CHEMICAL AND MINERALOGICAL FEATURES OF THE SHALE DEPOSITS IN ABO-THOR REGION, SOUTH WEST SINAI PENINSULA

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ABSTRACT

The current investigation was conducted to estimate the chemical mineralogical characteristics of shale deposits of Abo-Thor area, south west of Sinai Peninsula with the aim of determining the most suitable use of these shale deposits. X- ray diffraction pattern of the clay fraction of the sample revealed the dominance of kaolinite mineral followed by hydrous mica (illite), while the accessory minerals were dominated by quartz. The textural class of the investigated sample was a sandy clay loam of about 17.25% clay, 24.95% silt and 57.8% sand. The EC was excessively high (38.2dSm), the soluble cations were dominated by Na^+ and Mg^{2+}, while the soluble anions were dominated by Cl^-. Percentages of the major oxides of SiO_2, Al_2O_3, Fe_2O_3, TiO_2, MgO, CaO, Na_2O, K_2O, P_2O_5 were 27.5, 11.7, 18.2, 0.22, 13.3, 4.9, 2.2, 1.4 and 0.4%, respectively.

Thus, the aforementioned results indicate that the investigated shale deposits are more suitable for industrial purposes such as civil engineering works.

INTRODUCTION

Shale deposits are frequently available in many areas surrounding the Nile and Valley, as well as in Sinai and some formations of the Eastern and Western Deserts of Egypt (El-Sherif, 1987). Chemically, this complex assemblage consists of a considerable quantity of hydrous aluminum silicates, with less amounts of finely disintegrated quartz, feldspars, carbonates, oxides (mainly of aluminum and iron) and organic matter (Attia *et al.* 1978 and 1985). However, shale deposits are characterized by various physical, chemical and mineralogical properties which are suit for numerous agricultural and industrial uses. The dominance of montmorillonite and in turn, the large surface area of the shale deposits beside of their low content of soluble salts and prevalence of Ca^{2+} on their adsorption sites reveal the possibility of using these deposits for improving hydrophysical, chemical and biological properties of sandy soils as those related to plant nutrition (El-Sherif, 1987). On the other hand, if the shale deposits were dominated by non- expanding clay mineral such as kaolinite, they will be used mainly as a drilling mud for oil and water wells and in civil engineering works etc….. (Attia, *et al.,* 1978).

The current investigation represents a trial towards assessing the most important mineralogical, physical and chemical characteristics of the shale deposits in Abo-Thora area, south west Sinai. Such assessments will be helpful in determining the potential suitable use of such deposits.

MATERIALS AND METHODS

A representative shale deposit sample was collected from Abo-Thor area in south west Sinai, Egypt.

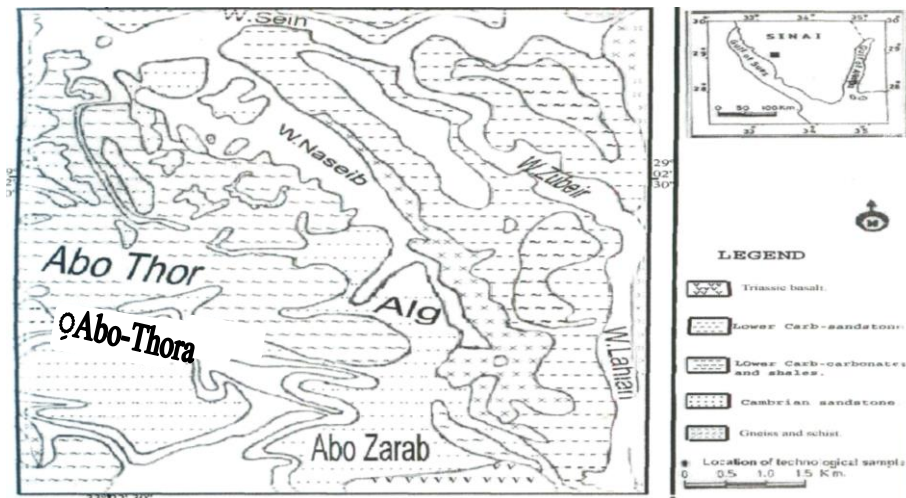Location of this sample is illustrated in Fig. (1).

Figure (1): Geological map of the study area showing the location of the sampled exposures (mainly after El-Assy et al., 1986).

The shale sample was air-dried, gently ground and sieved through a 2m sieve and used for the following analyses:

- Particle size distribution: The procedure adopted by Kilmar and Alexander (1949).
- Calcium carbonate using Collin's calsimeter method, Richard (1954).
- Organic matter content according to Walkely and Black method, Jackson (1967).
- Electrical conductivity (ECe) in the saturated paste extract by using standard conductivity bridge at 25°C and the result was expressed in dSm^{-1}.
- Soil reaction (pH) in the soil saturation paste extract, Jackson (1967)
- Soluble cations and anions in water saturated soil paste extrac, Jackson (1967). and sulphate was calculated by substracting the summation of determind soluble anions from the summation of total cation.

For determination of the major oxides, subsample of the previously crushed one were crushed again to 400 mesh grain size using pw 4018100 philips mini zirconia mil and the major oxides were measured using the conventional wet chemical techniques of Shapiro and Brannok (1962) as follows:

- SiO_2, Al_2O_3, TiO_2 and P_2O_5 were analyzed using unicam $Uv_2/100$ spectrophotometer method.
- Na_2O and K_2O were analyzed by the flamephotometric technique.

- Total iron as Fe_2O_3, whereas MgO and CaO were estimated by titration methods.
- Total organic matter (OM%) was determined by the loss on ignition method at 550°C.

X-ray diffraction analysis was carried out to identify the principal minerals which constitute the investigated samples. A Philips PW 1730 X-ray generator with Ni-filtered Cu K α radiation (λ=1.54 1$\overset{o}{A}$) run at 40kv and 25m$\overset{o}{A}$ and T.C.2 Sec., was used to examine both the clay fractions according to Brown *et al.,* (1979) and Hauff *et al.,* (1982). Three oriented specimens were prepared for XRD analysis: untreated, glycolated with ethylene glycol vapor at 60°C for one hour and heated at 550°C for three hours. The scans were limited to the range from 2θ 2° to 40° using a scanning speed of 2°2θ/min.

Due to the lack of suitable standard clay minerals to be used in semiquntitativ analysis of the samples under investigation, the relative preparation of clay minerals were calculated using Brooks and Ferrel method (1970)and the Triangle Method (Ulrich and Klaus, 1981).

The mineralogical composition of the clay fraction separated from the studied shale sample was carried out by X-ray diffraction analysis. This method is considered among the most essential tools for clay and minerals identification. The purpose of qualitative interpretation of X-ray diffraction pattern is to identify each of the crystalline species present in the clay fraction. The most characteristics diffraction spacing of layer silicate clay arises along the C-axis or in crystallographic symbols, the (001) spacing.

X-ray diffraction pattern is based on the presences of diffraction peaks characteristics for each of the crystalline species present in sample. The intensity of the sharpness of these peaks are dependent not only on the number and the corresponding diffraction plains present in the examined sample but also on the particle size, chemical composition, crystal imperfection, crystal orientation and pre-treatments during clay separation (Whittig and Jackson, 1965). Identification of clay minerals by X-ray diffraction analysis was carried out following the essential principles established by Jackson (1967) and Dixon and Weeds (1977) as follows:

1- Koalinite mineral is identified by presences of very sharp peaks at about 7.1-7.2°A (001) and 3.54-3.57°A (002) in the Mg-saturated samples. These peaks are not effected by glycerolated solution and they disappear upon heating to 550°C for four hours.
2- Hydrous mica (illite) minerals are detected by the presence of the basal reflections at 9.9-10.28°A peaks upon Mg-saturation which remain constant throughout the diffraction treatments.
3- Quartz is detected from the presence of 4.26 and 3.35°A stable diffraction peaks throughout the diffraction treatments.

RESULTS AND DISCUSSION

Particle size distribution of the shale deposit sample revealed that clay percentage of the studied shale sample is 17.25%, while the silt percentage was 24.95% and the total sand percentage was 57.8%. The corresponding textural class of the studied shale deposit sample is sandy clay loam.

The analytical data in Table (1) reveal that the studied shale deposit sample is almost of a natural pH (7.1).

The salinity of the shale sample expressed as electrical conductivity (ECe) and determined in the saturated shale paste extract is excessively high, 38.2 dSm^{-1}.

Table (1): Chemical properties of the shale deposit (saturation paste extract).

Saturation percentage SP%	pH*	EC, dS/m	Soluble ions								CaCO3
			Cations				Anions				
			Ca^{++}	Mg^{++}	Na$^+$	K$^+$	CO$^{3=}$	HCO^{3-}	Cl$^-$	SO$^{4=}$	%
78	7.1	38.2	41.9	64.4	457.0	41.0	-	2.8	569.0	32.5	1.17

* 1:2.5 shale deposits: water suspension.

The dominant soluble cations followed the descending order:
Na$^+$ > Mg^{2+} > Ca^{2+} > K$^+$, while the dominant soluble anions could be generally arranged in the descending order:
Cl$^-$ > SO$_4^{2-}$ > HCO$_3^-$.

The calcium carbonate content did not exceed 1.2%.

In general, the soil chemical composition is used to obtain a general idea about the mineralogical composition of the various rock types especially the shale deposits, where the chemical elements are held in the mineral portion of soils and soil parent materials. Therefore, the contents of elements may give some information about nature of sediments and minerals forming the soil matrix. The studied shale deposit sample was analyzed for the major oxides, SiO$_2$, Al$_2$O$_3$, Fe$_2$O$_3$,TiO$_2$, CaO, MgO, K$_2$O, Na$_2$O and P$_2$O$_5$. Results of analysis are presented in Table (2).

Table (2): The average chemical composition of the studied sample.

Element oxid (%)										
SiO$_2$	Al$_2$O$_3$	Fe$_2$O$_3$	TiO$_2$	MgO	CaO	Na$_2$O	K$_2$O	P$_2$O5	L.O.I.	Total
27.5	11.7	18.2	0.22	13..3	4.9	2.2	1.4	0.40	16.16	99.68

From these results the following characteristics can be outlined:

The SiO$_2$ content exceeded 27% of the shale deposit sample, this may lead us to suggest that the SiO$_2$ is the main constituent of the shale sample, where it may occupy the tetrahedral sites and may be found inserted inbetween as impurities, quartz may occur as fine disseminated crystalline particles in koalinite or deposited with tiny flasks of the clay mineral (Bain & Smith, 1987 and Moore & Reynolds, 1989).

The percentage of Al_2O_3 was about 11.71%. Alumina constitutes a considerable part of the clay mineral complex. Its percentage, generally, reflects the type and amounts of clay minerals presentage. Also, the data obtained reveal that $SiO_2 / Al2O3$ ratio in the studied sample is about 3/1, and this ratio indicates that the deposit under investigation consists mainly of koalinite and semictite (Ahmed, 1999). The Fe_2O_3 content reached 18.2% of the studied shale sample. The relatively high iron oxide content could be attributed to four polygenetic phases:

1- Secondary impregnation and staining by amourphous iron jell in the weathered samples.
2- The presence of different iron oxides mainly as goethite.
3- Iron substituting the octahydral Al^{3+} and Mg^{2+} in the clay minerals structure.
4- Iron replacing Ca^{2+} in the carbonate minerals structure.

At the end, SiO_2, Al_2O_3 and Fe_2O_3 constitute more than 50% of the analyzed sediments. This may indicate that the studied sediment has in general, a ferruginous and argillaceous nature. Minor amounts of TiO_2 were recorded in the analyzed sample and did not exceed 0.22% of its components. Two polygenetic phases may be suggested for the origin of TiO_2 in the studied sediments:

1- Titanium incorporated with detrital minerals such as rutile and ilmenite.
2- Titanium may be substantially concentrated in the octahedral Al^{3+} sites in clays, particularly those of terrestrial origin such as koalinite.

The percentage of MgO reached 13.3% of the studied shale sample. The MgO in the studied shale sediment sample may be present as:

1) Octahedral and interlayer cations in the clay lattice where it substitutes Al^{3+} in the octahedral sites of smectite and illite.
2) Substituting Ca^{2+} in the calcite to form dolomite.

The CaO content of the studied sample was 4.9%. CaO of the studied sediments which may be attributed to the following polygenetic phases:

1- Ca^{2+} incorporated within the carbonate minerals (calcite and dolomite) structure.
2- Ca^{2+} occurs in the interlayer sites of the clay lattice.

The Na_2O content of the studied sample reached 2.2%. Sodium oxide may be present in the shale sample in two distinct forms:

• First, as a constituent of the clay minerals structure especially Na smectite.
• Second, as water soluble salt.

The K_2O content in the shale deposite sample reached 1.4%. This content of K_2O in the studied area may be due to presence of K-bearing hydrous mica.

P_2O_5 content reached 0.4% of the studied shale deposit sample, the low content of P_2O_5 of the studied sample may be due to its low content in the natural sediments forming this shale deposit sample.

In general, the variation in the SiO_2 and Al_2O_3 in the bulk sample may reflect the relative abundance of quartz and aluminium silicate bearing minerals. On the other hand, Na_2O and K_2O contents may reflect the type of feldspar present in the shale sample. The contents of CaO and Na_2O may be

attributed to the presence of calcite and gypsum on one hand and presence of halite on the other hand, respectively.

The loss on ignition (L.O.I) is a measure of organic matter content, chemically combined water and CO_2 derived from carbonate. Its percentage was 16.6% of the studied shale deposit sample. This high value could be attributed to the presence of carbonates (calcite and dolomites) in substantial amount.

Mineralogical analysis of the clay fraction separated from the shale sample.

X-ray diffraction pattern of the clay fraction separated from shale sample representing Abo-Thora area is shown in Fig. (2).

Data reveal that, X-ray diffraction patterns of the clay fraction separated from the studied sample are dominated by koalinite followed by hydrous mica (illite), while accessory minerals are dominated by quartz.

The aforementioned results point out that the investigated shale deposits are not quite suitable for improving physical and chemical characteristics of sandy soils due their high contents of soluble Na^+ on one hand and the dominance of kaolinite , where cation exchange capacity is relatively low ranging from 3-15 $Cmol_C$ kg^{-1} on the other hand. However, these deposits seem to be more suitable for the industrial works.
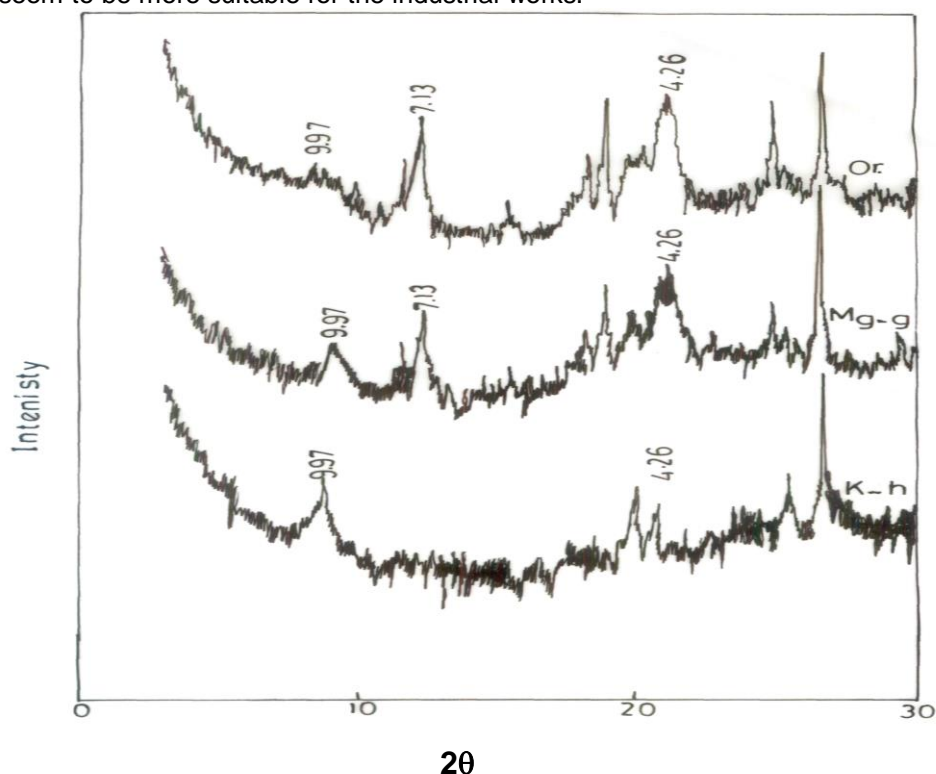

Fig. (2): X-ray diffraction pattern of the clay fraction separated from original sample.

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الملامح الكيماوية والمعدنية لرواسب الطفلة في منطقة أبوثور جنوب غرب سيناء

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تهدف الدراسة إلي عمل تقييم للخواص الكيميائية والمعدنية لرواسب الطفلة بمنطقة أبوثور المتواجدة بجنوب غرب سيناء مصر. حيث كان الهدف من ذلك هو تحديد الاستخدام الأمثل لمثل هذا النوع من رواسب الطفلة كما أوضحت نتائج التحليل بأشعة X سيادة الكاؤولنيت والأليت بين معادن الطين وسيادة معدن الكوارتيز بين مجموعة المعادن المصاحبة. كما أوضحت نتائج التوزيع الحجمي لحبيبات رواسب الطفلة أن قوامها طميية طينية رملية حيث بلغت نسبة الطين ١٧,٢٥% ، والسلت ٢٤,٩٥% أما الرمل فكان ٥٧,٨%. كما أوضحت نتائج دراسة الخواص الكيميائية لهذه الرواسب أنها تحتوي علي نسبة عالية من الأملاح بلغت ٣٨,٢ ديسيمنيز وكانت أكثر الكاتيونات الذائبة سيادة هو الصوديوم يليه الماغنسيوم أما أكثر الأنيونات سيادة فكانت الكلوريد كما أوضحت نتائج التركيب الكيميائي المتمثل في الأكاسيد الأتية SiO_2 , Al_2O_3 , Fe_2O_3 , TiO_2 , MgO , CaO , Na_2O , K_2O , P_2O_5 أن نسبتها كانت كما يلي ٢٧,٥ ، ١١,٧ ، ١٨,٢ ، ٠,٢٢ ، ١٣,٣ ، ٤,٩ ، ٢,٢ ، ١,٤ ، ٠,٤% وبناء علي النتائج السابقة فإن رواسب الطفلة لمنطقة أبوثورا لا تلائم الاستخدام الزراعي وإن كانت سيادة الكاؤولنيت لها ترجح أفضلية استخدامها صناعياً