarries is situated 30km the north of El-Fayoum city between latitude $29°$ 31' and $29°$ 35' north and longitude $30°$ 50' and $30°$ 59' east (Figure 1). The stratigraphy of El-Fayoum province has been dealt by many authors[10]. Qasr El-Sagha Formation is divided into five units as follows[11]:
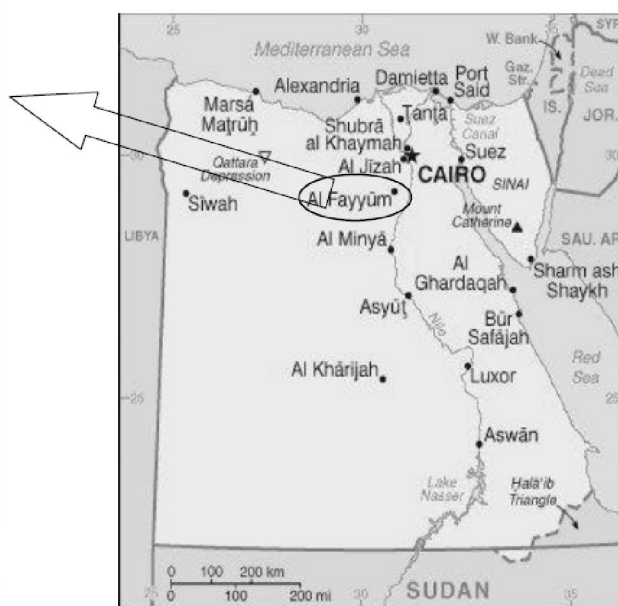

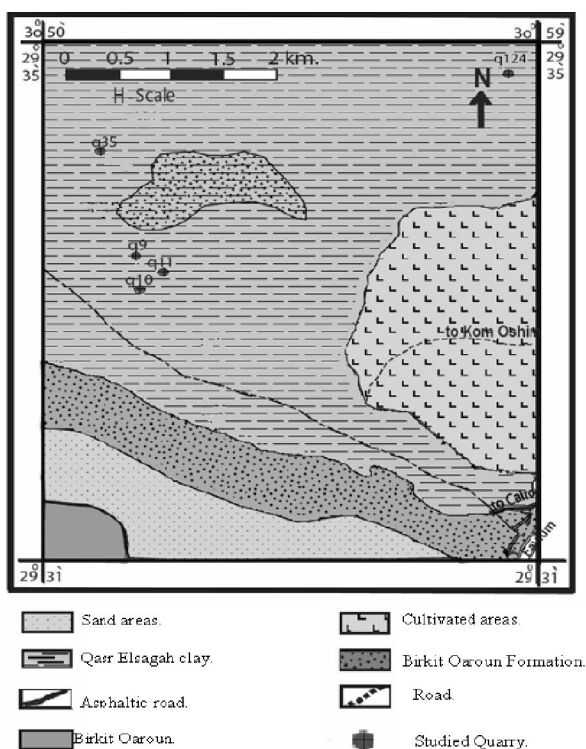|			
⬚ Sand areas.		⊏ Cultivated areas.	
▱ Qasr Elsagah clay.		▨ Birkit Qaroun Formation.	
◹ Asphaltic road.		▰ Road.	
▬ Birkit Qaroun.		✚ Studied Quarry.	

Figure 1 : Location map shows the studied claystone quarries at Kom Oshim area, El-Fayoum province, Egypt.

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Top 5 - Sandy limestone (1.5m)

    4 - Loose sands (19.0m)

    3 - Clay, calcareous sandstone and limestone intercalations (28.0m)

    2 - Interbedded purple clay with fine sand interbeds (19.0m)

Base 1- Gypsiferous sandy clay with fossiliferous calcareous sandstone (91.0m)

The lowest two units attaining a total thickness of about 110m representing bulk of the claystone-siltstone interbeds. Some of these have been exploited at Gebel Qasr El-Sagha as bentonitic clays[12] or around Kom Oshim village as bentonite[13]. The Qasr El-Sagha Formation differs widely in thickness and composition from one area to another in El-Fayoum province. The formation is greatly minimized in thickness from about 180m at Gebel Qasr El-Sagha to about 40m at Qaret El-Faras, north of El-Fayoum depression, with slight change in facies[14].

EXPERIMENTAL PROCEDURES

Materials

Five claystone samples were taken from the exposed surface of five inconsiderable exploited quarries located at Kom Oshim area, El-Fayoum province, Egypt. In an abbreviated notation, the studied samples were designated as q9, q10, q11, q35 and q124. The samples were taken from the fresh deposits using representative sampling method. The collected samples are mainly brownish grey to dark yellow, massive claystone.

Also in the present study, two types of activators were used; caustic soda (NaOH) and synthetic polymer (POLYPAC-R) as an attempt to upgrade the samples by activation process and hence improve their rheological properties.

Raw samples characterization

All collected claystone samples were dried at 60°C for 48h and then crushed using a jaw crusher to 100% below 5mm size. A representative batch of each sample was further ground to 100% pass through 200μm sieve diameter using a porcelain mill to avoid samples contamination. These sieved samples were used for mineralogical, chemical and dehydration analyses. These analyses were performed using X-ray diffraction (XRD),

X-ray fluorescence (XRF) and thermal differential and gravimetric (DTA and TGA) investigations. In addition to, international standards were used also in the study.

The used XRD apparatus was a X'Pert PRO PW3040/60 (PANalytical) diffractometer equipped with a Cu-Kα radiation source. The test was run at 40 kV and 40 mA. A continuous mode was used for collecting data in the 2θ range from 3° to 30° at a scanning speed 2°/m. The acquired data were analyzed using X'Pert high score software works with PDF-2 database. The used XRF was an Axios sequential spectrometer manufactured by PANalytical, Netherlands. Also, a traditional manual method prescribed in the American Society for Testing and Materials (ASTM) for determination of the loss on ignition[15], (LOI), was followed. The methods described in the ASTM[16] were used for the determination of soluble cations and anions (Na^+, K^+, Cl^- and SO_4^{--}). Also, the method recorded in a scientific paper[17] was used for the pH determination. It was measured at 22°C by a Jenway 3510 electronic pH meter, UK. The thermal analyses were carried out using computerized DT.50 thermal analyzer (Shimadzu Co., Japan). The heating rate was 20°C/min for the thermo-analytical instruments and the nitrogen atmosphere (30ml/min) was used. Textural analysis of the studied samples was conducted using laser diffraction grain size analyzer of Horiba model LA-930, France. Also, the textural classificat89ion was followed[18]. Physical properties of the studied samples were determined such as Atterberg limits[19] and free swell test[20]. Results of the free swell test were also explained[21]. Also, activity ratio of clay and its classes was calculated[22]. To measure rheological properties of the clay samples, viscometer instrument model 35A (USA) was used to measure viscosity and gel strength parameters. Also, the ASTM D5891-02 (2009)[23] test method was used to determine the filtrate loss of the clay slurry's.

Rheological tests

Rheological properties for the samples slurry before and after activation process were determined to assess their response to the used activators and consequently capability for using as a drilling fluid. Generally, the bentonite used in drilling fluids should follow the Oil Company Materials Association (OCMA) or the

American Petroleum Institute (API) specifications. In the present study, plastic viscosity (PV), apparent viscosity (AV), yield point (YP) and filtrate loss properties were determined[24].

Activation method

To determine the rheological properties of the studied samples, slurry of each sample (q9, q10, q11, q35 and q124) with distilled water were prepared at different concentrations from 4.5% up to 7.5 with an increment of 1%.

For making alkaline and polymer activated sample, slurry of 22.5g from each sample with 350ml of distilled water were prepared and mixed in a blender with the activators of 1.5% by weight caustic soda (obtained from Misr chemical industries, Egypt) and 0.5% by weight POLYPAC-R (polyanionic cellulose water soluble polymer). The used POLYPAC-R is white, powder, pH of 7 and specific gravity of 1.5. It is common and designed to control fluid loss and increase viscosity in water-based mud.

The prepared slurry was stirred for 20min at 600 rpm then it was aged overnight[25]. All the activators used were of industrial grade. The used concentration of the activators was added in the clay concentration slurry of only 6.5% taken into consideration achieving somewhat apparent viscosity of 15cP (centipoise) which is stated in the process of clay activation purpose[5] and traditionally used.

RESULTS AND DISCUSSION

Characterizations of raw samples

(a) Mineralogical composition

XRD patterns for the studied samples are illustrated in Figure 2. The mineralogical analysis shows that all samples are essentially montmorillonite, kaolinite and illite as clay minerals in descending order of abundance. Quartz and calcite minerals are also found in minor amounts as non clay components. The montmorillonite mineral is represented by a basal reflections (001) at 14-15A° in the air dried state which corresponds to montmorillonite with predominantly Ca as interlayer cation. After heating of the oriented samples at 550°C for 2h, montmorillonite main peak change to 9.5 A°, kaolinite mineral disappear and illite does not show

considerable changes. With glycolation of the oriented samples over night, montmorillonite peaks expand and exhibit change to 17-18A°, kaolinite and illite peaks did not show any changes in their positions. TABLE 1 shows the semi–quantitative percentage of detected clay minerals with respect to all fraction sizes of the studied samples. It is varied from 47 (q124) to 75% (q35) for montmorillonite, from 11 (q35) to 18% (q124) for kaolinite and from 2% (q35 and q10) to 5% (q124) for illite minerals.

TABLE 1 : Semiquantitative percentage of the clay minerals in clay fractions of the studied samples.

Sample no.	Montmorillonite, %	Kaolinite,%	Illite,%
q9	65	13	4
q10	66	14	2
q11	63	12	4
q35	75	11	2
q124	47	18	5

(b) Thermal analyses

DTA and TGA thermo-grams of the studied samples (Figure 3) show low temperature endothermic peaks at about 76-97°C reveal that the absorbed and exchangeable cations coordinate water are released. The variation in the peaks size may due to the variation in the montmorillonite content in the samples[26]. The peaks at about 270- 268°C may relate to the dehydration of goethite mineral [FeO (OH)]. Otherwise, these peaks represent the loss of the interlayer water of both montmorillonite and illite structures[27]. Presence of iron mineral is confirmed by the field observation whereas yellow and purple patches were enclosed in claystones. Endothermic peaks at about 511- 523°C represent both of starting removal of the structural OH- from montmorillonite, illite and kaolinite lattices and production of amorphous phase for kaolinite (disordered metakaolin). The relatively low peak temperature of dehydroxylation of the samples may be attributed to the presence of excess structural iron in the octahedral layer of the smectite. The small curves at high temperatures (890-941°C) indicated by S-shaped endothermic-exothermic reaction peaks refer mainly to the final structural breakdown of the montmorillonite and to the recrystallization of its components[28]. These system peaks are not accompanied by any loss of the weight since they are structural peaks. All the detected endothermic peaks of the samples are accompanied by a cor-

Ca-M: Calcic montmorillonite I: Illite K: Kaolinite Q: Quartz F: Feldspar C: Calcite
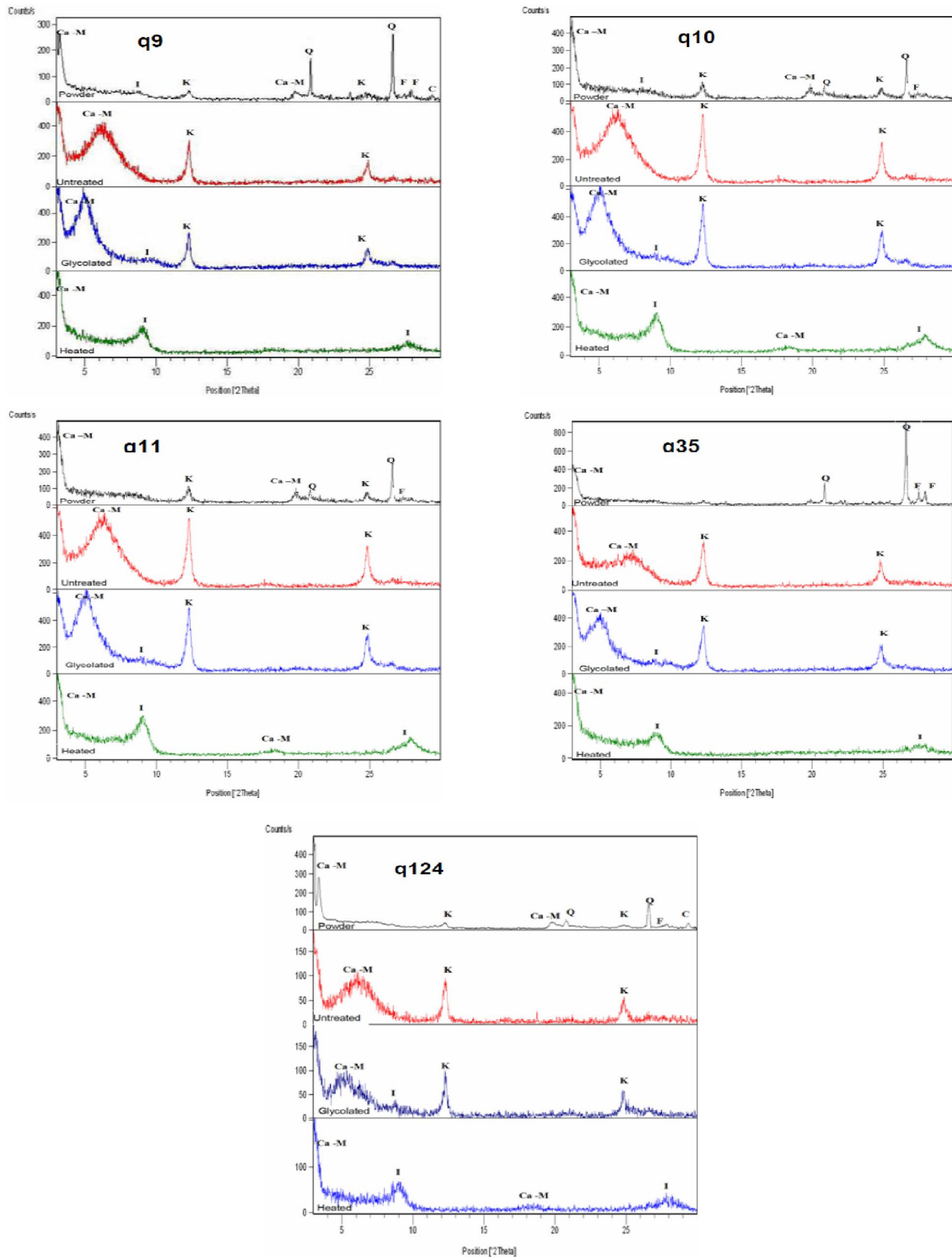
Figure 2 : X-ray diffractograms of the powder and treated clay fractions of different samples (q9, q10, q11, q35 and q124).
Ca-M: Calcic montmorillonite I: Illite K: Kaolinite Q: Quartz F: Feldspar C: Calcite

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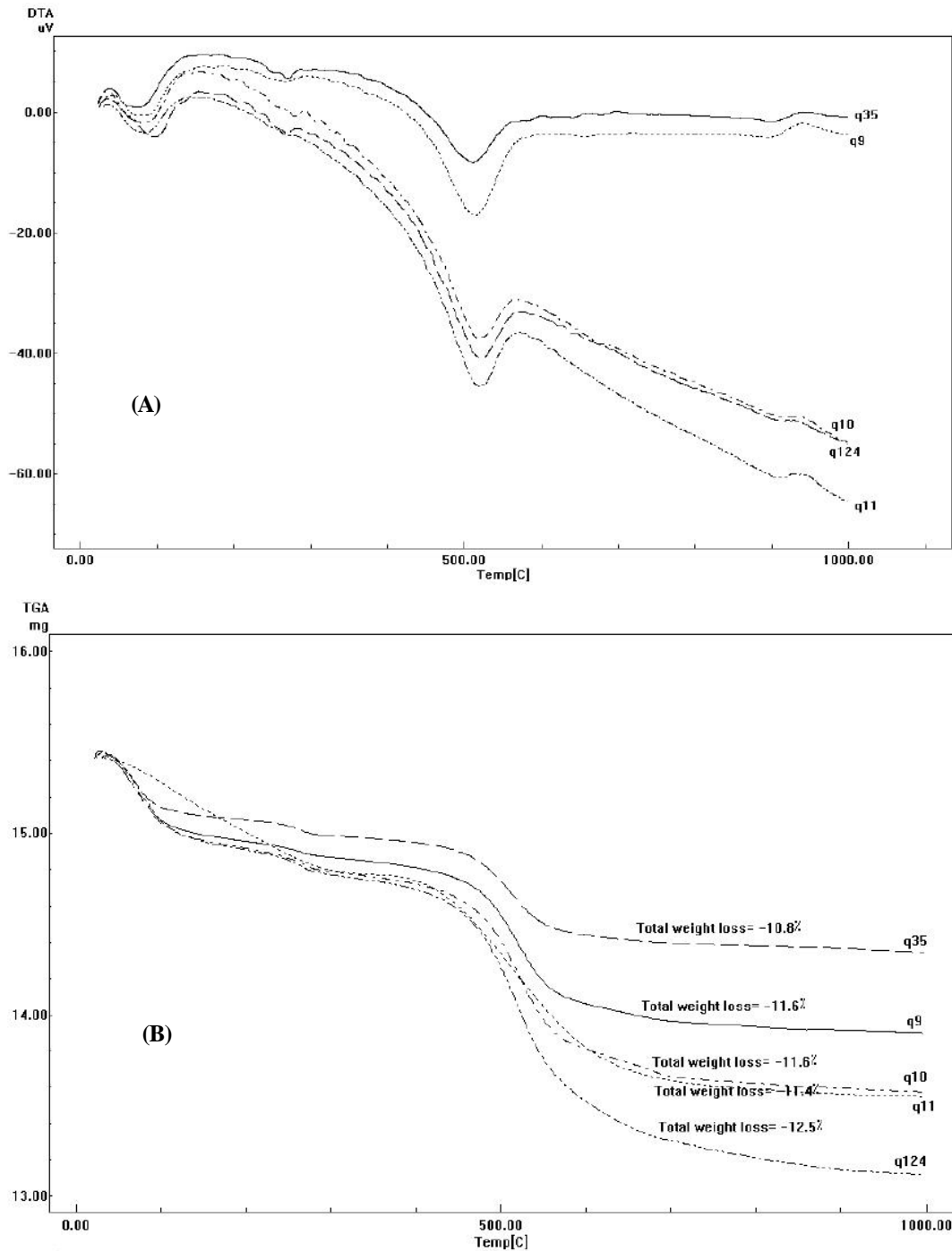responding total loss of weight (TGA) at a range of 10.8   (q35) to 12.5% (q124).

Figure 3 : DTA and TGA thermo-graphs of the studied samples.

(c) Chemical composition, soluble salts and pH value

TABLE 2 shows chemical composition of the studied samples. As expected, all the examined samples consist mainly of SiO_2, Al_2O_3 and Fe_2O_3 in descending order of abundance. A minor to trance amounts of CaO, MgO, Na_2O, K_2O, TiO_2, SO_3 and P_2O_5 were also detected. The percentage of the main oxides indicates the presence of smectite clay. The small percentage of CaO is attributed to the presence of lime concentration, as detected by the XRD analysis. The loss on ignition values primary are referred to

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the removal of hygroscopic water and loss of the interlayer water in the structure of clay minerals. Also, results of soluble salts content exhibit trace amounts (< 2%) of Na$^+$, K$^+$, Cl$^-$ and SO$_4^{2-}$. Moreover, the pH of the examined clay samples show alkaline medium. The values are between 8.35 (q9) and 10.17 (q124).

The rocks containing montmorillonite mineral produce an alkaline pH[29]. The results of the SiO$_2$ and Al$_2$O$_3$ are agreed with the relationship between the pH value and the solubility of these oxides. It is well known that both silica and alumina are increasingly soluble at higher pH values[30].

TABLE 2 : Soluble salts, oxide content, LOI and pH values of the studied samples.

Sample no.	Cations and anions of soluble salts, %				Oxide content, %										L.O.I. %	pH
	Na$^+$	K$^+$	Cl$^-$	SO$_4^-$	SiO$_2$	Al$_2$O$_3$	Fe$_2$O$_3$	TiO$_2$	CaO	MgO	Na$_2$O	K$_2$O	SO$_3$	P$_2$O$_5$		
q9	0.54	0.03	0.10	0.48	48.16	26.99	7.79	1.29	0.50	1.60	1.41	1.60	0.02	0.01	12.35	8.35
q10	0.99	0.15	0.02	0.33	48.86	19.40	13.17	0.31	1.88	2.03	2.62	1.66	0.06	0.01	12.11	9.75
q11	0.88	0.15	0.037	0.44	51.31	21.94	9.93	0.72	1.41	2.08	2.78	1.87	0.05	0.01	11.95	9.21
q35	0.27	0.03	0.15	0.54	48.56	26.18	8.02	1.37	0.81	1.80	1.74	1.65	0.01	0.01	11.22	8.63
q124	1.63	0.18	1.80	0.82	45.55	17.32	10.49	0.04	1.84	2.01	2.87	0.20	0.20	0.77	13.83	10.17

(d) Particle size distribution

Result of particle size distribution by the laser diffraction grain-size analyzer is listed in TABLE 3. All the studied samples are of a well-sorted class of the argillaceous sediments (rock contains more than 90% silt and clay). The samples nos. q9, q10 and q35 show a very fine-grained claystone class. The clay size fraction varies from 82.23 (q9) to 89.60% (q35). The q11 and q124 have appreciable amount of the silt fraction. These samples achieve a silty claystone category of fine–grained and very fine-grained classes, respectively. It is worthy to note that the samples q9 and q10 provide the highest content of the clay fraction (< 2μm) of about 82%. This result was confirmed by the XRD analysis given in TABLE 1.

TABLE 3 : Data of grain size analysis in weight percentage of the studied samples.

Sample no.	Size fraction (microns)								
	Sand				Silt			Clay	
	Coarse	Medium	Fine	Very fine	Coarse	Medium	Fine	Very fine	<2mμ	Total
q9	0.00	0.00	0.00	0.00	0.00	0.10	0.15	17.61	82.23	100.00
q10	0.00	0.00	0.00	0.00	0.00	0.10	0.11	17.35	82.53	100.00
q11	0.00	0.00	0.00	0.00	0.00	0.00	3.11	18.27	78.62	100.00
q35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.40	89.60	100.00
q124	0.00	0.00	0.00	0.00	0.00	0.26	5.94	23.10	70.70	100.00

(e) Atterberg limits, free swell test and activity ratio

Results of physical properties of the studied samples are summarized in TABLE 4. It was found that all the samples are inorganic clays of high plasticity (CH). The liquid limit (LL) varies from 74 (q124) to 185 (q10) with a corresponding plastic limit (PL) from 30 (q124) to 64 (q10). Liquid limit greater than 50% refers to the presence of montmorillonite[31]. The Atterberg limits (LL, PL and PI) are in a good agreement with the XRD results. The higher the clay as well as the montmorillonite contents, the higher the Atterberg limits. Results of free swell test show range from140 (q124) to 600% (q10) indicating samples of moderate (q124) to extremely high swelling potential (q9, q10, q11 and q35). The results explain that as the montmorillonite content increases, the free swelling increases.

Results of activity are pointed out that most of the samples show a high (q124) to very high potential (q9, q10, q11 and q35) for swelling[32]. Also, The samples no's q9, q10 and q11 are clays of the active class, q35 of normal class and q124 of inactive class. The obtained results from the activity ratios denote the presence of montmorillonite of calcic form with a strong potential for swelling.

As a comparison between the results of mineralogical analysis, clay activity and the free swell test, it was found a strong relationship between the high content of montmorillonite, the high free swell and the potential affinity for swelling.

TABLE 4 : Results of Atterberg limits, free swell (%) and activity of the studied samples.

Sample no.	LL	PL	P I	Free swell (%)	Activity (A)
q9	166	59	107	500	1.30
q10	185	64	121	600	1.46
q11	140	55	85	270	1.25
q35	150	56	94	550	1.04
q124	74	30	44	140	0.60

TABLE 5 : Results of rheological properties of the clay slurry for the samples no's. q9 and q10 at different concentrations.

Concentration % Sample no.q9	600 RPM	300 RPM	AV. cP.	PV. cP.	Yp. Ib/100 ft^2	Filtrate loss ml/30 min.
4.5	15	10.0	7.5	5.0	5.0	24.0
5.5	18	13.0	9.0	5.0	8.0	21.0
6.5	21	15.0	10.5	6.0	9.0	20.0
7.5	28	22.0	14.0	6.0	16.0	18.0
4.5	16.0	10.0	8.0	6.0	4.0	23.0
5.5	23.0	16.0	11.5	7.0	9.0	22.0
6.5	28.0	21.0	14.0	7.0	14.0	20.0
7.5	32.0	25.0	16.0	7.0	18.0	18.5

Rheological properties of the slurry before activation

Results of studied rheological tests of the non-activated samples are demonstrated in TABLES 5-7. The incremental concentration of the samples leads to increasing of the viscosity, yield point, gel strength and decreasing of the filtrate loss. Most of the obtained results are out of the recommended standard limits of OCMA and API specifications (TABLE 8) which means that the clays can not be applied as a drilling mud without activation. The viscosity is increased by decreasing of silt fractions or by decreasing particles surface area (clay fraction),[5]. The high content of silt (29.3%), as a non-swelling-fraction, and lowest content of the clay particles (70.7%) as well as montmorillonite content (65%) provide poor properties for the q124. Q11 and q35 show good results for the filtrate loss according to OCMA specification (16ml max.) but with only high clay concentration (6.5 and 7.5%). The YP should be high enough to carry cuttings out of the borehole but no so large as to create excessive pump pressure when starting mud flow. The samples that match

requirements of the OCMA specification for the filtrate loss will reduce the cake formation and prevent the hole packed off. These will run simultaneously with the cost reduction.

TABLE 6 : Results of rheological properties of the clay slurry for the samples no's. q11 and q35 and q124 at different concentrations.

Concentration % Sample no. q11	600 RPM	300 RPM	AV. cP.	PV. cP.	Yp. Ib/100 ft^2	Filtrate loss ml/30 min.
4.5	18.0	9.0	9.0	9.0	1.0	20.0
5.5	22.0	12.0	11.0	10.0	2.0	18.0
6.5	25.0	17.0	11.5	8.0	9.0	16.0
7.5	32.0	22.0	16.0	10.0	12.0	15.0
4.5	19.0	8.0	9.5	11.0	3.0	19.0
5.5	23.0	10.0	11.5	13.0	3.0	17.0
6.5	28.0	17.0	14.0	11.0	6.0	15.0
7.5	31.0	21.0	15.5	10.0	11.0	13.0
4.5	3.0	2.0	1.5	1.0	1.0	62.0
5.5	4.0	3.0	2.0	1.0	2.0	51.0
6.5	6.0	5.0	3.0	1.0	2.0	45.0
7.5	7.0	6.0	3.5	1.0	2.5	35.0

TABLE 7 : Results of gel strength of the samples no's. q9, q10, q11, q35 and q124 at different concentrations.

Sample no.	q9		q10		q11		q35		q124	
Concentration %	Gel strength, Ib/100 ft^2									
	10$^-$	10^{--}	10$^-$	10^{--}	10$^-$	10^{--}	10$^-$	10^{--}	10$^-$	10^{--}
4.5	4.0	8.0	5.0	8.0	10.0	12.0	7.0	11.0	1.0	2.0
5.5	5.0	10.0	6.0	10.0	11.0	13.0	9.0	13.0	2.0	3.0
6.5	8.0	15.0	11.0	15.0	15.0	16.0	11.0	14.0	2.0	3.0
7.5	13.0	19.0	13.0	23.0	17.0	18.0	15.0	17.0	3.0	5.0

Overall, presence of the montmorillonite in calcic form achieves unsatisfactory rheological results for the samples. To reduce the calcium content in the montmorillonite, the research directed to add Na activator materials (activation process). The Na ions are expected to replace Ca ions leading to the increase of repulsive attractive forces between particles and hence improve the technological properties. From the other hand, activation of bentonite may affect bentonite properties from two aspects; firstly, changing the water adsorption capacity and so swelling of bentonite and secondly, separation of bentonite plates.

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TABLE 8 : Limits of the studied rheological specifications of API and OCMA grade.
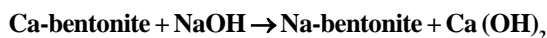
API Parameter	Requirement	OCMA Parameter	Requirement
Viscometer dial reading at 600 rpm	30.0 (min.)	Viscometer dial reading at 600 rpm	30.0 (min.)
Yield point/plastic viscosity ratio	3.0 (max.)	Yield point/plastic viscosity ratio	6.0 (max.)
Filtrate (fluid loss)	13.0 ml (max.)	Filtrate (fluid loss)	16.0 ml (max.)

Rheological properties of the slurry after activation

Results of the studied rheological tests of the activated samples are illustrated in TABLE 9 and Figure 4. It is observed that the added activators on the clay slurry increase the viscometer dial reading at 600 and 300 rpm. Addition of 1.5% caustic soda leads to enhance the rheological properties in spite of most of samples are still didn't satisfy both of OCMA and API specifications in one or more parameter values. Addition of 0.5% POLYPAC-R provides a remarkable enhancement in the rheological properties of the samples. Also, it was noted that the decrease of gel strength values with activators except for the sample q124. Also that decreasing is effective with the caustic soda addition. Generally, if the mud has the high gel strength, it will create high pump pressure in order to break circulation after the mud is static for long time. Furthermore, increasing gel strength indicates a build up of ultra fine solid. Therefore, the mud must be treated by adding chemicals or diluting with fresh base fluid.

All samples except q124 meet the specifications but may need a little amount of a filtrate reducer to minimize the filter cake thickness, such as starch or carboxymethyl cellulose (CMC), particularly in case of NaOH. Moreover, addition both of the used activators didn't provide good properties for the q124 to achieve the drilling fluid specifications. This could be attributed to the low content of montmorillonite and presence of high proportion of non-swelling fraction. This sample may need a high concentration of the used activators or other type of activators should be used. Overall, this sample is inactive as revealed from the result of activity ratios (0.60). It is worthy to note here that the plastic viscosity of the activated clay samples using both activators varies between 7 (q11: NaOH,q 35: POLYPAC-R) and 10 cP (q9: NaOH and q124: POLYPAC-R). It satisfies the oil grade bentonite requirements of 5.0 cP for Meycogel and relatively near to 11.0 cP for the Wyoming bentonites. Also, samples response to the activators by the addition of POLYPAC-R is better than those of NaOH. Moreover, NaOH reacts with a calcium bentonite as follows[33]:

Ca-bentonite + NaOH → Na-bentonite + Ca (OH)$_2$

The positive properties obtained by addition of the activators are attributed to the function of the materials added. Caustic soda is used in most water-base muds to increase and maintain pH and alkalinity of drilling fluids. Increasing the pH leads to the increase of fluid viscosity due to the action of hydroxyl radical (OH). It is expected that the NaOH is able to produce high amount of the hydroxide ion (OH$^-$) which imparts a higher pH and viscosity of the clay suspension.

The used POLYPAC-R is a polyanionic cellulosic polymer used essentially for controlling water loss in fresh and sea waters, stabilizing the bore-hole and improving viscosity of drilling. The polymer forms a thin, resilient, low permeability filter cake that minimizes the potential for differences sticking and invasion of filtrate and mud solids into permeable formation. In the other hand, polymers in the bentonite suspension interact with clay particles according to their ionic and non-ionic character. The ionic polymers induce electrostatic interactions but the non-ionic ones are adsorbed on the surface of clay minerals by steric interactions (repulsive and attractive forces).

When water-soluble polymers are added to bentonite suspensions, they disperse in the liquid phase (water), their functional groups dissociate and the polymeric chain assumes a straight configuration. The chains are adsorbed on clay particle surfaces according to their ionic nature[34].

The flocculation of water-bentonite system can be achieved and are explained by i) the formation of bridges, i.e., lateral interactions between hydrophobic groups of polymers that approach the clay particles; ii) segments of the same polymeric chains that are adsorbed on different clay particles linked to each other and interacting by attraction; and iii) the encapsulation phenomenon, i.e., formation of large flocs of particles or clay particle agglomerates[34].
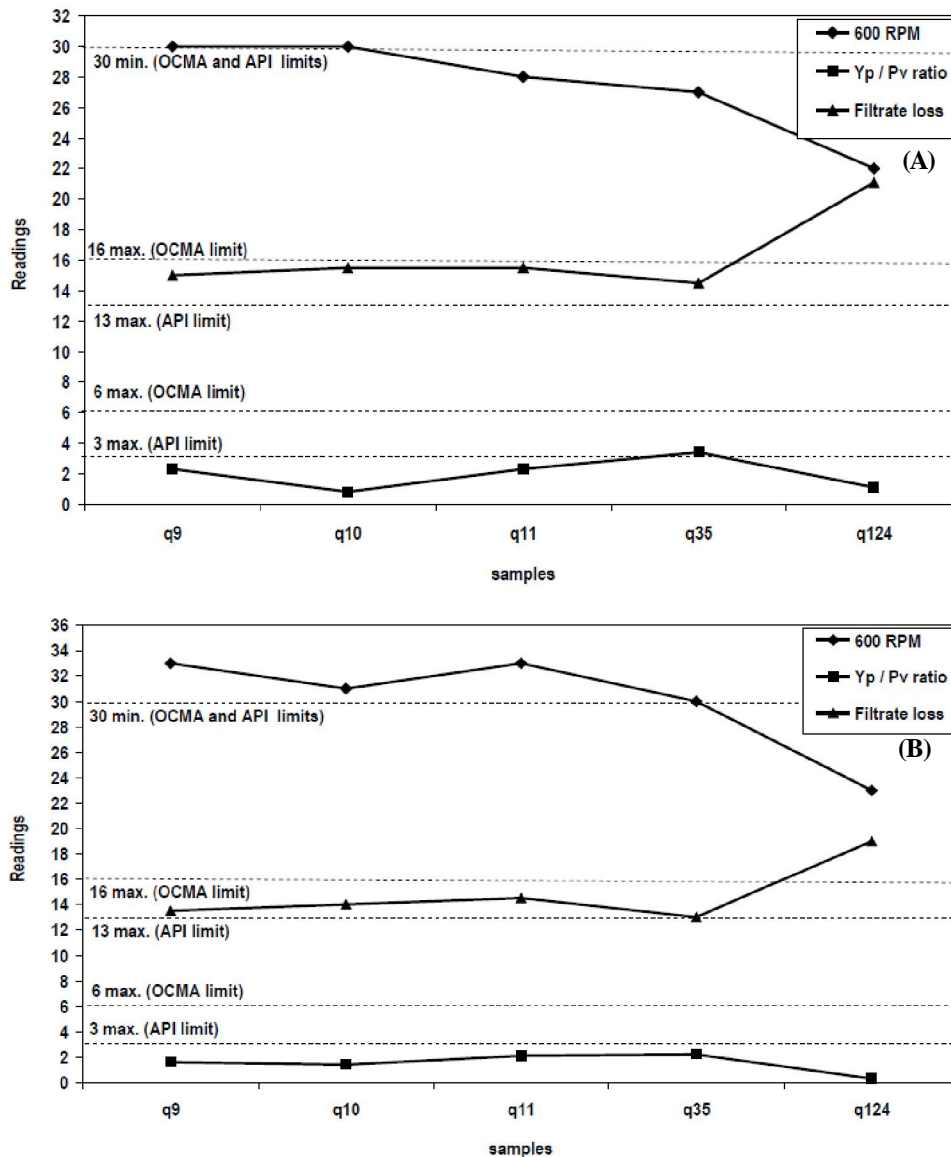
Figure 4 : Variation of rheological properties of the clay slurries at concentration of 6.5% activated by 1.5% caustic soda (A) and 0.5 POLYPAC-R (B) activators.

TABLE 9 : Results of gel strength of the clay slurries at concentration of 6.5% of the studied samples activated by 1.5% caustic soda and 0.5% POLYPAC-R activators.

Sample no.	q9		q10		q11		q35		q124	
activator %	Gel strength, Ib/100 ft2									
	10⁻	10⁻⁻	10-	10- -	10-	10- -	10-	10- -	10-	10- -
caustic soda, 1.5	11.0	12.0	13.0	14.0	12.0	12.0	11.5	12.2	7.0	9.0
POLYPAC-R, 0.5	12.0	13.5	13.0	1.4	12.0	14.0	12.5	13.0	9.0	11.0

It is stated that any additive, when added into the system, changes electrical double layers on surrounding clay particles; consequently, electrostatic behavior between clay particles and rheological properties will be changed.

CONCLUSIONS

The characterization of non-activated clays collected from quarries located in Kom Oshim area, El-Fayoum province, Egypt for the application as a drilling fluid (water-based mud) were investigated. Also, the activation capability for these clays were explained as an attempt to minimize the importation cost of the imported bentonite to Egypt by a local solution and maximize the usage of the studied clay sediments. The following main conclusions can be drawn from the present study.

Most of the studied samples are of clay-like bentonite of calcic form and exhibited different physical and

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rheological properties.

The studied non-activated samples can't be used as a drilling mud without activation.

All the studied clay samples, except q124 (inactive), can be used after activation as a drilling fluid where their rheological properties satisfied the OCMA and API requirements.

The technological properties of the activated samples by POLYPAC-R are significantly improved than those obtained by NaOH activator.

The obtained results revealed that most of the activated capable samples may express as medium grade bentonitic clay and this grade of clays can be used as a drilling fluid for shallow depth wells.

ACKNOWLEDGMENTS

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