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## Applied Geological Studies of Some Sinai, Egypt Ore Deposits to Utilized as Extender Pigments for Paint Manufacture

**Abstract:** In this present study an investigation is carried out to search for the appropriate local substitutes for the imported paint pigments, samples collected from North, Central and South Sinai includes white sand, coal, quartz, kaolin, gypsum, limestone, chalk.

The collected specimens were crushed and ground to powder varying in size between “5-50 um” for testing using laboratory mill.

Several laboratory tests were accomplished to identify and evaluate the decorative and protective paint pigment including specific gravity, moisture content, pH value, oil absorption, x-Ray analysis, microscopic studies and others to prove that the selected local ores possess the required characteristics for pigments that can be utilized in producing the paint material in Egypt.

The study indicates that the following local ores can be utilized as extender pigments to produce paint materials “calcium carbonate of south Sinai, white sand of Um Bogma, and gypsum of Ras Malaab.

The estimated reserves of the studied ores give an indication of presence the sufficient quantities for stream production of the some paint pigments needed for Egyptian market.

**Key words:** Field geology; Paint pigment; Extender pigment; Microscopic studies; X-ray analysis; Chemical analysis; Sinai; Egypt

### 1. INTRODUCTION

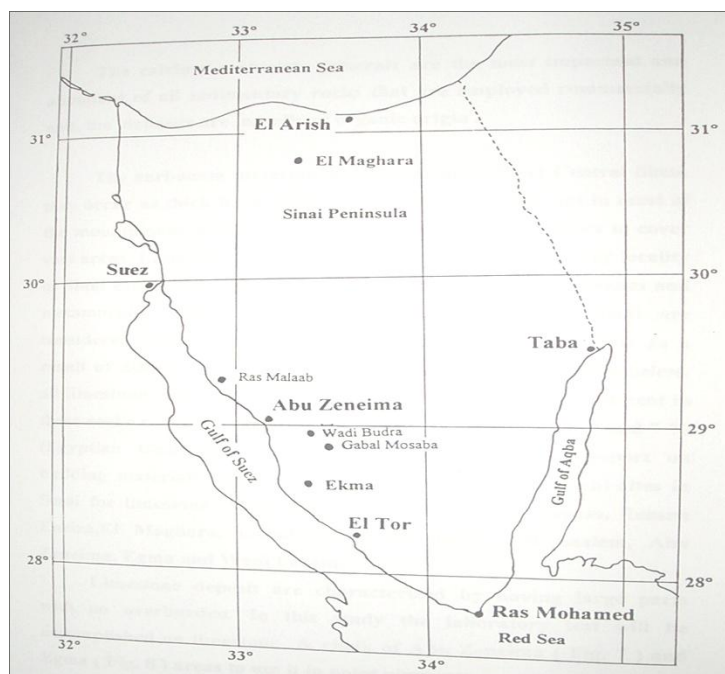
Modern paints have a complicated composition, their components are: binders, Pigments, Extenders, Solvents, additives (Paint handbook, 1981, Jotun coating manual, 1994, Industrial paints, 1964, Hempels paint coatings seminar, 1988 and Handbook of paint raw materials, 1989).

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The northern part of Sinai is covered by Meso-cenozoic sediments, among these, the coal-bearing Jurassic sediments are of particular value, carboniferous sediments with some of coal seams, manganese ore and white sand horizons outcrops in west central Sinai.

The ores of Sinai studied in this research incorporate: limestone, gypsum, kaolinite, white sand and coal (Fig.1)

Gaber (1999) studied some ores forming paint pigments in south Sinai can be utilized in producing paint pigments e.g. natural calcium carbonate, gypsum, white sand and kaolin. The main target of this study is to search for appropriate local substitutes for the imported paint pigments which may produced by ground of local ores to specified grain size and used as a part of protective and decorative paint components for petroleum production facilities protection.



**Fig. 1: Location Map of Studied Areas (•)**

## 2. METHODS AND TECHNIQUES

In the present study, a total of 50 collected samples were studied. The following is a brief description and techniques of the studies ores of Sinai, Egypt e.g limestone, chalk, gypsum, kaolin, white sand and coal.

### 2.1 Natural Calcium Carbonate

The name “whiting” for natural calcium carbonate originally referred to a very finely pulverized form of chalk but the terms now used more broadly to include all finely divided carbonates that are derived from high-calcium or dolomitic limestone (Ehlers, E.G. and Blatt, H., 1982) however, the important deposits of true chalk consist of pure amorphous carbonate formed of microscopic remains of small marine animals e.g. Foraminifera, Globigerina and Textularia.

The calcium carbonate minerals are the most important and abundant of all sedimentary rocks that are employed commercially and, the deposits are usually of organic origin.

The carbonate materials are abundant in West Central Sinai; they occur as thick beds of large extension. Therefore, limestone reserves in Sinai are considered unlimited. Examples of important sites for limestone, from north to south are Gabal Libna, Um Mafroth, El Hegam, Reasan Eneiza, El Mostan, El Maghara, El Halal, Ekma, Wadi Nukhul (Fig. 2 & 3), Wadi Ferain, and Wadi Matullah. Limestone deposits are characterized by having large parts of it with no overburden. The limestone differs in their hardness as a result of differences in their degree of crystallization. Nevertheless, all limestone could be considered hard to very hard, CaO per cent in these rocks range from 40 to 55.6 % and MgO between 0.0 and 7 % (Egyptian Geological Survey and Mining Authority, report on building materials of Sinai, 1994 and Soliman, 1998 ).



**Fig. 2: Limestone of Wadi Nukhl, South of Sinai**



**Fig. 3: Limestone of Gabal Egma, South of Sinai**

## **2.2 Gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ )**

Ras Malaab gypsum which will be used in the present work, occur on the Eastern shore of the Gulf of Suez at lat. 29°10' N & long. 32°50' E , 110 km south of Suez. The deposits are located close by the roads network in Sinai.

## **2.3 Kaolin**

The clay deposits represent a number of localities north and south Abu Zeneima. The north Abu Zeneima area includes Gabal Hazbar and Khaboba . South of Abu Zeneima area includes Wadi Abu Natash, Farsh El ghoazlan , Wadi Budra and El Dehesa . The kaolin reserves in Abu Zeneima district are estimated to be about 1,453,000 tons (Rashed & Amer, 1994).

The suitable kaolin for paint pigments are found in Farsh El Ghozlan and Dehesa . It contains more than 35 % alumina, silica less than 45 % and L.O.I about 14 % . Many authors explain the origin of kaolin deposits, it is suggested that, these deposits were derived from the weathering mantle of the underlined feldspathic rocks of the basement complex ( Boulis & Attia, 1994 ) and ( Abdel Razek, 1994). The representative samples were collected from Wadi Budra, Farsh El Ghozlan to determine the physical, optical, chemical properties to be utilized in manufacture of paint pigment. The mineralogy of the clay deposits South Abu Zeneima of Farsh El Ghozlan and Wadi Budra indicates that the main clay mineral is kaolinite & montmorillonite.

## **2.4 White Sands**

White sand occurs at several localities in Sinai namely Gabal Dalal, Wadi Maktab, Wadi Mussaba, Khabouba, Abu Kafas, Abu Natash at Abu Zeneima area and the area of El Gunna plateau in south Sinai. The ores of both north and south of Sinai belong to lower the Cretaceous and occurs in the form of lenticular beds that range in thickness from centimeters to 15 meters or so, with alternating beds of ferruginous sandstone, shale or kaolin. The ore reserves are huge, and exceed billions of tons but not yet evaluated and the  $\text{SiO}_2$  content is 99.54 % (Attia, Ghaalib, 1960) and (Geological Survey report on glass sand, 1994). The deposit has little or no overburden, and is exposed in extensive areas. Also many active quarries operated by public and private sector firms are operating in Abu Darag and Wadi Dakhal near Zaafarana on the Red Sea coast. The sands satisfying for production of paint pigment belong to the Malha formation of Cretaceous age and the content of  $\text{SiO}_2$  is ranging from 99.2 to 99.5 % (Hussein, 1990).

## **2.5 Coal**

Prospecting for coal carried out in 1958-1962 resulted in the discovery of the coal deposits of Maghara, Ayun Musa, and Wadi Thora in Sinai. Exposed coal deposits are known in two areas of Sinai, the Maghara district and Um Bogma district. Subsurface coal seams and coaly sediments have recorded in oil exploration well in the Gulf of Suez region and in the Western Desert. At present, the only deposit considered economic is that of Maghara in

north Sinai (Hussein, 1990). The occurrence of Maghara coal deposit was reported in the Bathonian sediments on the north western side of the Maghara anticline. The estimated reserves are about 51.8 million tons in a 30 km<sup>2</sup> area.

### 3. LABORATORY TESTS

Fifty ditch samples were collected from south and northern Sinai represent to carbonates, gypsum, white sand, and kaolin and coal ores, from which 25 representative samples were selected for thin section (10), scanning (5), x-ray (5) and chemical analysis (5).

The X-ray diffractograms were run using a Philips Diffractometer type PW 1730 used throughout this study.

The SEM model Philips XL 30 attached with EDX unit, with accelerating voltage 30 k.v., magnification 10 X up to 400,000 X and resolution for w. (3.5 nm) was used in the study of the studied samples were collected from Sinai, Egypt.

Also all samples were subjected to another number of tests to determine their suitability for application as pigments to be utilized in manufacturing of paints

These tests are explained and discussed in a number of text books and manuals including; Introduction to paint chemistry and principles of paint technology(1991), Encyclopedia of the chemical “ Inorganic pigment “ ( 1992 ), Paint Handbook ( 1981 ), Paint technology manuals part six pigments dyestuffs and lakes ( 1966 ), Handbook of paint raw materials ( 1989 ), The American Standard for Testing Materials ( ASTM ), and El Sawy, 1994. The tests may be summarized in the following: Specific gravity – ASTM D 153, Moisture content – ASTM D 280, Oil absorption – ASTM D 281 & D 234, Particle size, Particle shape, Hydrogen ion concentration ( pH value ) – ASTM D 2196, Matter soluble in water, Hardness ,Color of powder, Brightness, and Performance application tests of paint products (Fineness test “ Hegman scale” - ASTM D 1210 ), Viscosity test- ASTM D 562, Flow time - ASTM D 1200 , Wet film thickness, Dry film thickness, Opacity or hiding power ASTM D 2805, Gloss ASTM D 523, Flexibility or bend test, Adhesion, Pinhole or porosity test ASTM D 3891 ) as per indicated in evaluation sheet of studied ores (table 3, 4 & 5).

### 4. RESULTS AND DISCUSSIONS

In South Sinai area there are numerous ores that can be utilized in producing paint pigments as indicated in (table 1, 2, 3, 4 & 5) as follows.

#### a. Natural Calcium Carbonate (Limestone & Chalk)

The wide availability and the low cost of CaCO<sub>3</sub> make it the most widely used as extender pigments today. They are used in all kinds of decorative and protective coating.

The carbonate ore deposits are abundant in South Sinai, Abu Zenima and Egma. Abu Zenima carbonates were formed at the Miocene age (Fig. 2& 3). The CaO content in the carbonate rocks range from 51.0 % to 53.0 %. This means that the CaCO<sub>3</sub> % is more than 95 %. They possess the following physical properties; high brightness (96 % to 97 %), specific gravity (2.633 to 2.693), low oil consumption (26 to 40), pH (8), low moisture content (0.33% to 0.70%), low matter soluble in water (0.10% to 0.375%) and viscosity (90 to 112.5 cp.). These results comply with the standard required for paints Handbook of Paint Raw Materials,1989 and ASTM D 1199'. The petrographic study of the Miocene carbonate revealed that Abu Zeneima “Wadi Nukhul“ carbonate rocks are classified as biomicrite limestone, these limestone are silty and fossiliferous, they contain abundant iron oxides and have low porosity.

The SEM indicates that the composition of carbonate is mainly calcite crystal with very fine grain size suitable for paint industry. These carbonates are used in producing primers based on long alkyd. Chemical treatment may be needed with some types of limestone to remove impurities like silicate and iron oxide to be utilized as a whitening agent.

#### b. Gypsum

The principal significance of the anhydrous calcium sulphate pigments is its application in the resin compounds of the polyester / fiberglass type as an extender, in combination with high strength prime pigments in paint system.

The high grade gypsum deposits of Ras Malaab, possesses calcium sulphate content ranging from (93 % to 98 %), pH (7.65), matter soluble (0.65), high brightness (98 %), low oil consumption (20g/100g), specific gravity

(2.325), hardness (2.0 on the Moh's Scale) and relatively high moisture content (7.0 %). These results comply with the requirements of the Pigment Handbook, (1973).

**c. Kaolin**

The kaolin composition of Farsh El Ghozlan & Wadi Budra at southern Sinai is mainly composed of kaolinite and montmorillonite of Senonian age. The results of the chemical analyses show that, the ore contains (37.23%) Al<sub>2</sub>O<sub>3</sub> and (46.40%) SiO<sub>2</sub>. The physical characteristics display ideal conditions necessary for producing pigments. It possesses a specific gravity of (2.647), moisture content (0.53%), oil absorption (45 g/100g), pH (7.86), matter soluble in water (0.23), brightness (79%) and hardness (2.0). Kaolin was applied successfully in producing coal tar epoxy primer ( Colturite TCN 300 ) which is used as primer and finish coat for internal steel structures as indicated in (table 3). Testing results comply with Handbook Paint Raw Materials (1989) and ASTM D 603(1989).

**d. White Sand**

The Abu Zenima white sand is related to the Cretaceous age. It is chemically inert and contains (99 %) SiO<sub>2</sub>, with an ideal physical and rheological property for utilization as pigment for paints. The moisture content is (0.16 %), oil absorption (29g/100g), matter soluble in water (0.025), hardness (7.0), good brightness (86.6 %). It can be used in producing epoxy paint (Sigma cap EP primer) as indicated in (table 5).

**Tab. 1: Chemical and Physical Properties of Local ores Forming Pigments**

Ore Type	Chemical Composition	Physical Properties						
		Specific Gravity	Moisture %	Oil Absorp. at 100gm	pH	Matter Soluble	Hardness	Brightness
L.S & Chalk	92-96 CaCO <sub>3</sub>	2.633-2.693	0.33-0.70	26-40	8.0	0.10-0.375	2.5-3.0	96-97
Kaolin	49 SiO <sub>2</sub>	2.647	0.53	35	7.86	0.23	2.5	79.0
Glass Sand	99% SiO <sub>2</sub>	2.62	0.16	29	9.14	0.025	7.0	86.6
Gypsum	43% SO <sub>3</sub>	2.325	5.00	29	7.65	0.65	2.0	98.0

Also, the following tests were carried for the studies ores as follows:

**4.1 Particle Size**



**Fig. 4: Ball Mill for Grinding of Collected Samples to Very Fine Grain Size**

Pigments for paint manufacturing occurs in the form of a fine powder or lumps by using crushing and ball mill equipment's as shown in ( Fig. 4). The final condition in the finished paint must be such that there are no particles greater than a certain size limit. For example if a paint film has a thickness of say, 20 microns it is desirable that

the largest pigment particle should not exceed 3-4 microns in size. The vast majority of particles are much smaller in size than 3 microns; there is some evidence that a mixture of particle sizes is desirable for increased durability, reduced absorption and reduced permeability of the film.

#### 4.2 Particle shape

The particle shape also plays a part in these features; for example, plate-like particles which form an overlapping laminar structure in the film offer greater resistance to water permeation.

Particle size in conjunction with specific gravity influences the rate of the settlement in the liquid paint. The smaller the particle size the slower the rate of settling for specified specific gravity. On the other hand it appears that a proportion of extremely fine particles can result in the phenomenon of flotation in the applied film of paint.

Particle size, size distribution and shape have also an influence on other properties of the paint such as hiding power, consistency, oil absorption and the formation of absorbed layers as well as on such application properties as flow and brushability.

The particle shape for local ores was examined thoroughly by taking photographs of the powder pigments using high magnification.

The Particle shape for the limestone of Wadi Nukhul, Gabal Egma limestone is granular and ranges in shape from sub-rounded to round as shown in (Fig.10 & 11). The regular crystalline shapes give low oil absorption and allow high loading of pigment and dense packing. Gypsum of Ras Malaab is fibrous grains as indicated in (Fig.13).

This type of grains adds strength and reinforcement to paint film. Meanwhile need to relatively higher oil absorption and increase the effect of pigment load on viscosity.

#### 4.3 X- Ray Diffraction

The identified minerals from powdered samples are as follows

##### 4.3.1 Chalk & Limestone (Fig. 5 & 6)

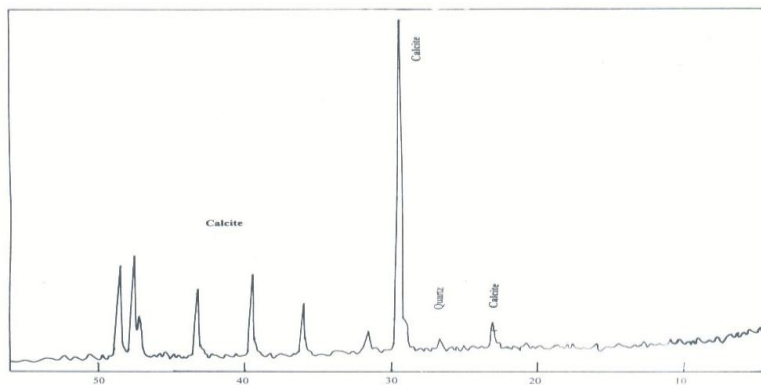


Fig. 5: X-ray Diffraction Pattern of Limestone of Gabal Ekma

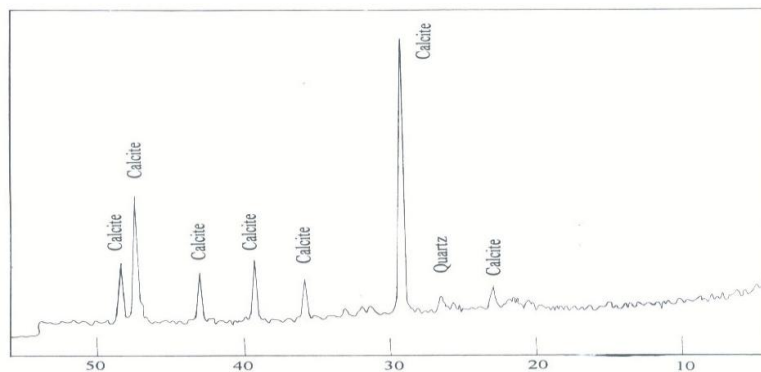


Fig. 6: X-ray Diffraction Pattern for Chalk of Wadi Nukhul

The studied samples were collected from Wadi Matula, Wadi Nukhule and Gabal Ekma; yield well defined peaks of calcite in addition to small traces of quartz. This means that the CaCO<sub>3</sub> ratio is more than 95 % as obtained from chemical analysis.

#### 4.3.2 Gypsum (Fig. 7)

Samples collected from Ras Malaab gypsum deposits show that the samples are composed mainly of CaSO<sub>4</sub>, this ratio coincides with results of chemical analysis which performed on five samples and give an average value of CaSO<sub>4</sub> ( 94 % ).

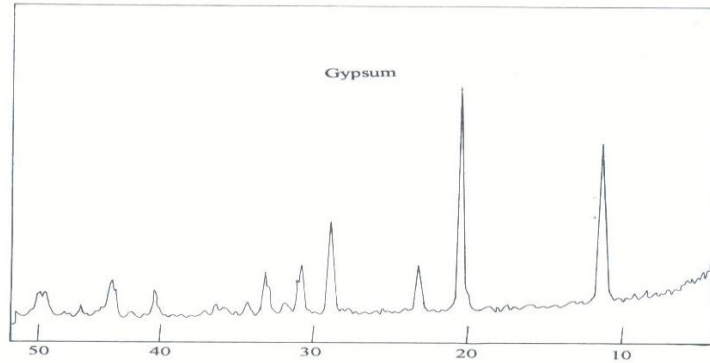


Fig. 7: X-ray Diffraction Pattern for Gypsum of Ras Mallab

#### 4.3.3 White Sand (Fig. 8)

The collected samples of Umm Bogma, South of Sinai indicated that the samples are composed mainly of quartz, the same ratio of quartz was obtained by chemical analysis, and SiO<sub>2</sub> is more than 96 %.

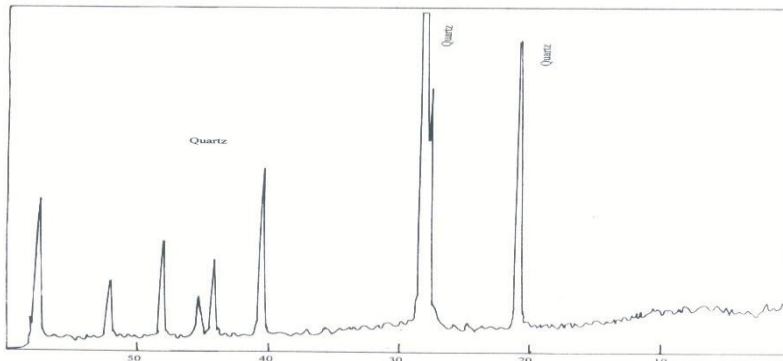


Fig. 8: X-ray Diffraction Pattern for White Sand of Um Bogma

#### 4.3.4 Kaolin (Fig. 9)

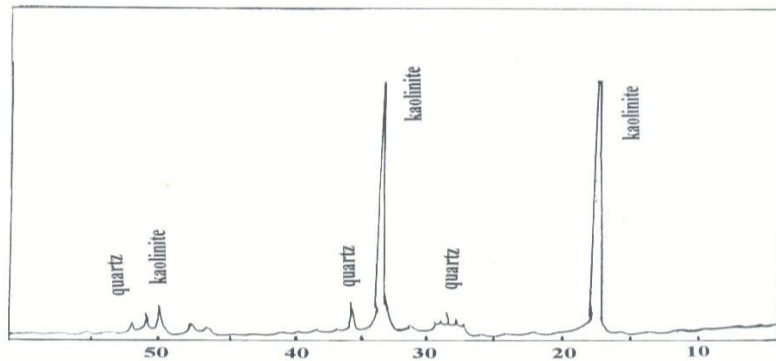


Fig. 9: X-ray Diffraction Pattern for Kaolin of Wadi Budra

The representative kaolin samples show that all samples are kaolinitic i.e composed mainly of kaolinite clay mineral; kaolinite is associated with quartz in variable ratios. The quartz content is occur as minor minerals as obtained from results of chemical analysis.

#### 4.4 Microscopic Studies

##### 4.4.1 Thin Section

###### a. Chalk of Wadi Matulla

Photographic studies show that chalk composed of rounded oolitic forms of calcite cemented by fine grains of calcite and little organic matter. The colorless or cloudy, fine to coarse aggregates and organic structure ‘ oolitic or spherulitic ’ are characterize the chalk of Wadi Matulla .

###### b. Chalk of Wadi Nukhul (Fig.10)

Photograph shows that the sample is composed mainly of calcite, and fossiliferous skeleton, organic matter and clay matrix.

###### c. Limestone of Wadi Nukhul

Photograph shows that Wadi Nukhul limestone is finely crystalline calcite containing few grains of quartz. The matrix composed of clay transformed to glauconite ‘Diagenetically ’. The presence of organic matter characterize the limestone samples.

###### d. Limestone of Gabal Egma (Fig.11)



**Fig. 10: Chalk of Wadi Nukhul**

(Composed of Calcite, Fossiliferous Organic Matter and Clay Matrix – XN- X100)



**Fig. 11: Limestone of Gebel Ekma**

(Composed of Foraminiferal Limestone, Contains Organic Matter, Some Dolomitic Grains XN- X10)



**Fig. 12: White Sand of Um Bogma**

(The quartz grains are predominant, sub- rounded to round, carbonate cement and clay matrix XN - X100)



**Fig. 13: Gypsum of Ras Malaab**

(Gypsum occurs associated with calcite, dolomite and halite, fibrous grain shape XN - X100)



Photograph shows that the samples are composed of Foraminiferal limestone contains organic matter. The limestone composed of fine aggregates. Dolomite and magnesite are associated with limestone.

**e. White Sand of Um Bogma (Fig. 12)**

Photograph shows that white sand has a clear appearance, lack of cleavage, sharp extinction and white to yellowish white interference color in thin section. The quartz grains are predominant and ranges from sub-rounded to round. Clay matrix and carbonate cement the quartz grains.

**f. Gypsum of Ras Malaab “CaSO<sub>4</sub>•2H<sub>2</sub>O” (Fig.13)**

Photograph shows that the gypsum of Ras Malaab has a colorless and fibrous structure. Fibrous grain shape gives a good reinforcement for the paint film after application on substrate. Gypsum occurs associated with calcite, dolomite and halite .

**4.4.2 Scanning Electron Microscope**

The electron microscope investigation provides a good mean in identifying the main characteristics of the studied rocks including “grain size, grain shape, matrix, and pore geometry; the SEM investigation of the studied samples was carried out on the following ores:

**a. Limestone**

The attached photograph (Fig. 14) shows that the limestone of Gabal Ekma is mainly composed of micritic with calcite crystals, limestone show organic structure e.g Foraminifera and Ostracoda, also the grain size less than 5 um.

**b. Chalk**

Photograph (Fig. 15) show that the chalk of Wadi Matulla is composed of snow white chalky limestone, fine grained, contain different types of fossils. The texture of sample is micritic chalky limestone with moderate porosity.



**Fig. 14: SEM of Gabal Ekma limestone**



**Fig. 15: SEM of Wadi Matulla chalk**

**4.5 Viscosity and Thixotropy**

**Tab. 2: Viscosity and Thixotropy of Different Local Ores Forming Pigments**

Rock name	Test Name	Pigment 20 %	Ratio 40 %	60 %
Chalk W. Matulla	Apparent viscosity	71	95	112.5
	Thixotropy	0.0	0.0	0.0
Chalk W. Nukhul	Apparent viscosity	75	93	115.5
	Thixotropy	0.0	0.0	0.0
Limestone Ekma	Apparent viscosity	65	80	90
	Thixotropy	0.0	0.0	0.0
Limestone W. Nukhul	Apparent viscosity	63	79	96
	Thixotropy	0.0	0.0	0.0

To be continued

Continued				
Rock name	Test Name	Pigment 20 %	Ratio 40 %	60 %
White sand of Um Bogma	Apparent viscosity	51	59	79
	Thixotropy	0.0	0.5	0.5
Gypsum Ras Malaab	Apparent viscosity	61.5	89	112
	Thixotropy	0.0	0.0	0.0

The viscosity of the studied samples were measured by mixing the different proportions of pigment powder 20%, 40% and 60% with linseed oil, the viscosity results were increased with the high pigment ratios as indicated in ( table 2).

#### 4.6 Paint Products of Studied Ores

The studied samples were mixed with paint formulation and the final paint product was determined and the results illustrated in (table 3, 4 & 5)

**Tab. 3: Kaolin Evaluation Sheet after Mixing with Paint Formulation**

Ore type	Kaolin
Paint name	Coal tar epoxy primer (Colturite TCN 300)
Pigment or filler %	20 % in paint formula
Oil absorption	35 mil / 100g
Color of ore before mixing	Yellowish
Fineness	45 um
Viscosity	40 – 50 poise
Wet film thickness	150 - 200 um
Drying time	4 hours
Opacity or hiding power	Good
Paint color	black & brown
Gloss	eggshell ( 15-30 / 60 °)
Hardness	Accept
Flexibility or bend test	no flaking or cracking of coating
Adhesion	GT0 ( no lifting of paint other than cutting)
Pin hole or porosity	No pin hole
Corrosion resistance	Very good

**Tab. 4: Calcium Carbonate (Limestone & Chalk) Evaluation Sheet after Mixing with Paint Formulation**

Ore type	Limestone & chalk
Paint name	Primer based on long alkyd (Comando)
Pigment or filler %	20 % in paint formula
Oil absorption	25- 30 mil / 100g
Color of ore before mixing	White
Fineness	45 um
Flow time	150 sec./ Ford cup 4
Wet film thickness	100 um
Drying time	1- 2 hours
Opacity or hiding power	Good
Gloss	flat ( <15 / 60 °)
Hardness	Accept
Flexibility or bend test	no flaking or cracking of coating
Adhesion	GT0 ( no lifting of paint other than cutting)
Pin hole or porosity	No pin hole

**Tab. 5: White Sand Evaluation Sheet after Mixing with Paint Formulation**

<b>Ore type</b>	<b>White sand (silica)</b>
Paint name	Anti-corrosive primer
Pigment or filler %	7 % in paint formula
Oil absorption	29 mil / 100g
Color of ore before mixing	White
Fineness	35 um
Flow time	175 sec./Ford cup 4
Wet film thickness	150 um
Drying time	1 - 2 hours
Opacity or hiding power	very good
Paint color	Red
Gloss	flat (< 15 / 60 °)
Hardness	Accept
Flexibility or bend test	no flaking or cracking of coating
Adhesion	GT0 ( no lifting of paint other than cutting)
Pin hole or porosity	No pin hole
Dry film thickness	75 um

## 5. CONCLUSIONS

The results from the present study lead to the following conclusions.

- a. The studied local ores are chiefly chalk of W. Matulla, chalk of W. Nukhl, limestone of Gabal Ekma, limestone of W. Nukhl, white sand of Um Bogma, gypsum of Ras Malaab and kaolin of W. Budra.
- b. These ores form the main constituents of the paint components for the decorative and protective paint material used for steel structures components.
- c. The evaluation techniques of the ore types incorporated laboratory work for material quality control together with laboratory testing in south Sinai in producing the paint extender paints e.g. natural calcium carbonates (limestone & chalk), gypsum, white sand and kaolin.
- d. Applied studies of these ore calcium carbonate, silica, kaolin may be utilized in producing coal tar epoxy primer (Colturite TCN 300), anticorrosive primer based on long alkyd, primer based on long alkyd (Comando) and under coat (Jumbo).

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