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CONTRIBUTION TO THE KNOWLEDGE OF THE MAGNESITE DEPOSITS IN BOSNIA AND HERZEGOVINA

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ABSTRACT
Contribution to the knowledge of the magnesite deposits in Bosnia and Herzegovina
Magnesite is an industrial mineral of magnesium, which most often occurs in the form of crystalline, massive and amorphous forms. Mineral magnesite has a wide and varied application in the production of high-strength materials: powder (flour), sinter, bricks (magnesite, magnesite-chromite, forsteric, etc.). In the construction industry it is used for the production of magnesium cement. In smaller quantities it is used in chemical, pharmaceutical, rubber and other industrial branches. The area of the so-called "Bosnian Serpentine Zone" are stand out in the area of the inner Dinarides of Bosnia and Herzegovina, among numerous phenomena and larger deposits of magnesite. In terms of quality, the variability from high quality to those that can not be used in the refractory industry is determined. Magnesite deposits mostly require certain preparation procedures in order to achieve higher quality magnesite. The paper presents deposits and the appearance of magnesite in Bosnia and Herzegovina, with emphasis on the results of previous research, quality, reserves, usability and laboratory testing, and the results of the latest X - ray examinations from one site have been presented.

KEY WORDS
magnesite, deposits and phenomena, quality, reserves, research, testing, use

1. Introduction

The mineral magnesite is carbonate magnesium by chemical composition, which consists of 47,82 % MgO and 52,18 % CO_2. Magnesite usually contains different benefits in the natural state: CaO, SiO_2, FeO, MnO, TiO_2, Fe_2O_3, Al_2O_3 etc. This mineral is found in crystalline aggregates in metasomatic type deposits, as well as in the form of cryptocrystalline to microcrystalline aggregates in deposits of hydrothermal - vein, hydrothermal - sedimentary and infiltration type.

This mineral is used in the production of high-quality refractory materials, then in the cement industry, the ceramic industry, the pharmaceutical industry, the sugar industry and other industries. In the refractory industry, this mineral is used for making magnesia bricks, magnesite-chromite, chromium-magnesite, forsterite bricks, and for the production of metallurgical magnesite powder (sinter magnesite).

The most widespread is in the area of the so-called "Bosnian serpentine zone" of the inner Dinarides. The rocks, in which there are phenomena and ore deposits of magnesite, are serpentinites, peridotites and serpentinised peridotites. Magnesite in these rocks usually occurs in the form of wires of different shapes and dimensions.

Deposits and occurrences of magnesite are located in the northwestern, northern, northeastern, eastern and partly central Bosnia. It is located on the Pastirevo mountain, Kozara, in the peridotites through which the rivers Ukrina and Usora originate, then on the left and right banks of Bosnia river (middle flow), on the Ozren Mountain, in the area of the Krivaja River, on the Konjuh mountain and in Zvornik and Visegrad.

Most magnesite deposits in Bosnia and Herzegovina are hydrothermal wires, and only minor occurrences in Bosanski Petrov village are infiltration type b. According to the level of research, the most important are the regions of Banja Luka and Kladanj, where there are significant deposits in size and quality. Until 1930, the authors did not study magnesite in detail, and they are generally referred to as the supporting mineral in the sepiolite deposit in Prnjavor (Walter, 1887, Radimsky, 1889, Kišpatić, 1893, Katzer, 1909 and 1912). Herbich (1880) states that there is magnesite in the vicinity of Kreševo outside the serpentine zone which, along with calcite, is caused by the decomposition of dolomite in the tetrahedrite deposit. A greater interest in studying magnesite began in 1930 when Schadler was published (1931) and after the war, when magnesite research was intensified primarily for the refractory industry's needs.

2.Methods and results of research of magnesite deposits of Bosnia and Herzegovina

In the teritory of Bosnia and Herzegovina, there are the following groups of Magnesite regions:
I. Regions in the Pastireva and Kozara massifs
II. Regions in the Krivaja-Konjuh massifs (or districts in the area of "Central Bosnia")
III. Regions in the western part of the Zlatibor massif.

The Magnesite regions consist of more than one magnesite field, most commonly related to the systems of faults and cracks. In the paper, the term deposit is used to show the economically interesting concentrations of magnesite, regardless of its size. The term occurrence is used for concentrations of magnesite that are not of practical interest or their practical significance is unclear.

Magnesite phenomena within the Pastireva and Kozara massifs represent a magnesite region where it has been established that the spikes of magnesite wires are rare and of no great economic importance. Krivaja-Konjuh massif is one of the largest massif in the inner Dinarides whose structure is dominated by serpentinized lherzolites, serpentinized harzburgites, dunites and pyroxenites. According to the degree of exploration of the Krivaja-Konjuh ultramafic massif, the following areas were separated:

1. the area of Banja Luka,
2. the area of Prnjavor,
3. the area of Mala Ukrina,
4. the area of Teslić,
5. the area of Moševac,
6. the area of Novi Šeher,
7. the area of Žepče,
8. the area of Bajvat,
9. the area of Dištica,
10. the area of Olovo,
11. the area of Kladanj.

Magnesite phenomena and deposits of the Banja Luka region were discovered at the latest, although they took a significant place in reserves. The research was carried out by performing excavations, exploration drilling, underground work, geophysical and geochemical tests. The appearance of magnesite is mainly in the form of wires. Investigations carried out in detail about 25 magnesite wires and partly over 40 wires.

The chemical composition was determined on about 500 samples of magnesite and the following results were obtained: MgO 44-47 %, SiO_2 0.08-3.80 %, CaO 0.21-3.40%, R_2O_3 0.17-1.5 0%. The results of qualitative test showed that only a small part of the ore can be used without prior preparation in the industry of high-refractory materials (about 25 %), most of it after hand triage (about 45 %) and the rest after separation (about 35%).

The explored reserves in this region amount to over 1.4 million tons, with most of them belonging to the C_2 category reserves. Considering that the share of industrial reserves is low, it is necessary to overwhelm the network of investigative works in order to translate the reserves of lower categories into more.bThe occurrence of magnesite in the Prnjavor region is concentrated on the Ljubić Mountain. Research in this region was done by excavations, exploration drilling, underground work and geophysical testing. The appearance of magnesite bodies is cracks.

Mineralogical - petrographic studies have determined the following mineral composition: magnesite, minerals of clay, sepiolite, dolomite, calcite, calcedon and iron hydrated minerals. The chemical composition was determined on about 100 samples of magnesite and the following results were obtained: MgO 44.70-46.38 %, SiO_2 0.08-2.77 %, CaO 0.82-2.28 %, R_2O_3 0.62- 1,81 %.
The total researched reserves of magnesite in the Prnjavor region amount to about 204 thousand tons, while the reserve C1 category is 12 424 t (Baulića Potok).

The Prnjavor area is characterized by a low concentration of ore bodies, some of which are located even at greater distances.bIn the area of Teslić, the following sites were identified: Blatnica, Bijela Rijeka, Skok-Crna Rijeka, Lipovac Potok, Vukovački Potok and Crna Rijeka. In the magnesite in this area the content of calcedons has been determined. The largest reserves are located at the locality Skok-Crna Rijeka.

In the area of Teslić, Žepče, Zavidovići and others, the magnesite chemistry differs from the typical hemisphere of magnesite. Namely, in the area of Teslić, Žepče, Zavidovići and other samples, the content of CaO is higher, and this is not a characteristic of the magnesite of other areas, such as those in Konjuh.
The magnesite quality in the Teslić region was determined by chemical and mineralogical-petrographic tests. The following mineral paragenesis was determined: magnesite, dolomite, calcite, calcedon, quartz, clay minerals, magnetite, pyrite and iron hydroxides. The chemical composition was examined on about 20 samples (from Blatnica, Milešov jarak, Bukovački jarak, Proleterov do) and the following results were obtained: MgO 36.10-47.14 %, SiO_2 0.07-19.57 %, CaO 0.05-10.31 %, R_2O_3 0.02-4.40 %.

The quality of the raw material is not satisfactory because the content of SiO_2 is high and the content of CaO is above the permissible limit. Paragenesis of magnesite and dolomite was determined by chemistry and X-ray tests.

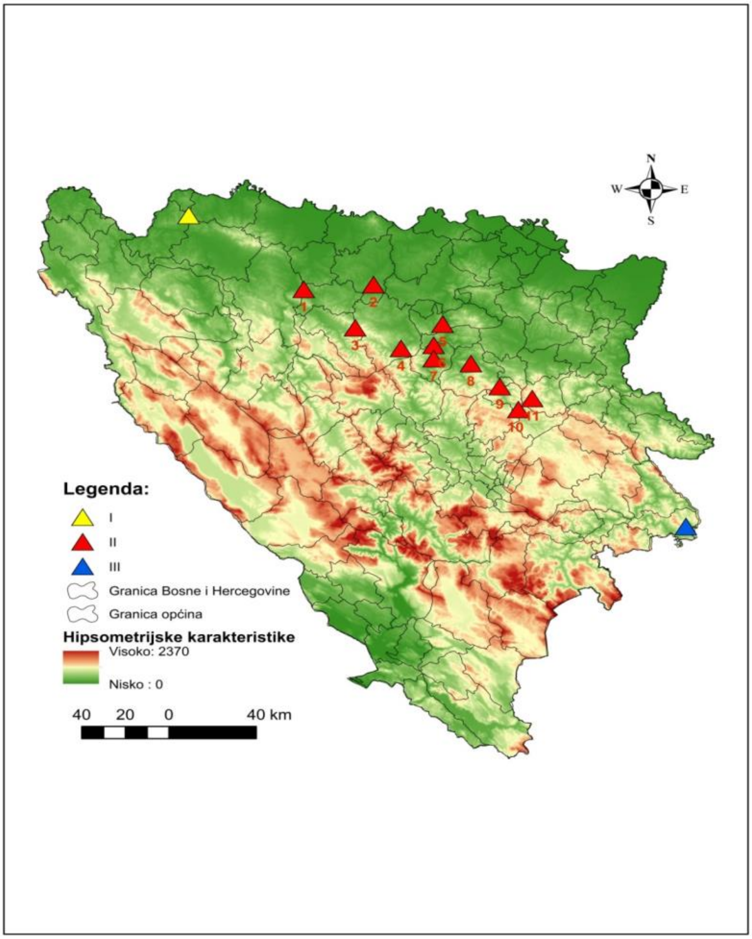

Figure 1: Geographical position of magnesite regions in Bosnia and Herzegovina.

I. Regions in the Pastireva and Kozara massifs
II. Regions in the Krivaja-Konjuh massifs (or districts in the area of "Central Bosnia"), 1. The area of Banja Luka; 2. The area of Prnjavor; 3. The area of Mala Ukrina; 4. The area of Teslić; 5. The area of Moševac; 6. The area of Novi Šeher; 7. The area of Žepča; 8. The area of Bajvati; 9. The area of Dištica; 10. The area of Olovo; 11. The area of Kladanj
III. Regions in the western part of the Zlatibor massif.

The magnesite-dolomite rocks of the locality Skok-Crna Rijeka, as well as in other central parts of the olyolite zone, have a high content of calcium oxide, and their use in the refractory industry is relatively limited compared to pure magnesites. Paragenesis of magnesite and dolomite was determined by chemistry and X-ray examinations. Magnesite is larger than dolomite and both minerals contain iron particles, which may be of practical importance (Table 1).

Table 1: Chemical composition (%) of magnesite and dolomite of the locality Skok-Crna rijeka.

Mark of sample	SiO_2	Al_2O_3	FeO	MgO	CaO	CO_2	Total
1	0,66	trace	1,68	22,37	28,92	46,91	100,54
2	0,28	0,61	2,87	38,22	8,29	49,74	100,01

1. Dolomite, with a slight admixture of magnesite and quartz; 2. Magnesite and dolomite.

Studies have shown that the magnesite-dolomite rocks of the Teslić and the Novi Šeher areas, especially if they contain a certain amount of iron, can be used in the industry (Jovanović et al. 1978).

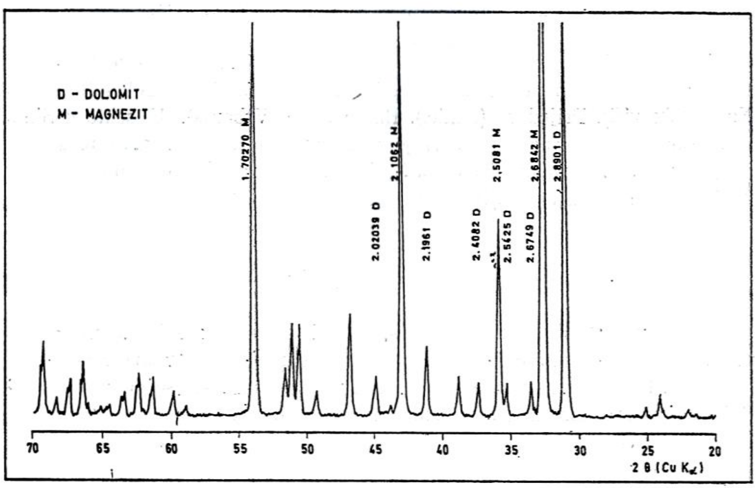

Figure 2: Dolomite-magnesite wire from the site Skok-Crna rijeka near Teslić.
Source: Barić & Trubelja, 1984

All works on the preparation of magnesite from the site Milešov jarak and Blatnica showed that except for the deposits of Blatnica type II, flotation can achieve satisfactory results. The total reserves so far explored in the Teslić region are about 1 million tons. Investigation works should be directed in two directions: to the recategorization of reserves from C_2 into C_1 category, respectively B or A category. More detailed data on magnesites in the area of Maglaj are found in works by Ilić, S. (1956) and Varićak, D. (1967). Ilić described the following sites: Han Moševac, Ošve, Paklenica, Bijeli Klanci, Rječica, Čobe and Adže (Novi Šeher) where magnesite phenomena are in the form of wires of different dimensions in serpentinised peridotites. The exploitation of megnesite was carried out at the locations of Ošva and Bijeli Klanci. The Magnesite region of Novi Šeher is located about 5 km north-northeast of the village of Novi Šeher. This region consists of only one Ošve deposit and several minor phenomena: Beša potok, Sač, Borov potok and others.

The research was carried out by excavation, exploration drilling and cave works. A small scope of investigative works has been carried out, which does not provide sufficient data on the potential of this region. The magnesite region of Moševac is located about 8 km north-northeast of Maglaj. The magnesite quality in this region is defined on the basis of chemical and mineralogical-petrographic tests. Data were obtained that the mineral composition is as follows: magnesite, calcedone, quartz and dolomite. Chemical testing was carried out on about 20 samples and the following results were obtained: MgO 28.50-45.10 %, SiO_2 0.43-36.85 %, CaO 0.40-11.63 %, R_2O_3 0.59-3.30 %.

The quality characteristics of magnesite from the Moševac area are very variable. Since little data can not be made definitive conclusions. The total reserves proved in this deposit are 473 thousand tons of magnesite C_2 category reserves. Region is perspective from the aspects of further research. Varićak (1967) selected several sites on the wider Ozren Mountain area: Rječica, Misurići, Savići, Ostovići and Ivanovići. The largest number of magnesite phenomena is found at the location of Misurići.

Magnesite phenomena are found in the areas of Žepče at locations: Bljuve, Osredak, Klupe, Čubino Brdo, Laznikovac, Matine, Mehići, Kose and Odobašići. At the site of Kljuve the content of manganesite is noticed, and at the site of the Klupe magnesite contains opal. In the area of the Krivaja River and in the Konjuh Mountain, ultrabasic rocks have a high distribution and usually contain the appearance of magnesites, which in part have larger dimensions and represent economically significant deposits. It can extract several interesting areas with magnesite. The occurrence of magnesite in the Konjuh area was most closely examined (Miladinović, D 1969, Panić and Ristić, 1972; Ristić, Panić and Janjić, 1965; Ristić, Panić, Mudrinić and Likić, 1967). Magnesite tests performed to determine the application in the production of refractory materials yielded positive results (Jovanović et al., 1978).

The magnesite region of Kladanj consists of 4 magnesite fields: Miljevica, Zeničica, Drinjača and Srebrenica. Magnesite phenomena can be distinguished in three separate rows: Miljevica, Zeničica and Drinjača, among which are the most important sites of Miljevica and Zeničica. A large number of investigative works were carried out, and most of them were excavated, exploratory wells and cave works. Out of a total of 31 drilled wells, only two were negative.

Magnesite is in the form of wires from ten to several hundred meters long, and their thickness ranges from a few centimeters to two meters and more. Except for the wire are serpentine magnesite breccias. So far, the only open and neglected magnesite deposit in BiH is 17 km from the main road Sarajevo-Tuzla near Kladanj. Before the war in this mine, about 36,000 tons of crude separated magnesite of various granulates was produced annually, which was used in the production process "Refractory" Zenica.

The total estimated reserves of magnesite in this area for 20 % exploration are about 1.7 million tons (of which about 81,000 tons are in category A reserves).

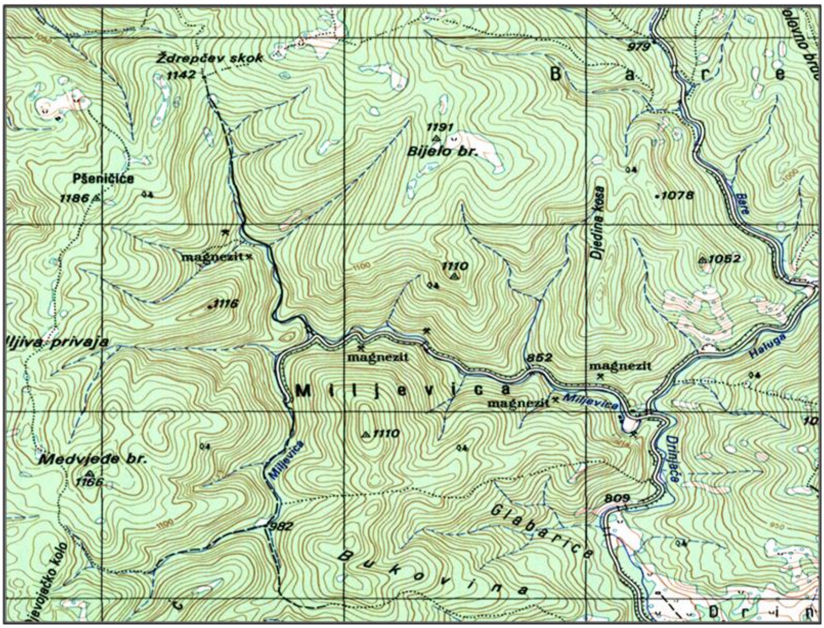

Figure 3: Geographical position of the magnesite mine.

Magnesites from the river Miljevica were examined by microscopic, differential-thermal and X-ray analyses. The following minerals have been found in ore mining: magnesite, calcedon, quartz, calcite, dolomite, clay minerals, iron hydroxides, sepiolite and serpentine. Important components of the mineral association are magnesite, calcedon, quartz and other carbonates (calcite and dolomite).

Magnesites are usually white and shell-like fractures, and rarely gray, brittle and uneven fractures. The structures are cryptocrystalline, microcrystalline, or amorphous. Optical tests have been found to contain quartz and sepiolite. If it contains the admixtures of iron oxide and serpentine it is painted yellowish to greenish.

Figure 4: Magnesite exploitation in the Kladanj area (at Konjuh).

The chemical composition of magnesite was carried out on 283 samples, which were taken using a rough coarse method. The results of numerous chemical analyses (83 analyses from 16 wires) indicate a small degree of contamination of the magnesite of the Konjuh Mountain (Table 2.), or insignificant silicates, calcium, aluminum and iron. The higher the content of the harmful components, primarily SiO_2, can be eliminated without additional investment in exploitation by triage or some other method of breeding.

Figure 5: Magnesite with quartz, Kladanj, Bosnia and Herzegovina.
Source: Operta, M., 2009

X-ray analysis by powder method and differential-thermal analysis also determined dolomite and serpentine as regular magnesite suppressors in wires (Barić, 1984).

Table 2: Chemical analyses of magnesite of the Konjuh mountain

Mark of wire	Number of analysis	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Loss by annealing	Moisture	Total
M-1	8	0,23	0,11	0,23	46,61	0,88	50,00	1,91	99,97
M-3	1	1,06	0,09	0,53	46,14	1,09	49,62	1,44	99,97
M-4	1	0,38	0,38	0,59	46,55	1,19	50,25	0,38	99,72
M-5	2	2,82	0,48	0,30	43,42	2,77	47,38	4,70	101,87
M-6	1	3,35	Tr	0,50	43,90	0,80	46,80	4,57	99,92
M-7	5	2,32	0,22	0,22	46,27	0,92	49,65	0,63	100,01
M-9	10	0,80	0,13	0,15	46,23	1,43	50,44	0,40	99,58
M-11	4	1,55	0,31	0,31	46,35	0,63	50,46	0,35	99,65
M-14	1	2,28	0,14	0,06	45,54	0,38	47,78	3,59	99,77
M-15	2	1,27	0,26	0,03	46,69	0,48	50,25	0,64	99,62
M-16	2	0,29	0,14	0,70	46,45	0,77	50,15	0,58	99,08
M-18	9	1,26	0,39	0,20	45,89	1,38	50,44	0,35	99,82
M-20	7	8,51	0,22	0,16	41,93	2,74	46,02	0,83	100,41
Z-2	27	3,88	0,10	0,006	45,03	1,68	48,31	1,42	100,48
Z-5	1	0,59	0,04	0,17	47,26	0,29	50,60	0,29	99,24
D-4	2	0,70	0,29	0,27	46,56	0,73	50,22	0,48	99,25

Site designation: M-Miljevica; Z-Zeničica; D-Drinjača.

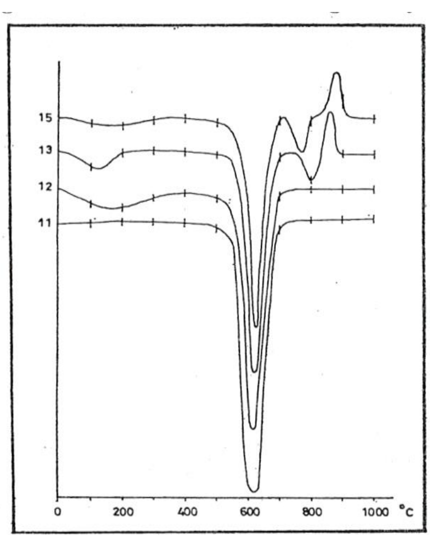

Figure 6: Differential thermal curve of magnesite, Konjuh planina.
Source: Ristić et al. 1965
11.12 and 13 Miljevica; 15 Zeničica.

About 100 smaller and larger magnesite phenomena have been recorded in the area of the Krivaja river and Konjuh Mountain (Čuništa, Srebrenica, Miljevica, Drinjača, Župeljeva, Zlačva, Maoča, Bajvati) (Varičak, 1965). In the area of Čunište, studies have also found that magnesite occurs in veins of varying thickness and length. The latest experiments carried out a chemical analysis and X-ray analysis, and found that magnesite contains dolomite, serpentine and sepiolite. The analyses have shown satisfactory results with respect to the content of the harmful components but are insufficient to make a definitive conclusion.

Figure 7: Magnesite sample from the region of Olovo.
Source: Operta, M., 2009

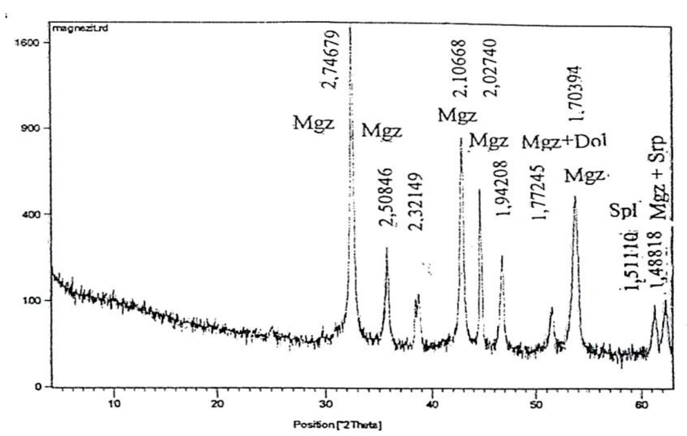

Figure 8: Magnesite with admixtures of dolomite, serpentine and sepiolite
Source: Operta, M., 2018

In the magnesite region of Olovo, magnesite fields can be distinguished: Donje Lanište, Mladoševac and Tovarnica. Research of these fields was carried out in a short period of time, only at the end of 1962, with 100 m3 of excavation and two chemical analyses done. The most significant results of these investigations are shown in Table 3. The chemical composition was determined only at the site Breznica (Donje Lanište). Two chemical analyses made satisfactory results regarding the content of harmful components, however, they are not sufficient to make a definitive conclusion.

Table 3: Chemical composition at Breznica (Donje Lanište).

Mark of sample	SiO_2	Al_2O_3+ TiO_2	Fe_2O_3	MgO	CaO
1	0,08	0,02	0,40	46,53	1,11
2	0,84	0,61	0,45	45,12	3,01

The most common form of magnesite is in the form of cracks. The rocks that are carriers are serpentinites and serpentinised peridotites. The magnesite ore magnitude is low as well as the reserves of several thousand tons. Reserves determined by previous research amounted to only 8500 t of magnesite C_2 category.

Magnesite is located in eastern Bosnia in the vicinity of Višegrad, Rudo and Zvornik. More detailed information on the magnesite miner located south of Vardište is found in the work of Polić (1938). The author mentions two types of magnesite: magnesite of the breccia-like appearance and in the form of a wire of unequal thickness with serpentine plugs. In some preparations, quartz was also determined. In the author's work, the results of two chemical analyses were also presented (Table 4).

Table 4: Chemical composition (%) of magnesite from Dubnica (Višegrad)

Mark of samples	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	CO_2	Total
1	0,83	0,19	0,33	45,70	2,44	50,37	99,98
2	0,37	4,07	-	44,50	1,45	49,72	100,11

Ilić, S. (1956) in the area of Dubnica and near the village of Borović lists the deposits and occurrences of magnesite. Varićak (1967) registered 36 major and minor phenomena of this mineral in the Višegrad area.

3. Discussion

Among the researchers of mineral resource deposits for many years, there was an ungrounded opinion that in Bosnia and Herzegovina there are no conditions for the appearance of significant concentrations of magnesite. Consequently, very small funds were invested and some significant results were not achieved.
According to the qualitative characteristics, there are large variations, and in order to perform the categorization of reserves, detailed research is required. Rare are deposits of magnesite that could be used without prior preparation in the refractory industry.

A significant part of the magnesite deposit contains an increased proportion of SiO_2 and CaO. It has been found that the SiO_2 content increases with increasing magnesite extraction that is digested while CaO does not change. During the digestion of magnesite there are new pollutions that are reflecting on quality and attention should be paid to this.

Magnesite deposits on the territory of Bosnia and Herzegovina were partially investigated with the exception of magnesite of the Kladanj region, which was investigated in more detail. The degree of research is only satisfactory for the Kladanj region, to a lesser extent for the regions of Novi Šeher and Teslić because B category are missing. The region of New Sheher isn´t of great economic importance, although the degree of research is satisfactory, but the total proven reserves are quite small (255. 000 t). For the Teslic region, the high content of harmful components in the magnesite is characteristic, which reduces its economic value. Rayon Dištice, as well as the Olovo area, have not been studied in detail. The research of these regions will be carried out only after research of other more promising magnesian regions of Bosnia and Herzegovina.

According to the results of previous investigations, magnesite deposits in Bosnia and Herzegovina have been partially researched, and the results achieved indicate high quality wire magnesite. Since the research of these deposits has not been completed, one can not speak of economic significance.
A large number of authors find that the wires are hydrothermal, ie, they are derived from hot aqueous solutions rich in carbonic acid and which, on their way through ultrabasic rocks, receive higher amounts of magnesium. Magnesium extraction was carried out at deeper depths, and the deposit of magnesite from saturated solutions was carried out at shallow levels in conditions where the temperature and pressure drops.

Hydrothermal solvents that were rendered are related to the magmatism that is younger than the peridotite. The Bosnian serpentine zone contains products of acidic to neutral magmatism of tertiary age. They belong to the magmatism which hydrothermal solutions are bond, which are subsequently enriched with magnesium hydrocarbons.

In the magnesian-dolomite vessels in the areas of Teslić and Žepče, the main problem is the source of significant amounts of calcium which are allowed the crystallization of dolomite. It is most likely that calcium is derived from amphibolite, amphibolite shales and basic-ultrabasic rocks that are rich in calcium minerals and they are located near magnesian-dolomite vessels.

4. Conclusion

Although the previous investments in magnesite research on the territory of Bosnia and Herzegovina were unsystematic, uneven and insufficient, some economically interesting deposits were found and partially researched, some of which are allocated according to reserves and quality, such as deposits in Banja Luka (Jelovac potok, Pločni potok, creek Četnja, Medenjak potok, Stanikova) and Kladanj (Miljevica and Zeničica).

The results of previous investigations of magnesite deposits indicate a high quality appearance of wired magnesite. Until now, the only open and neglected magnesite deposit in BiH is located 17 km from the main road Sarajevo-Tuzla near Kladanj. Until 1992, roughly 36,000 tons of raw magnesite of various granulates was produced in this mine, which was used in the production process "Vatrostalno" Zenica.

The total estimated reserves of magnesite in this area for 20% exploration are about 1.7 million tons (of which about 81,000 tons are in category A reserves).
Since 1992, this mine has been inactive, and since 2014, revitalization and preparatory work on exploitation started since 2016. Today, D.O.O. "Rudar" Tuzla is exploiting magnesite and exporting to Serbia, where baking occurs to the desired product. On the territory of Bosnia and Herzegovina it is necessary to carry out the categorization of magnesite based on quality, fieldwork and laboratory testing, and continue with technological research that started a few decades ago.

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