GEOME 2
Manuscript received: April 18, 1998
Accepted: November 11, 1998

Geologica Macedonica, Vol. **12**, p. 51–56 (1998)
ISSN 0352 – 1206
UDC: 553.31 : 553.481 (497.7)

Original scientific paper

MINERALOGY OF THE MAGNETITES IN THE RŽANOVO Fe-Ni DEPOSIT, REPUBLIC OF MACEDONIA

Blažo Boev and **Tena Šijakova-Ivanova**

Faculty of Mining and Geology, Štip, Republic of Macedonia

A b s t r a c t: The paper presents data about mineralogical investigations of individual magnetite types in the Ržanovo deposit obtained by the application of the method of electronic microanalysis. Special attention in the study of magnetites was paid to the distribution of nickel in the minerals.

Key words: mineralogy; magnetite; electronic microanalysis

INTRODUCTION

The Ržanovo deposit is situated near the village of Ržanovo, on the right side of the Porska River and the north-western slopes of the central part of the Kožuf massif close to the Macedonian-Greek border.

The geological characteristics of the Ržanovo deposit, its mineralogical composition, genesis, ore grade and reserves were first reported by Ivanov (1959, 1960).

The mineralogical composition, the sulphide parageneses in particular, were described in detail by Grafenauer and Strmole (1966). To date, detailed mineralogical and geochemical investigations of the ore have been carried out by Maksimović (1981), Boev (1982), Boev and Stojanov (1985), Boev and Serafimovski (1992), Boev and Lepitkova (1994), Boev and Serafimovski (1995).

GEOLOGY OF THE RŽANOVO DEPOSIT

The geological relationships in the deposit were first reported by Ivanov (1959, 1960) and modified by providing more detail by Boev (1982). The mineralization of nickeliferrous iron is situated at the contact between Jurassic serpentinites and schists located in the footwall as well as Cretaceous limestones located in the top part of the ore layer. The ore layer was investigated starting from peak 955 up to peak 470 meters (in a vertical interval of some 500 meters) and signs of wedging out were not encountered. The average thickness of the layer amounts to some 30 meters occurring as an uninterrupted ore body although tectonic events in the terrain were fairly intense.

In terms of its spatial position, the layer is subvertical, but the strong tectonic movements in the long evolution resulted in an inverse position of the deposit in the Ržanovo portion (Fig. 1).

Generally, the ore layer is of homogenous nature, but in terms of the geochemical and mineralogical characteristics of the ore present it can be inferred that the layer is heterogeneous and basically

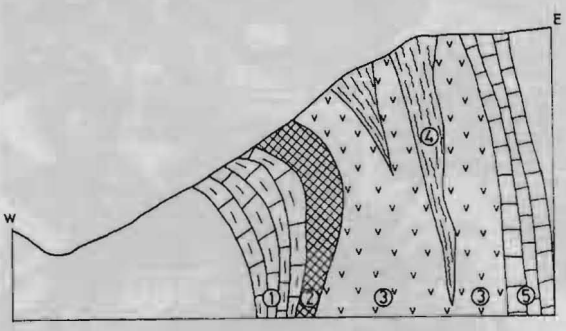


Fig. 1
1) Limestone flysch series of Turonian age. **2)** Ore layer (hematite-magnetite). **3)** Serpentinites of Jurassic age. **4)** Cretaceous schists. **5)** Limestones of Triassic age

composed of several lithological members of specific mineralogy and chemistry.

Based on knowledge available, the following lithologic rock types and ore can be distinguished:

1. Compact magnetite ore.
2. Schistose magnetite ore.
3. Oolitic hematite ore.
4. Schistose hematite ore.
5. Compact hematite ore.
6. Riebeckite schists.
7. Stilpnomelanic schists.
8. Dolomite-talc schists.
9. Talc schists.
10. Serpentinites.

METHOD OF WORK

The method of electronic microanalysis was applied in the investigation of the chemical composition of magnetites. It is the most appropriate method since it determines the chemical composition of the mineral in one point and permits analysis of mineral grains in profile which makes possible the determination of the zoning and the homogeneity of the grains. The method also defines how minerals fit into one another.

Measurements were carried out in the Max-Planck Institute, Mainz, Germany.

RESULTS AND DISCUSSION

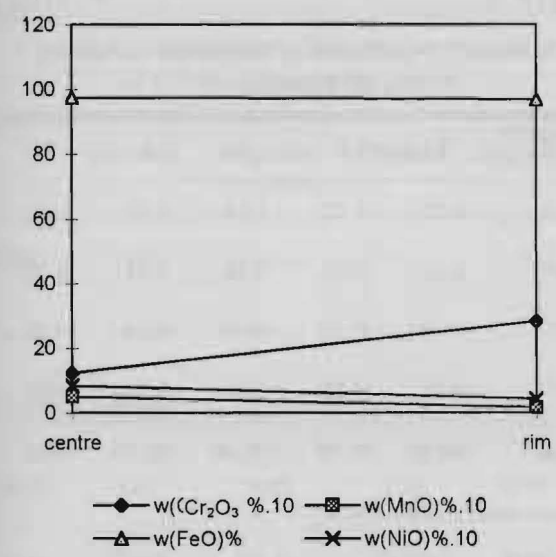
Examinations indicate that magnetite occurs in several forms such as large idiomorphic crystals, lamellae, magnetite grains with centres built of chromite, as a band in chromite grains as well as magnetite grains located in talc.

Fig. 2. Idiomorphic grains in magnetite

Table 1

Chemical composition of magnetites occurring as coarse idiomorphic grains

	Magnetite centre	Magnetite rim
SiO_2	–	–
Al_2O_3	–	–
MgO	–	–
Cr_2O_3	1.24	2.82
MnO	0.51	0.15
FeO	97.41	96.58
NiO	0.85	0.44
Total	100.00	100.01
Amount ions calculated on 4(O)		
Si	–	–
Al	–	–
Mg	–	–
Cr	0.05	0.11
Mn	0.02	0.01
Fe	3.87	3.82
Ni	0.03	0.02



The zoning of Cr, Mn, Fe and Ni (as oxide percentages) in magnetite grain

The diagram shows that the amount of chromium increases from the centre to the rim of the grain, whereas that of manganese decreases. Nickel content also decreases from 0.85 to 0.44%.

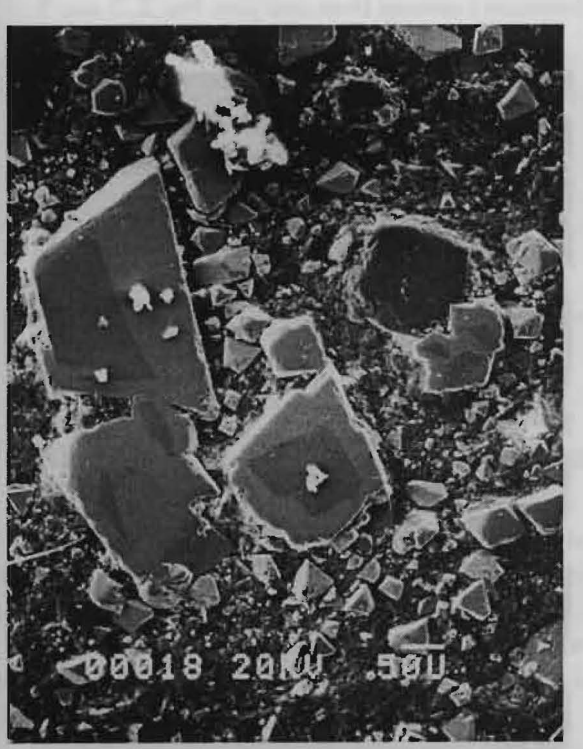


Fig. 3. Magnetite grains with chromite centre

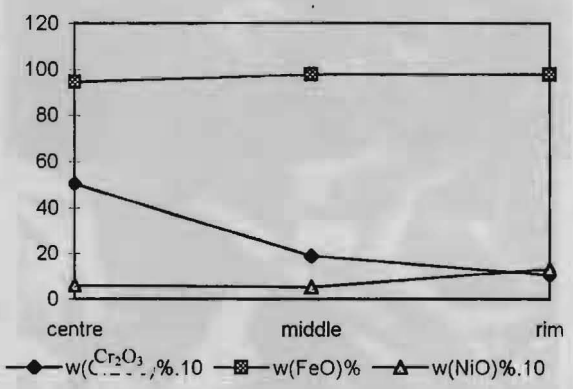
Table 2

Chemical composition of magnetite grains with chromite centre (Chemical composition of chromite)

	Anal. No 1	Anal. No 2
Al_2O_3	15.29	16.47
Cr_2O_3	60.70	61.36
FeO	23.87	22.02
NiO	0.15	0.15
Total	100.00	100.01
Amount ions calculated on 32(O)		
Al	4.85	5.09
Cr	12.90	12.73
Fe	5.37	5.24
Ni	0.03	0.03

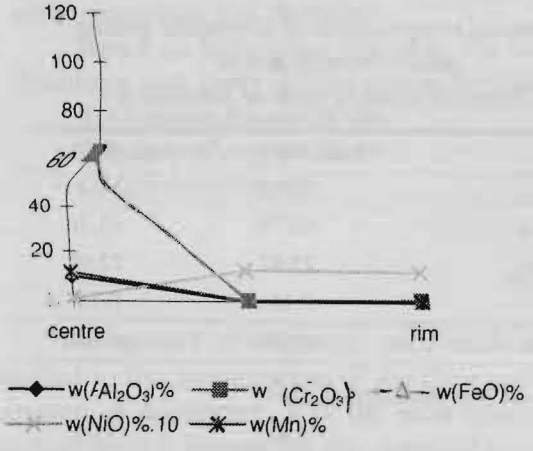
Chemical composition of magnetite

	Anal. No 1	Anal. No 2	Anal. No 3
Cr_2O_3	5.04	1.89	1.04
FeO	94.36	97.59	97.62
NiO	0.61	0.52	1.33
Total	100.01	100.00	99.99
Amount ions calculated on 4 (O)			
Cr	0.18	0.07	0.04
Fe	3.69	3.87	3.89
Ni	0.02	0.02	0.05



The zoning of Cr, Fe, Ni (as oxide percentages) in magnetite

The diagram shows that the amount of Cr decreases from the centre to the rim, whereas that of Ni increases from 0.61 to 1.33%.



The zoning of Al, Cr, Fe, Ni (as oxide percentages) in magnetite grain with chromite centre

The diagram shows that the chemical composition of chromite is of homogenous nature, whereas that of magnetite varies. The amount of iron increases from 22.02 to 97.62% from the centre to the rim of the grain, whereas that of nickel from 0.15 to 1.33%. The content of chromium decreases from 61.36 to 1.04% and makes possible the grain to transform from chromite into magnetite.

Table 3

Chemical composition of magnetite occurring as lamellae

Anal.No	1	2	3	4	5
Cr_2O_3	0.25	1.73	1.18	0.29	1.47
MnO	0.10	0.07	0.88	0.04	0.16
FeO	99.47	97.92	96.74	99.34	97.57
NiO	0.18	0.28	1.20	0.33	0.80
Total	*100.00*	99.99	*100.00*	*100.00*	99.99
Amount ions calculated on 4 (O)					
Cr	0.01	0.06	0.04	0.01	0.06
Mn	0.04	0.03	0.04	0.001	0.07
Fe	3.97	3.89	3.85	3.97	3.88
Ni	0.01	0.01	0.04	0.01	0.03

Analyses No 1 and 4 are those of magnetite occurring as a lamellae (lath). Analyses Nos. 2, 3 and 5 are those of magnetite occurring as a grain. Analyses No. 1 and 4 displays higher iron but lower chromium contents than analyses No. 2, 3 and 5.

Fig. 4. Magnetite occurring as lamellae

Fig. 5. Magnetite occurring as a band in chromite grain

Table 4

Chemical composition of magnetite occurring as a band in chromite grains

	Chromite	Magnetite as a band	Chromite	Magnetite
MgO	1.02	–	–	–
Al_2O_3	14.92	–	14.14	–
Cr_2O_3	60.02	3.16	61.19	2.86
MnO	3.05	0.43	3.33	0.39
FeO	20.81	92.21	21.09	92.99
NiO	0.19	4.21	0.24	3.76
Total	100.01	100.00	100.00	100.00
Amount ions calculated on 4(O)				
Mg	0.40	–	–	–
Al	4.72	–	4.52	–
Cr	12.73	0.12	13.11	0.11
Mn	0.69	0.02	0.75	0.02
Fe	4.67	3.65	4.78	3.68
Ni	0.04	0.16	0.05	0.14

Table 5

Chemical composition of idiomorphic magnetite grains in talc

	Anal. No 1	Anal. No 2
Cr_2O_3	1.93	1.88
FeO	95.88	94.85
NiO	2.19	3.27
Total	100.00	100.00
Amount of ions calculated on 4(O)		
Cr	0.07	0.07
Fe	3.81	3.77
Ni	0.08	0.13

Fig. 6. Idiomorphic magnetite grains in talc

CONCLUSION

Based on investigations carried out it can be inferred that the following types of magnetites can be found:

1. Magnetites occurring as coarse idiomorphic grains in which nickel amounts from 0.85 to 0.44%.

2. Magnetite grains with centres built of chromite with nickel amounting from 0.11 to 1.25%.

3. Magnetite occurring as lamellae of 0.18 to 0.28% nickel.

4. Magnetite occurring as a band in chromite grains with 4.21% Ni.

5. Idiomorphic magnetite grains in talc with nickel contents amounting from 2.19 to 3.27%.

REFERENCES

Боев, Б., 1982: *Метаморфизам на руднаша серија 'Ржаново-Студена Вода.* Маг. теза, Рударско-геолошки факултет, Белград, 93 стр.

Boev, B., Stojanov, R., 1985: *Metamorphisam of Ni-Fe* ores from *Rzanovo–Studena Voda and zone Almopias.* Geologica Macedonica, Vol. 1.

Боев, Б., Серафимовски, Т., 1992: *Состав на некои од главните минерални фази во продуктите од предредукцијата на никлоносните руди од наоѓалиштето 'Ржаново – Македонија.* 24. советување на рударите и металурзите, Бор, 1992.

Боев, Б., Лепиткова, С., 1994: *Минерални фази во предредуцираните пелети од металуршкиот процес на Фенимак, Кавадарци.* Зборник на трудови на РГФ, Штип, бр. 1. 1994.

Боев, Б., Лепиткова, С., 1994: *Квантитативна минералошка анализа на руда од железно-никлоносното наоѓалиште 'Ржаново – Република Македонија.* 24. октомвриско советување во Бор, 1994.

Boev, B., Serafimovski, T., 1995: *Metalogenetic features of the Fe-Ni lateritic deposits in the Vardar zone, Republic of Macedonia.* Second National Symposium "Metalogeny of Bulgaria", Sofia.

Grafenauer, Strmole, 1966: *Zlog in mineralna sestava nikljenosnih železovih rudRžanova.* Rudarsko-metalurški zbornik, 1, 51–62.

Иванов, Т., 1959: *Никлоносно гвожђе код Ржанова на Кожуфу (НР Македонија).* Трећи конгрес геолога Југоскавије, Будва, стр. 249–264.

Иванов, Т., 1960: *Никлоносна железна руда на планини Кожуф код села Ржаново.* Трудови на Геолошкиот завод, Скопје, св. 7. стр. 199–223.

Maksimović, Z, 1981: *Nickel-bearing phlogopite from the nickel-iron deposit Studena Voda (Macedonia).* Godišnjak Jugoslavenskog centra za kristalografiju, Vol. 16, Zagreb.

Резиме

МИНЕРАЛОГИЈА НА МАГНЕТИТИТЕ ОД НАОЃАЛИШТЕТО НА НИКЛОНОСНА ЖЕЛЕЗНА РУДА „'РЖАНОВО", РЕПУБЛИКА МАКЕДОНИЈА

Блажо Боев и Тена Шијакова-Иванова

Рударско-геолошки факултет, Штип, Република Македонија

Клучни зборови: минералогија; магнетити; електронска микроанализа

Во овој труд се прикажани резултатите од минералошките истражувања на поедини зрна на магнетит од наоѓалиштето на никлоносна железна руда 'Ржаново, вршени со примена на методот на електронска микроанализа. Треба да се нагласи дека посебно внимание во рамките на истражувањето беше посветено на дистрибуцијата на никелот во различните типови на магнетит.