

MINERALOGY OF IRON ORES OF OUENZA DEPOSIT, ALGERIA

KHOUDOUR DJAMEL¹, MEDDAHI RABAH² & EVTEKHOV VALERY DMITRIVITCH³

¹Department of Nature and Life Sciences, Faculty of Science, University of M'sila, Algeria

^{2,3}Department of Geology and Mineralogy Applied, KrivoyRog National University, Ukraine

ABSTRACT

Results of studies of mineral composition, individuals and aggregates morphology of Ouenza deposit were given. Results of IR-spectroscopic and thermographic studies of ore forming minerals such as hematite, goethite, siderite, calcite, dolomite, kaolinite were analyzed. Conclusion on ore formation staging was made. It was suggested to use mineralogical data for solving applied problems connected with ore bodies mapping, ore beneficiating.

KEYWORDS: Iron Ore Deposit, Ouenza, Hematite, Mineral

Received: Mar 03, 2017; **Accepted:** Apr 18, 2017; **Published:** Apr 21, 2017; **Paper Id.:** TJPRC: IJEEGSJUN20175

INTRODUCTION

Mining works started in the region in Classical Antiquity time. First operations dated IV-I centuries B.C., and main raw material mined by Romans was not iron, but copper ore. Ore mining ceased in Ouenza region with decline of the Roman Empire. Mining and geological investigations of the end of XIX century contributed into its restoration. First information on iron ores of the region appeared in a work of a French engineer G. Tiss (1875). Iron ore exploration works started in 1895, and in 1901 a French geologist Passiole determined reserves for several deposits including the Ouenza one. In 1902 he created Iron Ore Mining Company that started exploiting the deposit in 1913.



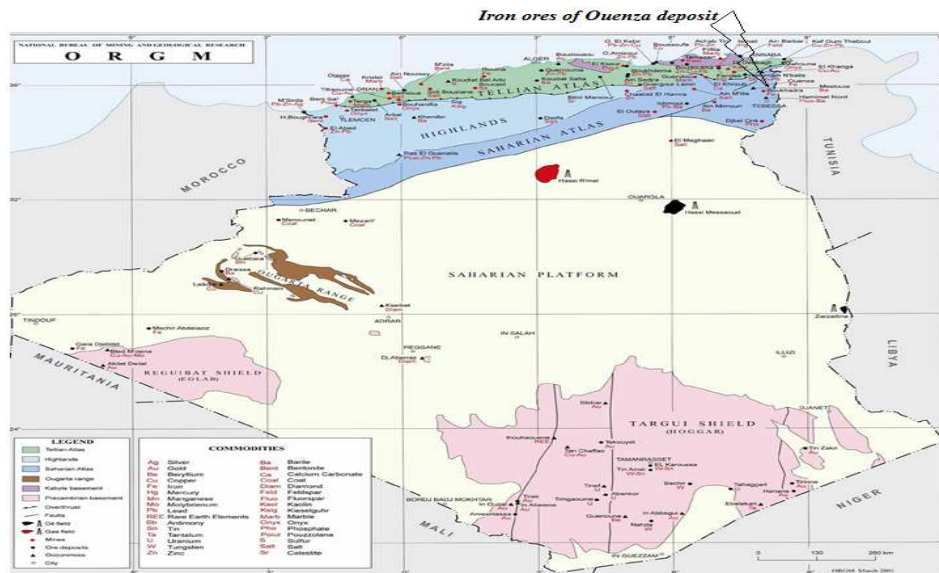
Figure 1: Geographical Location of the City of Ouenza (Google Earth, 2011)

Growing activity of geological exploration was connected with beginning of mass ore production in 1950-s. The most important investigations of geological structure of the deposit, of peculiarities of ore mineral and chemical composition, of its texture and structure were conducted by G. Dubordieux [4]. Detailed geological exploration works were fulfilled by Soviet, Polish, Algerian geologists in 1960-1970-s. In 1978 Tikhomirov I.I. carried out a detailed study of mineralogy, geochemistry of ores, peculiarities of their irregularity, as well as calculated reserves, that were evaluated to amount 120 million tons. Average iron content in ores is 52, 0%. Iron ores are mined using open-pit method and their output reaches 60% of all mined iron ores in the country [10].

Mining activity in Algeria is very old and mining potential are very diversified (over thirty substances). However the old deposits of iron, salt, zinc, lead, barite, marble were added to gold, wolfram, tin, which are the mining potential to exploit or explore in the future, and indices promising for diamonds, rare earths, rare metals and precious and semi-precious.

Most of the geological potential is located southwest of the country with 3.5 billion tonnes at 57% Fe. These are deposits MecheriAbdelaziz and GaraDjebilet, located 250 km east of Tindouf .

The potential located north of the country is estimated at about 70 million tonnes distributed between deposits and OuenzaBoukhadra - (60 million tonnes) and the index of Dj.Hanini -Sétif- (12 Million tonnes at 60% Fe).



Map Creation /National Office of Geological and Mining Research - Algeria

Figure 2: Map of Mining Potentialities in Algeria

The city of Ouenza is located 90km north of the capital of the Wilaya of Tébessa. It is located 120 kilometers south-southeast of Annaba. It is also bounded on the east by the Algerian-Tunisian border and north by the province of Souk Ahras. It is connected to Annaba the national road No. 82B and a rail which is fed by the entire production unit Ouenza towards the door installation or she would be shipped to the steel complex of El Hadjar.

The mining complex of DjebelOuenza is a unit of production of iron ore. The main activity of the company is the production of commercial product of this ore and commercialization by rail to the steel complex of El HadjarWilaya of Annaba. The mine el Ouenza is the largest of Algeria mine with a reserve of 120 million tonnes of ore at a grade of 55% on

average. It is a production unit IN FERPHOS (National Company of Iron and Phosphate) created by decree 82-448 of 16 July 1983.

The massive Ouenza is part of the Algerian-Tunisian border which are geologically known by their almost exclusively sedimentary character. The oldest formations exposed surface evaporites are intermingled (marl with gypsum, dolomite blocks more or less laminated, limestone, cagneules, sandstone and rarely ophites) Triassic.

The iron deposit of the Ouenza region represents one of the fundamental resources available to Algeria. This mine is the largest in Algeria with a reserve of 120 million tonnes of ore grading 55% average iron.

The iron deposit of Ouenza rests on the northern flank of a mountain range which rises to 1288m at the peak, it is about an 12km long by 5km largeur. Les metallic clusters come in the form of nipples roughly elliptical. They successively include the northeast to the southwest: the Coudiat Douamis the Coudiat Hallatif the region conglomerates, the Sainte-beard area, the deposit Chagoura and CoudiatZerga. The ore outcrops over lengths sometimes reaching 250 meters and height of 45 meters, making the standard conditions for surface mining [3].



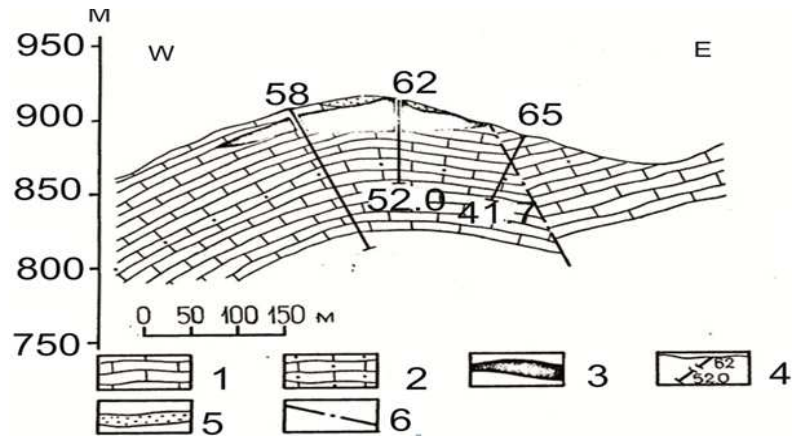
Figure 3: Different Walks of Iron Deposit of Ouenza

Ore bodies are located within sedimentary rock mass of Cretaceous age, mainly consisting of limestone and loamy marl interlayed with siltstones. Ore bodies shapes are mainly lentiform, boss, and pocket ones, more seldom vein ore bodies occur there [7].

Ore bodies occurrence is close to one that is conform with enclosing carbonate rocks, counter ore bodies occur more seldom, ore thickness reaches 100m, its continuity is about 1000m (figure 4).

Structurally ore bodies refer to huckles of subsidiary anticline, complicated with north-south strike faulting rupturing the huckle. Ore controlling structure is located in the western wing of a big anticline consisting of cretaceous carbonate rocks at the wings and Triassic age terrigenous-carbonate rocks in the core.

There exist several opinions about the ores formation. M. Madre [6] gave two major theories of ore origin: chemogenic-sedimentary one, the evidence of which is a layered or lenticular shape of ore bodies as well as their predominantly regular bedding within enclosing limestones; and hydrothermal-metasomatic one, proposed earlier by G. Dubordieux [4] and based on the presence of minerals (fluorite, pyrrotite and others) in ferruginous orestypomorphic for hydrothermal deposits. Later, Bryzgapina S.P. and others [2] also supported the hypothesis about contact-metasomatic ores formation, considering presence of relicts of enclosing carbonate rocks in ores and active metasomatic contacts of ore bodies with them to be the evidence for it.



1 – Limestones, 2 – Sandy limestones, 3 – Iron ores, 4 – Exploratory boreholes, their Numbers and drilled depth, 5 – Quaternary sediments, 6 – Faultings.

Figure 4: Geological Section of Kahkuh Ore Body.

Possible sources of iron according to M. Madre are:

- Magmatic, which is unlikely because of absence of noticeable manifestations of magmatic rocks in the area;
- Volcanogenic, which is also controversial because of absence of noticeable amount of volcanic material in enclosing rocks;
- Continental, assuming iron sedimentation due to iron compounds precipitation out of continental crusts of weathering and their sedimentation at shallow-water sea basin.

In the whole, the nature of Ouenza deposit ores is insufficiently understood, comparatively low level of their mineralogical studying is one of the reasons.

The purpose of this work is to study mineralogical composition, morphology of individuals and aggregates of ore forming minerals, some of physical and chemical characteristics, peculiarities of ores structure and texture.

Investigation of ores mineral composition is complicated because of ore crypto-crystalline structure that was mentioned in fulfilled earlier studies. Macroscopically, ores are earthy aggregate of crimson or reddish-brown color depending on correlation of iron oxides and hydroxides. Microscopical studies also make impossible conducting mineralogical identification of the main part of ore material.

Because of that methods of thermal analyses and of infrared spectroscopy were used in this work to determine mineral composition of ores [9, 12].

IR-analyses were carried out in the laboratory of physical methods of mineral studies of KrivoyRog Mining Institute (analysts L.A. Katolikova and I.B. Holoshyn). After the results deposit ores are divided into four main mineral varieties:

- Highly hematite and hydrohematite ores;
- Goethite-carbonate-hematite ores;
- Hydrohematite-carbonate- goethite ores;

- Goethite- hydrohematite- carbonate ores containing kaolinite.

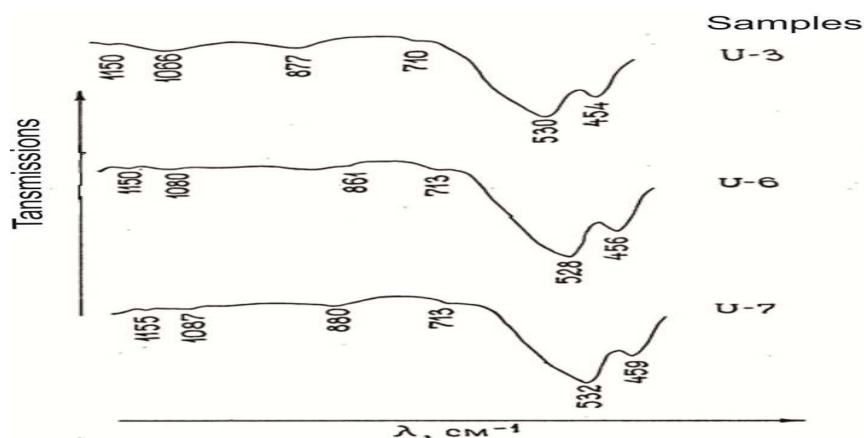


Figure 5: Infrared Spectra of Absorption of Hematite-Hydrohematite Ores of the Deposit

Infrared spectra of the first mineral ore variety are shown in the figure 5. Indicative band of hematite absorption corresponds to the wave frequency 536-527 cm^{-1} and 450-458 cm^{-1} [12]. When carbonates (mostly calcite, in less amount aragonite and siderite) are contained in highly hematite ores, spikes appear on IR spectra corresponding to absorption frequencies 1073-1087, 863-879, 772-787 и 706-716 cm^{-1} (figure 6). Typomorphic spike of goethite corresponds to absorption band 560-580 cm^{-1} . 433-460 cm^{-1} is a common spike for hematite and goethite. Kaolinite containing iron ores are identified by the spikes shown up at frequencies from 1146 up to 1073 cm^{-1} (figure 7 and 8). There are difficulties with determining presence of secondary minerals (quartz, sulphides and others) in ores using IR-spectroscopy method as their absorption bands superimpose ore-forming mineral ones.

Thermic is a high efficiency method for studying iron ores mineral composition of the deposit as it allows to identify to a high degree of certitude the main mineral phases :carbonates, oxides and iron hydroxides. Thermographic studies were carried out with the use of a derivatograph OD-102 in the laboratory of “Mechanobrchermet” institute (analyst Cherevyk V.V.).

Results of the tests for the most characteristic samples of three main ore varieties are shown in the figure 9. The leading spikes on the graphical layout of ores heating, that allow to refer the latter to marked mineral varieties, are end ospikes of hematite (640-660°C), hydrogoethite (120-130°C), goethite (350-380°C) and carbonates : calcite (890-910°C) and dolomite (740-750 and 910-920°C) [4] .

The use of infrared spectroscopy together with thermo-graphic studies allows diagnosing quickly and efficiently mineral ores varieties.

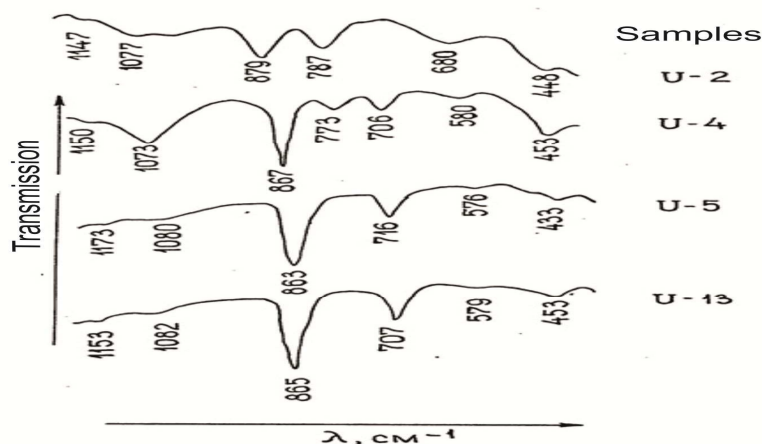


Figure 6: Infrared Spectra of Absorption of Goethite-Carbonate-Hydrohematite Ores

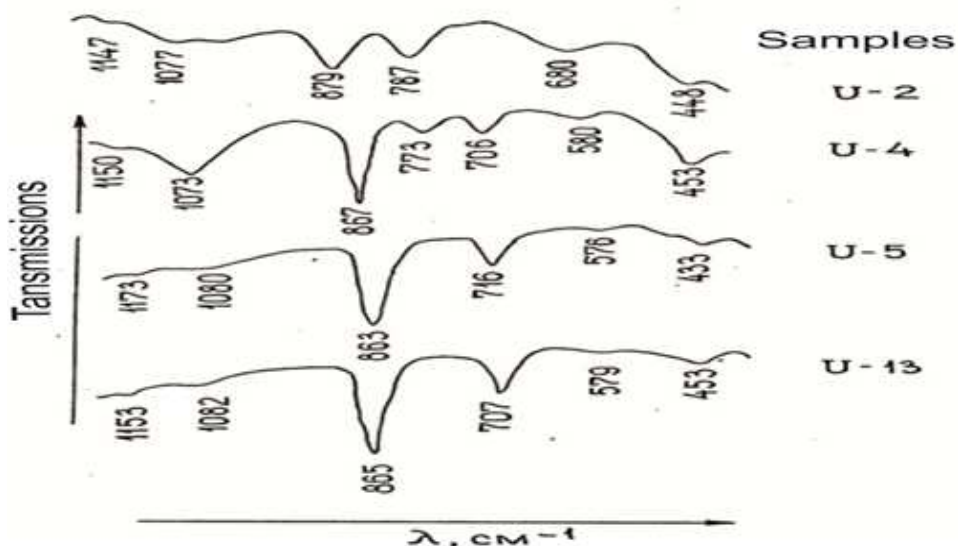


Figure 7: Infrared Spectra of Absorption of Hydrohematite-Carbonate-Goethite

As it was mentioned above, ores of the deposit differ by their crypto-crystalline structure. Because of this, studies of morphology of individuals and aggregates of ore forming mineral were fulfilled with the use of scanning electronic microscope in the laboratory of "Krivorojstal" Works (analyst Shilivskaya E.N.). General results of morphological studies are shown in the figure 10. For hydrohematite, which is a predominating mineral in ores, globule structure is specific (figure 10a), globule size varies from deciles up to 3-4 μm . Quite often inheriting of rhombohedral cleavage of initial carbonate is registered by sizing of globule aggregates (figure 10b).

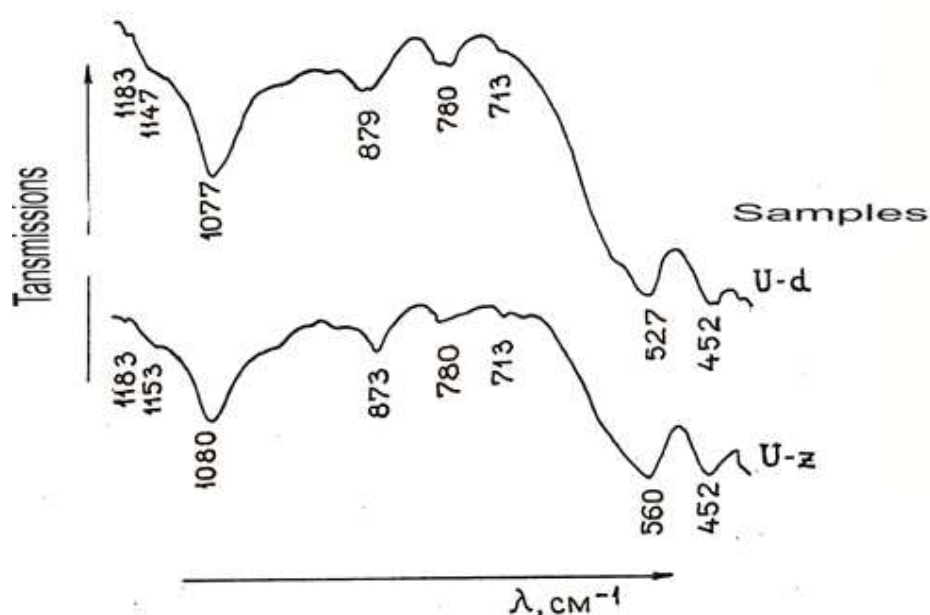


Figure 8: Infrared Spectra of Absorption of Kaolinite-Goethite-Hydrohematite Ore with Carbonate

Goethite containing ores have two major morphological varieties of iron hydroxide. Metacolloidal crypto-crystalline aggregates forming continuums, lenses and partings in microglobulhydrohematite ores (figure 10) are more abundant. Spherulitic aggregates of acicular crystals occur less often and fill cavities in ores (figure 10д).

Specularite formation presumably took place throughout both the process of ore formation and later, in relation with recrystallization of microglobularhydrohematite. In the first case platy crystals of specularite are relatively evenly distributed throughout the whole volume of ore (figure 10д).

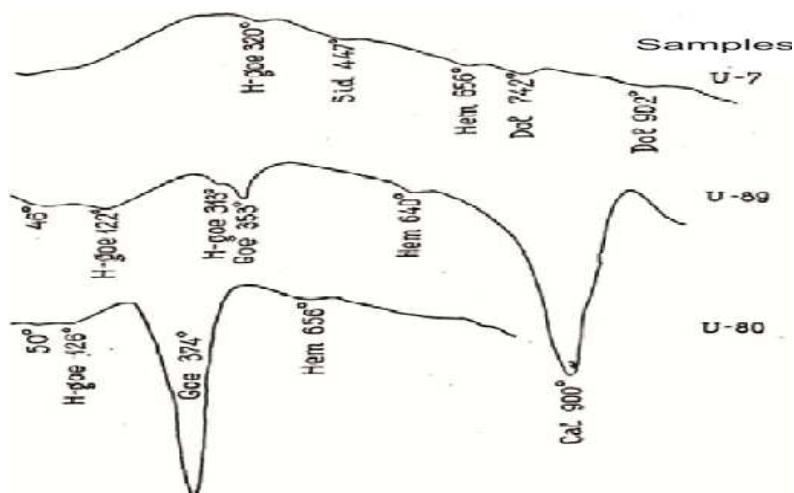


Figure 9: Differential Curves of Heating Hydrohematite-Hematite (U -7), Goethite – Carbonate- Hematite (U- 89) and goethitehydrohematite(U- 80) Ores

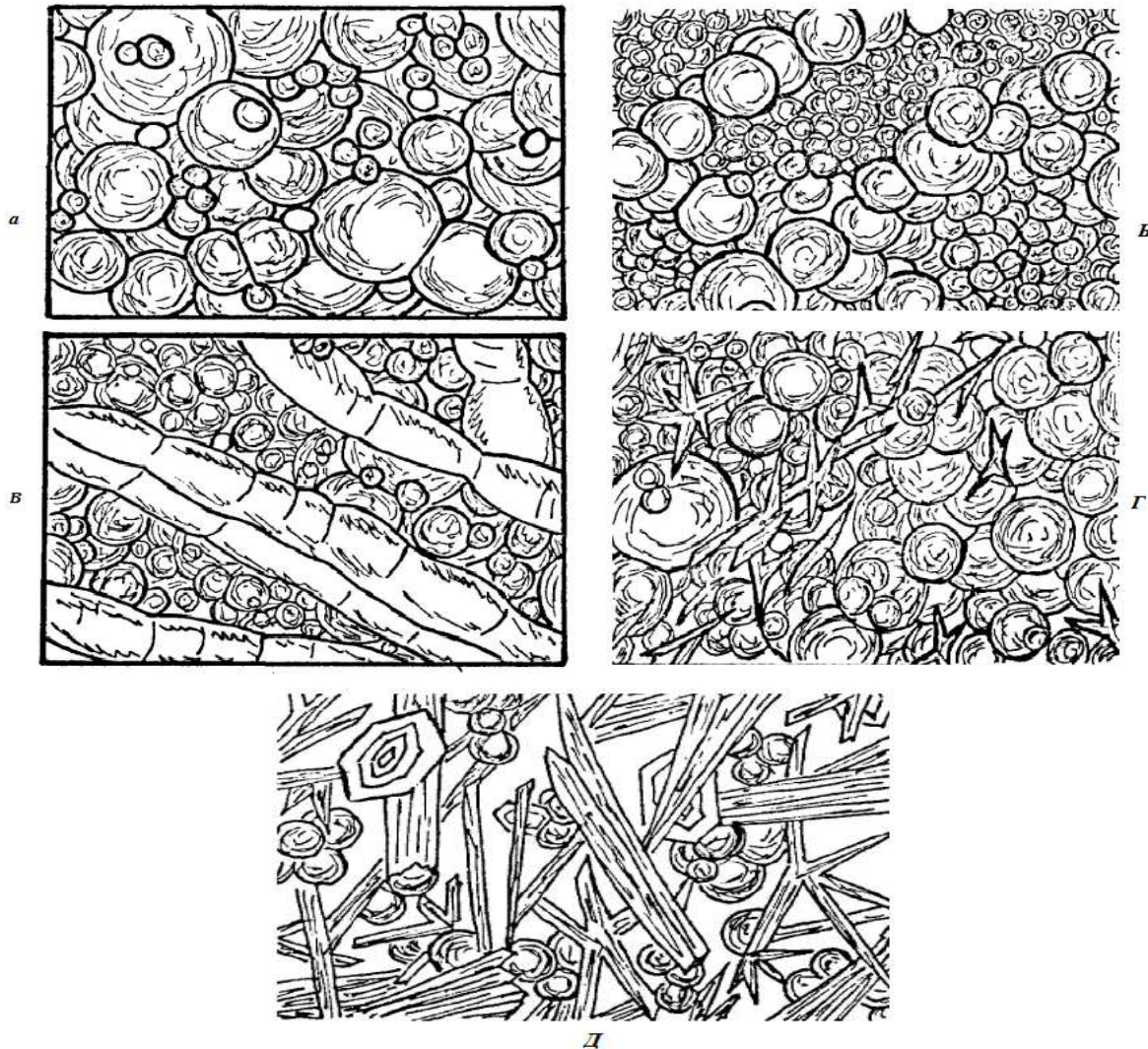


Figure 10: Peculiarities of Morphology of ore forming minerals Scanning electronic microscope 620x magnification. Explanations are given in the text

Confinedness to linear weakened zones (fractures) in ores is specific for epigenetic specularite (figure 10 r). Size of plate crystals of specularite changes from 5-10 to 50mkm and more.

Investigations of features and character of spatial relationship between metalliferous and non- metalliferous minerals were carried out using samples taken from ores of different varieties in open-pit faces and from cores of exploratory boreholes from majority of sites of the deposit. Results of studies showed the proximity of structural and textural peculiarities of ores within the deposit. Main features of morphology of individuals and aggregates of metalliferous and non- metalliferous minerals are determined by the process of metasomatic replacement of initial carbonates by hematite, hydrohematite and goethite [1.8.11]. Figure 11 shows staging of metasomatic replacement in general. At its early stages even impregnation of hydrohematite in carbonate crystals is more common (figure 11a), less often selective replacement of carbonate crystals with ore minerals takes place (figure 11b).

In case of predominant distribution of metasomatizing solutions along intergranular cracks, carbonates replacement began from the periphery of crystals towards their central parts (figure 11c).

At all stages of metasomatic replacement inheritance of carbonate crystals cleavage by forming ore mineral aggregates took place (figure 11г, д). Rhombohedral cleavage of original carbonates came out to be contained in the memory of formed monomineral massif ore aggregates. In this connection, the use of weakened planes in massif hematite-hydrohematite ores corresponding to cracks of cleavage of original carbonates (figure 11e) is often noticed.

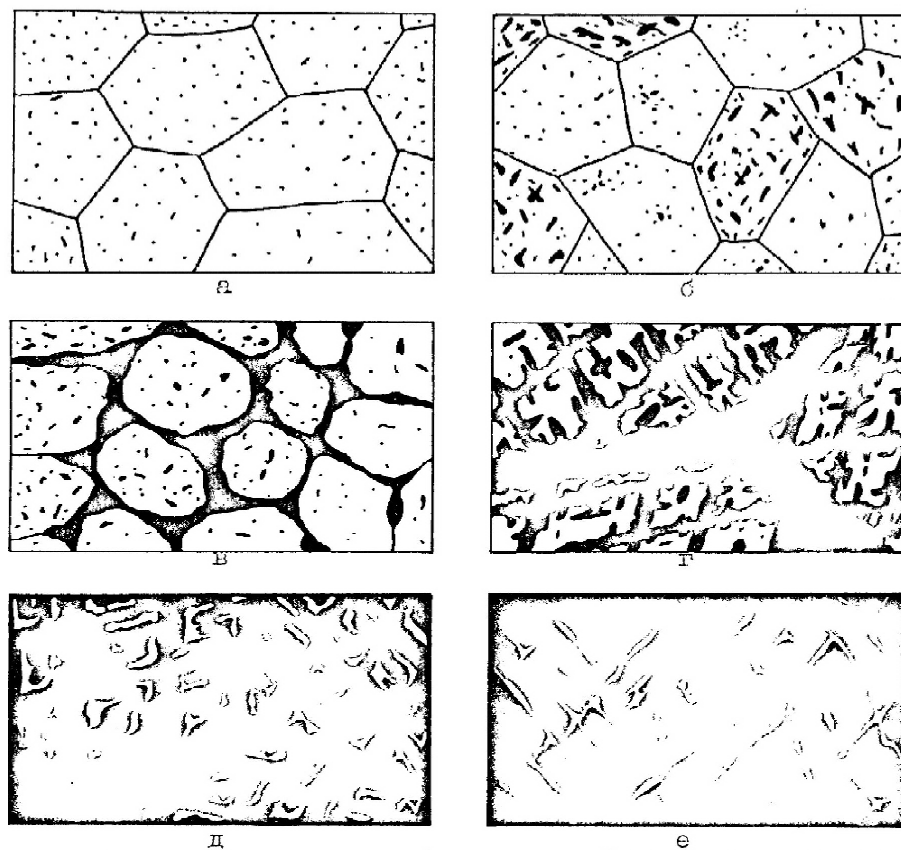


Figure 11: Some Features of Metalliferous Minerals Morphology and Staging of Metasomatic Replacement of Original Carbonates

Reflected light; Nicol prism; 85x magnification. White colour-carbonate, black colour-hematite and hydrohematite.

CONCLUSIONS

The deposit ferriferous mine of the Ouenza is located 120 km south south east of Annaba and 80 miles north of Tebessa. The mine is one of the most important iron production units throughout the Algerian territory.

Mineralogical studies of iron ores of Ouenza deposit allowed defining their four main mineral varieties, which are:

- Highly hematite and hydrohematite;
- Goethite-carbonate-goethite;
- Hydrohematite-carbonate-goethite;
- Goethite-hydrohematite-carbonate containing kaolinite ones.

Ores have crypto-crystalline structure that complicates macroscopic identification of their mineral varieties. The most efficient methods for ore varieties determining were thermographic and, in some cases, IR-spectroscopic ones.

For major ore mineral, which is hydrohematite, globular structure of aggregates is a characteristic feature, globule size changes from decimals to 3-4 μm . Specularite is represented by scaly crystals, their sizes vary from 5-10 to 50 μm and more. Its formation took place during both ore genesis and in postmetasomatic stages of ore formation by globular hydrohematite recrystallization. Goethite is represented by crypto-crystalline aggregates or acicular crystals forming radially fibrous aggregates.

Studies of peculiarities of metalliferous and non-metalliferous minerals fabric showed the fact that the major process determining structural and textural pattern of ores is metasomatic replacement of carbonate rocks by ore minerals.

Results of mineralogical studies allow reconsidering the issues of ore deposit localization, structural and textural features of ores, staging of their formation. Obtained results may become a basis for mineralogical and technological mapping of ore bodies, ore dressability studies as well as other applied issues decision.

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