

# **GEOLOGICAL AND GEOPHYSICAL SURVEY ON THE METALLOGENIC OF THE MANGANESE MINING SITE OF BOUARFA, HIGH ATLAS, MOROCCO**

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## **Abstract**

The Bouarfa manganese site is located a few kilometers west of Bouarfa city on the "border chain" of North Tamlelt Moroccan High Atlas. Our Geological and geophysical investigations, helped to highlight some structural elements. It also helped to characterize the mineralized levels and point out that Bouarfa manganese is a Mississippi Valley Type (MVT). The manganese oxide beds were observed at the lower part of the banded dolomite. Manganese deposit occurs also as karsts within the massive dolomite. Mineralization is associated to the dolomite bench Middle Lias. Therefore, iron oxide and manganese forms irregular clusters and a more capricious distribution. Generally, the manganese indices are numerous and are scattered over a relatively large area allocated to Lias Medium. Manganese mineralization in the study area is in the following forms: 1. Carbonate mineralization diffuse low, but with anomalous zones of 2 to 3%, which seems to exist in the entire series of the cover to the top of the bar Hamaraouët. 2. A syngenetic manganese oxides beds mineralization with lamination (level benchmark of Hamaraouët) (several kilometers). 3. An alternative mineralization in the Hamaraouët bar, which unlike the previous one, is closely related to tectonics. 4. Epigenetic vein mineralization in the upper conglomerates. Earlier in the mineralized series, it also appears to be linked to fairly significant flaws. 5. Mineralization type "run" in Ain Beida is indeed related to a discontinuity surface that corresponds to a paleosurface emersion.

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**Keywords:** Bouarfa, manganese, oxides, MVT

## **Introduction**

The manganese mines object of this study is part of ferruginous manganese deposits of Bouarfa. Hence, they are located a few kilometers west of the city of Bouarfa (Figure 1). They are accessible using the main road to the village of Bouanane. Also, it has a track in the North which is about 6-7 km away.

## **Geological Background**

The region of Bouarfa was studied for the first time by Russo in 1927. However, the deposit was the subject of the investigative work by Poldini in 1932. It is located in a lenticular level of limestones and dolomites, and is dislocated by a major EW accident. Thus, the work on the lithology of Bouarfa started with Dresnay from 1948 to 1963. However, Dresnay helped in defining the two together:

1) A Precambrian basement (PII?) and Paleozoic metamorphic formed satin shale recovered and injected into an altered volcanic rocks, as veins are covered.

2) Calcareo-Jurassic dolomite coverage that forms the mineralized lenses Ain Beida of Hamaraouët, which pens the passage of the lower Lias. However, this includes the Lias Avg. levels stratigraphics phases of emersion, and the fluvial conglomerate Discordance aaléno-bajociennes dolomites.

## **Stratigraphy of the Massive Bouarfa Region**

Consequently, the authors agree on the delicacy to establish the stratigraphic series of Bouarfa region due to:

- The scarcity of fossils in most seats Jurassic.
- The tectonic that affected the series, fragmenting, and thus avoiding in following some continuous layers.
- The dolomitization has been fairly affected generally. This entails all of these formations, which gives them a degree of uniformity that hides their different stratigraphic origin.
- The lack of benchmarks layers: upper arkose, where it was thought to find a common thread. It has shown a stratigraphically different age according to Points.

Therefore, this corroborates with the findings of this study.



Figure 1. Area of study Location map

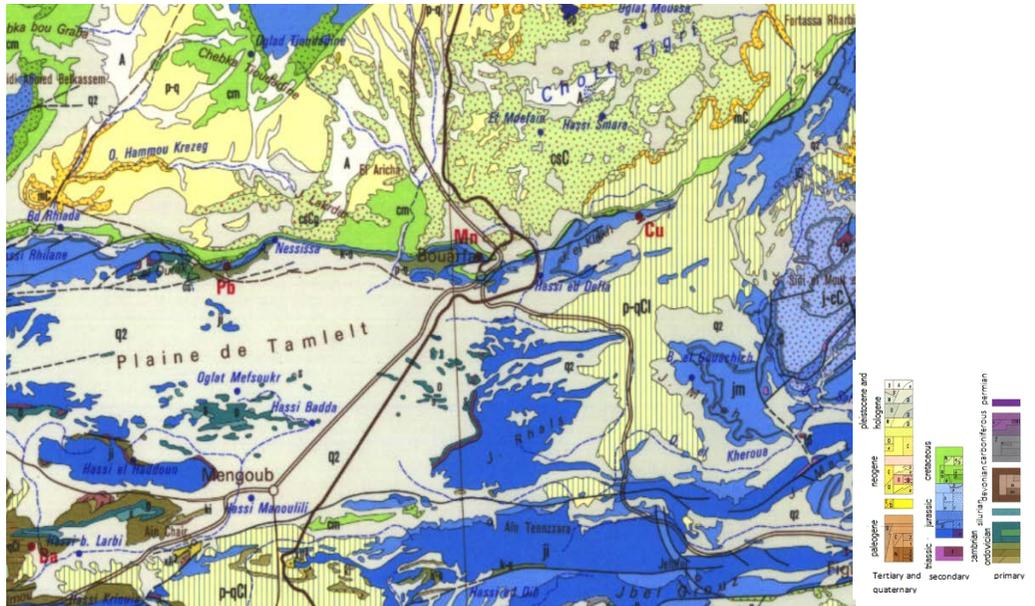


Figure 2. Extract from the geological map 1/200 000 of Bouarfa region, Chefchaouni et al. (1963), according to the compilation of Ayme, Borocco, Bouladon, Choubert, Cheylan, Clariand, Cornet, Lady Deau, Escaleau-Bendeyt, Fallot, Flemish Golmier, Gautier, Jouravsky, Lebedeff, Leca, Lucas, Manderscheid, Massa, Melveleff, MEINDRE, Menchikoff, Mortier, Moulard, Mossu, Pareyn, Perrodon Paimour, Poldini, Pouit, Raguin, Rey, Roch, Russo, Savarnin, Schlund, Snoep, Stretta, Termier, and Vincienne.

Above the Precambrian and the primary base formed from the metamorphic schist, comes a satin Jurassic series which can be described below.

Over 100 meters thick, the series begins with a thick pudding. Thus, their elements consist mainly of granite, pegmatite, and aplite. In addition, rocks are not exposed in the region, and the region has less abundance of shales, rhyolites, and andesite. The elements of these conglomerates and shales for base layers are made of granite to the upper layers. Thus, this comes from a granite massif which shows that one can imagine farther north, in order to recover Highlands. Thin manganiferous layers of 10 to 30 cm, and past impure dolomite usually appears at the top. Here, the polianite forms small nodules and parallel ribbon lamination.

Then, a calcareous-dolomitic episode begins whereby the mineralized deposits of Hamaraouet are located. The calcareous-dolomitic series have variable power, and includes a reduced thickness of 30 cm Hamaraouët. However, this is rapidly reduced to the North and West (business Hamaraouët) so as to disappear within the overlying clastic series. In finding this series, you have to move 40 km to the West until Haouanite jbel. Thus, this series increases by 180m towards the east in Ain Beida, and 250 m in Hassi Fallet. After then, it later decreases. It first includes some benches detrital dolomite elements of quartz and black mica. Also, 10 to 20 meters of massive dolomitic limestone roses to white calcite crystallized flies (2-5 mm). This series forms the "mineralized lens", which contains manganese ore mines already operated by the Society of Bouarfa ("lower ledge" Bouarfa).

For bouarfa (Ain Beida) especially Hamaraouët, the series is divided into a lower horizon which originally forms clear dolomites, but often stained dark brown ("dolomites chocolate"). Consequently, this is followed by a thicker series usually formed from limestone. However, this might have also been dolomitized. This series forms the cliff of the Hamaraouët sector. The beds are separated by clay horizons which is more or less detrital. Therefore, it often shows emersion indices (polygonal structures). Also known is the gypsum lenses which are sometimes thicker. Limestone beds, usually roses, are often dotted with calcite flies; a horizon big pisolites to locally form a remarkable layer. The limestone beds are becoming less and less thick up in the series. Hence, they are generally formed over white limestones. In addition, one might wonder if a gap in the sedimentation does not separate the past limestone beds from the previous ones.

In most western sector of Ain Falet, the sequence of dolomitic calcareo-series is more constant. We noted above that dolomites forms the basis of the series (sometimes pisolithiques at the top, at Kif al-Hamar for example). Therefore, this is a series of limestone in small shoals, variable,

and calcite speckled coloring. The separation between these two complexes is the net stratigraphic, but the exact limit is often rather difficult to specify the field. Consequently, many fractures and dolomitization phenomena often occur, and this mask the boundary between the two series. In addition, it should be noted that it is often at this level that mineralization occurs in the area of Hamda-Falet. Furthermore, it can also occur in the lower dolomitic horizon.

On top of that chalky dolomite bedrock, appears again a thick series of arkosic conglomerates ten meters which is thick especially in the cup of Jebel Bouarfa. They have the same nature as the lower conglomerates, and one meets pebbles of various petrographic nature e.g. granites, pegmatites, aplite, mica, etc. These conglomerates are found in all the massifs of the Bouarfa area. The cuts made in each of these massives shows significant differences from one to the other. While in the area of Falet and Jbel Bouarfa, the arkosic series is homogeneous, and limestone (fossil) benches of 0.5 to 1 m was interbedded with entrelits marl. This contains the beautiful mineralization Ain Beida in Kif-elHamar in their upper part, as well as at Jbel Kounif, about 10 miles East of Bouarfa. But between these two points, Jbel Bou to Mokhta, we observed a very significant reduction in these arkose. Here, south of the North Atlas overlap are replaced within the Liassic limestone series of quartz grain limestone horizons. However, gravelly limestone becomes quartz grain dolomites with the approach of the frontal accident, which cuts in a sling. Above, clastic facies become a second level of limestone and dolomite. Facies analogies and paleontological arguments led De Dresnay (1962) to link with Lias limestone. Therefore, this episode was once attributed to the Permo-Triassic. Above is a detrital series called discordant which is slightly higher. Its thickness is 250 m. Very similar to the lower series, the red clay to gypsum sometimes tinged manganese arkose and granite pebble conglomerates, pegmatite, aplite, mica schists etc.

This arkose limestone and dolomite-arkose series is overlain by dolomite which is a new series that forms the upper ledge of Jebel Bouarfa. Consequently, it also forms several massive peaks that surround the village of Bouarfa (western part of Jbel Bou-Mokhta, Kif al-Hamar, industry-Hamda Falet). It corresponds to the advancement of the slab in the Highlands, which extends from the area of the Moulouya and mountains of Oujda into the Bouarfa sector. Although this ledge is majorly a dolomitic fossil, they are rare and some levels spared dolomitization which delivered aaléniennes ammonites. This slab can be considered to represent the Aalénien and part of Bajocian (Dresnay, 1962). The discrepancy between the foundation of the previous series, Hamda, is visible especially in the southern part of Kif al-Hamar. In addition, it corresponds to a major tectonic embryonic phase already reported in many parts of the Atlas. It is this discrepancy that

explains the curious look of the map showing the Falet sector. The design appears as a kind of "anticline" Jurassic resting on the Paleozoic. However, dolomites of "cornice" are either based on different terms of the previous series (which are reduced) and are directly in contact with the Paleozoic buttonhole Falet.

Above is a constant series of enough cuts of marl limestone beds (or dolomite), including age bajocien sup which can be established according to the echinoderm fauna and the brachiopods that it contains.

Furthermore, a new discordance (not visible in the Bouarfa sector) is regarded to be the great transgression of the Cretaceous. The Cretaceous series is well represented in the circus of Bouarfa, and its outcrops used for reconstructing the design of fault-fold Bouarfa basically includes:

- A red sandstone episode, starting with conglomerates limestones elements.

- After a few limestone beds in small schools, marly series Cenomanian formed depression in the topography.

- Over a white limestone cornice, it is sometimes flint and often contains some of the rudist Cénomaniens- Turonian;

- The Cretaceous series ends with a thick detrital series consisting of pink sandstone, gravel, and even conglomerates, with some limestone at the base level. This detrital series is attributed to Senonian flush in the circus of Bouarfa for central filling. It also forms the bottom of the great depression of Chott-Tigri in North-East Bouarfa.

f) The culmination of the series of Bouarfa is formed by several ridges exposed along the railway serving the mine. Thus, it is formed from limestone conglomerates elements ranging from Jurassic to Cretaceous. These conglomerates are probably very recent (perhaps Pontico-Pliocene). They are affected by faults which marks the axis of the fault-fold Bouarfa.

## **Tectonics**

The main tectonic direction is substantially parallel to the main fault of Ain Beida oriented EW (see geological map). However, three important points must be put into consideration. They include:

1. The paleogeographic diagram which shows the approximated position of the main faults on the Atlas. It was observed that the relief of the base is also a function of these flaws, especially the small dome. Thus, sandstones and basal conglomerates do not exist here, and they are bordered by faults. This confirms that not only large Atlasic fault on the pool edge existed before the folding, but also the existence of smaller breaks. Therefore, one may wonder if these faults were not actually observed when filling the basin as fault subsidence.

2. The existence of this Liassic Epiro-engineering already mentioned elsewhere in Eastern Moroccan Atlas (Dubar, 1948 - the Dresnay, 1957, 1962) was confirmed by other retail observations. Sometimes in Ain Beida, the presence of cracks showing beautiful mid-roirs Hamaraouët in the bar was observed. Also, those "passed" step in the series of Ain Beida were also observed.

3. The bar Hamaraouët underwent special tectonics, probably a differential detachment. Indeed, especially in areas that led to the operation, there is a considerable number of fractures and fault planes that appears. Most often, this usually corresponds to horizontal rather than vertical movements. Furthermore, this seems to be an earlier tectonic mineralization, and the contours are regular, especially with the veinlets crossing the bar.

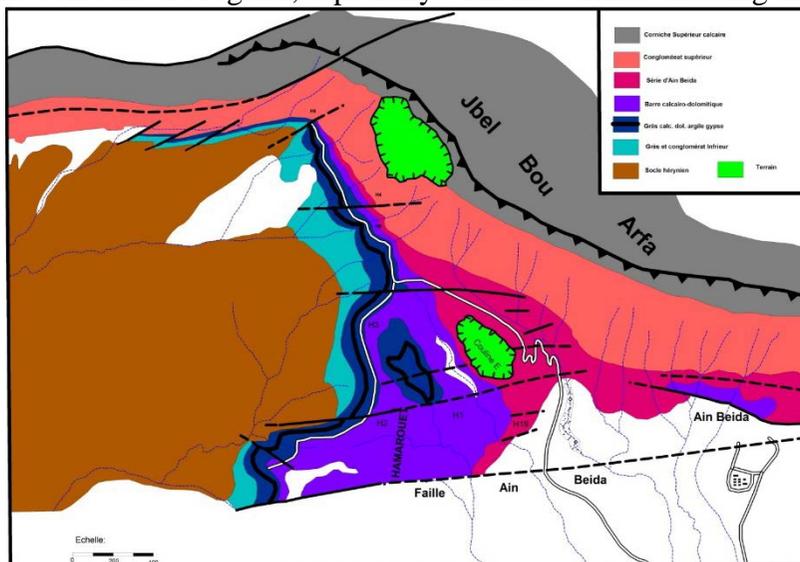


Figure 3. Regional geotectonic map of the study area

### Manganese Occurrence

According to the work of Dresnay (1962) and this study, there are five superimposed types of manganese mineralization in the region of Bouarfa. These include:

- A low grade mineralization which is fairly regular (2-3%) in limestone and dolomite chocolate patina. However, a relatively high content in the series that frames should be noted.
- Mineralization in the form of thin layers of manganese oxides (benchmark level of Hamaraouët).
- Clusters and alternative veins related faults and fractures in the Hamaraouët bar.
- "Channels" (runs) more or less regular, connected by a clay seal, and hématiteux located in the transition formations between the bar and the

**Hamaraouët series of Ain Beida.**

- Veins related to flaws in the upper conglomerates impregnation to the walls.

Thus, we find ambiguous characters in Bouarfa, and it is so common in stratiform cottages where several types of mineralization are superimposed. In addition, we would describe each particular type, emphasizing those already exploited which are better known.

- Limestone and Dolomite chocolate patina.

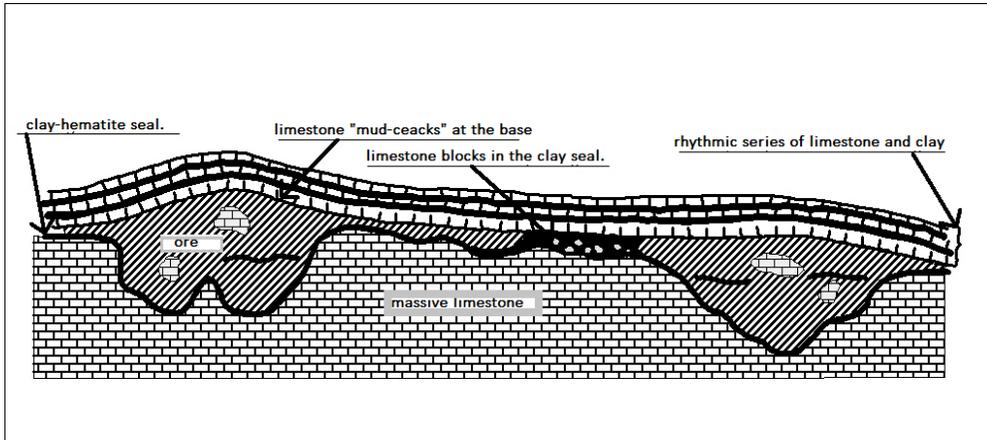


Figure 4. Form of manganiferous lenticular mineralization (From Dresnay, 1962)

Consequently, we note that such intercalations are common throughout the series as limestone and dolomite chocolate, but they do not have the continuity and regularity of the latter level. Moreover, we will see later that limestone and dolomite of the Hamaraouët bar contains about 1% Mn. It therefore seems probable from the amount of analyzes, that a large portion of filling formations in Bouarfa basin contains manganese with a much higher level than the overall average of the limestone (or geochemical background clarke about 0.05% MnO by FW Clark, 1924: The data of geochemistry, p 30).

Nature of Mineralization: It was determined chemically on three samples which yielded the following results:

**Level-chocolate in Hamaraouët-4:**

2,075 Mn as carbonates (calcite manganese-0.025% Mn; rhodochrosite: 2.05% Mn);

0.02 Mn oxide form

No silicates.

Idem, to Hamaraouët W-6:

2.95% Mn in the form of carbonates (calcite manganese-1.00% Mn;

rhodochrosite: 1.95% Mn);

0.01% Mn in the oxide form;

No silicates.

Level carbonated brown, 10 m under the previous:

1.90% Mn in the form of carbonates (calcite manganese-0.35% Mn;

rhodochrosite: 1.55% Mn);

0.02% Mn in the oxide form;

No silicates.

This method of analysis has not been applied to dolomite, which is the case of many carbonate rocks in Bouarfa. This is why determining manganese in the form of carbonates of the three samples above is correct, but the distinction between the carbonate minerals themselves is uncertain. Nevertheless, the presence of carbonates, complete absence of silicates, or substantially complete oxides shows that the mineralization corresponds only to bivalent manganese minerals. Therefore, they are formed under reducing conditions.

### **The Level of Benchmark Hamaraouët**

This is a stratiform manganiferous training, continuous, and which follows along the entire route of the cliff Hamaraouët between chocolate dolomite and dolomite from the top bar. To the North where the power of the coverage is low, it is 1 m or 2 m of the Hamaraouët bar wall. Thus, it departs from the bar due to the increase in the power of the series and is 5 m below the bar in the career area and 8 m to the South.

During mineralization in the form of pyrolusite, sometimes a little psilomelane Barite (most likely romanechite) localizes into thin single beds (a few meters or centimeters) forming continuous strata in dolomites and dolomitic clays. Numerous mineralized beds and close together, and are very powerful (0.5 to 1 m). However, there are often scattered with a discontinuous mineralized beds in a much wider area (up to 6 m). This is characterized by an alternation of thin layers of dolomite and clay. Dolomites are always very finely crystallized and quite rich in quartz chips and flakes of sericite. They have the character of dolomites syngenetic (primary).

### **Mineralization of the Bar Hamaraouët**

This bar consists essentially of red dolomites, but it may also contain red limestone whose distribution in the bar is not known. Dolomites, which contain detrital components (quartz, feldspar, mica) are recrystallized either entirely or in the form of white veins. Also, they possess certain characteristics of epigenetic dolomites. Sometimes in the vicinity of the mineralized deposits, they contain impregnations of quartz and barite. The

limestone summit are of special facies, characterized by numerous fragments always blunt. Sometimes, they are perfectly rounded, possess very fine crystallization, and are rich in hematite coated in a clear coarsely crystalline calcite.

Dolomites and limestones forms the Hamaraouët bar which is ferruginous manganese. Thus, the échantillons collected dolomites base of the bar contains 1.46 and 1.03% Mn. Also, a sample of limestone pisolitique of the upper part of the bar contains 1.16% Mn and 1, 50% Fe.

Subsequently, mineralization occurs most commonly in two forms. Thus, these forms include:

- Clusters and rich ore veins are sometimes quite in representative reserves. In other cases, the mineralization is a more diffuse form of veinlets, filling geodes, and anastomosing tasks or stock works in the mass of dolomite. Clay seals are rare. Therefore, these different mineralization is always related to faults or fractures which shows beautiful sliding mirrors.

- Stratiform lenses to trend, especially at the base of the Hamaraouët bar along faults or breaks. It seems then that the mineralization substantially follows the bedding planes, but with marked differences and genuine mineralization interbedded. Indeed, the lateral extension from the flaw rarely exceeds 10 to 20 m and is usually only a few meters. Moreover, in detail, the mineralization often cuts stratification benches and abuts abruptly on a dolomite bed. It does not continue to the roof and the wall by a few inches mineralized joint gets stuck faster.

Hamaraouët -6 in the Liassic series are very thin and are upright at 70 °. Mineralization is located in both the bar and the "arkose" which surmount.

Note especially that the mineralization in the Hamaraouët bar is always intimately related with the brittle tectonic and the richest areas are the most tectonised. This character joins the deposit patterns and the general absence of dissolution and clay breccias suggests that this mineralization was introduced by substitution rather than filling karst. Thus, hypothesis sometimes has to be formulated.

### **The Mineralogical Composition**

Hamaraouët of minerals is fairly well known, but the distribution of different types of mineralization based on geological factors poses many unresolved issues. Mineralization consists of the following minerals: manganite polianite (most likely its variety pyrolusite) Hausmannite, cryptomelane, limonite, hematite, goethite, calcite, quartz, and barite. Also, a clear separation of manganiferous and iron mineralization was observed in some cases, particularly in career 3. Here, we see the roof of the cluster association mineralized zoned goethite fiber of several decimetres and

pyrolusite few fibers centimeters forming alternating bands. However, this separation was the best highlighted for Hamaraouët-6.

In the iron-bearing areas of the roof, the ore forming the wall consists of a limonite colloidal structure containing lamellae goethite and hematite visible immersion. The matrix is composed of quartz and calcite.

In manganeseiferous area, manganite prisms were observed as a slightly oxidized pyrolusite in a matrix of quartz, barite, and calcite.

Elsewhere, mixed iron ore and manganese that seem most typical consists of manganite (or pyrolusite) associated with psilomélane and limonite in a calcite matrix (Hamaraouët-7 and 8).

Hausmannite is quite rare. Normally, it is associated with a cryptocrystalline cryptomelane in a calcite matrix. Its distribution in the mineralization of the bar is little known. Thus, the presence of massive blocks of Hausmannite in clusters adjacent to the EW faults should be noted (including Hamaraouët-4 where the faults to a relatively large Atlas were rejected).

### **Mineralization in Ain Beida**

Mineralization is localized at the boundary of the Hamaraouët bar and the clay-carbonate rhythmic series of Ain Beida. It extends over 1200 m in length and was recognized on a vertical drop of nearly 200 m. Mineralization is not continuous over the entire width, but it forms channels dug in the separate wall together by sterile areas of about the same width. Therefore, this appears to become more and more narrow at the lower levels. The channels are oriented NE and it follows the stratigraphic level. Therefore, the dip of the rocks sub-horizontal to the outcrop, gradually reached 45° to 50° in the lower levels. The main features of these channels are as follows:

- The wall is neatly cut through mineralization. In a studied lense (Lens 6 niv 1273), it consists of a limestone-containing fragments or perfectly round oval of a finely crystalline limestone, reddish, encapsulated in a clear calcite, and are coarse. The few elements include detrital quartz chips feldspar and sericite flakes. This therefore has a similar limestone facies of the upper part of the bar Hamaraouët. These includes:

- The channel bottom sometimes contains limestone wall protuberances

- The roof is regular, sometimes forming only a blister above the ore zone, characterized by a seal clay (illite, chlorite, hematite). There is often at its base, polygonal surfaces in relief, which may be an old desiccation cracks (mud-cracks). Thus, this is current at the base of several limestone beds in the series of Ain Beida.

Nevertheless, it seems that the mineralized level of Ain Beida is a

striking discontinuity surface, or a gap in the sedimentation with violent currents that dug the canals. Also, it can be an emersion which could indicate the drying of surfaces roof. Moreover, in the series of Ain Beida, we noted a few meters above the mineralized level. Further, we also observed the presence of small bowls leaching, erosion in limestone, filled arkosic conglomerates, and the frequency surfaces drying.

This mineralization is hosted by dolomite and limestones during liasic sedimentation process. It is the mississippi valley type of mineralization.

### Geophysical Survey

Electrical tomography was used in order to characterize the geology and structural elements that can assist the precipitation of manganese and of course in determining the horizontal and vertical structure of the above-mentioned ore and mineralization density.

Tomography profiles were positioned perpendicular to the main direction of the mineralized structures with clues surface. Eight profiles (C1-C8) were executed vertically in the direction of the mineralized structures with lengths ranging from 75 to 300 meters and inter-spacing profile which depends on the geological setting of the vein chosen to perform these profiles (fig. 5). However, only the results of C6 and C8 should be represented here (fig. 7 and fig. 8).

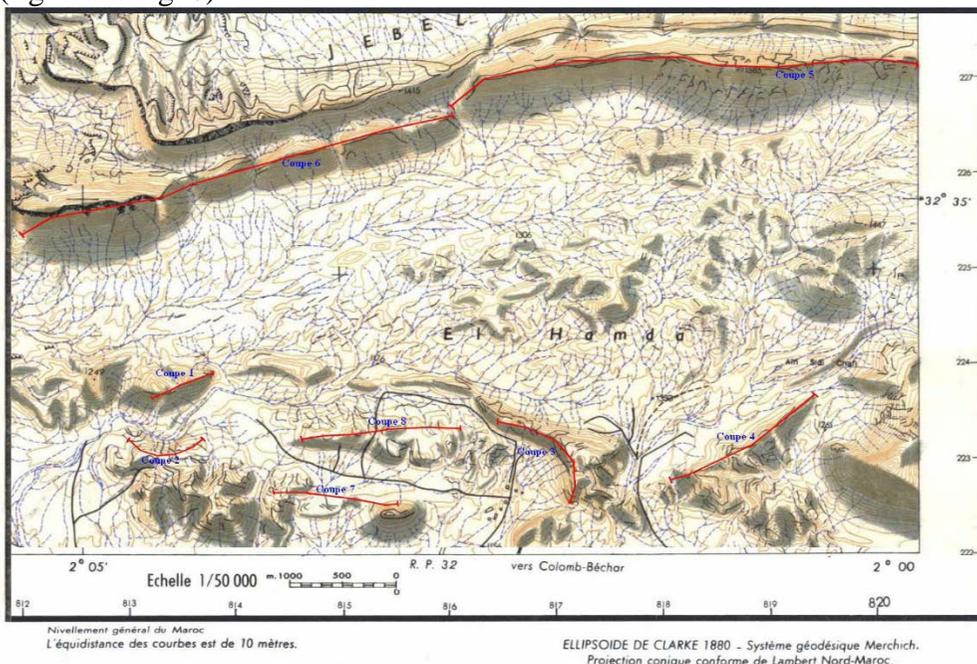


Figure 5. Topographic map of the Manganese Mine Bouarfa showing the different geological sections performed

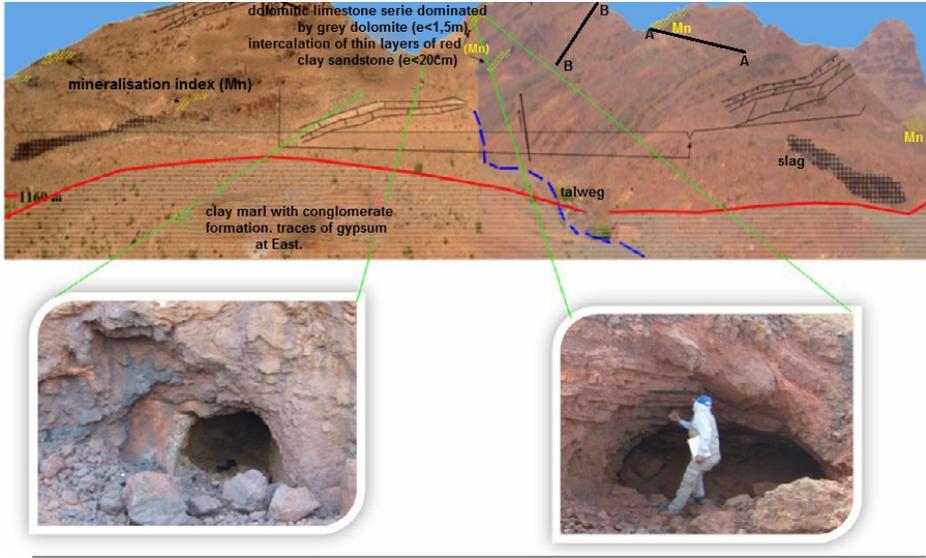


Figure 6. Field photography of section 8

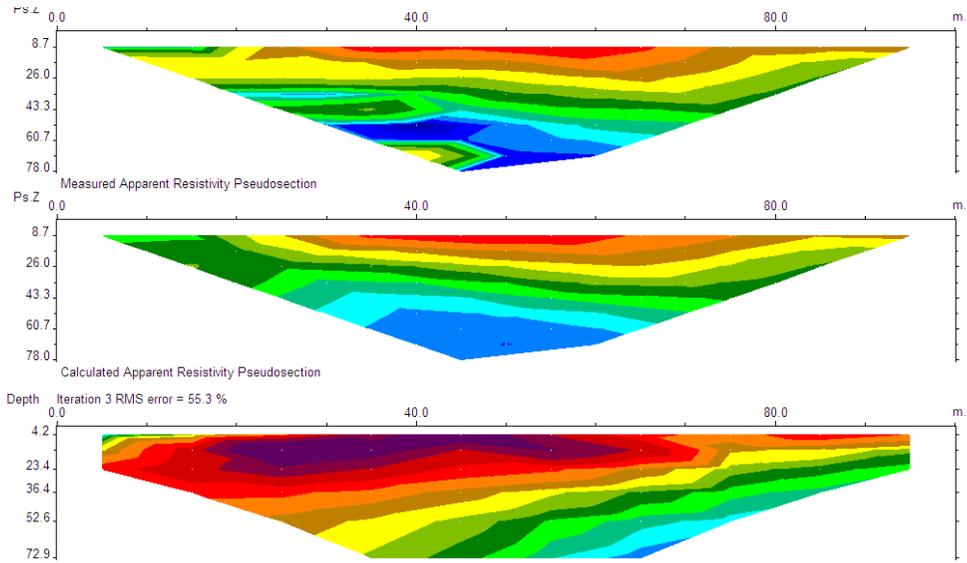


Figure 7. Made electric Profiles  
LINE 1

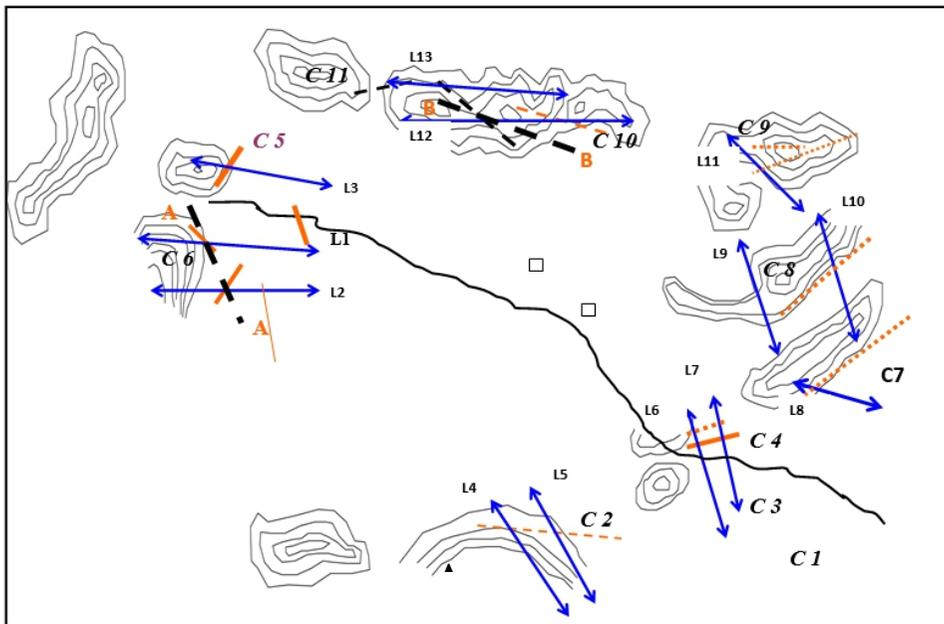
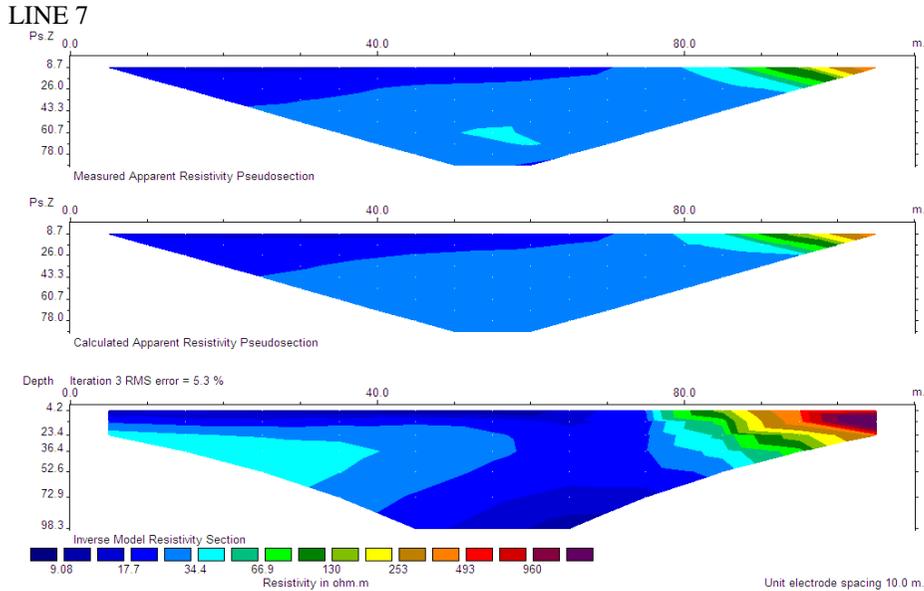


Figure 8. Map of the various mineralized structures identifiedMains Results

Geological and geophysical investigations are used to highlight some structural elements and to characterize the mineralized levels. These mineralized levels are usually at the base of the limestone series. It can be observed at the lower part of a dolomite banded characteristic manganese oxide beds. The mineable deposit is above and has huge dissolution pockets

created. Therefore, thanks to the breaks in the massive dolomite. Mineralization is attached to the dolomite bench. Here, iron oxide and manganese form irregular clusters and a more capricious distribution. The dip of the formation itself is a variable, and is sometimes subhorizontal with flaws and frequent setbacks.

Probably resulting from a partial substitution or at least reorganization within the dolomitic limestone, ore is characterized by poverty in the presence of silica and iron oxide. Also, manganese accompanies the variable proportion.

Generally, the manganese indices are numerous and are scattered over a relatively large area. They cannot lead to significant mining operations.

The manganiferous mineralizations in the study area involves the following forms

Stratiform lenses to trend, especially at the base of the limestone bar along faults or breaks. It seems then that the mineralization substantially follows the bedding planes, but with marked differences and genuine mineralization interbedded. Indeed, the lateral extension from the flaw rarely exceeds 10 to 20 m and is usually only a few meters. Moreover, in detail, the mineralization often cuts stratification benches and abuts abruptly on a dolomite bed. It does not continue to the roof. Thus, the wall by a few inches mineralized joint gets stuck faster.

The mineralized limestone is framed by two powerful detrital series resulting from the dismantling of a granite massif hidden today, westward and eastward. These series are thinning and the limestone disappears. The aberrant Lias is attributed to Dogger which forms the crest of Jbel Bouarfa.

Note in particular that the mineralization in the study area is always intimately related with the brittle tectonic and the richest areas are the most tectonised. This character joins his deposit patterns. Therefore, the general absence of dissolution and clay breccias suggests that this mineralization was introduced by substitution rather than filling karst as hypothesis have been formulated sometimes.

The observations outlined in this note are possible to define several types of ferruginous manganese formations and propose hypotheses as to their implementation mode.

Carbonate mineralization diffuse low, which is known for the moment only by scattered analyzes. Nevertheless, this seems to exist in the entire series of the cover to the top of the bar Hamaraouët. In this sequence, rocks high Clarke detach highly continuous layers of dolomite-chocolate whose manganese contents are in the order of 2 to 3%. This mineralization formed in a reducing environment, has a contemporary evidence on the sedimentation of rocks that it contains.

It has a perfect concordant mineralization with lamination (level benchmark of Hamaraouët) that contains continuous manganese oxides beds over large areas (several kilometers). It has no relationship with tectonics mineralized levels compared with flaws like any sedimentary formation. No enrichment appears near fossil and there is no selectivity mineralization relative to the nature of the rocks. Under these conditions, this layer seems syngenetic as was defined above.

An alternative type of mineralization in the Hamaraouët bar, which is unlike the previous one, is closely related to tectonics. It helps in solving the difficult problem of palaeotectonics. Thus, there is strong evidence for the existence of an epeirogeny of Liassic age. The location of the massive Hausmannite in the vicinity of Atlas age faults was noted, but probably has a previous game.

Vein mineralization is in the upper conglomerates and is much earlier in the mineralized series. It also seems related to fairly significant flaws.

5. A type of mineralization runs in Ain Beida that presents interesting features, although still insufficiently known in detail. It is related to the effect of a discontinuity surface, and it appears to be of sedimentary origin, whether it corresponds to a period of emersion and gully erosion, or sedimentation with a gap erosion diving. It includes the presence of blunt blocks enclosing limestone in the clay seal, the steep shape of the channels, and the regular roof which is consistent with these observations. The hypothesis of lateral migration of mineralizing solution with hematite - clay seal is the trace with local substitutions phenomena. However, it should not be ruled out yet. Nevertheless, this is still poorly understood due to the location on the edge of the great flaw of Ain Beida and tectonics in the area.

A long term complex problems to solve comes from a part of the original manganese in both epigenetic kinds syngenetic and the other relationships between different types of mineralizations.

However, the issue of whether a stratiform mineralization was fed by remobilization epigenetic mineralization will always be difficult to be established based on simple observations. It seems rather difficult to determine precise observation criteria for distinguishing an epigenetic mineralization from epithermal solutions to those resulting from a remobilization of pre-existing mineralization. Only the mechanisms by which the mineralization is in place can illuminate the problem. Thus, these will be considered only when the ore deposit and mineralogical study will be pushed enough to choose a reasonable hypothesis about the origin (or origins) of manganese. According to morphology and texture, this mineralization is the Mississippi Valley Type (MVT).

Finally, the Lias of the central and eastern High Atlas and Middle

Atlas contains several cottage manganese indices. Outside Tiaratine (High Atlas Midelt) which corresponds to a deposit of a particular type, there are different types defined in Bouarfa. This include M-Koussa (High Atlas Demnat) type of channels in Ain Beida; thus, Boulbab (Causse middle Atlas) associates a level marker in a red sene with Triassic dolomitic bar whose surmounts contains Hamaraouët type mineralization. However, the study of these last two houses can bring about new elements in the knowledge of the Bouarfa.

## **Conclusion**

Investigative work has enabled us to detect the presence of a number of vein ore bodies form or stratiform. Generally, the low extensions and thicknesses range mostly between 10 cm and 85 cm.

These ore bodies are mainly associated with tectonic structures affecting chalky formations dolomiotiques Secondary.

Thus, at the hill 6, our investigative work has uncovered a vein thickness of between 45 and 85 cm in the upper part. In addition, it is cut by a strong rejection flaw on the eastern flank of the hill. The vein reappears 15 meters, but then splits into dykes small thicknesses.

Other relatively less important veins were located on the SE side of the hill and 6 along the trough that separates the hill 5. However, it is clear that the spatial extension of these veins laterally and in depth remains very limited.

At Hill 5, investigations have located two unequal magnitudes veins. The first vein is located in the upper part with a thickness varying from 40 to 65 cm deep and it extends along the dip of the surrounding ground. The shots fired in that part of the mine have allowed us to confirm our findings. The second vein is located on the western side of the hill 5, although its extension is greater than that of the first vein thickness and its depth cannot justify its use.

Between hills 5 and 6, and more specifically at the trough draining the hills south of the mine, a manganiferous vein was identified over a length exceeding 5 m and a thickness of between 55 cm and 75 cm.

On the hill 10 (northern part), mineralization indices were well located. However, the investigations have shown that the levels of stratiform were thin and discontinuous.

At the big hills, particular attention was paid on the South side due to the presence of a significant number of manganese occurrences associated mostly with iron oxides. Our investigations and mechanical surveys recognition of studies have shown that these levels of stratiform have a very limited thickness (about 10 cm). In addition, it has a relatively low extensions with no economic reserves.

At Hill 4, the mineralization is hosted in highly complex structural discontinuities. The intense tectonic affecting this part of the study area had led to the emergence of several discontinuities families faults, cracks, and fractures borrowed by hydrothermal ore flows. Consequently, we propose to extend the mining work towards the center of the hill by the technique of room and pillar. Cored surveys are also needed in this area to supplement the results of our investigations.

	Type	Morphology	Thickness	depth
hill1	Manganese	Irregular vein	40 – 80 cm	4 – 5 m
hill 3	Manganese	vein+ stratiform	35 – 75 cm	3-8 (center)
hill 4	Manganese	vein + stratiform	30 – 80 cm	5 – 9 m
hill5	Manganese	vein	40 – 65 cm	1,5 m
hill 6	Manganese	vein	45 – 85 cm	2 – 4,5 m
hill 10	Manganese + iron oxides	vein	about 10 cm	0,5 m – 3,5m

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