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Review Article

Spotlight on Geochemical Studies Outcomes for Mn Ore Deposits of Um Bogma, West-Central Sinai, Egypt

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ABSTRACT

Manganese ore is essential in industry, mining, laboratory experiments, and for whole life in general, that's only because it's widely used as sulfur-fixing, deoxidizing, and alloying metallic material. In this regard, Mn has medically considered a trace element that is present in a relatively small amount in the human body, an average of 20 mg.

Manganese is the 12th most abundant element in the Earth's crust, which occupies about 1000 ppm of it, with a percentage of 0.1%. All soils in general contain about 440 ppm of such an element. In addition, the atmosphere's manganese ratio is 0.01 μg/m^3.

The geology and mineralogy of the Mn deposits of the Um Bogma Region, in west-central Sinai, had been previously studied by some investigators. There is a dispute between investigators about the origin of the most economic Mn ore deposits in Egypt, located in the Um Bogma Region.

Many investigators had put the evidence for the Mn deposits to be epigenetic in origin and maintained that these deposits had been deposited as a result of the activity of mineralized hydrothermal fluids. Other investigators maintained that these Mn ore deposits are considered primary sedimentary-type in origin.

In the present paper, the geochemical studies of the manganese deposits of Um Bogma Region, West-central Sinai, Egypt, done by some investigators will be surveyed and discussed, on the way to determine the origin of such deposits. The present paper is mainly based on the graduation project thesis of the paper's author.

Keywords: Manganese; Manganite; Sedimentary origin; Mineralization

INTRODUCTION

Manganese (Mn) as a metal, is an essential ore to the production processes of iron and steel, due to some properties which not existed in other metallic ores, unlike manganese. That's only because it has the ability to act as a deoxidizing agent which plays an important role in removing the oxygen content during the manufacture of steel. In addition, manganese can be used as a sulfur-fixing and an alloying metal. During the manufacture and production processes of steel, manganese metal is a most remarkable demand, at least, from 85% to 90% of the total. Ferromanganese and silicomanganese components unite together forming manganese ferroalloys which are used in providing the manganese metal as a key ingredient to iron and steel manufactural processes. Construction, machines making, and transportation are all the other different usages of this metal. Broadly speaking, this metal can be widely used as colorants for bricks, plant fertilizers, and animal feed. In addition to its effective presence in dry-cell batteries.

There is a high similarity between Manganese and Iron in their chemistry, strictly speaking, they are mostly associated with each other in the different rocks. Also, this remarkable similarity is in their valence states, as they chemically occur in divalent and tetravalent states as the most famous ones; Mn^{+2} and Mn^{+4}. In the divalent state (Mn^{+2}) manganese can easily form soluble compounds, then can be transported in solution. Oppositely, in the tetravalent state (Mn^{+4}), it forms insoluble compounds. So, any solution containing manganese in such a valence state (Mn^{+4}) will quickly precipitate a tetravalent compound by oxidation such as Pyrolusite (MnO_2).

Manganese ore deposits occur in some localities in different countries worldwide, but they do the utmost occurrence as most valuable economic amounts in special localities. The tiptop of such localities in Africa, which hosts over 80% of the manganese

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deposits of the whole world's land-based manganese ores resources, and produced about 6,200,000 million tons (41.1%) of the total amount of the manganese metal in ores (18 million tons). Africa's manganese deposits are classified into four main categories; BIF-hosted, black shale-hosted, oolitic, and finally supergene/karst-hosted deposits [1]. The second of these localities is China, which produces 3,000,000 tons on average of the world's manganese deposits, these deposits are of different origins and categorized into main six types; sedimentary, supergene, volcanic-sedimentary, metamorphosed, hydrothermally-modified, and hydrothermal. The two first ones of the aforementioned types are the most abundant and then more economic than the others. And so on, in Australia (2,900,000 tons), Gabon (1,800,000 tons), Brazil (1,000,000 tons), India (950,000 tons), Malaysia (400,000 tons), Ukraine/ Kazakhstan/Ghana (both 390,000 tons), Mexico (240,000 tons), Myanmar (100,000 tons). These aforementioned statistical ratios of manganese production, all over the world, are based on the United States Geological Survey, accessed in 2016.

Manganese ore deposits are found in several places in Egypt, but they show a remarkable and large presence in a few places to consider them as economic deposits with a great commercial and financial return, e.g., Gebel Abu Shaar El Qibli, north of Hurghada; Um Bogma area, West-central Sinai; Gebel Elba, the southern part of the Eastern Desert. In addition, these deposits do occur as minor occurrences in some places, such as in Ras Banas and Abu Ghosun, Southern Eastern Desert. The most essential and exploitable manganese deposits are those of the Um Bogma, which are mainly concentrated in the lower dolomitic part of the Um Bogma Formation of the Carboniferous age [2]. Accordingly, we will shed the light on manganese deposits in such a region, focusing on the geochemical studies of these deposits done by different investigators which will lead to us detecting the origin of such deposits.

The outcrops of the Paleozoic Um Bogma Region, West-central Sinai, had been grouped by Barron, et al. [3], into three main classes; lower sandstones, middle limestone, and upper sandstone series. In addition, Kora et al. [4], subdivided these outcrops of such a region into six formations, from the base upward; Sarabit El Khadim (Cambro-Ordovician), Abu Hamata (Cambro-Ordovician), Nasib (Cambro-Ordovician), Adedia (Cambro-Ordovician), Um Bogma (Carboniferous), and Abu Thora (Carboniferous). Basaltic sill intrusion and lava flows of about 40 meters in thickness follow the aforementioned formations upward. Bearing in mind, the Um Bogma and the Abu Thora two formations represent the lower limestones and the upper sandstones series of Barron et al. [3]. broadly speaking, the most economically essential Um Bogma formation lies in three lithostratigraphic rock units from the base upward; Ras Samra, El Qor, and Um Shebba Members [5,6]. The first-mentioned member is very fortunate that it contains economical manganese deposits within.

Egypt as a part of Gondwana land drifted southward, During the Cambrian period reaching the paleolatitude 70° S [7]. Additionally, during the Ordovician, the Silurian, and the Devonian time span, Egypt was confined by the epeiric sea [8]. The transgression phase of the aforementioned sea occurred, and consequently covered the only southwestern part of Egypt [9]. The Um Bogma Region was topographically positive land under erosion as one of the parts of Egypt which not covered by such a transgression phase of this epeiric sea. During the Lower Carboniferous, there were two successive transgression and regression phases of the epeiric sea. The transgression phase occurred over the whole Um Bogma Region depositing the Mn-bearing Um Bogma Formation, followed by the regression phase depositing the overlying fluviomarine Abu Thora Formation.

The present paper aims to make a survey of the previously published scientific papers in this context to study the geochemical properties of these important and absolutely irreplaceable manganese deposits in Egypt. From this context, we will spotlight the genesis and the geochemistry of manganese deposits and their relations with host Carboniferous sediments and the surrounding rocks in the Um Bogma region, west-central Sinai, Egypt.

GEOLOGIC SETTING OF REGION

There are basaltic sheeted-like bodies of the Permo-Triassic age over the clastic sediments of the Abu Thora formation at the Um Bogma region. Tectonism played an important role in the forming and arranging of the Um Bogma Region during the lower carboniferous [10]. This geological consideration is evidenced by some field facts by which the Mn-bearing Um Bogma Formation does not expose in some places such as at Wadi Ferin, Wadi Mokattab, and Gebel Abu Durba in the southern part of the Um Bogma region, consequently the Abu Thora Formation overlies directly the Cambrian Naqus Formation [11,12]. Abu Thora Formation rests directly on the Cambrian Naqus Formation in the northern part of Wadi Qena, Eastern Desert [13]. At Wadi Araba, along the western side of the Gulf of Suez, the Um Bogma Formation is also missing. Faults are the most dominant structural elements which widely appeared in the Um Bogma Region and greatly left their prints on the rock units of such a region. There are three main classes of these faults:

A. NNW-SSE trending normal faults (Red Sea trend) along the Permo-Triassic basaltic dykes.

B. NW-SE trending faults (Gulf of Suez trend) along which the main Wadies of the Um Bogma Region were incised, such as the Wadies of Nasib, Baba, Bala, and El Lehian.

C. E-W trending faults along which the two Wadies of Sahu and Abu Thora were incised.

GEOCHEMICAL STUDIES OUTCOMES

Saad et al. [14], did a geochemical analysis for tens of Mn ore samples, from the lower dolomitic member of the Um Bogma Formation containing the economic deposits. It has been found that there is an inverse relation between manganese and iron oxides in these samples, suggesting that a fractionation process between the two elements occurred during their deposition in such a region.

Mn ore deposits are observed to be highly rich in Pb, Cu, Zn, and Ba. Otherwise, there is a depletion in some elements such as Co, Ni, Be, Mo, Sr, and Sn [14]. By dint of field observations, MnO content, Fe_2O_3 content, and MnO_2/Fe_2O_3 ratio, Khalifa et al. [15], grouped these Mn-Fe ore deposits of such a region into three main classes; Mn-rich, Fe-rich, Mn-Fe rich ores.

A strong negative correlation between MnO and Fe_2O_3 is observed, then reflects that the precipitation of these deposits occurred under different environmental conditions [14,15]. K_2O, Al_2O_3, MgO, Co, Cu, Zn, Sr, and Sn components are positively correlated with Mn, and negatively correlated with Fe [14].

Khalifa et al. [15], finds that Ba and Cu have a positive correlation with MnO. In addition, Ba and MnO correlation coefficient (r) is 0.75 and equals 0.63 between Cu and MnO. Finally, there are positive correlation coefficients between some trace elements, such as Co-Ni (r=0.63), Co-Cu (r=1.00), and so on.

Um Bogma Mn ore origin

Gindy et al. [16], Nakhla et al. [17], and Saad et al. [18], gathered and agreed on the epigenetic origin of Um Bogma manganese deposits, and maintained that these manganese deposits such economic ones, deposited as a result of mineralized hydrothermal fluids activity within the carbonate host rock. These considerations are mainly based on some evidence mentioned below:

- The most abundant structural element in the area under investigation is the faults. The manganese deposits are highly related to these faults. In addition, manganese deposits tend to accumulate at points near these faults.
- Whenever these manganese deposits occur, suddenly the dolomitic limestones partially disappear. And they tend to completely disappear in some regions adjacent to Um Bogma Region, where only a small part of the limestone series disappeared near these deposits. It is always the lower part of the aforementioned series that is gone with the upper parts left.
- Some Mn-bearing minerals such as manganite and hausmannite are found in such areas where manganese deposits occur [19,20].
- Relict, core, and rim replacement textures were reported by Saad et al. [18], within the Mn-Fe ore deposits.
- Some foraminiferal tests of *Fusilina sp.* are completely replaced by polianite.

Other investigators; Mart et al. [21], Magaritz et al. [22], Kora et al. [4], put some evidence for the primary sedimentary origin of the manganese deposits, as outlined below:

- Manganese deposits occupy the same stratigraphic horizons, and these deposits are older than the structural elements such as faults and folds preponderant in such a region. In addition, there is a displacement occurred by the faults of the region.
- Goethite and hematite dominantly associate with Pyrolusite and Manganite.
- The difference in the type of insoluble residue between the inner and the outer regions of the Mn ore lenses indicates that the bulk of this ore was not formed at the expense of the surrounding sandy dolomitic rocks, but rather is associated with different ones.
- There is no transition in mineralization between the manganese ore bodies and the upper incompatible beds, in contrast to the narrow transition zone between the laterally surrounding ore and dolomite.
- There is a steady synchronization between the dolomitzation and the mineralogical and chemical reconstitution of the zoned deposits in this region.

Broadly Speaking, during the mature stage of the carboniferous karstification, the weathering and its related processes served in the accumulation of manganese deposits [10].

According to the aforementioned author, the presence of quartz-sand grains in such deposits reflects karst-related mineralization. Ore bodies existed in the Um Bogma Region vary in composition from pure Mn to pure Fe, but overall, they occur as a mixture of variable concentrations.

DISCUSSION

According to the observations by Roy et al. [20], which reflects the presence of manganite in such a region under study can be considered strong evidence for the hydrothermal origin of such deposits because this manganite forms by low-temperature hydrothermal action in veins in association with barite, calcite, and siderite.

Otherwise, goethite and hematite which are formed by the action of external geological factors such as weathering process, are also found associated with manganite and hausmannite minerals according to Mart et al. [21], Magaritz et al. [22], and Kora et al. [4].

These textures found by Saad et al. [18], microscopically act as evidence stronger than the presence of the aforementioned minerals. That's only because these textures are associated with the hydrothermal features of such deposits [23-30].

Additionally, *Fusilina sp.* is found completely replaced by polianite mineral as a variety of pyrolusite mineral which chemically composes of MnO. It's geologically known that hydrothermal fluids can easily flow through the fault planes as suitable channels to go out, on the way to precipitate their carried ores.

The positive correlation coefficients between Co-Ni (r=0.63) and Co-Cu (r=1.00) according to the geochemical analysis done by Saad et al. and Khalifa et al. [15,18], act as conclusive evidence for the hydrothermal origin of Um Bogma manganese deposits.

Bearing in mind, the correlation coefficients (r) between Ba and MnO (0.75) and Cu and MnO (0.63) according to the analysis of Khalifa et al. [15], reflect that Ba and Cu are selectively adsorbed on manganese oxides.

CONCLUSION

The Um Bogma region is an essential spot for Manganese deposits of economic impact, that's only because its manganese reserve is a remarkably high and get exploited since ancient times. There is a dispute between different investigators over the origin of the manganese deposits in the Um Bogma region. Some of them consider the origin of such deposits is from hydrothermal fluids, while others prove that they are of sedimentary origin. By and large, the microscopic investigation of the ore is considered one of the best methods that were used by investigators on the way to detect the origin of the ore under survey in the present paper, which in turn shows the origin of the ore with fairly high accuracy.

The microscopy of the Um Bogma Mn Ore shows that textures of this ore are such as Relict, core, and rim replacement textures indicating the hydrothermal origin of this ore. From the previous studies conducted by a number of investigators interested in these manganese deposits, which state that these deposits are of hydrothermal origin, and this was confirmed by a geochemical analysis as published in the most recent articles. Concluding, the utmost importance of the Um Bogma Manganese ore deposits lies in their economy, so such differences in their origin do not diminish their economic importance in trade, industry, and also laboratory.

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