

CHEMICAL AND MINERALOGICAL CHARACTERISTICS OF
MAGNETITE FROM GEBEL EL-HADID,
EASTERN DESERT, EGYPT.

BY

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ABSTRACT

Magnetite has been separated from the iron ore deposits of Gebel El-Hadid and studied by chemical analyses, XRD, IR and DTA. Chemical analyses of the separated magnetite revealed that Fe_2O_3 of magnetite from the magnetite ore is lower and FeO is higher than that from the magnetite-hematite ore. The present magnetite has the chemical formula $Fe_1^{+3} (Fe^{+2} Fe^{+3})_{1.85} O_4$ which lies between magnetite $Fe_1^{+3} (Fe^{+2} Fe^{+3})_2 O_4$ and maghemite $Fe_1^{+3} (Fe^{+2} Fe^{+3})_{1.725} O_4$. The unit cell of the present magnetite (8.3729 Å) lies between that of magnetite (8.3963 Å) and maghemite (8.32 Å). XRD shows that the magnetite characteristic peaks are between those of standard magnetite and maghemite. The present magnetite has also absorption bands of IR analyses for both magnetite and maghemite. DTA proved the oxidation of magnetite. All the above techniques characterize and confirm that the present magnetite has a composition between magnetite and maghemite which is called maghemomagnetite.

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INTRODUCTION

This paper deals essentially with chemical and mineralogical studies on the magnetite of the Precambrian iron ore deposits of Gebel EL-Hadid, Eastern Desert, Egypt. Gebel El-Hadid lies in the Central Eastern Desert of Egypt at the intersection of latitude $25^{\circ}21'19''N$ and longitude $34^{\circ}7'53''$ (Fig. 1).

The geology, mineralogy and geochemistry of the iron ore deposits of Egypt have been studied by quite a number of authors such as Attia (1950), Nakhla (1954), Akaad (1959), Shukri et al. (1959), Sabet (1958, 1961), El Ramly et al. (1963), Anwar et al. (1964), Dardir (1967), Hilmy et al. (1972), Bishara and Habiş (1973), Zaghoul et al. (1978), Abdallah et al. (1980), Akaad and Dardir (1983) and Sims and James (1984).

According to the ore mineralogy three ore types can be recognized in the present iron ore deposit (Sharkawy, 1990). These are magnetite ore type, magnetite-hematite ore type (hematite is predominant) and hematite ore type. The main task of the present work is to determine the nature and composition of the magnetite. In order to fulfill this task and on the basis of magnetic susceptibility, magnetite can be separated from other minerals in both magnetite ore type and magnetite-hematite ore type.

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Thirteen magnetite grains from magnetite ore type and two magnetite grains from magnetite-hematite ore type were separated and subjected to chemical analysis, cell dimension, X-ray, infrared and differential thermal analysis.

CHEMICAL DATA:

The chemical analysis of separated magnetite grains has been carried out at Helwan Iron and Steel Company using X-ray quantometer (ARL) apparatus.

Table 1 gives the chemical analysis (in weight percent) of the separated magnetite grains. The SiO_2 content is nearly similar to the magnetite grains separated from both magnetite ore type and magnetite-hematite ore type with an average amount of 1.37% in both ore types. The presence of SiO_2 indicates a deficiency of the magnetic separation process.

The TiO_2 content reaches 0.04% and 0.02% for the magnetite separated from magnetite ore type and magnetite-hematite ore type respectively. This low content of TiO_2 detected in the present magnetite revealed that it is not titanite type. The recorded amount of Ti is attributed to the titanium present in the internal atomic structure of magnetite. Deer et al. (1962) stated that a considerable amount of Ti could enter the magnetite structure. This conclusion is supported and confirmed microscopically by the absence of ilmenite-magnetite intergrowth.

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The average content of Fe_2O_3 is 79.09% for the magnetite separated from magnetite-hematite ore type which is higher than that for the magnetite separated from magnetite ore type (76.07%). This is attributed to the greater concentration of oxidation products such as maghemite, martite, and goethite in magnetite-hematite ore type. The degree of iron oxidation (O) of magnetite separated from the magnetite-hematite ore type (82.43%) is higher than that of magnetite separated from the magnetite ore type (79.21%) which reflects that most of the hematite in this type is of secondary origin. The same result was obtained and confirmed microscopically where the majority of hematite is recorded as martite arranged along the (111) planes of magnetite.

The average FeO content for magnetite of the magnetite ore type (19.97%) is higher than that of magnetite from the magnetite-hematite ore type (16.85%). This means that the divalent iron is readily oxidized to trivalent state in magnetite-hematite ore.

CaO has an average of 0.22% and 0.27% for the magnetite from both the magnetite and magnetite-hematite ore types respectively. The recorded amount of CaO may be attributed to that present in the internal atomic structure of magnetite where small proportions of Ca^{+2} may replace Fe^{+2} and enter the internal atomic structure of magnetite.

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MgO reaches up to 0.02% for magnetite from the magnetite ore type. Vincent and Phillips (1954) observed that the magnesium in the magnetite of Skaergaard intrusion decreases rapidly in the later stage of crystallization. Accordingly, the lower MgO content in the present magnetite indicates lower temperature of formation of this ore. The maximum contents of MnO, K₂O and P₂O₅ in the analyzed samples reach 0.04, 0.05 and 0.11% respectively.

The triangular diagram of TiO₂-FeO-Fe₂O₃ (Fig. 2) shows that the present magnetite is free from ulvospinel and has composition between magnetite and hematite. Also magnetite separated from the magnetite-hematite ore type is richer in Fe₂O₃ than that of magnetite separated from the magnetite ore type. This conclusion is in well concordant with the degree of iron oxidation.

Table 1 shows that the average contents of SiO₂, Al₂O₃ and CaO of the present magnetite are higher than those of magnetite and maghemomagnetite (Basta, 1957), magnetite and maghemite (Newhouse and Glass, 1936) and magnetite (Takeuchi & Nambu, 1954). The average content of FeO is lower and average content of Fe₂O₃ is higher in the present magnetite than those in magnetite and maghemomagnetite. The present analyses show that the average contents of Fe₂O₃ and FeO, which represent the main constituent of magnetite have

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intermediate values between magnetite (Basta, 1957) and maghemite (Newhouse and Glass, 1936). The magnetite is somewhat more similar to the maghemomagnetite of Basta (1957) than other analyses.

RESULTS OF STRUCTURAL FORMULA:

The structural formula calculations have been carried out to check the correct values of the chemical analyses of magnetite. Magnetite can for instance be oxidized to maghemite without loss of its structural planes and both have similar spinel structure.

The normal spinel has $8A^{+2}$ ions occupying the eight tetrahedral positions and $16B^{+3}$ occupying the sixteen octahedral positions. The inversed spinel has chemically different atoms occupying structural equivalent positions in which $8A + 8B$ occupy the octahedral positions. The present magnetite crystallizes as inversed spinel and has the following structural formula $(Fe_1^{+3} (Fe^{+2} Fe^{+3})_{1.85}O_4)$, i.e. the present magnetite lies between magnetite $(Fe_1^{+3} (Fe^{+2} Fe^{+3})_2O_4)$ and maghemite $(Fe_1^{+3} (Fe^{+2} Fe^{+3})_{1.725}O_4)$.

In magnetite 12 O atoms are associated with 9 Fe atoms, while in maghemite 12 O atoms are associated with 8 Fe atoms (Basta, 1962). The chemical analysis of the present magnetite (Table 1) gives the structural formula of $Fe_{8.57}O_{12}$ for

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magnetite in the magnetite ore and $\text{Fe}_{8.44}\text{O}_{12}$ for magnetite in the magnetite-hematite ore type, i.e., the present magnetite is oxidized to the mineral between magnetite and maghemite.

X-RAY AND CELL DIMENSION DATA:

Ten magnetite grains separated from magnetite ore type were studied by X-ray diffraction at the Central Laboratory of Tanta University, using PW 1840 Philips diffractometer with silica glass tube and nickel filtered copper radiation (Cu-K λ = 1.5418).

The complete pattern of magnetite appeared in all the examined samples (Fig. 3). The most characteristic lines of magnetite appear at d , 2.53 Å° at (311), 1.48 Å° (440), 1.614 Å° (511), 2.953 Å° (220), 2.098 Å° at (400), 1.713 Å° (422), 4.847 Å° (111) and 2.423 Å° (222).

Hematite is also detected in the studied magnetite samples. It is only observed at two characteristic lines 2.69 Å° (104) and 1.692 Å° (116). Quartz is sparse in the investigated samples, it has only one characteristic line detected at 3.34 Å° (101) and its presence indicates some deficiency in the separation process. The XRD pattern of magnetite shows that these most characteristic lines are intermediate between those of standard magnetite and maghemite (Table 2).

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The powder pattern of XRD of magnetite is measured and compared with those from ASTM index card d₁₋₁₁₂₀. Using the readings of 2θ and indices hkl, the cell dimension is measured using following equations of Cullity (1978).

$$\frac{1}{d^2} = \frac{h^2 + k^2 + l^2}{a^2}$$

$$\lambda = 2d \sin \theta$$

$$\frac{\sin^2 \theta}{h^2 + k^2 + l^2} = \frac{\lambda}{4a^2}$$

Where,

a = Cell dimension (unknown)

hkl = Lattice plane indices

d = interplanar spacing

λ = Wave length

θ = Diffraction angle

The precise determination of cell dimension of ten magnetite samples ranges from 8.3395 Å° to 8.3917 Å° with an average 8.3729 Å°. Table 3 gives the cell dimensions of some artificial magnetite grains. Basta (1957) recorded that the cell dimensions of Bisperg magnetite is a = 8.3963 ± 0.0005 Å°. Dimensions of Bisperg magnetite is due to either atomic

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substitution (Ca^{+2} substitutes Fe^{+2} and Si, Al substitute Fe^{+3}) or to the partial oxidation of magnetite to maghemite ($a = 8.32\text{\AA}$). Basta has also reported the existence in nature of a mineral intermediate in composition between magnetite and maghemite with cell dimension of $a = 8.369 \pm 0.001 \text{\AA}$.

Finally, we can confidently confirm that the average unit cell dimension of the studied magnetite (8.3729\AA) is intermediate in composition between that of magnetite and maghemite.

INFRARED DATA:

The infrared analysis was carried out using Perkin-Elmer 683 infrared spectrometer at the Central Laboratory of Tanta University.

The absorption bands of the separated magnetite are due to Fe-O bond. According to Estep (1977) magnetite has two major bands at wave lengths 570 cm^{-1} and 375 cm^{-1} while maghemite exhibits different absorption bands at wave lengths 680 cm^{-1} , 625 cm^{-1} , 540 cm^{-1} , 375 cm^{-1} , 310 cm^{-1} and 225 cm^{-1} . Referring to Neil & William (1964) magnetite exhibits two absorption bands at wave lengths 570 cm^{-1} and 385 cm^{-1} while maghemite ($\gamma \text{Fe}_2\text{O}_3$) exhibits three absorption bands. The absorption bands are presented graphically (Fig. 4) and their wave numbers are also tabulated (Table 4).

The present magnetite shows two major absorption bands at wave lengths $580 - 560 \text{ cm}^{-1}$ and 385 cm^{-1} (Table 4). Almost all samples show some absorption bands of maghemite at wave lengths 650 cm^{-1} , 340 cm^{-1} and 310 cm^{-1} , i.e., the present magnetite lies between magnetite and maghemite (Table 2). Hematite exhibits only one absorption band at wave length $460-450 \text{ cm}^{-1}$.

DIFFERENTIAL THERMAL ANALYSIS (DTA) Data

Only two magnetite from the magnetite ore type were analyzed using Shimadzu DT.30 differential thermal analyzer in the range of $30-950 \text{ C}^\circ$ by $30 \text{ C}^\circ/\text{min}$. The DTA curves are given in Fig. 5 and Table 5 and show an endothermic peak recorded at $330-370 \text{ C}^\circ$ and exothermic peak at:

1. $200-230 \text{ C}^\circ$ due to the oxidation of magnetite to maghemite as reported by Lepp (1957) in temperature range $200-400 \text{ C}^\circ$.
2. $550-580 \text{ C}^\circ$ due to the diffusion of oxygen into magnetite structure which caused the transformation of magnetite to hematite. This peak is similar to that reported by Schmidt and Vermass (1955) and Lepp (1957).
3. $150-170 \text{ C}^\circ$ (only in one sample).
4. $660-690 \text{ C}^\circ$ similar to synthetic magnetite on a DTA curve recorded by Weith (1952) of temperature range $600-700 \text{ C}^\circ$.

SUMMARY

The main conclusion of this paper is that present magnetite is oxidized to a mineral intermediate in composition

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between magnetite and maghemite. This result is confirmed by the following techniques.

1. Chemical analysis reveals that it has composition between standard magnetite and maghemite, i.e., it is similar to maghemomagnetite. The average Fe_2O_3 content of magnetite in the magnetite-hematite ore (79.09%) is greater than that of magnetite from the magnetite ore (76.07%). This result reflects that oxidation of ferrous iron to ferric iron is greater in the magnetite-hematite ore and is confirmed by calculation of the degree of oxidation which increases from 79.21 in magnetite ore to 82.43 in magnetite-hematite ore.

2. The structural formula of the present magnetite gives the formula of $\text{Fe}_{8.55}\text{O}_{12}$ which is intermediate between standard magnetite (Fe_9O_{12}) and maghemite (Fe_8O_{12}).

3. The average cell dimension of the present magnetite is 8.3729 \AA and the average cell volume (a^3) is 586.986 \AA^3 . This value is intermediate between standard magnetite ($a=8.39 \text{ \AA}$) and standard maghemite ($a=8.32 \text{ \AA}$) and similar to the value recorded by Basta (1957) for the mineral between magnetite and maghemite ($a=8.369 \text{ \AA}$).

4. The characteristic lines of X-ray diffraction for the present magnetite lie between those of standard magnetite and maghemite.

5. The study of infrared absorption bands shows and confirms the presence of bands of magnetite and maghemite.

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6. DTA shows exothermic peak at 200–230 C° due to oxidation of magnetite to maghemite (Lepp, 1957) at 150–170 C° and at 550–580 C° due to the diffusion of oxygen into magnetite structure leading to transformation of magnetite to hematite (Schmidt and Vermass, 1955).

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Table 1 : Chemical analyses, number of ions, degree of oxidation and cell parameters of the separated magnetite

Ore type	Magnetite ore															Magnetite - hematite ore			1	2	3	4	5
	Sample No	80M	59M	54M	67M	51M	46M	49M	69M	96M	53M	39M	30M	61M	Av.	75M	61M	Av.					
SiO ₂	1.84	1.29	1.72	1.55	1.97	1.40	1.56	1.00	0.49	1.24	1.10	1.14	1.37	1.36	1.30	1.44	1.37	0.73	0.27	1.07	1.15	0.03	
TiO ₂	0.03	0.01	0.03	0.03	0.01	0.01	0.03	0.02	0.04	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.05	tr.	0.16	1.37		
Al ₂ O ₃	0.91	0.15	0.07	0.93	0.52	0.35	0.57	0.34	0.69	0.54	0.74	0.76	0.56	0.60	0.56	0.31	0.43	0.94	0.21	0.34	0.04	0.19	
Fe ₂ O ₃	73.79	73.93	74.17	74.64	74.87	75.39	75.52	75.73	76.15	77.60	78.15	78.87	80.03	78.07	78.12	80.06	79.09	57.55	68.85	69.88	89.15	68.95	
FeO	21.35	22.90	20.07	20.84	20.84	20.33	20.58	21.35	19.55	19.55	18.52	16.72	16.98	19.97	17.75	15.95	16.85	31.43	30.78	27.93	6.67	30.82	
MnO	nil	0.04	0.04	0.01	0.03	0.04	0.01	0.03	nil	tr.	nil	0.03	0.04	0.02	0.01	0.01	0.01	0.05	-	0.07	-	-	
NiO	tr.	nil	tr.	nil	nil	nil	0.02	0.01	nil	nil	nil	nil	0.01	0.003	nil	nil	nil	0.10	-	0.14	tr.	-	
CaO	0.37	0.01	0.05	0.04	0.02	0.05	0.87	1.03	0.09	0.19	0.03	0.84	0.06	0.22	0.48	0.06	0.27	0.01	-	0.03	tr.	6.02	
K ₂ O	0.02	0.03	0.03	0.03	0.02	0.02	0.61	0.01	0.01	0.04	0.04	0.85	0.04	0.027	0.02	0.02	0.02	-	-	-	-	-	
P ₂ O ₅	0.11	tr.	0.06	nil	0.03	0.09	0.06	0.06	0.02	0.04	0.02	0.03	0.06	0.05	0.06	nil	0.03	-	-	-	-	-	
Total	98.42	98.38	97.04	98.07	98.31	97.7	99.23	98.60	95.99	99.23	98.65	97.66	99.17	98.15	98.32	97.87	98.09	107.04	100.11	99.62	106.83	100.01	
Fe ₁	58.24	69.54	67.51	68.44	68.60	68.56	68.85	69.60	68.52	69.51	69.12	68.20	62.21	68.76	68.47	68.43	68.45	-	-	-	-	-	
a(A ⁵)	8.369	8.378	-	8.351	8.383	8.376	8.392	8.371	8.395	-	8.385	-	8.34	8.373	-	-	-	8.396	8.395	8.394	8.343	-	
O	77.56	76.35	78.70	78.17	78.23	78.76	78.58	78.01	79.58	79.88	80.85	82.51	82.50	79.21	81.48	83.39	82.43	68.25	69.11	71.44	91.14	69.11	
Numbers of ions on the basis of 32 (O)																							
Si	0.56	0.36	0.52	0.464	0.592	0.40	0.464	0.24	0.288	0.375	0.32	0.344	0.408	0.408	0.352	0.43	0.392	0.24	0.083	0.32	0.334	0.008	
Al	0.32	0.055	0.32	0.32	0.176	0.123	0.20	0.104	0.216	0.175	0.24	0.264	0.192	0.208	0.192	0.106	0.144	0.016	0.077	0.12	0.014	0.072	
Fe ⁺³	7.12	7.584	7.16	7.216	7.232	7.472	7.336	7.656	7.486	7.45	7.44	7.392	7.40	7.384	7.456	7.464	7.464	7.736	7.84	7.528	7.358	7.92	
Ti	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.008	-	0.032	0.294	-	
Total	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	
Fe ⁺³	9.52	9.28	9.76	9.68	9.648	9.704	9.576	9.36	9.92	9.92	10.08	10.448	10.36	9.816	9.904	10.51	10.208	7.832	8.046	8.402	11.746	8.04	
Fe ⁺²	5.34	5.84	5.12	5.24	5.2	5.168	5.12	5.416	4.904	4.88	4.64	4.16	4.19	5.01	4.43	4.00	4.216	8.08	7.896	7.04	2.065	7.92	
Mn	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.016	-	0.016	-	-	
Ca	0.12	-	-	-	-	0.02	0.264	0.256	0.024	0.056	-	-	0.0176	0.058	0.152	0.016	0.02	0.004	-	0.008	-	0.037	
Ni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-	0.064	-	-	
Total	14.98	15.12	14.88	14.92	14.947	14.89	14.95	15.03	14.818	14.856	14.72	14.61	14.57	14.89	14.485	14.526	14.504	16.01	15.84	15.53	13.811	15.967	

1 - Magnetite, Bispevåg Säter, Dalcarlia, Sweden (Basta 1957)

2 - Magnetite (Newhouse and Glass 1936)

3 - Magnetite, iron ore, Bovey Tracy Devonshire (Basta 1959)

4 - Magnetite, Alameda Co., California (Newhouse and Glass, 1936)

5 - Magnetite, contact metamorphic deposit (Takeuchi & Nambu 1954)

Table 2 : Comparison between the studied magnetite and both the standard magnetite and maghemite using X-ray and infrared analyses

X - ray						Infrared				
Magnetite		Maghemite		Studied magnetite		Magnetite		Maghemite		Studied magnetite
d	I	d	I	d	I	Estep (1977)	Neil and William (1964)	Estep (1977)	Neil and William (1964)	
4.852	8	4.85	6					680		650
				4.815	15			625		
2.967	30					570	570			580-560
				2.957	30				555	
		2.95	30					540		
2.53	100								468	
				2.522	100		385			385
		2.514	100			375		375		340
2.424	8								336	
				2.413	20			310		310
		2.403	2					225		
2.099	20									
				2.095	35					
		2.085	15							
1.714	10									
				1.712	15					
		1.701	9							
1.616	30									
				1.61	60					
		1.604	20							
1.424	40									
				1.48	60					
		1.474	40							

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Table 3 : Cell edge of Fe_3O_4 (Å)

Cell edge (Å)	References
8.434	Holgersson (1927)
8.361 ± 0.003 or 8.389 ± 0.003	Clarke, Ally and Badger (1931)
8.397	Hagg (1935)
8.427	Gaglioti and D'Agostino (1936)
8.390 ± 0.002	Benard (1939)
8.437	Frank-Kamenecky (1939)
8.413	Pouillard (1949)
8.441 ± 0.004	Van der Marck (1951)
8.394 ± 0.0005	Abrahams and Calhoun (1953)
8.394 ± 0.0005	Tombs and Rooksby (1951)
8.396 ± 0.0005	Basta (1957)
8.373	Magnetite under study

Table 4 : IR data for magnetite

61 M		49 M		46 M		67 M		96 M		80 M		39 M		59 M		69 M	
Wave No.	Int.	Wave No.	Int.	Wave No.	Int.	Wave No.	Int.	Wave No.	Int.	Wave No.	Int.	Wave No.	Int.	Wave No.	Int.	Wave No.	Int.
		260	m,sp			260	w,sp										
310	w,sp	310	w,sp	310	w,b	310	w,b	305	w,sp	310	w,b	310	w,sp	310	w,b	310	w,b
340	m,b	340	w,b	340	w,b	340	w,b	360	w,b	340	w,b	345	m,sp	340	w,b	340	w,sp
385	w,sp	385	w,b	385	w,b	385	w,sh	635	w,b	385	w,b	385	w,b	385	w,b	385	w,sp
460	w,b	450	w,b	450	w,b	450	w,b	470	w,b	460	w,b	460-450	w,b	450	w,b	450	w,b
580-560	m,b	580-550	w,b	580-560	w,b	580-560	w,b	530	w,b	570	w,b	580-560	m,b	580-560	w,b	580-560	w,b
660	w,sh	650	w,sp	650	w,b	650	w,b			650	w,b	650	w,sp			645	w,sp

vs = very strong

s = strong

w = weak

sp = sharp

b = broad

sh = shulder

Table 5 : Differential thermal analyses of the separated magnetite

Separated magnetite			
30 M		96 M	
End.	Exo.	End.	Exo.
	150-170		
	200-215		220-230
330-370		350-370	
	550-570		550-580
	660-680		660-690
920-930		905	

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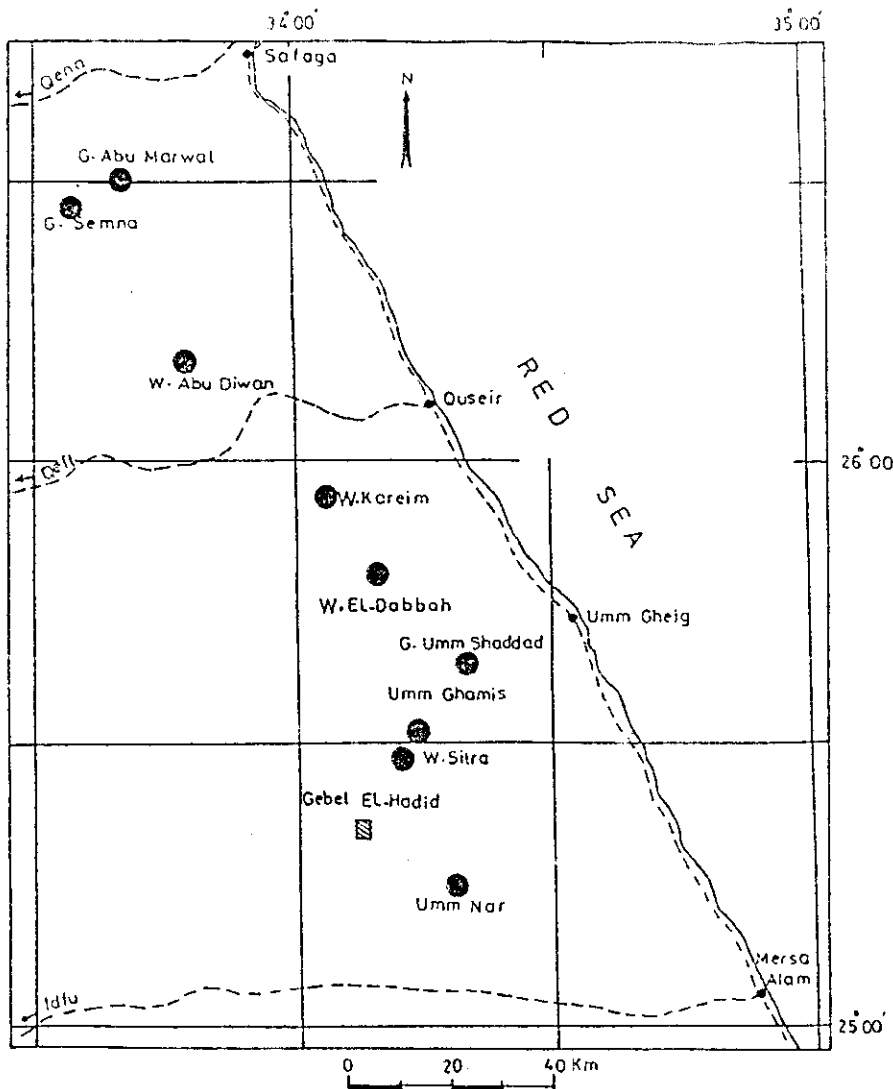


Fig. 1: Map showing the location of Gebel EL-Hadid and some other iron ore localities in the Central Eastern Desert, Egypt.

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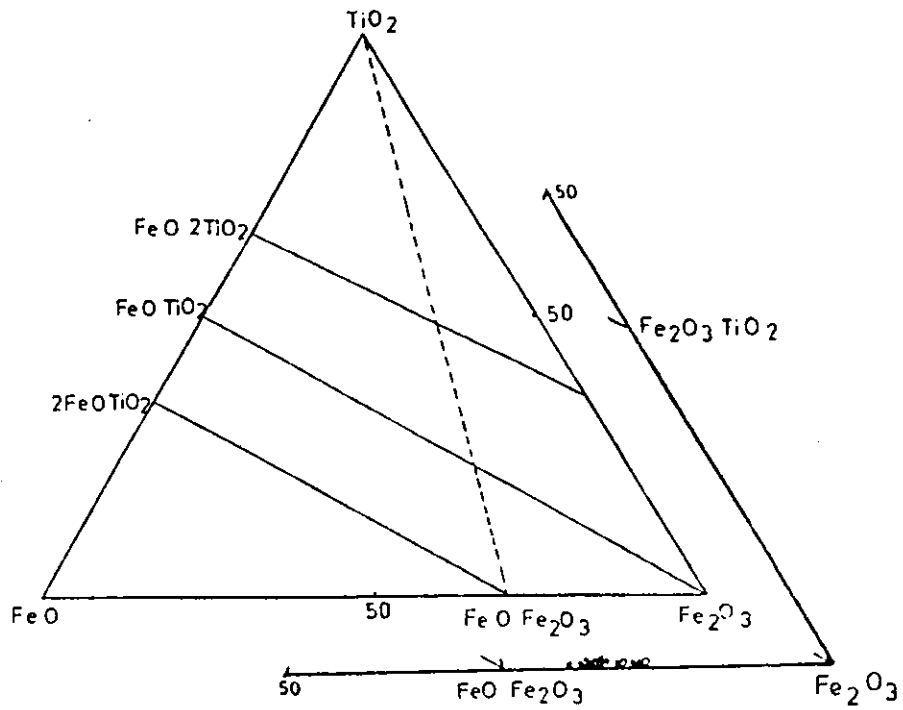


Fig. 2: Variation of FeO, Fe₂O₃ and TiO₂ in the separated magnetite, after Deer et al, 1962.

- Samples from magnetite ore type,
- Samples from magnetite-hematite ore type.

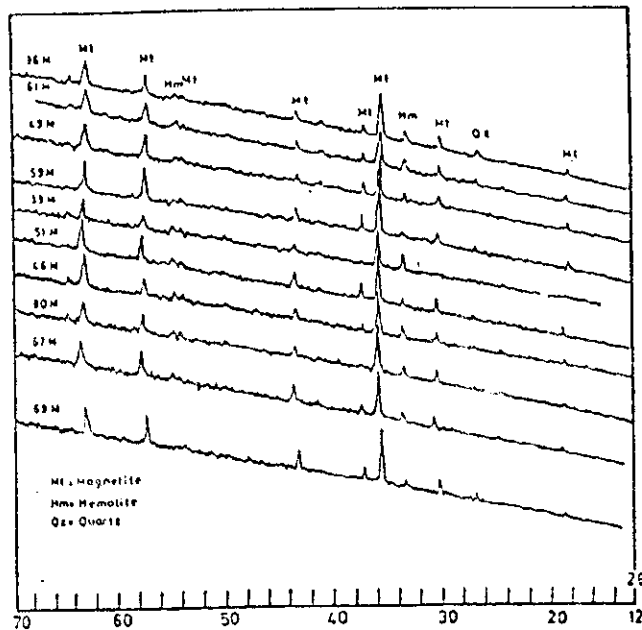


Fig. 3: X-Ray diffraction pattern of magnetite separated from magnetite ore type.

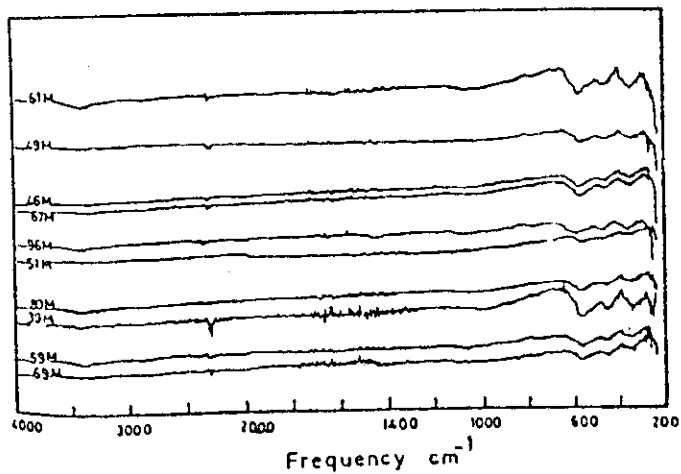


Fig. 4: Infrared absorption curves of magnetite separated from magnetite ore type.

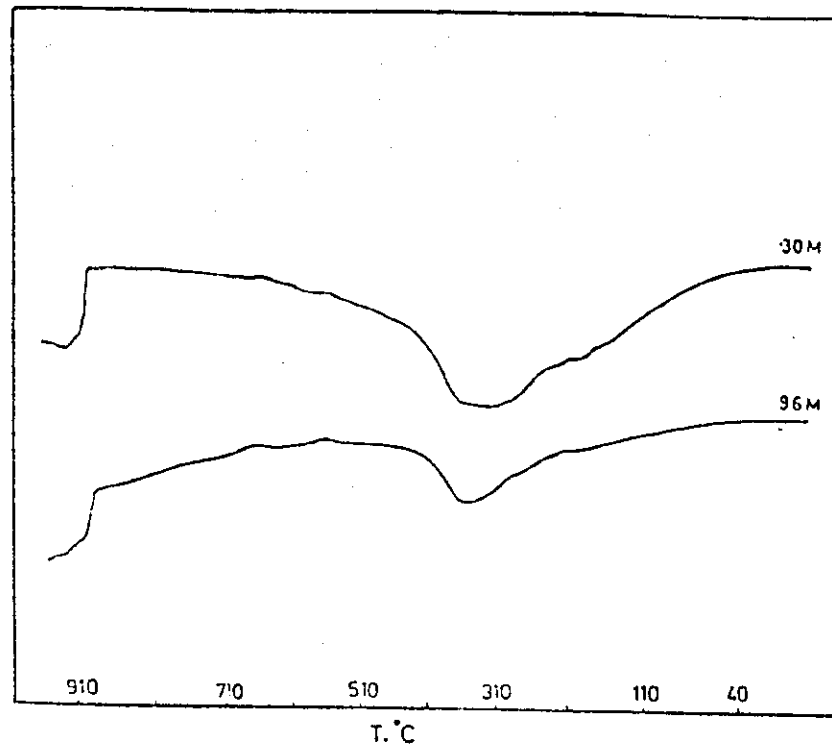


Fig 5 : DTA curves of magnetite separated from magnetite ore type.

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الخواص الكيميائية والمعدنية للماجنتيت من جبل الحديد الصحراء الشرقية - مصر

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يتناول هذا البحث دراسة كيميائية ومعدنية لماجنتيت رواسب خام حديد ما قبل الكمبرى بجبل الحديد بالصحراء الشرقية المصرية ، بغرض معرفة طبيعة وماهية هذا المعدن وعلى أساس الخواص المغناطيسية لهذا المعدن ثم فصله بطريقة يدوية وذلك باستخدام اسطوانة مجوفة من الألمنيوم يتحرك بداخلها نراع من الألمنيوم مثبت فى نهايته مغناطيس ، ثم التكد من درجة نقاء المعدن المعصوم باستخدام الميكروسكوب نو العينيةين .
اشتملت الدراسة الكيميائية والمعدنية على التحليل الكيميائى ، أشعة اكس ، الامتصاص الطيفى للأشعة تحت الحمراء ، والتحليل التفاضلى الحرارى .

استنتج الباحثون أن هذا المعدن النقى تم فصله له قانون كيمائى

$$C^{3+} (C^{2+} C^{3+}) A \quad \text{وهو يتوسط القانون الكيمائى للماجنتيت}$$

$$C^{3+} (C^{2+} C^{3+}) A^{185} \quad \text{ومعدن الماجنتيت } C^{3+} (C^{2+} C^{3+}) A \quad \text{كما أن الصيغة}$$

$$C^{3+} (C^{2+} C^{3+}) A^{173}$$

التركيبه لهذا المعدن هى $C^{3+} 185 A^{12}$ وهى تتوسط الصيغه التركيبية لكل من الماجنتيت $C^{3+} 9 A^{12}$ والماجهميت $C^{3+} 18 A^{12}$ كما أثبتت دراسه أبعاد الخلية للمعبدن الحالى أنها تتوسط أبعاد الخلية لكل من الماجنتيت والماجهميت وأيضا دراسه المعدن الحالى بواسطة أشعه اكس أثبتت أن معظم منحنياته تقع منحنيات معدنى الماجنتيت والماجهميت . أما الأشعه تحت الحمراء فقد أثبتت أن المعدن يحتوى على أطياى كل من الماجنتيت والماجهميت .

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وخلصه القول فان ماكان يعرف باسم الماجنتيت برواسب خام الحديد
بجبل الحديد وهو معدن آخر يتوسط في كل صفاته الكيميائيه والمعدنيه كل مسن
معدنى الماجنتيت والماجهميت وهو الماجهميت والماجننتيت •