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STRATIGRAPHIC SETTING AND MINERALOGICAL STUDY ON THE EOCENE IRONSTONES OF GABAL GHORABI MINE AREA, EL BAHARIYA DEPRESSION, WESTERN DESERT, EGYPT

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ABSTRACT: Eocene ironstone of Gabal Ghorabi mine area (El Bahariya depression, Egypt), represents an unconformity-bounded condensed succession, exhibiting a lateral facies change towards the equivalent relatively thicker carbonates of the surrounding scarps. It rests unconformably on different horizons of the underlying folded Cenomanian Bahariya Formation and is subdivided into two main shallowing-upward ironstone sequences, separated by an intra-Eocene (paleokarst) unconformity. The lower ironstone sequence comprises four ironstone facies namely: a) lagoonal/tidal flat mud-ironstone facies, b) lagoonal fossiliferous ironstone facies (proximal tempestite), well developed in the southern sector of Gabal Chorabi mine area, c) shallow subtidal-intertidal nummulitic-ooidal-oncoidal ironstone facies, dominated in the southern and central sectors of Gabal Chorabi, and d) Shallow subtidal nummulitic ironstone facies, that dominated in the northern sector. The upper ironstone sequence begins by the deposition of shallow subtidal green mudstone facies as a result of a new marine transgression followed by a peritidal ironstone sequence, which consists of three repeated shallowing-upward cycles. The upper ironstone sequence is intensively lateritized and karstified and iron ore laterite and stratabound karst-related barite are formed. The main valuable minerals founded in the area are haematite and goethite, and the main gangue minerals are quartz, dolomite, apatite and barite.

Key Words: Ironstone, Stratigraphy, Mineralogy, Gabal Ghorabi, El-Bahariya, Egypt.

Gabal Ghorabi (El Bahariya Çöküntüsü, Batı Çölü, Mısır) Madenindeki Eosen Demirtaşlarının Stratigrafik Konumu ve Mineralojik İncelemesi

ÖZET: Cabal Ghorabi maden alanındaki (El Bahariya depresyonu, Mısır) Eosen demirtaşı, eşleniği olan çevredeki yüksek yerlerin daha kalın karbonatlarına yatay fasiyes değişikliği gösteren, uyumsuzlukla sınırlanmış sıkı bir istifi temsil eder. Senomanian yaşlı, kıvrımlanmış Bahariya Formasyonu üzerinde uyumsuzlukla yer alan Eosen demirtaşı, intra-Eosen (paleokarst) uyumsuzluğu ile ayrılan ve yukarı doğru sığlaşan iki ana demirtaşı istifine ayrılır. Alt demirtaşı sekansı dört demirtaşı fasiyesinden oluşur; a) lagünel/gel-git düz çamur-demirtaşı fasiyesi; b) Gabal Chorabi maden alanının güney kesiminde iyi gelişmiş lagünel fosilli demirtaşı fasiyesi (başlangıç evre fırtına çökeli); c) Gabal Chorabinin merkez ve güney kesiminde yoğunlaşmış, sığ, gel-git altı ve içi numulitik-ooidal-onkoidal demirtaşı fasiyesi; d) kuzey kesimde belirgin, sığ gel-git altı numulitik demirtaşı fasiyesi. Üst demirtaşı istifi, yeni bir deniz ilerlemesi sonucu oluşan sığ, gel-git altı yeşil çamurtaşı fasiyesinin depolanmasıyla başlar, ve üç kez tekrarlanan ve yukarıdoğru sığlaşan çevrimden oluşan gelgit içi ve üstü demirtaşı istifi ile devam eder. Üst demirtaşı istifi yoğun olarak lateritleşmiş ve karstlaşmış, ve demir cevheri lateriti ve tabaka dokanaklı karst-ilişkili barit oluşmuştur. Çalışma alanında bulunan başlıca eonomik mineraller, hematite ve götit, ve ana gang mineralleri ise kuvars, dolomit, apatit ve barittir.

Anahtar Kelimeler: Demirtaşı, Stratigrafi, Mineraloji, Gabal Ghorabi, El-Bahariyə, Mısır.

INTRODUCTION

Ghorabi-Nasser area is located at the extreme northeastern corner of the Bahariya Depression at about 25km west of El Bahariya-Cairo road (Fig. 1). It is bounded by the following coordinates: 29° 00' 00'' to 29° 04' E, and 28° 29' 30" to 28° 30' 30" N. The area is a topographically high feature, attaining about 2.3 sq. km and it is completely separated from the surrounding Eocene carbonate scarp by deep structural and erosional wadis. To the north, the structurally controlled fault wadi separates Gabal Ghorabi from the scattered hills of Nasser area and the karstified Eocene carbonates. At the south, Gabal Ghorabi directly overlooks the Bahariya Depression and the surrounding wadis are opened into the main Depression. The core of Gabal Ghorabi is made up of the Cenomanian clastics of the Bahariya Formation, which is unconformably overlain by Eocene ironstone succession and the related duricrusts. In some places, discontinuous Oligocene pebbly sandstone beds unconformably overlie the Eocene ironstone succession.

El Aref et al. (2001) studied the "Lutetian" ironstone succession (Naqb and Qazzun formations) of EI Harra and El Gedida mine areas and subdivided it into four ironstone units; being arranged from base to top as follows: Lower variegated mud-ironstone, Lower ooidal, oncolitic and nummulitic ironstone, Upper variegated mud-ironstone and Upper nummulitic ironstone. They also studied the "Lutetian" carbonate succession and differentiated it into five stratigraphic units, which can be easily traced allover the northeastern Plateau of EI Bahariya Depression. These are lower dolomitic Limestone and dolostone, Lower nummulitic limestone, Upper dolomitic limestone and marl, Middle nummulitic limestone and Upper nummulitic chalky limestone. They concluded that the ironstone succession represents a reduced section relative to the surrounding equivalent thick carbonate succession and they are deposited on a ramp depositional environment.

The present study deals with the stratigraphic setting and mineralogy of the ironstone succession of Gabal Ghorabi mine area. To achieve these goals, four representative lithostratigraphic sections covering the ironstones of Gabal Ghorabi mine area are measured, described and correlated with each others. The stratigraphic measurements and mega- features tend to define the main ironstone units, internal lithologic subdivisions, discontinuity surfaces as well as their lateral and vertical lithologic changes. The bulk chemical composition of the different ironstone types is determined by XRF and the mineralogical analysis determined by XRD.

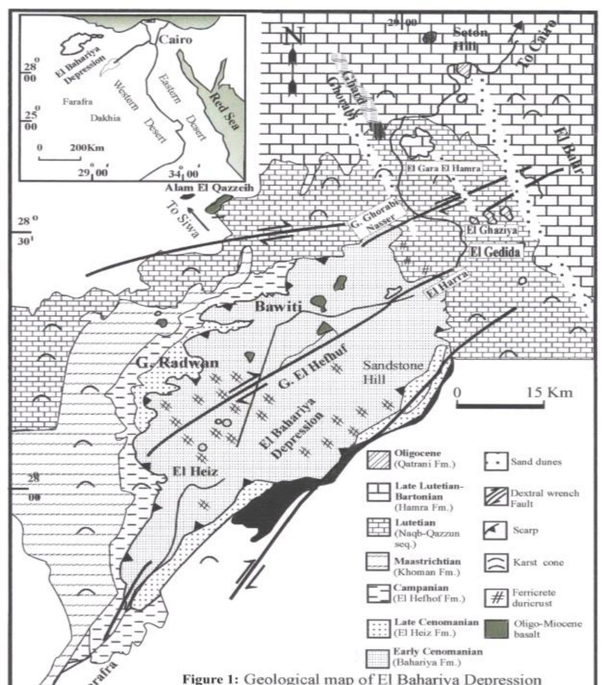

Figure 1: Geological map of El Bahariya Depression (After El Aref et al.,1999; modified after Hermina *et al.*, 1989,detailed strucrural elements are shown in Sefim, 1993)

REGIONAL STRATIGRAPHY AND STRUCTURES

The stratigraphic succession of the northeastern plateau of El Bahariya depression includes the following rock units, being arranged from younger to older (EI Aref et al., 1999):

8- Wadi and playa deposits and eolian sand dunes, Quaternary

7- Duricrusts (calcrete, silcrete and ferricrete), Miocene?-Quaternary

--------------------- Unconformity --------------------------
6- Volcanic rocks (basalt), Oligo-Miocene
5- Qatrani Formation, Oligocene
--------- Regional unconformity (paleokarst) ---------
4- EL Hamra Formation, Eocene
------------------ paleokarst ------------------------ Eocene
3- Qazzun Formation, Eocene
2- Naqb Formation, Eocene
------------------ Regional unconformity -----------------
1- Bahariya Formation, Cenomanian
------------------ Base unexposed --------------------------

The Bahariya, Naqb and Qazzun formations are represented in Gabal Ghorbi mine area. The Early Cenomanian Bahariya Formation (Said, 1962) forms the floor of the Bahariya Depression and the foot of the surrounding scarps. The most obvious feature of the Bahariya Formation is the occurrence of the ironstone bands, particularly in the lower and upper intervals of the exposed sections. In Gabal Ghorabi area, the studied ironstone succession truncates the upper mudstone-sandstone member in the southern and northern sectors and truncates the sandstones of the middle Member in the central sector.

The Eocene Naqb and Qazznn formations (Lutetian, Said and Issawi, 1964; Ypresian, Strougo, 1996) are dominated by karstified nummulite-rich limestones, which differ from the underlying clastic-dominated Bahariya Formation and the overlying mixed carbonate-clastic lithologies of El Hamra Formation. The Naqb Formation is composed mainly of yellowish white dolomitic and nummulitic limestones with distinct pinkish and reddish tones. The Qazzun Formation is characterized by its snow-white chalky and nummulitic limestones with remarkable zones of large melon-shaped silicified limestone concretions (average diameter 50-60 cm). The carbonates of the Naqb and Qazzun formations are dominantly caverneous and display diagnostic megascopic and microscopic karst features and intimately associated with soil processes, comprising dissolution, cementation, dolomitization, dedolomitization and deposition of autochthonous soil residual materials and allochthonous cave deposits. Such alteration processes obscured, to a large extent, the original lithofacies, bedding geometry, internal sedimentary structures and obliterated their fossil content (EI Aref et al. 1987 and Lotfy, 1988).

The Bahariya area is dissected by several fault belts, among which there are two master fault systems: 1) El Gedida-El Harra dextral fault (El Bahariya mid fault). This fault system extends from El Gedida to El Harra mine areas and crossing through the floor of the Bahariya Depression, 2) Ghorabi-EI Ghaziya fault system, which extends from Gabal Ghorabi to EI Ghaziya area in a NE direction for about 36 km with an average width of about 9 km (Fig. 1). Gabal Ghorabi represents the central segment of the giant Ghorabi-EI Ghaziya structural belt (Fig. 2).

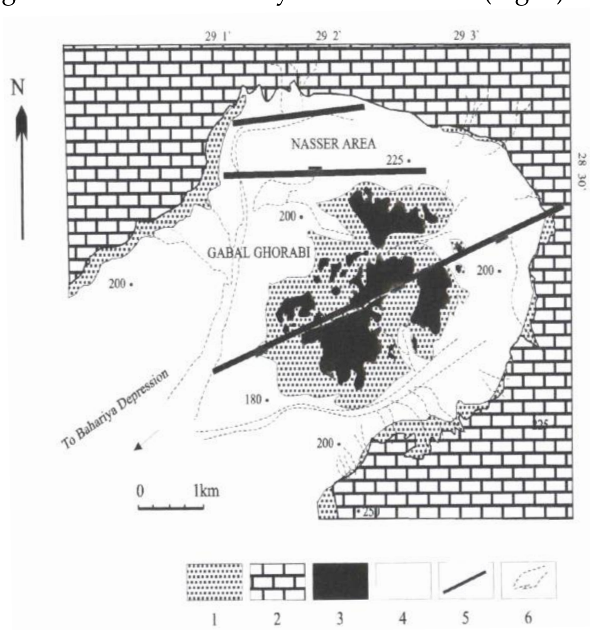

Figure 2. Simplified geological map of Ghorabi – Nasser area (simplified after El Aref and Lotfy, 1989) 1= Clastic rocks of the Cenomanian Bahariya Fm. 2= Karstified limestones of the Middle Eocene Naqb Fm. 3= Iron ore deposits; 4= Quaternary sediments; 5= Faults; 6= Drainage lines.

The eastern segment of this structural belt affects the Eocene rocks on the eastern plateau of the depression and is represented by several small right-stepped, en-echelon folds. The western segment of Gabal Ghorabi-EI Ghaziya structural belt consists of W- to WNW-oriented, left-stepped en-echelon faults. The master fault displaces the southern sector of abal Ghorabi downward (hanging wall). Gabal Ghorabi fault (master fault) dips at 62° due south with a vertical displacement of about 40 m (EI Akkad and Issawi, 1963). A set of minor step normal faults trending E-W cuts across the Eocene ironstone succession of the southern and northern sectors. The crest of this anticline was continuously eroded, whereas its flanks were subsequently onlapped by the Eocene ironstone succession. The Eocene ironstone succession unconformably overlies the Cenomanian clastics of the Bahariya Formation with clear angular unconformity relationship at the fault plane due to drag. Two phases of movement are recorded on the master fault; the earlier movement is indicated by the southward dipping of the Bahariya Formation on the southern side of the fault due to drag. The later movement led to the displacement of the Eocene ironstone succession of the Naqb Formation, which unconformably overlie the dipping Bahariya beds.

STRATIGRAPHIC ARCHITECTURE OF GHORABI IRONSTONES

Four detailed lithostratigraphic sections representing the ironstone successions of the study area are carefully measured and described in Figure (3) (El Aref et al., 2006). The ironstone succession of Gabal Ghorabi represents a relatively reduced and condensed section (up to 23 m thick) relative to the surrounding thick carbonate succession of the northeastern plateau of EI Bahariya Depression (68 m thick) as recorded by Said and Issawi (1964). According to the lithological characteristics of the ironstone successions, Gabal Ghorabi area is subdivided into three main sectors separated by two major NE-SW right lateral strike-slip and normal faults (Fig 2). These are: southern, central, and northern sectors. The Ghorabi ironstone succession can be subdivided into two characteristic sequences; the lower and the upper ironstone sequences, which are correlated with the lower and upper iron ore units of Said and Issawi (1964). The geographic distribution of the lower ironstone sequence allover Gabal Ghorabi mine area indicates that it displays great lateral and vertical variations in thickness and lithological aspects. These variations are related to the paleotopography and the configuration of the underlying Cenomanian Bahariya Formation as well as the syntectonic elements prevailed during the Post-Cenomanian-Pre- Eocene time span. The different rock-stratigraphic units of these ironstone sequences and their lateral variations as well as the associated paleosols and surficial duricrusts are shown in Table 1.

The lower ironstone sequence is rich in fossil molds and casts as well as ferriferous ooids, peloids and oncoids. It is separated from the underlying Cenomanian Bahariya Formation by a thin layer of oligomictic, intraformational conglomerates and separated from the overlying lateritized (karst) iron ore unit by a characteristic brick red hematitic mud-ironstone (paleosol horizon).

The upper ironstone sequence forms the vertical cliff segment of the main scarp of Gabal Ghorabi and consists mainly of a basal of olive green to greyish white laminated mudstone unit grading upward into three repeated shallowing-upward cycles of mud- and nummulitic-bioclastic ironstones and thin bed of stratiform barite. Thin sandstone beds of the Oligocene Qatrani Formation with or without hard cap of silcrete or ferricrete duricrusts are often observed. The upper ironstone sequence has the same lithological characters and is highly lateritized giving rise to highly collapsed iron ore type with varieties of redeposited crustified and colloform iron and manganese oxides and hydroxides together with surficial ferricrete duricrust.

MINERALOGICAL ANALYSIS

Major-element analysis of minerals was carried out with JEOL super probe (JXA-8800) at Center for Cooperative Research of Kanazawa University. We adopted an acceleration voltage of 20 kV, a specimen current of 20 nA and a beam diameter of 3 μm.

Table 1. Distribution of the different rock-stratigraghic unit of the lower and upper ironstone sequences of Ghorabi mine area (El Aref et al., 2006).

<table>
<tr><th rowspan="2">Age</th><th rowspan="2">Formation</th><th rowspan="2">Sequence</th><th colspan="3">Sectors (Fig. 2)</th></tr>
<tr><th>Southern sector (sections 1and 2 Fig. 3)</th><th>Central sector (Section 3 Fig. 3)</th><th>Northern sector (Section 4 Fig. 3)</th></tr>
<tr><td rowspan="2">Oligocene</td><td rowspan="2">Qatrani</td><td rowspan="2">---------</td><td colspan="3">Silcrete or Ferricrete Durricrusts</td></tr>
<tr><td colspan="3">Ferruginous and silicified fluvial planar and trough cross-stratified gravely sandstones and conglomerate lenses with subordinate limonitic mudstone interbeds</td></tr>
<tr><td colspan="6">Unconformity</td></tr>
<tr><td rowspan="4">Eocene</td><td rowspan="4">Naqb</td><td rowspan="2">Upper Ironstone Sequence</td><td>Lateritized (karst) ironstone unit</td><td>Lateritized (karst) ironstone unit associated with stratiform and stratabound barite deposits</td><td>Lateritized (karst) ironstone unit</td></tr>
<tr><td colspan="3">Mudstone unit</td></tr>
<tr><td colspan="4">Paleosol and Ironstone Breccias</td></tr>
<tr><td>Lower Ironstone Sequence</td><td>- Nummulitic-ooidal-oncolitic ironstone unit
- Fossiliferous ironstone unit
- Mud ironstone unit</td><td>- Nummulitic-ooidal-oncolitic ironstone unit
- Stromatolitic ironstone unit</td><td>- Nummulitic ironstone unit
- Mud ironstone unit</td></tr>
<tr><td>Cenomanian</td><td>Bahariya</td><td>---------</td><td>Kaolinitic and glauconitic mudstones containing ironstone bands and lenses</td><td>Barite-bearing ferruginous sandstones</td><td>Kaolinitic and glauconitic mudstones containing ironstone bands and lenses</td></tr>
</table>

As seen from this table based on chemical analysis of different montmorillonite (an. - 2, 3, 5, 11), glauconite (an. 18, 19), manganese (an. 5, 6, 7, 8, 9, 15, 16, 17) and hematite-goethite ore. All chemical analysis according to the method Avdiona (Avdion, 1968, 1970, 1976) has been converted to the quantitative mineralogical composition (Table 2). Identify chemical differences in the iron ore are set quantitative mineralogical composition. Moreover, for the manganese hematite-goethite ores calculated availability psilomelane and pyrolusite. These manganese minerals are involved in different quantitative ratios. They associate as psilomelane.

As the proportion of iron hematite ore predominates. However, a variable quantity of goethite and hydro-goethite were calculated. Obviously, the latter are products of oxidation of primary hematite. Occasionally find the presence of limonite and iron hydroxide. In quantitative terms, among the host mineral of iron ore is dominated by quartz, montmorillonite, kaolinite, glauconite, anhydrite, and in some cases, barite, dolomite, etc.

All of these mineral phases are confirmed by X-ray diffraction analysis (Fig. 4). The results of the ore and host minerals compared with the relevant standards (ASTM). Based on X-ray diffraction analysis compiled a bar chart (Fig. 4). As seen from these bar charts the most intense lines characterize the presence of a dominant mineral phase. Ghorabi iron ore deposits studied petrographically. The results of these studies revealed a number of additional minerals, which include hydromica, calcite, gypsum, chlorite, magnesite, etc. Thus, based on a comprehensive study revealed that the lateral and vertical quantitative mineralogical composition of rocks composing Ghorabi iron ore deposits have several differences among themselves.

At the same time in the basement of Ghorabi iron ore deposits from the Early Cenomanian time, perhaps before going sinking Bahariya Oasis, which was accompanied by the filling of river and sea waters. In other words, oasis is represented gulf. In this regard, in clay slates and poorly sorted sandstones founded relics of the African and Mediterranean fauna. Of these residues fauna characterize certain groups of freshwater regime (river), they both lived in marine environments furthermore in sections differentiate of gradual transitions between ferruginous sandstones with sandy clay slates, which are indicative of Bahariya shallow sea bay, and relatively interlaminar mode of the oasis development.

In general, by analyzing Bahariya oasis can be noted that the accumulation of iron ores occurred passively. Evidence of this is weak ferruginization poorly sorted sandstones. They occur at different stratigraphic levels of Bahariya formation section. As seen from the stratigraphic column (Fig. 3), hematite-goethite mineralization of Ghorabi iron ore deposits are localized in the lower, middle and even upper parts of the section. At the same time as noted above, within the basal conglomerate occurs at the base of the Eocene ore-bearing horizon, they are represented by medium and Upper Eocene iron ore, limestones, argillites, sandstones and others (Fig. 3).

Table 2. Chemical analysis of Ghorabi iron ore deposit (wt.%) (Modified after El Aref et al., 2006).

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	SO_3	BaO	Σ
1	7.86	0.16	4.1	83.48	1.74	0.83	0.29	-	0.32	0.29	0.36	0.13	0	99.56
2	12.53	0.05	2.96	79.5	0.85	0.46	0.46	-	0.02	1.67	0.35	0.46	0.63	99.94
3	7.54	0.1	4.14	74.54	1.03	2.48	2.48	-	0.16	3.23	0.84	0.14	2.91	99.59
4	5.27	0.09	0.91	91.36	0.43	0.29	0.3	-	0.14	0.72	0.27	0.12	0.09	99.99
5	18.95	0.35	5.51	62.62	8.77	0.69	0.65	-	1.13	0.18	0.34	0.25	0.56	100
6	0.78	0.03	0.02	86.89	11.04	0.33	0.16	-	0.04	0.12	0.25	0.07	0.24	99.97
7	1.05	0.04	0.38	85.51	10.56	0.47	0.36	-	0.04	0.26	0.31	0.18	0.83	99.99
8	1.05	0.04	0	84.6	10.91	0.85	0.35	-	0.12	0.55	0.12	0.2	1.22	100.01
9	5.69	0.08	1.21	83.08	6.58	1.31	0.28	-	0.13	0.48	0.19	0	0.98	100.01
11	4.72	0.05	2.24	85.76	1.88	0.61	0.61	-	0.08	1.72	0.44	0.8	1.02	99.93
12	19.09	0.02	1.9	75.11	0.21	0.38	0.38	-	0.07	1.49	0.34	0.72	0.27	99.98
13	8.15	0.06	1.55	87.69	0.28	0.32	0.91	-	0.08	0.24	0.32	0.31	0.08	99.99
14	31.37	0.04	0.41	51.56	5	0.81	0.81	-	0.07	9.12	0.25	0.27	0.28	99.99
15	0.74	0.03	0.08	87.91	8.01	0.74	0.41	-	0.1	0.58	0.14	0.25	0.93	99.92
16	0.26	0.02	0.17	77.91	18.76	0.87	0.23	-	0.07	0.33	0.25	0.14	0.98	99.99
17	1.51	0.04	0.91	84.41	11.01	0.67	0.28	-	0.09	0.39	0.21	0.19	0.28	99.99
18	45.25	1.44	20.34	15.93	0.24	2.68	1.29	-	3.44	6.04	0.39	0.45	2.49	99.98
19	42.91	1.37	21.9	19.59	0.18	1.9	0.31	-	3.07	7.45	0.16	0.2	0.89	99.93
20	3.71	0.14	0.37	92.62	0.63	0.24	0.08	0.19	0.21	0	0.179	0.52	-	99.37
21	2.49	0.16	0.53	91.34	1.34	0.31	0.03	0.25	0.2	0	0.176	0.56	-	98.3
22	3.81	0.17	0.32	90.84	1.28	0.67	0.16	0.18	0.24	0	0.139	0.42	-	99
23	2.79	0.12	0.41	92.78	1.47	0.28	0.05	0.23	0.21	0	0.136	0.46	-	99.39
24	7.68	0.49	3.71	74.25	0.82	1.43	0.09	2.74	0.57	2.96	0.161	0.45	-	97.93
25	28.53	0.65	3.47	3.12	0.21	1.02	10.37	15.27	0.62	16.61	0.183	14.81	-	98.11
26	23.03	0.52	3.09	2.81	0.18	2.93	0.17	29.07	0.72	33.27	0.134	0.67	-	99.6
27	4.08	0.18	0.76	62.66	0.37	1.76	0.13	13.21	0.17	15.06	0.197	0.8	-	100.4
28	9.94	0.31	4.01	66.39	0.76	1.61	9.28	0.17	0.19	0	0.139	4.24	-	100.3

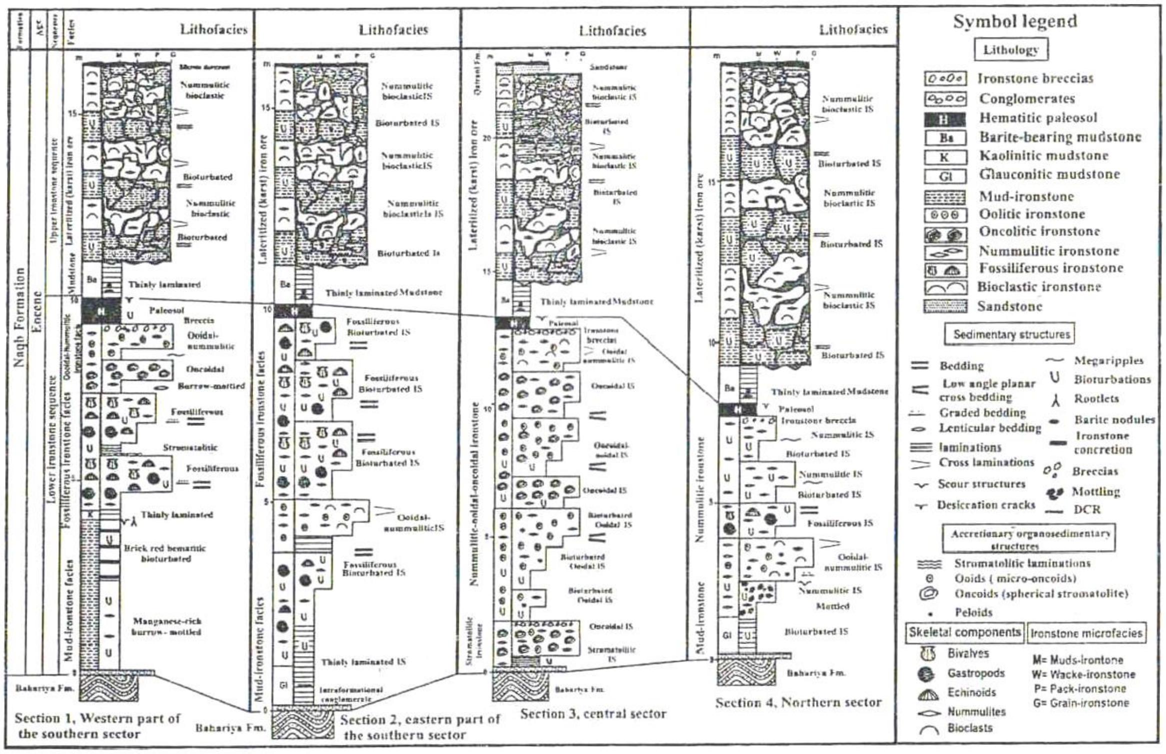

Fig.3. Stratigraphic sections showing the distribution of the different ironstone units and related facies in the different sectors of Gabal Ghorabi area (after El-Aref *et al.*, 2006)

Table 3. Quantitative minerals composition for Ghorabi iron ore deposit.

	Het	Hem	Hal	Sil	Ba	Psi	Mont	Kal	Dal	Xl	Ap	Gl	Q	Anh	Rut	∑
1	2	75	0.4	-	0.1	3.7	1.1	-	-	-	0.4	-	17	-	0.3	100
2	3.6	67	6.3	0.1	0.6	1.5	-	-	1.6	1	-	-	18.2	-	0.1	100
3	-	60	11.7	0.2	3.2	1.9	14.5	-	-	-	0.8	-	7.5	-	0.2	100
4	77.5	3.5	2.8	0.2	0.1	0.9	6.2	-	-	-	0.3	-	8.3	-	0.2	100
5	0.8	42	1.1	-	0.8	15	15.2	-	3.2	-	0.5	6.5	14.7	-	0.5	100.3
6	2	72.8	0.9	-	0.2	21.4	0.2	-	0.2	-	0.5	-	1.6	-	0.1	99.99
7	1	72.5	0.9	0.1	1.5	20.4	2.3	-	-	-	1.2	-	-	-	0.1	100
8	1	68.1	1.9	0.2	1.8	20.1	2.7	0.4	3.3	-	0.4	-	-	-	0.1	100
9	-	67	3.1	0.4	1.3	11.9	2	-	4.2	-	0.5	-	9.3	-	0.1	99.8
11	1	69.1	6.3	0.1	4.1	3.5	8.5	0.1	2.7	-	-	-	4.5	-	0.1	100
12	1	50.1	8.8	0.1	0.8	0.3	5.9	-	-	-	-	-	29.6	3.2	0.1	99.99
13	1	75.4	0.8	0.2	0.3	0.5	7.5	-	-	-	-	-	11.5	2.3	0.1	99.6
14	-	27	21.4	0.1	0.3	5.9	3.4	-	-	-	0.7	-	40.2	0.1	-	100
15	2	72.2	4.1	0.3	1.8	15.1	2.2	-	1.8	-	0.5	-	-	-	-	100
16	1.7	58.2	2.1	0.2	1.7	2.7	31	1.7	-	-	0.7	-	-	-	-	100
17	-	72.6	2.8	0.2	1.1	21.3	0.8	-	-	-	1.2	-	-	-	-	100
18	-	-	24.3	-	-	0.2	-	-	0.1	-	0.8	48.3	25	-	1.1	99.8
19	-	5.6	41.6	-	1.2	0.5	-	-	-	-	0.2	37.3	10.2	-	3.4	100
20	6	85.9	0.5	0.4	0.03	-	2.8	-	-	-	0.8	-	3.64	-	0.01	100
21	2	90.5	0.7	0.3	-	0.5	5.8	-	-	-	-	-	-	-	0.2	100
22	3.19	89.2	0.5	0.4	-	0.3	2.8	-	-	-	0.4	-	3.2	-	0.01	100
23	3.4	90	0.6	0.3	0.6	2.6	1	1	-	0.2	0.3	-	-	-	-	100
24	2.4	74.5	6	1	0.6	0.9	11.6	0.8	-	1.4	0.3	-	-	-	0.3	99.8
25	-	5.6	40	1	-	-	-	15.5	10.2	0.7	0.2	-	11	15.4	0.4	100
26	1.2	0.5	60	1	-	-	6.4	2.3	3.6	0.4	0.2	-	12.5	11.3	0.6	100
27	48.7	2.7	35.2	0.5	-	0.4	-	2.1	5.3	-	-	-	3.8	1	0.3	100
28	64.5	3.2	-	-	0.2	0.8	6.2	0.8	15.3	-	1.2	-	4.5	3.2	0.1	100

Minerals index: Het – goethite; Hem – hematite; Hal – halite; Sil – sylvite; Ba – barite; Psi – psilomelane; Mont – montmorillonite; Kaol – kaolinite; Dol – dolomite; Xl – chlorite; ap – apatite; gl – glauconite; Q – quartz; anh – anhydrite; ru – rutile.

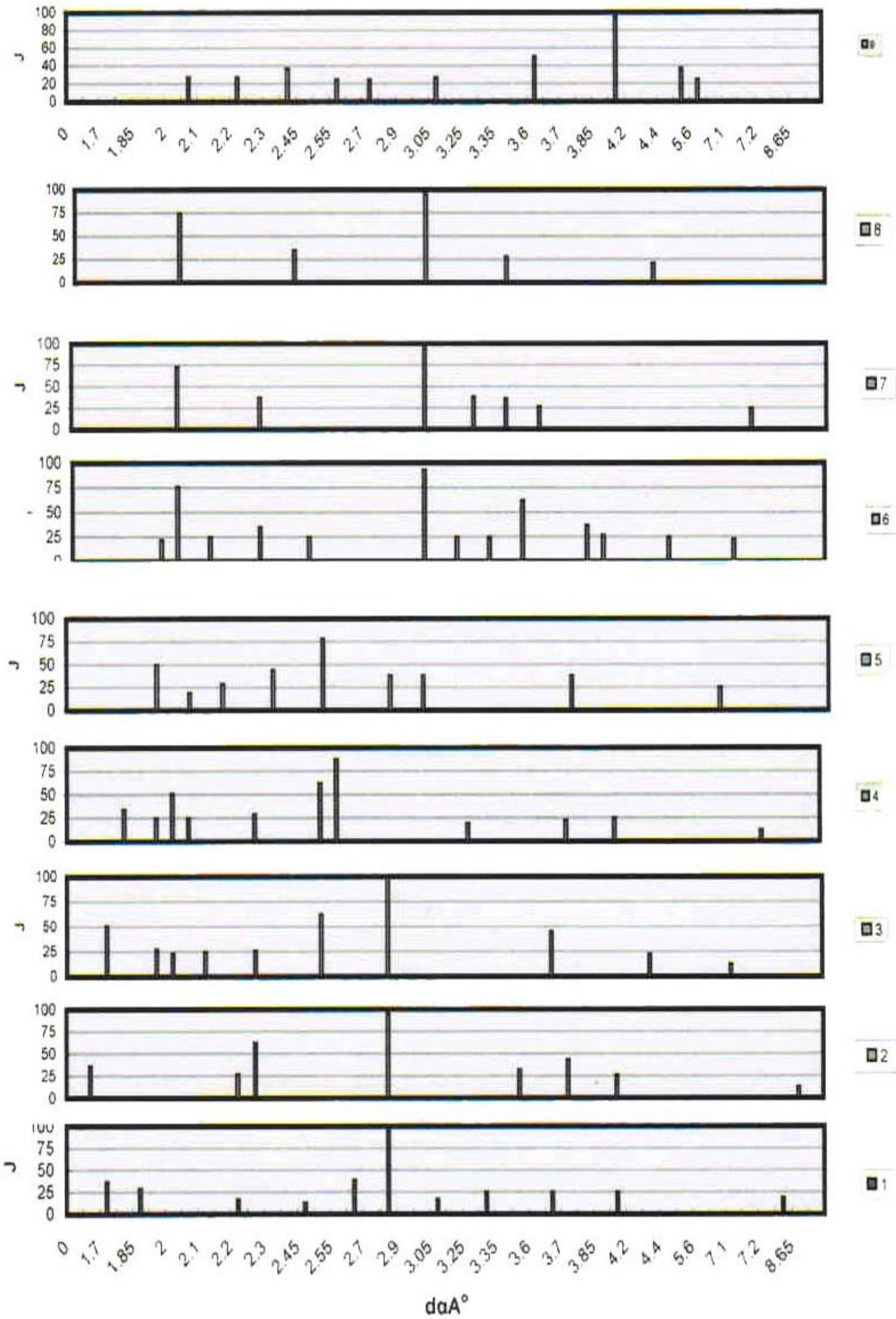

Fig. 4: Line diagram of powder pattern of X-ray diffraction for Ghorabi iron ore minerals analysis.

According to, (El Aref, et al, 1999) and others, these iron ore deposits are divided into two parts (Fig. 3): 1) the lower and 2) the top. In the lower part of the section is dominated by fine-grained manganese-rich mottled mud-ironstone. It is obvious mineralization did not occur in the deep lagoon conditions. Accordingly, mineralization was accompanied by granulometric sorting derived sediment. In the upper part of given ore-bearing members formed subaerial condition, i.e. be present shallowing basin. In this case the lower fine-grained of ore-bearing horizons are replaced by a sufficiently compacted, fine-grained nummulitic ore and argillites. Formation of this horizon also takes place in circumstances where shallowing lagoon conditions. Here in the shallowing of marine conditions occurred karst and laterite transformation of ore material. Also in this case subaerial condition of mineralization continued, and weathering of primary hematite-goethite mineralization occurred. In this regard, in samples of this ore material, together with hematite and goethite found both of hydrogoethite, limonite and etc were recognized.

Thus, after the Upper Cretaceous time, i.e. Maastrichtian Bahariya oasis is completely immersed and filled with sea and river water. This process or transgression continues to Lutetian stage. Structural floor mid-Upper Eocene formed after this period. Based on these studies can be noted that Ghorabi block in the Late Cretaceous was a positive structure. In the Eocene period, a block divided into three sectors: the southern, northern and central (Fig. 2). Southern and northern blocks were characterized with respect to the central lowland relief. In other words these blocks as underwater depressions delineate Glauconitic iron ore.

Changes in lithofacies within the marine lagoon were formed due to the tidal currents. During this period, iron-rich colloidal material in the medium-and Late Eocene times, gradually formed and redeposited Ghorabi iron ore deposit. However, in the early middle Eocene after transgression occurred the accumulation and formation of fine-grained nummulitic iron ore deposit. Nummulitic limestone formed in the most intense tidal current that occurred in the central unit.

During the late Eocene time Ghorabi field was completely flooded by sea water. In this regard, formation of green argillaceous lithofacies takes place, which contains small diagenetic barite mineralization. It should be noted that in this situation bioturbated fine-grained iron ore was formed. But in isolated small water pools, which occurred in the central block, salt-bearing horizons were formed. At the end of the late Eocene marine regression helped to re-enrich the marked blocks of useful ore.

CONCLUSION

The main results obtained from this study are summarized below;

A- Stratigraphical characteristics of the Ghorabi ironstone were determined;

1- It is subdivided into two main shallowing-upward ironstone sequences, separated by an intra-Eocene (paleokarst) unconformity.

2- The lower ironstone sequence comprises four ironstone facies namely: a) lagoonal/tidal flat mud-ironstone facies, b) lagoonal fossiliferous ironstone facies (proximal tempestite), c) shallow subtidal-intertidal nummulitic-ooidal-oncoidal ironstone facies, and d) Shallow subtidal nummulitic ironstone facies.

3- The upper ironstone sequence begins by the deposition of shallow subtidal green mudstone facies followed by a peritidal ironstone sequence, which consists of three repeated shallowing-upward cycles. The upper ironstone sequence is intensively lateritized and karstified and iron ore laterite and stratabound karst-related barite are formed.

B- The main valuable minerals founded in the area are hematite and goethite, and the main gangue minerals are quartz, dolomite, apatite and barite.

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