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MAGNETITE-ILMENITE-HEMATITE MINERALIZATION RELATED TO THE METAGABBROIDE AND GRANITOIDE ROCKS IN THE ŠIPKOV RID LOCALITY (ESTERN MACEDONIA)

Orce Spasovski

Faculty of Mining and Geology, Goce Delčev 89, MK-2000 Štip, Republic of Macedonia

A b s t r a c t: Recent field and laboratory examinations carried out on the Fe-Ti mineralization in the vicinity of Šipkov Rid offered new knowledge on the type of mineralization related to the metagabbros and granitoids. Microscopic and electronic microprobe made it possible to obtain new information about the properties of the major minerals. Examinations determined the composition of major minerals and revealed new data about the content of microelements in monomineral probes of magnetites and their geochemical features. Ore textures and structures determined made it possible to determine the sequence of development of ore minerals and their genetic type.

Key words: ore occurrence; ore minerals; textures; structures; magnetite; ilmenite; hematite

INTRODUCTION

The Šipkov Rid magnetite-ilmenite-hematite occurrence is situated 20 km northwest of the town of Berovo. Several scientists investigated the geological structure of this mineralization and its surrounding, the most important are those of Kovačević and Petkovski et al. (1981) when compiling the page for Delčevo. In 1996 Petkovski et al. investigated the area within the complex geologic work of the Delčevo-Pehčevo-Berovo ore district. Spasovski and Serafimovski (1998) studied the metallogeny the occurrence.

GEOLOGICAL SETTING

The Šipkov Rid occurrence and its surrounding are made up of gabbroamphibolite, metadiabases, metamorphosed rhyolites, granite porphyry, coarse-grained granites etc. (Fig. 1).

Gabbroamphibolites were determined in the south parts of the area as large schistose masses, medium to coarse-grained, dark green and decomposed on the surface. The rock is made up of epidote, hornblende, chlorite, calcite, talc and relicts of plagioclase and pyroxene. Quartz occurs locally as thin vein-like lenses. Epidote occurs in medium size aggregates, most commonly of irregular shapes. Calcite occurs as large lenses and veins, most commonly as large crystals. Plagioclase occurs as oblong hipidiomorphic crystals that occur at random. Amphibole and epidote can be found interstitially. Amphibole occurs as plate-like and thin rod-like shapes of pale greenish pleochroism. Amphibole transitions to chlorite are also common. Ore minerals seldom occur as irregular aggregates along thin irregular net made up of crackles with limonite material.

Metadiabases often occur in the area and their relationship to other greenschists is gradual. Bedded portions as sills and schists (stratified) can be found sporadically. In some places metadiabases occur massively, fairly broken with limonitized quartz veinlets. They are green to dark-green under a microscope with schistose texture and typical ophite fine-grained structure. Plagioclase occurs as coarse and hipidiomorphic crystals transformed mostly to secondary products (sausseritized), whereas pyroxenes are often calcitized.

Epidote, chlorite, calcite, biotite and seldom quartz were determined as secondary petrogenous minerals. Limonite, magnetite and titanium occur as secondary minerals.

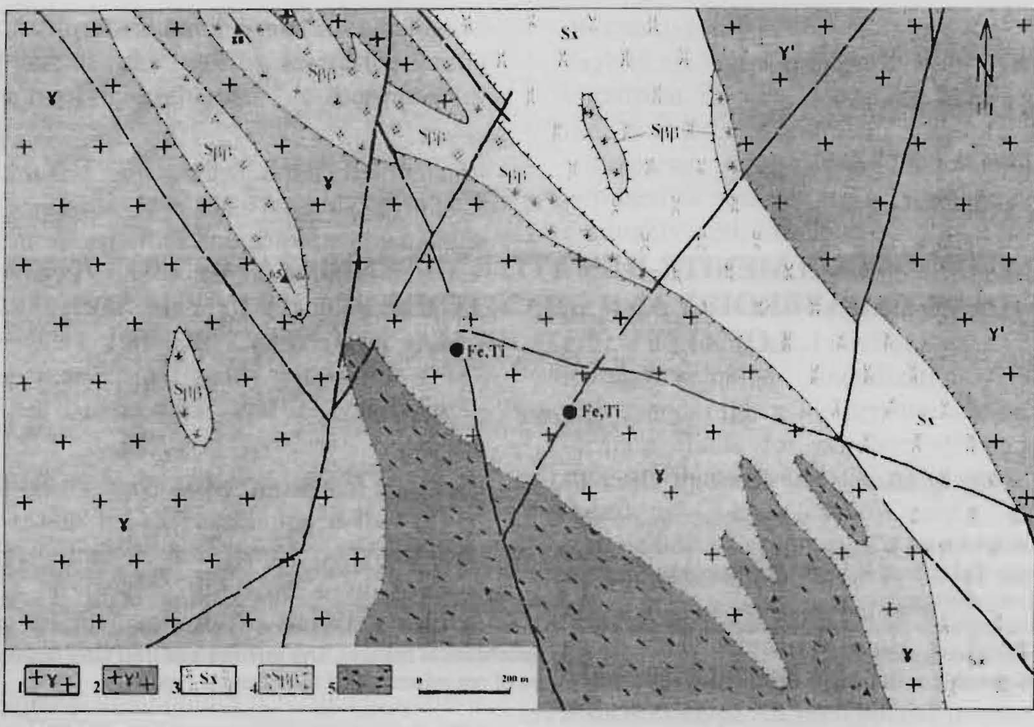

Fig. 1. Geological map of the Šipkov Rid mineralization (Spasovski, 1997)
1. Granite porphyry, 2. coarse-grained biotite granites, 3. metamorphosed rhyolites, 4. metadiabases, 5. gabbroamphibolites

Metamorphozed rhyolites are holocrystalline rocks, fairly stiff, light grey to yellowish pink. Their texture is schistose with limonite drosses on the surface. Under a microscope they exhibit porphyry or oligophyre structure (because of the rare phenocrysts in the groundmass). Quartz, orthoclase, plagioclase and seldom microcline occur as phenocrysts as idiomorphic shapes or twins with common micropertite separates. The groundmass is fine-grained microcline, made up mainly of quartz seldom quartz-sericite-clayey material.

Coarse-grained biotite granites comprise the fundament of the Delčevo granitoide mass occupying a large area. They are rocks of coarse-grained structure, most commonly pink-yellow or pink-green, alterized or broken. Their structure is alotriomorphic grain-like. The mineralization consists of quartz, potassium feldspar, less plagioclase transformed to chlorite. Chlorite, epidote and sericite occur as secondary minerals and magnetite and rarely apatite as accessory minerals.

Granite porphyries are distinguished as special differentiates of granitoide magma within coarse-grained biotite granites and in medium size pink granites. They exhibit gradual transition towards both types of granites. They are hard porphiroid medium-size-grained rocks. They are light yellowish with or without presence of coloured component parts. They are made up of quartz, potassium feldspar, plagioclase and rarely biotite and muscovite. An important variation between them and the granites is their structure which most commonly is granophire or micrographite conditioned by the co-temporaneous crystallization of quartz and feldspar.

MINERALOGICAL FEATURES

The mineralogical composition, structural-textural properties, paragenetic relationships and type of mineralization in the Šipkov Rid ore occurrence were not studied in the past. Examinations of minerals carried out by the present author consisted of ore microscopic and electronic microprobes. Several petrographic polish sections taken from basic rocks were made in order to define the medium in which Fe-Ti mineralization occurred. Thick sections were also made of the same samples in order to determine the major ore parageneses related to the basic rocks. During field investigations Fe-Ti mineralization related to granitoid rocks present mainly as magnetite and hematite accompanied by ilmenite, specularite, mushketovite, martite, goethite, lepidocrocite and limonite were also found. Bearing in mind that mineralization related to granitoid rocks can be important to the interperation of the metallogeny of magnetite mineralizations in the locality, samples for thick sections were taken from the granitoid rocks. Ore microscopic examinations of samples determined the following minerals: magnetite, hematite, ilmenite, titanomagnetite, rutile, mushketovite, specularite, martite, limonite, lepidocrocite, pyrite, pyrrhotine, chalcopyrite and bornite. The major minerals are magnetite and ilmenite accompanied by hematite, rutile, pyrite, pyrrhotine, chalcopyrite and bornite, whereas in granitoid rocks magnetite and hematite predominate accompanied by specularite, mushketovite and martite.

It can be said that the Šipkov Rid contains fairly simple mineral association consisting of minerals formed in different geological environments and physico-chemical conditions. In order to give a close interpretation of the characteristics of the major ore minerals, their relationships, and accompanying minerals the paper will give a brief account of the most important characteristics of the major and accompanying minerals in the occurrence.

Magnetite occurs as medium- and fine-grained crystalline shapes. It is developed in idiomorphic octahedra and combinations of cubic systems (Fig. 2a, d). Magnetite was affected by martitization process, individual small magnetite grains are completely replaced, while in large crystals martitization extends along crystallographic strikes (110 and 111). Magnetite also occurs in association with other iron minerals such as specularite, hematite and mushketovite. Within gabbroamphibolites magnetite occurs as small and irregular grains most commonly in association with ilmenite and pyrite. Magnetite can also be found as large hipidiomorphic grains in which submicroscopic pyrrhotine enclosures can be seen.

Hematite is a common mineral, particularly within granitoids. It occurs as acicular shapes or as large alotriomorphic grain-like aggregates. It also occurs as large rod-like shapes that build radial structures. Hematite occurs as leaf-like crystalline shapes (specularite) as well as mushkovite that often build mosaic structural shapes.

Fig. 2. Micromorphological shapes and occurrence mode of the major minerals of Šipkov Rid.
a) Idiomorphic grain-like magnetite (brown) and rod-like hematite (white), **b)** aggregate of rod-like hematite (white), **c)** relicts of pyrrhotite (white) in limonite (grey), **d)** idiomorphic and alotriomorphic grain-like magnetite with marked processes of replacement into hematite (brown) and alotriomorphic grain-like hematite (white).

Ilmenite is less common than hematite or magnetite. However, his presence is a supplement to the mineral paragenesis of the minerals. In gabbroamphibolites ilmenite occurs as larger hipiomorphic or alotriomorphic grains that have been transformed to sphen in the rim parts. Ilmenite can also be seen as small lamellar separations in magnetite from granitoid rocks. Ilmenite in granitoid rocks occurs as small alotriomorphic grains, seldom as medium size alotriomorphic grains. In some ilmenite grains wave-like darkening can be seen, most probably due to the influence of regional metamorphism.

Rutile is much less common compared with ilmenite and can be found in mineralization related to gabbro amphibolites. It occurs as small irregular, seldom as larger and elongated grains. In the periphery parts its transition to sphen is marked due to a decrease of Fe and Ti components and the increase of Ca and Si.

Sphen is very common particularly in gabbro-amphibolites. Its occurrence is related to the occurrence of ilmenite and rutile, in other words, the periphery parts of the former are largely transformed to sphen.

Of the iron ore minerals quite common are limonite, rhythmic colomorph occurrences of gaethite and lepidocrocite. These minerals owe their occurrence to pyrite replacement to limonite and gaethite. Within limonite, very small pyrite grains are common as relicts (Fig. 2c).

Pyrite is less common in the samples studied, but occurs as irregular and small grains occurring as impregnations in non-ore material. Pyrite can also be found as relicts within limonite, seldom in chalcopyrite.

Pyrrhotine is very rare and occurs as very small irregular grains unevenly distributed in gabbroamphibolites. Although seldom, it can also be seen hosted by magnetite.

Chalcopyrite is present is large quantities compared with pyrrhotine. However, its presence is of no importance. It can be found as small or medium size grains. It occurs as alotriomorphic grains, but several hipidiomorphic chalcopyrite grains were also found in the studies.

Bornite is the least common and occurs as several small and irregular grains within gabbro-ampibolite.

Chemical composition of some ore minerals

The chemical composition of magnetite and its accompanying minerals can, to some extent, be used to determine the environment of their origin as well as the physico-chemical processes present at the time of their development.

Electronic microprobe determined the composition of magnetite, hematite and limonite. Three analyses were performed on magnetite and hematite and one on limonite. The results obtained are shown in Table 1. The sites of magnetite, hematite and limonite grains are given in Figs. 2a, b, c and d.

Table 1

Quantitative X-ray spectral microanalyses of magnetite, hematite and limonite of Šipkov Rid (%)

Elements	1	2	3	4	5	6	7
Fe	72.04	70.77	68.25	68.19	68.95	60.98	71.18
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mn	0.65	0.54	0.68	0.85	0.85	0.40	0.42
Ni	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Co	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.00	0.00	0.00	0.00	0.00	0.24	0.00
Si	0.67	0.25	0.42	0.45	0.00	3.78	0.00
O	26.63	28.44	30.54	30.52	30.14	34.60	28.12
Σ	99.99	99.99	100.00	99.99	99.94	100.00	99.30

Note: * Analyses 1, 2 and 7 are magnetite; 3, 4 and 5 are hematite; no. 6 is limonite.

** Analyses were performed in the Laboratories for Geochemical Studies AD Sofia by H. Stančev.

Table 1 shows that magnetite is characterized by constant chemical composition seen from iron contents ranging from 70.77 to 72.04 %. Manganese and silicium were determined as accompanying elements. The table also shows that values obtained for the chemical composition of magnetite are close to the theoretical ones for solid magnetite with no impurities (Чвилева et al., 1988).

Structural and textural features

Structural-textural features of magnetite-hematite and magnetite-ilmenite-titanomagnetite mineralization have not been studied in detail. The paper gives a brief account of a small number of polished sections studied.

Based on macroscopic survey of polished sections the following textures have been determined:

a) disseminated texture and

b) massive texture.

Disseminated texture is characterized by irregular distribution of small aggregates (individual grains or their intergrowths) in mineralized rocks. This type is more marked with gabbroamphibolites in which magnetite and ilmenite grains are unevenly distributed and are mostly of irregular shape.

Massive texture is characterized by the presence of parts that are entirely filled with ore minerals, mainly magnetite and hematite. This kind of texture is found only in granitoid rocks.

The most significant types of structures distinguished are as follows:

Sideronite structure is characterized by the presence of more or less idiomorphic grains of pyroxene, amphibole and plagioclase as well as ore minerals (magnetite, titanomagnetite, ilmenite and sulphides). The void spaces between the petrogenous minerals are filled with ore minerals. This type is characteristic of magnetite and ilmenite related to gabbroamphibolites.

Disseminated texture is of morphologic type.

Decomposition of solid solutions is due to the change of the physico-chemical conditions present during the time of ore deposition. As a result, a change of earlier deposited titanomagnetite took place which was unstable in the newly created conditions and decomposed into simple mineral compounds (magnetite and ilmenite). This type of structure is very rare and is characteristic only of several magnetite grains that contain ilmenite lamellae.

Decomposition of solid solution represent is mostly normal break up of ilmenite as small lamellae oriented into two directions along cleavage planes of titanomagnetite. It is worth mentioning that gradual decrease of temperature is essential during the development of decomposition structures of solid solution like those during the development of crystal aggregates.

Lamellar structure is morphologic type of decomposition of solid solution.

Replacement structures are the most common types in the magnetite-hematite mineralization studied in the granitoid rocks. They are much less common in magnetite-ilmenie-titanomagnetite mineralization in gabbroamphibolites.

Microscopic studies determined two kinds of replacement: corrosive and pseudomorphose.

Pseudomorphose replacement leads to the development of a new mineral or aggregate mineral, which gets the shape and structure of the mineral, replaced. An example of pseudomorphic replacement is pyrite replacement to limonite as well as that of magnetite to martite when it is done from the periphery to the middle parts (Fig. 2c, d).

Corrosive replacement is characteristic of magnetite of the granitoid rocks where corrosion occurs along cleavage directions which results in the creation of lattice like structure (magnetite is replaced by fine-acicular hematite along cleavage directions). The most common structures occurring are lattice-like, acicular corrosive and relict.

Genetic features

The development of spatial dislocation of magnetite-ilmenite and magnetite-ilmenite-hematite mineralization within the Šipkov Rid occurrence is a complex polyphase process related to the evolution of gabbroamphibolites and granitoid rocks. Scant information about the mineral composition and structural-textural characteristics of mineralization obtained point out to the existence of two mineralzatioin types:

– magmatic type present as magnetite-ilmenite-titanomagnetite accompanied by poorly expressed sulphide phase (pyrite, pyrrhotine, chalcopyrite) that is genetically and spatially related to gabbroamphibolites;

– hydrothermal type present as magnetite and hematite accompanied by ilmenite, pyrite and limonite genetically related to the Delčevo granitoid intrusion and spatially related to the gneisses.

The conclusions mentioned so far regarding the genetic characteristics of the Fe-Ti mineralization of the Šipkov Rid occurrence should be taken as preliminary and informative since they are based on a small number of investigations.

CONCLUSION

Based on the results of investigations carried out so far and those obtained during the investigations of magnetite-ilmenite-hematite mineralization the following can be inferred:

– Magnetite-ilmenite mineralization related to the gabbroamphibolite and magnetite-ilmenite-hematite mineralization related to the granitoids located within the gneisses was determined in the Šipkov Rid area.

– Magnetite-ilmenite mineralization occurs as disseminations, whereas that of magnetite-ilmenite -hematite as massive magnetite-hematite mineralization most commonly accompanied by ilmenite is probably a metasomatic product of hydrothermal solutions activities.

– The development and spatial distribution of magnetite-ilmenite and magnetite-ilmenite-hematite mineralization within the occurrence are a complex polyphase process directly connected with the evolution of gabbroamphibolites and granitoid rocks.

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Резиме

МАГНЕТИТ-ИЛМЕНИТ-ХЕМАТИТСКА МИНЕРАЛИЗАЦИЈА ПОВРЗАНА СО МЕТАГАБРОИДНИТЕ И ГРАНИТОИДНИТЕ СТЕНИ НА ЛОКАЛИТЕТОТ ШИПКОВ РИД (ИСТОЧНА МАКЕДОНИЈА)

Орце Спасовски

Рудрско-геолошки факултет, Штип, Република Македонија

Клучни зборови: рудна појава; рудни минерали; структури; текстури; магнетит; илменит; хематит

Со најновите теренски и лабораториски испитувања на Fe-Ti-минерализацијата во околината на Шипков Рид се добиени нови сознанија за овој тип орудување поврзан со метагаброидите и гранитоидите. Најновите лабораториски испитувања, во прв ред рудномикроскопски, а делумно и испитувањата со електронска микросонда, овозможија покомплетно осознавање на особините на главните рудни минерали. Со овие испитувања за прв пат е одреден составот на главните рудни минерали, а исто така се добиени податоци за содржината на микроелементите во рамките на мономинерални проби на магнетит, односно најнови сознанија за геохемиските карактеристики на магнетитите. За прв пат се одредени позначајните структури и текстури на рудите, што овозможува да се одреди редоследот на создавањето на рудните минерали, а наедно да се одреди и генетскиот тип на рудната појава.