International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.9, No.10, pp 241-249, 2016

Morphological characteristics and chemical properties of dominant geological clay deposits for agriculture in Egypt

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Abstract : The overlooking of the geological clay deposits distribution in Egypt gives us idea about their deposition locations which are mainly in oases and in deep and extensive depressions, cut down nearly to sea level. Successive sedimentary formation dipssteadily at a very small inclination. This makes it such that each type has a wide outcrop. The total area of these geological clay deposits exposed as surface outcrop is about ~ 41,484 km² which represent about 4% of the total area of Egypt. These deposits have relatively high capacity to retain water and nutrients and mainly located in the desert parts of the country. For these characteristics they considered as important land resources from agriculture point of view. The inventory of such land resources is rather essential to help the decision makers in propose planning. This inventory could be achieved throughout an integrated soil survey and classification plan. This plan should include field survey, chemical, physical, mineralogical and micromorphological analyses as well as, accurate mapping with suitable scale. The current study aims to identify the morphological and chemical characteristics of these deposits and differentiate between shales and mudstones of the studied geological clay deposits in Egypt. The study showsthat the same clay deposits are distributed in different locality in the country. They are named as Qarara, Beni Suef, Qasr El Sagha, Wadi Rayan, Maadi, Dakhla, Quseir, Esna, Maghagha, Pale grey, Dark grey and Wadi Abbad clay deposits. Qarara and Beni Suef clay deposits consider as shale deposits, while the rests are mudstones. The studied chemical parameters show that Dakhla, Maghagha and Wadi Abbad deposits are highly recommended for agriculture investments. While Quseir clay deposit is moderately; Wadi Rayan, Maadi, Esna, and Dark grey shale are low. Qasr El Sagha, and Qarara shale areas are very low suitable for agriculture. Beni Suef and pale grey shale areas are with extreme limitations for agriculture.
Keywords: geological clay deposits, names, morphology, chemical composition, Egypt.

Introduction

The overlooking of the geological clay deposits distribution in Egypt gives us idea about their deposition locations which are mainly in oases and in deep and extensive depressions, cut down nearly to sea level. Successive sedimentary deposi dips steadily at a very small inclination. This makes it such that each geological clay deposit has a wide outcrop.[1]showed that Qasr El Sagha clay in Fayoum region was mainly smectitic clays consists of claystone, silty claystone, clayey siltstone and silt mudstone. Particle size analysis showed that the clay deposits consist of 64% clay, 32% silt and 4% very fine sand. XRD analysis indicates that the main clay mineral present is montmorillonite followed by kaolinite [2].[3] reported that Maadi clay deposits are made up mostly of shales with intercalated limestone. The clay is grayish green, highly calcareous, fossiliferous and partly sandy. Dakhla clay deposit is assigned by[4] as an upper Maastrichtin age; grey in colour, becoming marly at base and recognized in Dakhla, Kharga, Kurkur, Dungul scarp, the Nile Valley, Quseir and Safaga areas. He mentioned that clay deposit consists of two units, the lower part rich in calcareous material and the upper shale unit.[5] mentioned that the Quseir clay deposit is related to the Companion age, extent in Quseir area; also noted in other Stable Shelf areas (Wadi Qena, Nile Valley and Oases). [6] described Quseir clay deposits are varicolored clay deposit, siltstone and flaggy sandstone containing freshwater gastropods. The term of Esna clay deposit was first mentioned as such by both [7,8]**.** [9] stated that the term Esna clay deposit was given by Barron and Beadnell to the series of unfossiliferous clay and shale which they mapped from Esna to Qena. Several geologists have discussed the petrography of Maghagha clay deposits and their mineralogy[6] showed that this deposit is an open marine limestone and marl with planktonic fauna and in the east underlain by shale. [6] showed that Beni Suef clay deposit is marine clay, marl and limestone, were located in Beni Suef area.[3] found that Qarara clay deposit made up of a basal 20 m thick, related to the middle Eocene age. While its origin is related to marginal marine to marine deposits, shale at base, grading into siltstone with occasional carbonaceous bands and it is partly coeval with Rayan formation [6]. A comprehensive study on lower Esna clay deposit has been carried out by [10]. They found that from their LANDSAT-1 satellite images interpretation, the lower Esna clay deposit could be differentiated into two members, namely the *dark grey* and *pale grey* deposits. They also indicated that Wadi Abbad sediments form small outcrops mainly in the northeastern part of Tushka basin area, but they extend further northeastwards to form larger outcrops especially at its type locality, Wadi Abbad. This clay deposit has been observed also at some places along the southwestern side of Kiseiba Escarpment but mostly covered by scare of the overlying sediments.

Materials and Methods

Twelve geological clay deposits samples collected for laboratory analyses, representing different geological clay deposits types in Egypt (Fig.1). Samples crushed, grounded and used for chemical and particle size distribution analyses. While the undisturbed samples used for the morphological identification according to [11] guidelines. The disturbed samples subjected to the following determinations according to[12]**.**The chemical composition of saturated soil extract carried out following the methods described by [13]as follows :the electrical conductivity of the saturated paste extract, using a conductivity bridge. It expressed in dS/m at 25 °C.

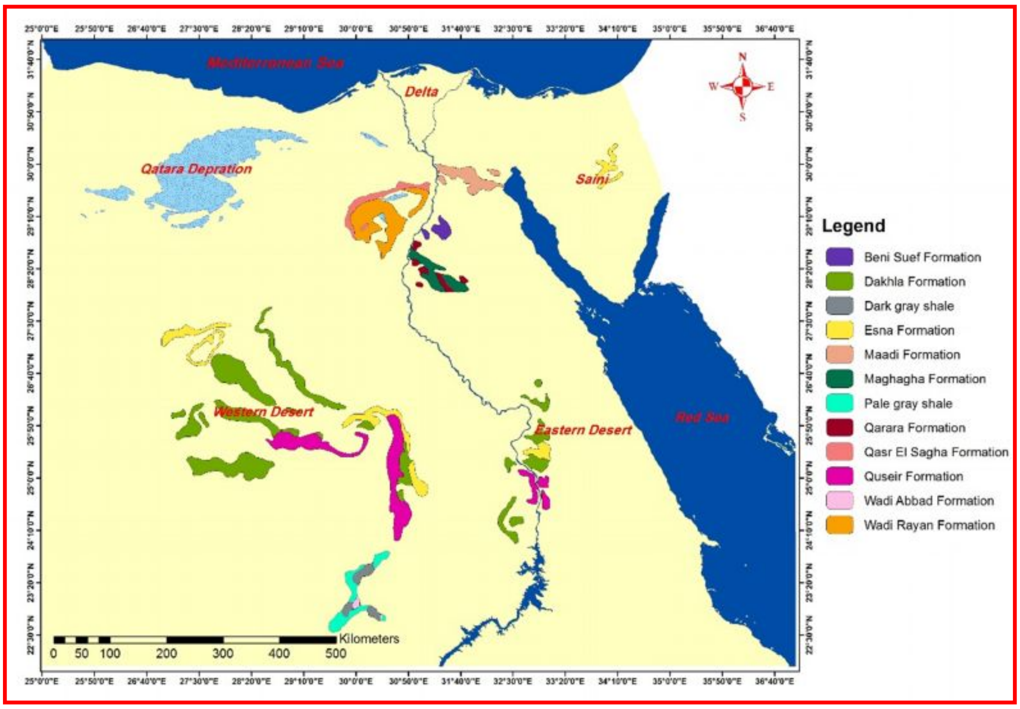

Fig. (1) : The distribution of geological clay deposits, as extracted from the geological map of Egypt after [14] pH in 1:2.5 suspension, measured with a Beckman pH-meter. Organic matter content (OM%): determined by Walkely and Black rapid titration method according to[15] Total calcium carbonate content ($CaCO_3$%) by calcimeter. Gypsum($CaSO_4.2H_2O$%)determined by extracting gypsum in 1:50 soil-water extract [16].Amorphous iron and manganese oxides according to the method described by[17]. Iron and manganese determined by atomic absorption equipment. Cation Exchange Capacity (CEC) measured using method described by[12].Particle size distribution by pipette method according to[18]. Texture class recorded according to [12]triangle.

Results and Discussion

Twelve geological clay depositsnamed as Qarara, Beni Suef, Qasr El Sagha,Wadi Rayan, Maadi, Dakhla, Quseir, Esna, Maghagha, Pale grey, Dark grey and Wadi Abbad clay deposits in Egypt[19].**Dakhla clay deposits:**The maximum depth of this sediment is about 130 m thick [20]. Landscape is varied from one area to another. Dakhla clay considered to be slightly hard, partly fissile. The sediment is generally fossiliferous, occasionally ferrugineous[21]. The boundary between layers is diffuse and the stratification was not observable. The dominant clay colour is olive which ranged from pale olive to grayish olive and sometimes bright yellowish brown, while reddish brown, reddish and yellowish brown are the main colour characterized the mottles constitute. Structure is subangular blocky (Fig. 2).Table (1) indicate that the Dakhla clays are distinctly saline (EC is 8.1 dS/m).$CaCO_3$% content is low (4.3%). Free of gypsum. pH tends to be neutral (8.1). Amorphous Fe_2O_3 value is 915 ppm. MnO content is130 ppm. CEC is 48cmol (+)/kg. Table (2) show that Dakhla clay content is high as 79.7%.

Fig. (2). Dakhla clay, considered to be slightly hard, partly fissile. The sediment is generally fossiliferous, occasionally ferruginous. The boundary between layers is diffuse and the stratification was not observable. The dominant colour of these formations is olive which ranged from pale olive to grayish olive and sometimes bright yellowish brown.

Table (1):Chemical composition of studied geological clay deposits

Clay deposits name	pH 1:2.5 H_2O	EC dS/m	TSS %	O.M. %	$CaCO_3$ %	Gypsum %	CEC cmo(+)/kg	Amorphous oxides(ppm)	
								Fe_2O_3	MnO
Dakhla	8.1	8.1	0.4	0.1	4.3	0.0	48	915	130
Esna	7.8	26.5	1.8	0.3	24.5	9.9	25.7	775	167
Maadi	7.5	190.7	12.0	2.7	11.0	4.7	42	1830	141
Maghagha	7.3	145.7	9.2	1.9	3.5	8.6	54	14533	225
Beni suef	7.5	171.9	10.8	2.5	12.0	20.3	66	3392	144
Qarara	6.9	82.5	5.1	0.4	2.5	12.1	55	17176	113
Qasr el Sagha	8.0	43.5	2.6	0.2	2.6	5.0	33	10495	127
Wadi el Rayan	7.9	24.0	1.5	0.2	2.3	2.8	45	1992	118
Quseir	7.7	156.6	9.5	1.0	4.0	3.2	40	4146	163
Pale gray	7.0	17.3	1.1	0.8	1.4	8.6	71	14214	215
Dark gray	7.0	38.0	2.6	0.9	1.1	6.9	76	15829	237
Wadi Abbadi	7.4	7.0	0.3	1.1	1.3	7.4	77	378	136

Esna clay deposits:

The colour is grey. These clays are mainly hard, occasionally very hard and extremely hard, has a tree-like shape as a finger print on the ped faces. Salty spots and patches of gypsum are encountered. It is rich in carbonaceous material, which inherited from the parent rock [22]**.** The stratiform mode of deposit has observed in Esna clay in various localities, indicated by the lateral extension with planar shape of the platy structure as in (Fig.3). Table (1) show that salt content of Esna clay is 26.5 dS/m. It is mainly calcareous and $CaCO_3$%is 24.5%.[22] reported the same results for Esna deposits collected from Gebel El Aheigba at north Sinai. Gypsum content is 9.9%. Value of pH is7.8. pH value is slightly alkaline due to its higher $CaCO_3$ content as mentioned above. CEC is well affected with $CaCO_3$% and associated well with the amorphous Fe_2O_3. The value of CEC is25.7 cmol(+)/kg. Amorphous Fe_2O_3 content indicates that there are positive relationships between the clay fraction content and amorphous iron content in most cases. Value of amorphous Fe_2O_3 is 775ppm. Value of amorphous MnOis 167ppm. Esna deposits is silty loam. Clay content is 22.1%.[23]found montmorillonite clay mineral is the dominant clay mineral in Esna shale. These results are in agreement with [22] who showed that smectite was relatively the main clay mineral of the studied Esna deposit in east Central Sinai. [4] indicated that the Maadi deposits has a maximum thickness of about 64 m at desert east Maadi, south of Cairo. This type of deposit is intercalated with brown limestone, sand and shale. Maadi clays considered to be hard to very hard. The stratification of layers is very clear with abrupt and wavy boundary due to the presence of limestone layer(Fig.4). The presence of moderately developed medium and coarse platy structure and thin to very thin salt and gypsum layers between these plates are observed. Moreover, mottles of light olive, brown, dark reddish brown and dark red are common. Table (1) shows that Maadi clay is highly saline, EC 190.7 dS/m. It is worth mentioning that the underlying layer is hard limestone and the surrounding plateau has the same origin. Maadi clay tend to be neutral and pH is7.5.Total $CaCO_3$% content is 11.0%. The source of the lime content is possibly the windblown calcareous sand and silt from the surrounding desert plateau. Gypsum content is low,4.7 %. Maadi deposit is relatively high in organic matter content, 2.7%due to its high salt content, which inhibits the decomposition process. Table (1)indicate that Esna clay have 1830 ppm Fe_2O_3 and 141 ppm MnO and CEC is 142 cmol (+)/kg. Texture of Esan deposit is silty clay loam(Table2) and clay content is 39.5 %.

Table (2):Particle size distribution and texture class of studied geological clay deposits.

Clay deposits name	Particle size distribution			Texture class
	Clay %	Silt %	Sand %	
	<2μ	0.05-0.002 mm	2-0.05 mm	
Dakhla	79.7	18.3	4.9	Clay
Esna	22.1	53.4	24.6	Silty loam
Maadi	39.5	43.0	17.6	Silty clay loam
Maghagha	69.5	29.2	1.4	Clay
Beni suef	63.6	16.3	20.1	Clay
Qarara	52.7	38.7	9.6	Clay
Qasr el Sagha	27.6	31.0	41.3	Loamy
Wadi el Rayan	39.8	24.5	35.8	Clay loam
Quseir	88.7	10.1	1.2	Clay
Pale gray	67.4	23.7	9.0	Clay
Dark gray	75.0	24.6	0.3	Clay
Wadi Abbadi	75.1	19.6	5.4	Clay

Mokattam group deposits:

According to[4] Mokattam group deposits consists of three deposits named as Maghagha, Qarara and Beni Seuf clay deposits. These deposits have various colours as the following: Maghagha clay is light brownish grey and light yellowish brown (Fig.5). Beni Suef clay is light grey and brownish yellow(Fig.6). While Qarara clay is grayish brown and pale brown in colour and light grey colour(Fig.7). Mode of stratification is observed well in the different deposit as indicated by the platy structure (Figs.5 & 6 and 7) and scattered gypsum precipitation as thin sheets (Fig.5). Table (1) show salt content are extremely high in these deposits, EC values are 82.5, 145.7and 171.9 dS/m for Qarara, Maghagha and Beni Suef deposits respectively. Total $CaCO_3$%content of Maghagha and Qarara depositsare low,3.5 and 2.5% respectively. While Beni Suef clay is 12 %, which most probably took place due to weathering of the calcareous rocks of Gebel Qarara [24] Gypsum content is considerably high in Mokattam group. Maghagha deposit is characterized by gypsum precipitations as thin scattered layers (Fig.5), 8.6%. Beni Suef clay gypsum content is 20.3%. While Qarara clay isas a thick fluffy layer ,12.1%.pH values indicate the neutral reaction in most of the samples in Mokattam group. Values of pH are 6.9in Qarara clay, 7.3 Maghagha clay and 7.5 in Beni Suef clay. Acid reactions are recorded in Qarara clay due to relatively high content of gypsum coupled with low content of calcium carbonate in addition to its high content of amorphous iron 17176 ppm. CEC of Maghagha and Qarara clays has always the same valuesof 54and 55cmol(+)/kg. While it is 66 cmol(+)/kg in Beni Suef clay. Amorphous Fe_2O_3 and MnO contents (Table 1) indicate that Maghagha depositshas a high amount of amorphous MnO,225 ppm compared with Beni Suef and Qarara clay which has lower amounts,144 ppm and 113 ppm respectively. While amorphous $Fe_2O_3$is concentrated in Qarara and Maghagha clay, 17176 and 14533 ppm,respectively.On the other hand, Beni Suef clay has lower values,3392 ppm.Mokattam group are clayey (Table 2). Clay fraction percent are69.5;63.6 and 52.7% in Maghagha, Beni Suef and Qarara clay respectively.

Fig. (3). Esna clay, rich in fossils. The black things in this shale are carbonized fossil plant materials, mainly plant stems has a tree-like shape as a finger print on the ped faces. Esna clay is grey which characterize this type of sediments and it is mainly hard, occasionally

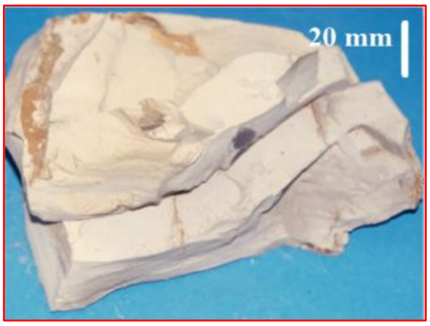

Fig. (4). Maddi clay, silty clay loam; strong, very coarse, platy. The stratification is very clear due to the presence of completely different colours.

Fig. (5).Maghagha mudstone is light brownish grey and/or light yellowish brown colour. The close-up view shows soft and hard segregation, fine, irregular and flat, white and translucent accumulation of gypsum and salts

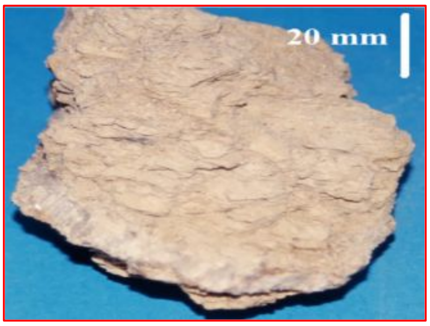

Fig. (6). Beni Suef clay characterized byclastic, splintery texture and muddy appearance, light grey and brownish yellow colour, common, medium, elongate and flat, hard, translucent salt and gypsum crystals.

Qasr El Sagha and Wadi Rayan clay deposits:

Field observations indicate that Qasr El Sagha clays differs in both thickness and composition from one area to another in Fayoum region. [25] pointed out that the deposit greatly reduced from its maximum thickness of about 180m at Gabel Qasr El Sagha to about 40m at Qaret El Faras. The landscape is nearly flat and covered with a thin sheet of wind-blown sand on the surface. This type of deposit considered to be extremely hard to hard. The stratification of layers was not clear with wavy to irregular boundary.A wide range of colours could be marked in this sediment from weak red, bright brown and light yellow. Coarse to very coarse subangular blocky structure are dominant (Fig.8 &9). Table (1) shows that Qasr El Sagha and Wadi Rayan clays are highly saline,EC 43.5 and 24.0 dS/mrespectively. pH value is 8, Qasr El Sagha and 7.9, Wadi Rayan clay. Total $CaCO_3$%content is relatively low, <3 %. Gypsum appear in Qasr El Sagha clay as,5.0%. While it low in Wadi Rayan clay ,2.8%. Organic matter is extremely low <0.5 %, due to absence of vegetations and fauna. The values of amorphous Fe_2O_3 and MnO are low. CEC associated withclay percent as well as amorphous materials. CEC values are 33 cmol(+)kg for Qasr El Sagha clay and 45 cmol(+)kg in Wadi Rayan clay.Table (2) shows loamy and clay loam textures of these deposits. Qasr El Sagha and Wadi Rayan contain 27.6 and 39.8 % clay, respectively. Similar result was reported by[1]for Qasr El Sagha deposits.

Quseir clay deposit:

It**is** characterized by various shades of red, yellow and olive colours. Occasionally is colour-banded or mottled. It is mainly moderately hard, rarely fissile, waxy in places and invariably ferrugeneous. Intersecting gypsiferrous veinlets and or salt spots and patches are encountered, have a stratiform mode of occurrence, a lateral extension with rather irregular thickness, planar shape and a carbonaceous matter content (Figs.10).Table (1) indicate the very high salt content in Quseir sediment, EC value is 156.6 dS/m. $CaCO_3$% and gypsum precipitation is low. pH,values is slightly alkaline,7.7. CEC is associated well with the clay percent. Amorphous iron content is 4146 ppm, while amorphous manganese 215 ppm. CEC value is 40cmol(+)/kg with 88.7 % clay percent (Table 2).

Tushka Basin clay deposits:

Tushka Basin area occupying the South Western portion of Egypt, the lithologic, stratigraphic and structure aspects of south Egypt are reported by [26,27]**.** Three samples representing the most dominant deposits are selected. They are named as pale grey, dark grey and Wadi Abbad clay deposits. Colour of these deposits is one of the main important morphological characters used to differentiate between the various deposits. Pale grey deposits have a light grey colour (Fig.11). Dark grey deposit has a grey and greyish olive colour (Fig.12) and both deposits have a sharp yellowish brown mottles. Wadi Abbad clay is completely different from those deposits due to the specific stratified mode of occurrence and from the colour variations, which are light grey(Fig.13). Generally, these deposits are slightly hard to hard. The exposed deposits of Tushka Basin area have almost flat topography.Table (1) shows that Dark gray deposit is extremely saline ,38dS/m, while pale gray deposit is moderately saline,17.3 dS/m and Wadi Abbad deposit is slightly saline, 7.3 dS/m. Tushka Basin deposits, have a very low content of $CaCO_3$, 1.1 -1.4%. Gypsum presents also as scattered thin layers Wadi Abbad deposit with a value of 7.4 %. While irregular distributions are occurred in Dark grey and Pale gray clay with a values of 6.9 & 8.6% respectively. pH are neutral and CEC are >70 cmol (+)/kg in Tushka Basin deposits. Amorphous iron oxides reflect its influence on the deposit colour as mentioned. Amorphous Fe_2O_3 content are high in Pale and Dark gray deposits as 14214 and 15829 ppm respectively. While it is low in Wadi Abbad clay as 378 ppm. Amorphous MnO are 215, 237 and 136 ppm in Pale grey and Dark grey and Wadi Abbad clay. Tushka Basin deposits have a heavy clay texture with less than 30% silt and sand contents in most cases.

Fig. (7). **Qarara**clay ischaracterized byclastic, splintery texture and muddy appearance, grayish brown and pale brown and/or light grey colour, silty clay, weak, very fine and thin platy; very friable; very sticky and plastic. It is breaks into thin pieces with sharp edges.

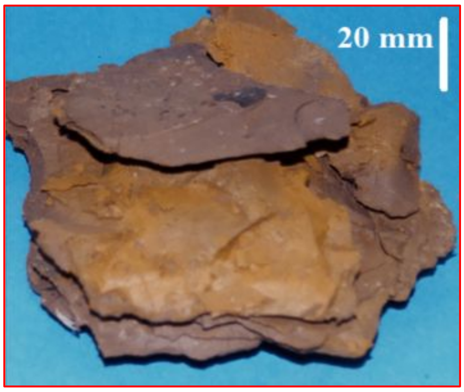

Fig. (8).Qasr El Sagha clayis a red with greenish mottling. Both colors indicate iron oxide coatings on the clastic grains. The red color indicates fully oxidized iron whereas the green color indicates iron coatings with partially reduced iron.

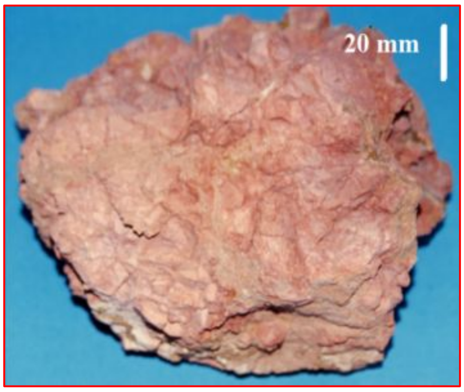

Fig. (9). Wadi Rayan clay is an olive yellow, reddish brown colour. prominent, few, medium, dusky red mottles.

Fig. (10).Quseirclay showed various shades of red, yellow and olive colours. Occasionally is colour-banded or mottled. These deposits are mainly moderately hard, rarely fissile, waxy in places and invariably ferrugeneous. Intersecting gypsiferrous veinlets and or salt spots and patches are encountered.

Fig. (11). Pale grey clay has a light grey colour. Have a sharp yellowish brown mottles.

Fig. (12). Dark grey clay has a grey and grayish olive colour.have a sharp yellowish brown mottles.Few, soft segregations, medium, flat and irregular, white gypsum and salts crystals.

Fig. (13). Wadi Abbad clay, is a mudstone: instead of breaking into thin chips and plates, it breaks into irregular blocks.

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