The manganese deposits of Egypt are logged in many different localities in the Eastern Desert. Several manganese deposits were exploited by open cast mining excavation in the Red Sea coastal plain, particularly in the area covering from south-west of Halayeb Village to around the flood plain of Wadi Elba north-east of Abu Ramad. Our study discussed the manganese deposits in twelve areas named as wadi Bashoya, Oshbia, N-Gabal Toyo, El-Hebal, Mateet, Blowmay, Adeeb, Sarara, Sirmatai, Aqilahuq, Eikwan and N-wadi Ajway. There are two types of manganese deposits it can occur either as massive manganese ore type or mangneferous sandstone ore type.

The area is situated at the Abu Ramad fault system which is the major belt of shearing within the NW–SE striking fault system. It forms part of Red Sea on south Eastern Desert in NW–SE direction with sub vertical dip. The deformation history attributed to Arc accretion tectonic of the Pan African Orogeny, also lies at the eastern part of North Hamizana Shear Zone.

Binary diagram between (Co + Ni) wt. % versus (As + Cu + Mo + Pb + V + Zn) wt. % display the hydrothermal origin and supported by the MnO (wt. %) Fe₂O₃ (wt. %) and ppm (Cu + Co + Ni) 1000 triangle diagram and also by the Mn (wt. %) Fe (wt. %) and 10*(Ni + Co + Cu) wt. % triangle diagram. These deposits are characterized by low concentration of Cu, Ni and Co. The geochemical composition of manganese ores reflect formation by chemical precipitation from hydrothermal solution but occurrence...
of colloform texture, oolites in the manganiferous types denote to the redeposition by sedimentation processes.

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1. Data

The data of this article provides informations on the origin of Elba manganese. Fig. 1 show Google Earth photo of the area and also sample locations and Mn occurrences. The Figs. 2–8, representing the geochemical analysis interpretation of the origin. Fig. 9 represent photo for the manganese outcrops in the field. Table 1 represent the nature, geology and coordination of manganese deposits and also host rocks. Table 2 represent the raw data of the major and trace element of the rocks.

2. Experimental design, materials, and methods

Twenty representative samples from Elba manganese were analysed for major oxides and trace element. SiO₂, TiO₂, Al₂O₃, and P₂O₅ were measured by using spectrophotometer. Na₂O and K₂O were determined by the flame photometric technique. Fe₂O₃, FeO, MgO, MnO, and CaO were calculated by titration methods and LOI was determined gravimetrically at a temperature of 1000 °C. Cr, Co, Ni, Cu, Zn, Zr, Rb, Ba, Sr and V concentrations were determined using X-rays fluorescence by Philips X unique II machine. These chemical analyses were approved out at the Laboratory of Nuclear Materials Authority in Qatameia, Cairo.

2.1. Geologic setting and stratigraphy

The manganese deposits of Egypt are logged in many different localities in the Eastern Desert. Several manganese deposits were exploited by open cast mining excavation in the Red Sea coastal
plain, particularly in the area covering from south-west of Halayeb Village to around the flood-plain of Wadi Elba north-east of Abu Ramad. The deposits are lenticular bodies filling faults and fractures within the Tertiary marine sediments of the Red Sea.

Our study discussed the manganese deposits in twelve areas named as wadi Bashoya, Oshibia, N-Gabal Toyo, El-Hebal, Mateet, Blownay, Adeeb, Sarara, Sirmatai, Aqilahuq, Eikwan and N-wadi Ajway.

Late Proterozoic granodiorite rocks occurs in the Hebal area which lies in north-west of Wadi Kiraf and south east of Wadi Diit. These rocks intruded within the metavolcanics and metagabbros rocks; and also intruded by basic volcanic dykes swarm with general NW – SE trend.

The Middle Miocene is represented by two formations, Gabel Al-rusas formation (conglomeratic sandstone and shale, rare marle and limestone bands) and Abu-Dabbab formation (thick, massive anhydrate and gypsum beds intercalated with marle, silty clay, sandstone and dolomitic limestone).
The Pliocene composed essentially of Sermatai Formation (grey clay, sandstone, and conglomerate) with manganese pockets. Manganese occurs in sedimentary rocks of Miocene age in some sites within Halaib area. It occurs as fracture fillings in igneous rocks especially, granites. Manganese minerals befall either in veins or interchanging in the Miocene conglomerates. The mineralogy of the ore includes pyrolusite, psilomelane and cryptomelane adding to irregular goethite and hematite. The gangue minerals consist of quartz, calcite and barite.

All data of geology and stratigraphy and also the nature of manganese deposits are briefly represented in Table 1. There are two types of manganese deposits it can occur either as massive manganese ore type or mangneferous sandstone ore type.

- Mangneferous ore type which described by highest average values of SiO₂ >20%, Fe₂O₃ >5.5%, Al₂O₃ >2%, lowest average values of MnO (28%) and LOI (8.56%), less in resistance and associated with calcite.
- Massive manganese ore type which described by the highest average contents of MnO (50.5%) and LOI (16.8%) and lowest values of Fe₂O₃ (3.9%), SiO₂ < 20% and Al₂O₃ <1% accorded with mangneferous ore.

Fig. 3. Si/Al diagram [2] showing the hydrothermal origin.

Fig. 4. Fe-Al-Mn triangular diagram [3] to define the Venarch Mn ore type. (ANS BIF) Field of data points of Banded Iron Formation in the Arabian–Nubian Shield, after [4].
The trace elements of the two types mostly Sr, Pb, V, Ba, Zn and Cu which are remarkably of high values while Zr, Ni, Cr, Co, Mo, Y and Li are less concentrated.

2.2. Geochemistry and identification of the origin of Elba manganese deposits

The geochemical composition of manganese ores (Table 2) reflect formation by chemical precipitation from hydrothermal solution but occurrence of colloform texture, oolites in the manganiferous types mean to the redeposition by sedimentation processes. Binary diagram between (Co + Ni) wt. % versus (As + Cu + Mo + Pb + V + Zn) wt. % (Fig. 2) [1] display the hydrothermal origin and supported by Si versus Al binary diagram (Fig. 3) [2]. Also by using Al (wt. %), Fe (wt. %), Mn (wt. %) ternary diagram (Fig. 4) [3], and Mn (wt. %), Fe (wt. %), ppm (Cu + Co + Ni)*10 ternary diagram (Fig. 5) [5]. Co/Zn versus Cu + Co + Ni (ppm) binary diagram (Fig. 6) [7] also SiO2 (wt. %) versus Al2O3 (wt. %) (Fig. 7) [2,7]. and

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**Fig. 5.** Ternary diagram (Ni + Co + Cu) x10-Fe-Mn [5] with notronites of Aden Gulf [6].

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**Fig. 6.** Co/Zn versus Co + Ni + Cu diagram [7]. The Venarch samples plot in the field of deposits with the hydrothermal origin.

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finally, (Co + Ni) wt. % versus (V + Pb + Zn + Cu) wt. % (Fig. 8) [8] all are reflect the hydrothermal origin of Elba manganese deposits.

An epigenetic low temperature origin was suggested by Ref. [11] based on the predominance of stable higher oxides of manganese and absence of manganese silicates, carbonates and sulphides,
| No | Location name | Location Co-ordination | Nature of Mn deposits | Host Rocks | Age              |
|----|---------------|-------------------------|-----------------------|------------|------------------|
|    |               | Latitude Longitude      |                       |            |                  |
| 1  | Wadi-Bashoya  | 22° 22' 15" 36° 16' 30"| Mn Veins and lenses, Magniferous sandstone and Multi-veins and pockets | Interbedded with sandstone, conglomerate, clay, siltstone and calcareous sandstone | Miocene |
| 2  | Oshbia        | 22° 21' 50" 36° 16' 57"| Mn pockets in fractures and fault plane | Lie between mederatly high Quaternary terraces, clay, siltstone and calcareous sandstone | Quaternary-Miocene to Post Miocene |
| 3  | North Gabal Toyo | 22° 23' 15" 36° 11' 00" | Mn veins and horizontal beds with calcite | Clay, siltstone and sandstone | Middle Miocene |
| 4  | El-Hebal      | 22° 26' 30" 36° 06' 23"| Mn deposits are unconformable ovelain by Miocene sediments, veinlets of calcite are associated with Mn veins | Coarse and calcereous sandstone, |                      |
| 5  | Mateet        | 22° 19' 15" 36° 25' 34"| Mn Veins and lenses | Lie between mederatly high Quaternary terraces and Miocene to post Miocene are represented as low hills of clay, siltstone and sandstone | Quaternary-Miocene to Post Miocene |
| 6  | Blownay       | 22° 20' 15" 36° 26' 25"| Mn pockets in fractures and fault plane and isolated lenses | Clay, siltstone and sandstone |                      |
| 7  | Adeeb         | 22° 18' 10.30" 36° 28' 34"| Mn veins accured near surface | Clay, siltstone and sandstone | Miocene |
| 8  | Sarara        | 22° 16' 12" 36° 29' 58"| Mn deposits are unconformable ovelain by Miocene sediments both lenses and veins along mineralized zone | Coarse and calcereous sandstone, | Middle Miocene |
| 9  | Sirmatai      | 22° 15' 32" 36° 30' 00"| Mn deposits are unconformable ovelain by Miocene sediments to post Miocene occurred as cement material inbetween conglomerate grains | Conglomerate sandstone and calcereous conglomeratic sandstone within sandstone and syanogranite | Miocene to post Miocene |
| 10 | Aqilahuq      | 22° 07' 15" 36° 39' 58"| Mn deposits are unconformable ovelain by Miocene sediments to post Miocene occurred as cement material inbetween conglomerate grains |                       |                  |
| 11 | El-kwan       | 22° 07' 00" 36° 40' 44"| Mn deposits are unconformable ovelain by Miocene sediments to post Miocene occurred as cement material inbetween conglomerate grains |                       |                  |
| 12 | North wadi Ajway | 22° 07' 09" 36° 40' 44" | Mn deposits are unconformable ovelain by Miocene sediments to post Miocene occurred as cement material inbetween conglomerate grains |                       |                  |
| Sample No | Major oxides (wt. %) | Major elements (wt. %) | Trace elements (ppm) |
|-----------|---------------------|-----------------------|---------------------|
| 1         | SiO2 20.15          | V 1084.00             |
| 2         | TiO2 0.15           | Cr 163.40              |
| 3         | Al2O3 1.82          | Co 22.90               |
| 4         | Fe2O3 6.16          | Ni 25.50               |
| 5         | MnO 33.40           | MgO 25.14              |
| 6         | MgO 0.15            | Mn% 25.87              |
| 7         | CaO 19.43           | Na% 39.43              |
| 8         | Na2O 0.80           | Trace elements (%)     |
| 9         | K2O 0.91            |                      |
| 10        | P2O5 0.08           |                      |
| 11        | LOI 15.57           |                      |
| 12        | Si % 9.42           |                      |
| 13        | Al % 0.96           |                      |
| 14        | Fe % 4.31           |                      |
| 15        | Mn% 25.87           |                      |
| 16        | Mg % 0.09           |                      |
| 17        | Na % 0.59           |                      |
| 18        | Trace elements (%)  |                      |
| 19        | V % 0.11            |                      |
| 20        | Co % 0.00           |                      |
| 21        | Ni % 0.00           |                      |
| 22        | Trace elements (%)  |                      |
| 23        | V % 0.11            |                      |
| 24        | Co % 0.00           |                      |
| 25        | Ni % 0.00           |                      |

Table 2
Major and trace elements of the studied rocks.

Sample No | Major oxides (wt. %) | Major elements (wt. %) | Trace elements (ppm) |
|-----------|---------------------|-----------------------|---------------------|
| 1         | SiO2 20.15          | V 1084.00             |
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| 18        | Trace elements (%)  |                      |
| 19        | V % 0.11            |                      |
| 20        | Co % 0.00           |                      |
| 21        | Ni % 0.00           |                      |

Table 2
Major and trace elements of the studied rocks.
|        | Cu % | (Co + Ni)% | (Co + Cu + Ni)% | (Co + Cu + Ni)%*10 | (As + Cu + Mo + Pb + V + Zn) % |
|--------|------|------------|----------------|---------------------|--------------------------------|
| Zn %   | 0.11 | 0.99       | 0.10           | 0.15                | 0.14                          |
| Mo %   | 0.00 | 0.00       | 0.00           | 0.00                | 0.00                          |
| Ba %   | 0.59 | 0.57       | 0.45           | 1.80                | 0.47                          |
| As %   | 0.09 | 0.09       | 0.08           | 0.08                | 0.08                          |
| Pb %   | 0.00 | 0.00       | 0.00           | 0.03                | 0.00                          |
|        | 0.31 | 1.14       | 0.25           | 0.27                | 0.25                          |
which replicate near—surface deposition of the ore. According to the chemical composition particularly the ratio of Mn, Fe and the concentration of Cu, Co and Ni, iron—manganese deposits can be genetically categorized into three major types which reflect their depositional processes lie hydrogenic, hydrothermal and digenetic [12], Figs. 5, 7 and 8.

2.3. Structural analysis

The area is positioned at the closeness of Abu Ramad fault system that is major belt of shearing within the NW —SE striking fault system with sub vertical dip. The deformation history of the area is accredited to Arc accretion tectonic of the Pan African Orogeny, also the area deceits at the eastern part of North Hamizona Shear Zone which is abroad zone of deformation [9]. Several transverse fractures perpendicular to the Red Sea and linear magnetic anomalies parallel to the Red sea are related deep, seated dikes [10]. Bedding and laminations are mainly detected in the metavolcanics, Miocene deposits and Post Miocene sediments. The beds are nearly horizontal sometimes are dipping few degree towards the NE.

The structural elements of the area basically pronounced as the following:-

- Fractures include joints and faults, most of them extend parallel to major fault, and they have mainly ENE—WSW, NW —SE, E-W and NS trends.
- Faults are rejuvenated during various tectonic cycles most of them have left lateral movement. Most of the major wadies, sloping towards the Red Sea are controlled by ENE direction faults from crossed and parallel system. The ENE trending normal faults form graben delimitated from S by Aigan plain and Gabal Sol Hamed (Fig. 1). The surface of this graben is mainly serene of highly weathered rocks. The strike slip movement of ENE fault evacuated the mineralized manganese zone parallel to the Red Sea shore line. The Quaternary NW normal faults are cutting across the alluvial deposits and along the coastal plain.

Acknowledgments

The first author is grateful to Shalaten Mineral Resource Company for helping during geologic field work. He also, thanked his wife for continuous support and his baby Sela.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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