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CHLORITE GROUP MINERALS FROM THE AMPHIBOLITE FACIES METAMORPHIC ROCKS OF KRIVAJA-KONJUH ULTRAMAFIC MASSIF IN BOSNIA AND HERZEGOVINA

M. Operta[1], S. Hyseni[2] and S. Salihović[3]
[1]Faculty of Science, University of Sarajevo, Bosnia and Herzegovina
[2]Faculty of Geosciences and Technology, Mitrovica, Kosovo
[3]Faculty of Geology and Mining, University of Tuzla, Bosnia and Herzegovina
E-Mail: sylejmanhyseni3@hotmail.com

ABSTRACT

In amphibolite rocks, in the southern edge of Krivaja-Konjuh ultramafic massif, six samples are separated (from localities Stupčić I, Stupčić II, Pobilje, Donja Vijaka and Selište) in which occurrences of minerals of chlorite group are confirmed using optical tests. Mineral composition of samples of rocks is checked using x-ray analysis on the instrument of brand Philips with CuKα radiation with graphite monochromator. Chemical composition of mineral-chlorite in rocks was determined using electronic microsonde (ARL-SEMQ). Analyses of chlorite were calculated in accordance with recommendations of HYPER-FORM (S. Borg, A. Moggesie and E-Bjerg, 1991). Calculation of formulas of chlorite was done on the basis of 28 O and 36 (O, OH). In Bosnia and Herzegovina, minerals of chlorite group are very frequent and developed compounds in igneous, sedimentary and metamorphic rocks. Even though they are mentioned in numerous petrography and mineralogy papers, most of the authors of petrography papers describe chlorites as members of the mineral groups, and articles where more detailed selection or description of certain types of chlorite are given are more rare. Quantity of chlorite in amphibolite rocks in the area of Vijaka is variable. Chlorite in amphibolite rocks in the area of Vijaka occurs in the shape of bands at contacts of amphibolite rocks with ultramafic rocks. In the crust of decaying of amphibolite rocks. As inclusions in corundum, garnets, amphiboles, pyroxene, plagioclase, and in celyphitic rim of garnets as a product of retrograde metamorphism in the hydrothermal conditions of metamorphism.

Keywords: chlorite, amphibolite rocks, corundum, garnet, edenite amphibolite schist, pargasite amphibolite schist, clinochlore, ripidolite.

INTRODUCTION

In Bosnia and Herzegovina, minerals of chlorite group are very common and compounds distributed in igneous, sedimentary and metamorphic rocks. Even though they are mentioned in many petrography and mineralogy papers, level of their exploration is not high. Most of the authors of petrography papers describe chlorites as members of mineral group, and articles in which certain types of chlorite are studied in more detail or described are very rare.

We can find chlorite in Bosnia and Herzegovina in smaller or greater scope in different rocks of serpentines zone, products of middle Triassic and Tertiary volcanism. In igneous rocks, they mostly originate as a product of chlorination of pyroxene and other Ferro-igneous minerals in late igneous to post igneous stage. In basal igneous rocks of serpentines zones (gabbro) that were exposed to hydrothermal processes, chlorites collect in cracks into individual mineral lodes. In the vicinity of corundum amphibolite and other igneous rocks at the edge of serpentinite-peridotite massif, chlorite frequently occurs in the bends where it creates sheet like aggregates. In Palaeozoic rocks of northwest, central and eastern Bosnia, chlorites are regularly compounds of sediments, semi metamorphites and schist's of low level of metamorphism. Rocks with chlorites are fairly common in the mountains Prosara and Motajica. Small sheets of chlorites are also placed in various clastic sediments and also in bauxites. Chlorites of hydrothermal genesis also occur in the ore occurrences (middle Bosnian schist mountains, Srebrenica etc.). In the area of contacts of serpentine and edenite amphibolites schist at locality of Selište confirmed are greater quantities of chlorite in shape of foliated aggregates that occur in bands. Researched chlorite belongs to a type of clinochlore. Clinochlore occurs sporadically in hornblende garnierite and amphibolites schist at locality of Donja Vijaka. X-ray tests of mineral composition of the crust of decaying of edenite-pargasite amphibolites schist at locality of Stupčić and confirmed are occurrences of clinochlore in decaying crust.

In garnet diopside amphibolites schist at deposit Stupčić II and plagioclase garnet rocks at locality of Pobilje researched chlorite belongs to a type of ripidolite. It occurs in shape of inclusions in garnet and at some places garnet is at its edges retrograde changed into chlorite. In amphibolites schist (at locality of Donja Vijaka) and hornblende garnets (at locality Stupćić II) clinochlore occurs as inclusions in amphibole, and in garnet diopside amphibolites schist at the same locality ripidolite is fit into garnet. Microsonde analyses of corundum from pargasite of amphibole schist from locality Stupčić I and porphyroblast corundum from the crust of decaying from the same locality determined are inclusions of chlorite in corundum. Researched chlorite belongs to a type of clinochlore.

The goal of this paper is to represent mineral composition of chlorites in amphibolite rocks of the southern edge of Krivaja-Konjuh ultramafic massif (area

of Vijaka) and data are collected during procedures of optical tests, x-ray and microsonde analyses.

GEOLOGICAL CHARACTERISTICS

Among the oldest data about chlorite that occurs in the rocks of Bosnian serpentine zone we can take into count those represented in papers of Hauer, John and Kišpatić. Hauer (1897) and John (1897) mentioned chlorite in diabase of the Doboj's fortress. Besides to that, John represents data about chlorite that he microscopically determined in other rocks also (diabase of Majevica; diorite from Kladanj; diabase from Žepča).

In papers of M. Kišpatić (1897 and 1900) chlorite is mentioned only at several places. Author determined this mineral in Maglaj's granite, diabase, melaphyres, gabbros, amphibolite and granite phyllite from several localities, and mainly as secondary mineral as a product of chlorination of biotite, augite and garnets.

In and esite-basalt from Brnjačin Jarak on Kozari, chlorite occurs in a shape of sheet like clusters (Golub, 1961).

In igneous rocks from surrounding area of Višegrad, chlorite is also very common compound (Trubelja, 1957, 1960 and 1963).

Chlorite in rocks of Bosnian serpentine zone is also mentioned very often by J. Pamić. So Pamić and Kapeler noted chlorite as frequent compound of serpentine rocks of Krivaja-Konjuh massif.

In hydrothermal-metasomatic rocks (talc-listvenite) from the north edge of Ozren's serpentine-peridotite massif, chlorites are frequently auxiliary compounds. Represented types are prochlorite and corundum-phyllite (Pamić and Olujić 1974).

In various rocks and areas of Bosnian serpentine zone, many other authors also mentioned or described in more details chlorite on the basis of results of mainly microscopic analyses.

Krivaja-Konjuh ultramafic massif and joined ophiolite with amphibolite covers area of about 500 km^2 and it represents faulted plate that is thick about 2000 m, which overlaps ophiolite melange. In its most part, it is composed of moderately seprentinised porphyroblast lherzolite tectonic rocks. In its southeast parts, in the floor, they are composed of different varieties of amphibolite (Figure-1). The most exposed and the greatest belt of amphibolite is located in the area of village Vijaka, about 18 km in the northeast of Vareš.

Foliation in amphibolite is parallel foliation of lherzolite tectonites.

Contact between amphibolite and ophiolite melange is tectonic.

In Vijaka amphibolite complex, the following varieties of the rocks are confirmed: bimineral amphibolites schist, diopside amphibolite schist, garnet-diopside amphibolite schist, mono mineral amphibolite schist and rarely corundum amphibolite schist. Complete amphibolite complex is characterized with presence of the rocks of different metamorphic level together with rocks of green schist facies in their lowest parts which level increases towards epidote amphibolite facies, amphibolite facies to the boundary of granulite amphibolite facies (Pamić *et al*., 1977; 2001). Zone division from rocks of green schist facies to rocks of granulite-amphibolite facies also indicates variation in composition from potassium plagioclase to anorthite, hornblende to actinolite-tschermakite-edenite to pargasite and garnets enriched with pyrope and almandine component.

Corundum amphibolite occurs only in parts of Vijaka's amphibolite of the greatest range of metamorphism. They are unevenly divided within the zone of emerald green pargasite and edenite-pargasite amphibolite, in over 10 mainly narrow zones that could hardly be represented in the map. Exceptions are localities of Donja Vijaka, Stupčić and Crni potok, where thickness of those zones is exceeding 100 m.

As a rule, amphibolites are similar in space and they are connected to narrow and lengthen zones of greatly or completely seprentinised ultramafic accumulations that have bands of inserted amphibolite (Figure-1).

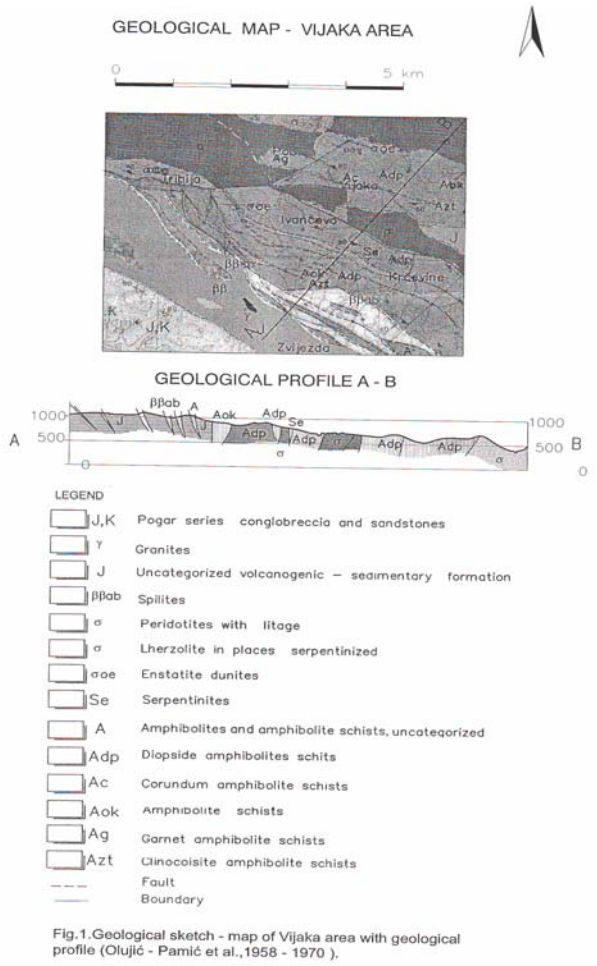

Fig.1.Geological sketch - map of Vijaka area with geological profile (Olujić - Pamić et al.,1958 - 1970).

J. Pamić and I. Kapeler (1970) claimed that quantity of chlorite in serpentine was increased and that along the contacts of serpentine and corundum amphibolite was also increased. Going further from the

contacts towards serpentine, quantity of chlorite decreased until it came to a level of an auxiliary compound (5-10%). Along the contact of serpentine and corundum amphibolite, they noticed a centimetre zone of clean chlorite schist. From the partial analyses, they have concluded that the subject was aluminium-magnesium chlorite with about 5% of iron oxide.

METHODS OF INVESTIGATIONS

On nineteen selected samples of amphibolite rocks from amphibolite zone Duboštica-Vijaka in the south edge of Krivaja-Konjuh massif, detailed optical analyses were done with use of polarization microscope, chemical analyses of microelements, also microelements of rare grounds, x-ray-florescent spectroscopic analyses, and chemical analyses of minerals (amphibole, garnet, plagioclase, pyroxene, corundum, spinel, chlorite, magnetite, titanite, ilmenite, zeolitic minerals, prenite, rutile, serpentine, olivine, apatite, analcime) with electronic microsonde. Samples are optically analyzed with standard polarization microscope of brand Leitz, when structural-texture characteristics and mineral composition were determined. Mineral compositions of the samples were checked using x-ray analyses on instrument of brand Philips with CuKα rays with graphite monochromator.

Chemical composition of mineral - chlorite in rocks was determined using electronic microsonde (ARL-SEMQ). Noted analyses were completed in Institute for Mineralogy and Petrography in Innsbruck.

Analyses of chlorite were recalculated in accordance with recommendations HYPER-FORM (S. Borg, A. Moggesie and E-Bjerg, 1991). Calculation of formulas of chlorite was done on the basis of 28 O and 36 (O, OH) - Table-1.

RESULTS OF TESTS

Quantity of chlorite in amphibolite rocks in the area of Vijaka is variable. Chlorite in amphibolite rocks from region of Vijaka occurs as follows:

- In the shape of thin bends at the contact of amphibolite rocks with ultramafic rocks
- In the crust of decaying of amphibolite rocks
- As inclusions in corundum, garnets, amphibole, pyroxene, plagioclase, in celyphitic edge of garnets as retrograde product of metamorphism in conditions of hydrothermal metamorphosis.

From laboratory analyses of pargasite and edenite-pargasite amphibolite schist at locality of Stupčić I it was confirmed that corundum in this rocks occur as important, auxiliary and accessory compound and as porphyroblast in size of up to several centimeters.

Detailed analyses of porphyroblast corundum in mentioned rocks using method of microsonde and x-ray analyses confirmed that porphyroblast of corundum, besides the inclusions of tschermakite hornblende, plagioclase-anorthite and margarite, also consist of inclusions of clinochlore. Increased content of SiO_2, MgO, CaO and Na_2O in ballast of corundum is a result of presence of tschermakite hornblende, plagioclase, mica-margarite and clinochlore.

In the crust of decaying of pargasite and edenite-pargasite amphibolites schist's in mentioned locality, x-ray analyses confirmed an occurrence of great leaves clinochlore.

In the area of contact of serpentine and amphibolites rocks at locality of Selište chlorite occurs subordinately as a product of alteration of biotite. Analyzed chlorite belongs to clinochlore.

During optical analyses of garnet-diopside-hypersthenes amphibolites schist it was noted that chlorites occur at some places as inserts in zoned orthopyroxene and that together with amphibole, clinopyroxene, orthopyroxene, plagioclase, magnetite, pyrite, spinel and rutile compose kelfite crust around garnets (Figure-2b). Garnets in garnet-diopside-hypersthenes amphibolites schist are more rarely removed with myrmekite composed of amphibole, chlorite and magnetite (Figure-2a).

Figure-2(a). Locality Stupčić II, garnet-diopsid-hypersthene amphibolite. Garnet completely suppressed by worm-like myrmekite made of amphibole, chlorite and magnetite, 110 x, N-.

Optical analyses and chemical researches of mineral stages with electronic microsonde confirmed inclusions of chlorite in garnets of garnet-diopside amphibolite schist. Analyzed chlorites belong to type of ripidolite and they occur in garnet-diopside amphibolite schist in association with amphibole (pargasite and ferro-magnesium hornblende) and clinopyroxene Fit into chlorite-ripidolite in beans of garnets they wrap amphibole and clinopyroxene (Figure-3a). In contact with clinopyroxene, amphibole is pargasite and in contacts with chlorite-ripidolite is ferromagnesian hornblende.

Figure-3(b) represents reaction between garnets and clinopyroxene and chlorite-ripidolite as a product of

that reaction. This reaction was created as a result of cooling and infiltration of fluids that are reaching in H_2O. Microsonde analyses with point method and optical tests indicated that chlorites in shape of inclusions occur also in plagioclase garnet rocks and hornblende garnets.

Matrix of plagioclase garnet rocks is composed of plagioclase (albite-andesine) in which they are dipped.

Optical tests confirmed that hornblende garnets are composed of porphyroblast of cracked garnets and plagioclase (that are in greater part prenitised) and hornblende. Cracked garnets are without celyphitic rim and that content inserts of titanite and clinochlore. Clinochlore occurs sporadically also in amphibolite schist's at locality Donja Vijaka.

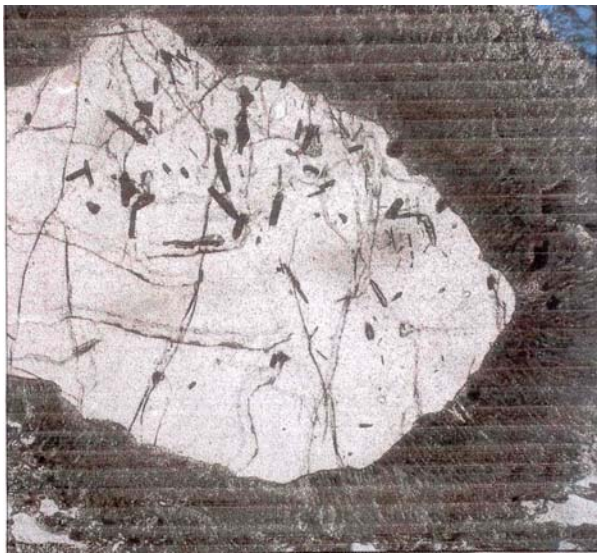

Figure-2(b). Locality Stupčić II, visible inserts of rutile in porphyroblast garnets. Celyphitic wrapping aroundgarnets is composed of chlorite, amphibole, clinopyroxene, orthopyroxene, plagioclase, magnetite, pyrite, spinel and rutile, 110 x, N-.

Figure-3(a). Division of minerals in ballast of garnets (garnet-diopside amphibolite schist) Legend: Amp-amphibole; Grt-garnet; Cpx-clinopyroxene; Chl-chlorite.

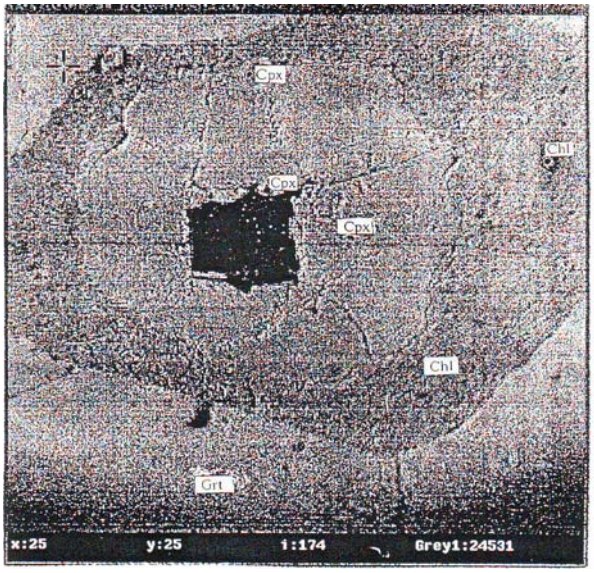

Figure-3b. Division of minerals in ballast of garnets (garnet-diopside amphibolite schist's) Legend: Cpx-clinopyroxene; Chl-chlorite.

Samples	1	2	3	4	5	6	7
SiO_2	30.23	29.29	32.12	32.44	36.17	25.56	32.74
TiO_2	0.04	0.00	0.00	0.00	0.02	0.04	0.34
Al_2O_3	19.37	21.82	16.42	16.80	20.26	19.12	12.96
Cr_2O_3	1.44	0.85	0.02	0.44	0.35	0.03	0.27
Fe_2O_3	2.84	1.62	1.09	1.70	1.03	3.80	0.68
FeO	3.88	3.34	14.10	18.63	13.90	30.96	9.50
MnO	0.00	0.09	0.22	0.65	0.15	0.27	0.04
MgO	28.47	28.73	22.73	17.35	13.39	8.36	28.56
CaO	0.02	0.19	0.39	0.71	0.90	0.11	0.61
Na_2O	0.10	0.13	0.14	0.07	0.07	0.18	0.07
K_2O	0.10	0.00	0.02	0.06	0.17	0.18	0.18
ZnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H_2O+	13.75	13.80	12.75	10.98	13.15	10.94	13.67
H_2O-			0.01	0.19		0.19	
Total	99.64	99.86	100.01	100.02	99.56	99.74	99.62
Si	5.738	5.502	6.163	6.570	7.098	5.581	6.784
Al	2.262	2.498	1.837	1.430	0.902	2.419	1.513
Al	2.070	2.331	1.876	2.578	3.783	2.501	1.532
Ti	0.006	0.000	0.000	0.000	0.003	0.007	0.051
Cr	0.432	0.252	0.000	0.141	0.109	0.010	0.085
Fe^{3+}	0.855	0.846	2.188	0.287	0.000	0.513	0.000
Mg	8.09	8.028	6.448	5.226	3.909	2.716	8.411
Fe^{2+}	0.000	0.000	0.035	3.285	2.449	5.841	1.646
Ni	0.000	0.000	0.000	0.00	0.000	0.000	0.000
Zn	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	0.000	0.014	0.036	0.111	0.025	0.050	0.007
Ca	0.004	0.038	0.080	0.154	0.189	0.026	0.130
Na	0.037	0.047	0.052	0.028	0.027	0.076	0.027
K	0.024	0.000	0.049	0.016	0.043	0.050	0.046
OH	16.000	16.000	16.310	15.120	16.000	15.930	16.000

Table-1. Selected chemical analyses of chlorite in amphibolite schist's, hornblende garnets, garnet-diopside amphibolite schist's and plagioclase garnet rocks from the area of Vijaka (locality: Donja Vijaka, Pobilje, Stupčić II and Selište); Weight % and calculation on the basis of 28O and 36 (O, OH); where OH is given as 16, 00 calculation was done on the basis 28 O and in other cases on the basis 36 (O, OH).

CONCLUSIONS

Minerals of chlorite group are mainly products of low temperatures and mainly of hydrothermal or low temperature genesis. They also occur as products of transformation of ferromagnesian minerals - biotite, amphibole, pyroxene and others in amphibolite rocks of the area of Vijaka. Analyzing different varieties of amphibolite rocks of the area of Vijaka, it is represented that genesis of chlorite in them is often followed with complex processes of mineral genesis, where besides chlorite, created were other secondary minerals like prenite, epidotite, clinocoisite, serpentine, spinel, especially zeolitic. Also, occurrence of chlorite together with appropriate minerals is important because on the basis of this mineral association we can determine affiliation to metamorphic facies.

Chlorite in the garnets rim to celyphitic of garnet diopside-hypersthenes schist's amphibolite in the area of Vijaka occurs as a product of retrograde metamorphism on the hydrothermal conditions of metamorphism.

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REFERENCES

Barić Lj. 1969. Korund aus der Umgebung des Dorfes Vijaka in Zentral Bosnien. Min, petr. Mus. Univ., Mitteil. 2., Zagreb.

Ćirić B. 1954. Neka zapažanja o dijabaz rožnjačkoj formaciji Dinarida. Ves. Zav. Geol. geof. Istr. 20: 31-88.

Dimitrijević M.D., Dimitrijević M.N. 1973. Olistrome mélange In the Yugoslavian Dinarides and late Mesozoic plate tectonics. Journ. Geology. 81: 328-340.

Hietanen. 1974. Amphibole pairs, epidote minerals, chlorite and plagioclase in the metamorphic rocks, northern Sierra Nevada, California. American Mineralogist. 59: 22-40.

Katzer F. 1906. Istorijsko razvijanje i današnje stanje geoloških proučavanja Bosne i Hercegovine, Glas. Zem. Muzeja B i H. 18: 37-68.

Kišpatić M. 1897. Kristalinsko kamenje serpentinske zone u Bosni. Rad Jugosl. Akad. znan Umj. 133: 95-231.

Lanphere M., Coleman R., Pamić J. and Karamata, S. 1975. Age of amphibolites associated with alpine peridotites in the Dinaride Ophiolite zone, Yugoslavia. Earth Plan Scie. Lett. 26: 271-276.

Lugović B., Altherr R., Raczek I., Hofmann A. W. and Majer V. 1991. Geochemistry of peridotites and mafic igneous rocks from the Central Dinaridic Belt, Yugoslavia. Contrib. Mineral. Petrol. 106: 201-216.

Majer V., Kreuzer J., Harre W., Seidel E., Altherr R. and Okrusch M. 1979. Petrology and geochronology of metamorphic rocks from Banija, Yugoslavia. Inter. Ophiol. Symp. Abstracts, Nicosta. pp. 46-47.

Olujić J., Pamić O., Pamić J., Mihajlović R., Veljković D. and Kapeler I. 1977. List Vareš, Geol. Zavod sarajevo. 1958-1970, savezni geol. Zavod Beograd.

Operta M., Pamić J., Balen D. and Tropper P. 2003. Corundum-bearing amphibolites from the metamorphic basement of the Krivaja-Konjuh ultramafic massif (Dinaride Ophiolite zone, Bosnia). Mineralogy and petrology, Springer-Verlang. 77: 287-295.

Operta M., Salihović S. 2004. Istraživanje pukotinskih minerala iz amfibolitskih stijena južnog oboda krivajsko-konjuškog ofiolitskog kompleksa, Zbornik radova Rudarsko-geološko-građevinskog fakulteta u Tuzli, broj. XXVII, str. 49-55, Tuzla.

Operta M. 2006. Distribucija makroelemenata i mikroelemenata u različitim varijetetima amfibolitskih stijena na južnom obodu krivajsko-konjuškog masiva, Geološki glasnik br. 36, str. 191-211, Federalni zavod za geologiju-Sarajevo.

Operta M. Hyseni S., Balen D., Salihovic S. and Durmishaj B. 2011. Garnet group minerals from the amphibolite facies metamorphic rocks of Krivaja-Konjuh Ultramafic massif in Bosnia and Herzegovina. ARPN Journal of Engineering and Applied Sciences (JEAS). 6(7): 20-28.

Pamić J. and Kapeler I. 1971. Korundski amfiboliti na južnom obodu krivajsko-konjuškog ultramafitskog masiva. Geol. anal. Balk. Poluostr. 35, 399-408.

Pamić J. Šćavničar S. and Medjimorec S. 1973. Mineral Assemblages of Amphibolites Associated with Alpine - Type Ultramafics in the Dinaride Associated with Alpine - Type Ultramafics in the Dinaride Ophiolite Zone (Yugoslavia), Journ. Petrology. 14: 133-157.

Pamić J., Sunarić-Pamić O., Olujić J. and Antić R. 1977. Petrografija i petrologija krivajsko-konjuškog ofiolitskog kompleksa i njegove osnivne geološke karakteristike. Acta. Geol. 9, 39-135.

Pamić J., Gušić I. and Jelaska V. 1998. Geodynamic evolution of the central Dinarides Tectonophysics. 279, 251-268.

Pamić J. and Hrvatović H. 2000. Basic data on the geology and petrology of the Krivaja - Konjuh ophiolite complex, Pancardi, Dubrovnik. pp. 60-67.

Pamić J. Tomljenović B. and Balen D. 2002. Geodynamic and petrogenetic evolution of Alpine ophiolites from central and NW Dinarides: an overview, Lithos. 65: 113-142.

Spear F. S. 1981a. Amphibole - plagioclase equilibria: an empirical model for the relation albite + tremolite = edenite + 4 quarz, Contrib. Mineral. Petrol. 31: 235-266.

Spear F. S. 1981b. An Experimental Study of hornblende Stability and Compositional Variability in Amphibolite., Am. Jour. Sci. p. 281, 697.

Spear F. S. 1993. Metamorphic Phase Equilibria and Pressure-Temperature-Time Paths. Mineralogical Society of America, Washington, D.C. p. 799

Trubelja F., Marchig V., Burgath K. P. and Vujović Ž. 1995. Origin of the Jurassic Tethyan Ophiolites in Bosnia: A Geochemical Approach to Tectonic Setting, Geol. croat, Zagreb. pp. 49-66.