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PETROGRAPHIC CHARACTERISTICS OF MAFIC EXTRUSIVE ROCKS ALONG THE SOUTHWESTERN PART OF MAJEVICA

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SUMMARY

Total number of nineteen mafic extrusive rock samples is subjected to the detailed optical examination. Based on definition of mineral composition, structure, texture, type and intensity of alteration processes, and taking into consideration the recent classification schemes, different lithotypes are defined. The most frequent are spilites distinguished by classical "spilite" mineralogy (albite), and very often with "quench" texture and amygdaloidal structure. Diabases consist of primary plagioclase and clinopyroxene which are often decomposed and disintegrated. Diabase rocks are mostly characterised with ophitic texture and massive structure. Coarse grained varieties are characterized as dolerites, the rocks in which intensity of alteration process is significantly lower than in previous lithotypes. Varieties with frequent occurrences of amphibole got adjective amphibolic. The most common and the most intense alteration processes are albitization and chloritization. Alteration processes of lower intensity are actinolitization, pumpellytization, zeolitization, carbonation-calcitization, limonitization, kaolinitization and silicification. Depending on alteration degree a certain lithotypes are named with prefix meta (metadiabases and metadolerites).

Key words: *optical examinations, spilites, diabases, dolerites, alterations, Majevica Mountain*

INTRODUCTION

Mafic extrusive rocks of the Majevica area have not been researched systematically, so the data about these rocks are very scant. Geological setting of the wider Tuzla area, including ophiolite rocks of the Majevica, in the context of his doctoral dissertation has been explored by the Velimir Kranjec [1]. Authors Pamić i Jelaska [2] described appearance of the Upper Cretaceous volcanic-sedimentary formations and ophiolite melange from northern Bosnia and point out their importance in geological structure of the area. The same authors have considered sedimentary and igneous Mesozoic processes in the northern parts of Bosnia, and led it in correlation with the plate tectonics [3]. Characteristics of the Senonian volcanic-sedimentary formations and ophiolite melange of Majevica have been analyzed by Pamić [4]. The latest results were published before more than half a century. As a part of the research project "Petro-chemical characterization of igneous mafic extrusive rocks of Konjuh and Majevica" and as a part of M.Sc.Alisa Babajić dissertation, mafic extrusive rocks of Konjuh and Majevica are systematically sampled and defined in the petrological and geochemical terms. This paper shows only a small segment of obtained research results, which refers to the petrographic characteristics of subjected ophiolite rocks from Majevica area. Discussion about genesis and geodynamical conditions of Majevica mafic extrusive rocks formation are not presented.

GEOLOGICAL SETTING OF THE MAJEVICA

In morphostructural term Majevica represents horst - anticlinorium which streches from the northwest to the southeast. Geological structure of Majevica conditionally can be divided into three sub-parallel tectonic units which have direction same as Dinarides: ridge of Majevica, folded complex of Majevica and Sibosnica-Lopare Neogene basin [5,6,7,8]. The structural-facial unit ridge of Majevica, which streaches from Gornji Srebrenik to the southeast till village Jasenice, presents tectonized ophiolite melange in which occur olistolites and fragments of extrusive (basalt, diabase, dolerite), metamorphic (serpentinite, less often amphibolite), and sedimentary (greywacke, chert) rocks (figure 1).

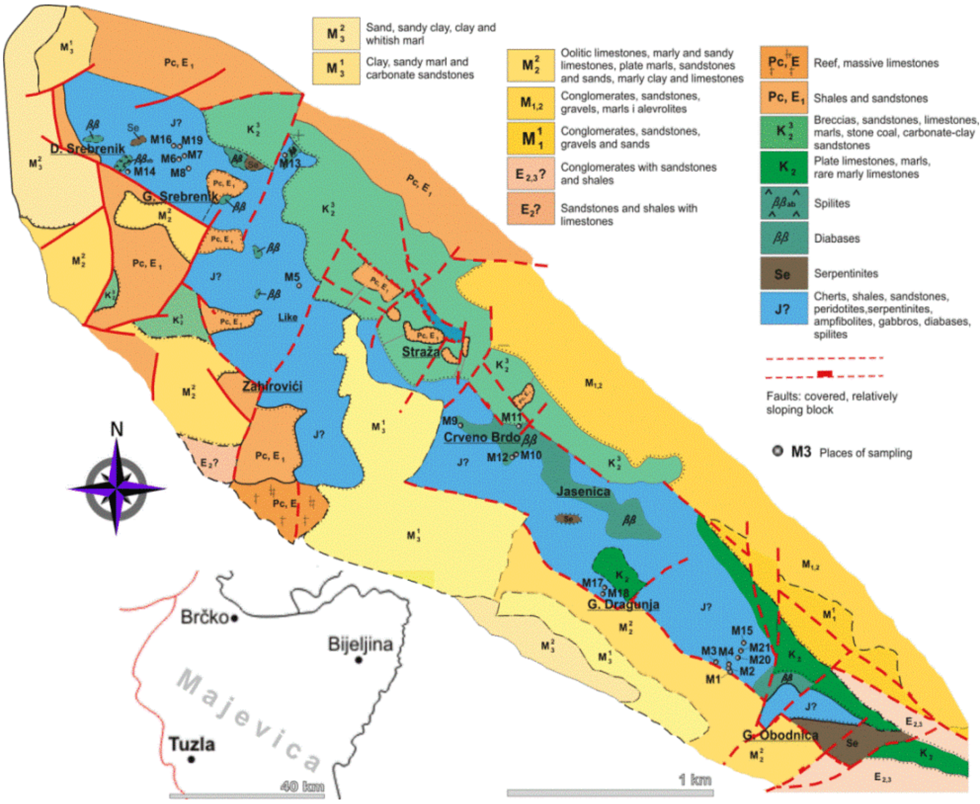

Figure 1. Simplified geological map of ophiolite melange along the southwestern part of Majevica

Igneous-sedimentary complex is represented by melange, creation in which all lithologic members (igneous, metamorphic and sedimentary) have chaotic distribution. During field observations it was recorded complete development of ophiolite profile or any part of it. Compositionally, there are two different types of the melange. The first type occurs in narrow zones and consists of serpentinite, diabase, basalt and less frequent other rocks fragments, which are embedded in the schistose serpentinite matrix. The second type is characterized by the presence of sedimentary (greywacke, cherts and limestones dominate) and igneous rocks fragments as olistolites embedded in the matrix that consists of shale. Olistolite size varies from meter to hectometre dimensions. Approximate thickness of the melange is 200-300 m [5,6,7,8].

RESEARCH METHODS

During southwestern part of the Majevica field observations (2014 – 2016), it was repeatedely collected 35 rock samples, whose number after macroscopic determination is reduced to 19 (table 1). The samples for petrographic examinations were taken directly from discovered outcrops, from stream banks, and from the quarries. Number of samples taken in the field was determined depending on geological characteristics of the terrain, its approach, observed mineralogical, structural and textural varieties and freshness of the rocks.

Petrographic thin sections for microscopic examinations were made at the Faculty of mining, geology and petroleum engineering Zagreb, Croatian geological survey in Zagreb and Faculty of mining and geology in Belgrade. Optical examinations were done at the Faculty of mining, geology and civil engineering in Tuzla using polarized petrographic microscope Leica DM 2500P. Microphotographs were recorded in orthoscopic conditions, both with and without analyzer. Due to used light, applied software has done white light balance adjustment, in order to obtain realistic colors on the microphotographs. Classification and nomenclature is done according to the instructions of Le Maitre et al. [9], and abbreviations for mineral names are according to Whitney & Evans [10].

Table 1. Marks and geographical positions of collected rock samples

Sample marks	Gauss-Krüger coordinates X	Gauss-Krüger coordinates Y	Location	Sample marks	Gauss-Krüger coordinates X	Gauss-Krüger coordinates Y	Location
M1	4 944 336	6 551 310	Marinovići	M11	4 947 851	6 548 224	Jasenica
M2	4 944 395	6 551 292	G. Obodnica	M12	4 947 405	6 548 184	Jasenica
M3	4 944 487	6 551107	G. Obodnica	M13	4 951 821	6 544 901	G. Srebrenik
M4	4 944 426	6 551 313	G. Obodnica	M15	4 944 514	6 551 362	Marinovići
M5	4 949 855	6 545 058	G. Srebrenik	M16	4 951 825	6 550 104	G. Srebrenik
M6	4 951 661	6 543 256	G. Srebrenik	M18	4 945 414	6 549 501	Dragunja
M7	4 951 710	6 543 326	G. Srebrenik	M19	4 951 735	6 543 537	G. Srebrenik
M8	4 951 727	6 543 390	G. Srebrenik	M20	4 944 409	6 551 281	Marinovići
M9	4 947 860	6 547 371	Crveno Brdo	M21	4 944 440	6 551 322	Marinovići
M10	4 974 447	6 547 184	Jasenica				

RESEARCH RESULTS

Mafic extrusive rocks of Majevica are dark gray, gray-blue, gray-green, violet-brown or yellow (result of surface alteration) colored. Rocks consist of macroscopically visible sialic and ferromagnesium minerals, while in some samples grains are as small as cryptocrystalline. The most common structural types are homogenous, amygdaloidal, vesicular and brecciated structure. Textural types are various. Based on petrographic examination selected are spilite, diabase and amphibole dolerite.

SPILITE OF THE MAJEVICA

The term spilite originally refers to altered phenocrystal-poor or aphyric basaltic rocks [11], but later being used for altered (often albitized) basaltic lavas [12,13]. Spilite rocks at the Majevica mountain appear as outflow masses which are interstratified in shales and often occure together with greywacke. These rocks are various in dimensions, forms of several tens of square kilometers can often be found. Larger spilites forms occur massive or in the form of pillow lavas. Pillow lavas, as indicators of submarine volcanism, are discovered in several locations around the village Jasenica. Marginal parts of these elliptical-spherical forms are intensively alterated. Besides pillow lavas, at the locality of Gornji Srebrenik occur subordinate fragments of brecciated lava, consisting of polygonal lithoclasts. These mafic extrusive rocks fragments, whose dimensions are several centimeters in size, "lie" in the matrix.

In terms of mineral composition they are characterized by classic "spilite" mineralogy - plagioclase is albitized and clinopiroxene is transformed into aggregate of chlorite and/or actinolite. General characteristics of these rocks are presence of amygdales filled by secondary calcite, chlorite, zeolite and secondary quartz. Opaque minerals belong to ilmenite, while magnetite is less frequent. Mineral composition and locations of spilite sampling are shown in table 2.

Table 2. Locality and mineral composition of Majevica spilite based on optical examinations

Sample	Locality	Mineral composition
M2	G. Obodnica	Pl, Ab, Chl, Cal, Pmp, Mag
M3	G. Obodnica	Pl, Ab, Aug, Chl, Pmp, Cal, Ilm, Lm
M10	Jasenica	Pl, Aug, Chl, Cal, Ilm, Lm
M11	Jasenica	Pl, Cal, Zeo, Qz, Ilm
M12	Jasenica	Pl, Chl, Cal, Zeo, Pmp, Ilm
M13	G. Srebrenik	Pl, Caj, Zeo, Lm
M15	Marinovići	Pl, Ab, Chl, Cal, Si, Ilm
M16	G. Srebrenik	Pl, Cal, Chl, Pmp, Mag
M18	Dragunja	Pl, Chl, Cal, Si, Mag
M19	G. Srebrenik	Pl, Cal, Aug, Chl, Pmp, Zeo, Mag,

Ab –albite, Pl –plagioclase, Aug –augite, Chl –chlorite, Cal –calcite, Zeo –zeolite, Pmp –pumpellyte, Lm –limonite, Ilm –ilmenite, Mag –magnetite, Qz –quartz [9].

Although intensively altered (mainly albitization of plagioclase), their primary structural and textural characteristics have been preserved. Textural types are mostly presented with ophitic, hyaloophitic and skeletal-dendritic "quench" texure. Amygdaloidal, homogenous and vesicular are the most common structural types in observed spilite rocks.

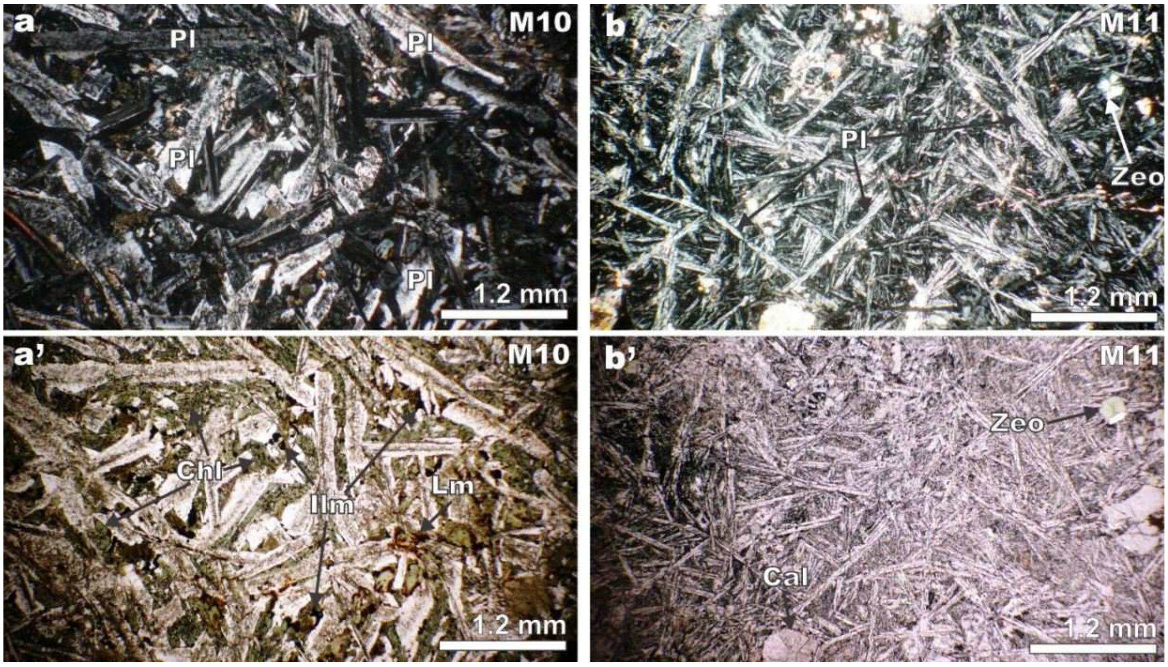

Figure 2. Micrphotographs of spilite M10 and M11 samples (XPL (a and b) and PPL (a' & b'))
Chl –chlorite, Zeo –zeolite, Cal – calcite, Ilm – ilmenite, Lm –limonite.

Texture of sample M10 is ophitic (figure 2a and 2a'), with characteristic prismatically elongated reticulated plagioclase. Due to strong alteration processes (primarily albitization and chloritization) presence of secondary minerals is dominant. Plagioclase grains are almost completely altered, blurred and "eroded" by magmatic resorption. Chlorite originated from pyroxene transformation, fills the space between altered plagioclase. Presence of limonite can be noticed interspersed in thin section. Opaque minerals are represented with ilmenite. Structure of the rock is homogeneous.

Sample M11 (figure 2b and 2b') is characterized by mineral composition typical for spilite. Main petrogenous minerals are albite grains formed by transformation of primary basic plagioclase, which occur in a form of very thiny needles. Interstitial space is filled by glassy groundmass whose mineral composition can not be microscopically determined. The secondary minerals are represented by radial zeolites and calcite, which often fill amygdales in the rock. Rock texture is hyaloophitic, while structure is amygdaloidal.

Chilled or „quench“ texture (sample M2, figure 3a and 3a') appears in the outer parts of elliptical-spherical pillow forms. This rock consists of volcanic glass and skeletoidal-dendritic and radial plagioclase aggregates. Specific minerals which appear in sample M2 are characterised by pumpellyte occurrence, which comes in a form of fine grained greenish-brown pleochroitic dendritic aggregates. Its creation in the peripheral pillow parts probably is a result of volcanic glass devitrification during submarine hydrothermal activity, what is indicated by relics of the glass. Microlites or interstitial needle-shaped or radial plagioclase grains in the sample represent products of rapid crystallization. Except in sample M2, mentioned structural and textural characteristics also have been observed in samples M16 and M19.

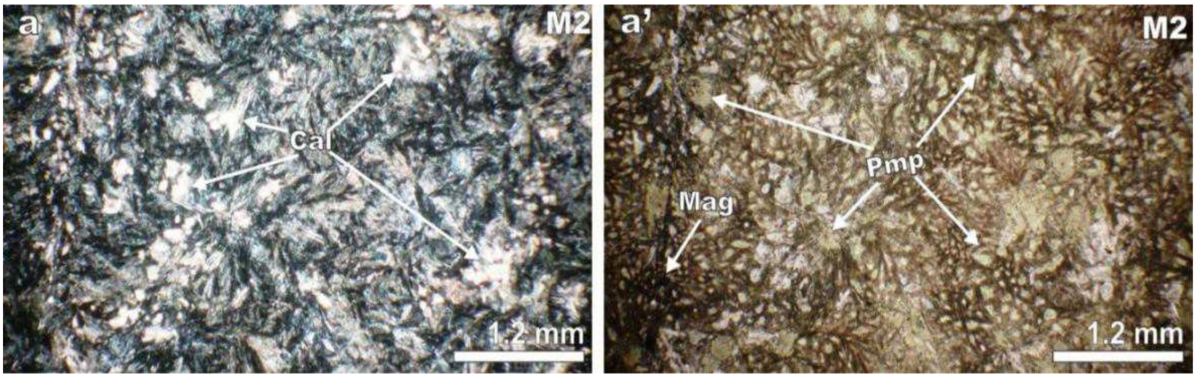

Figure 3. Microphotographs of spilite sample M2 (XPL (a) and PPL (a'))
Cal –calcite, Pmp –pumpellyte, Mag -magnetite

DIABASE AND METADIABASE OF THE MAJEVICA

A term diabase refers to medium-grained rocks of basaltic composition that have been heavy altered and mostly characterized by the ophitic texture. The original definition included a transitional texture between basalts and coarsegrained rocks [15,16]. Now is regarded as being synonymous with dolerite and an approved synonym for microgabbro [17]. These rocks appear mostly in the form of larger extrusions (Crveno Brdo) or as meter - hectometer. sized fragments in the ophiolite melange (figure 1). Diabase and metadiabase of Majevica mainly are massive rocks, rarely can be observed appearance of polygonal or columnar forms which indicate multiphase lava injection.

Texture of these rocks are: ophitic (with distinctive prismatic elongated plagioclase), porphyric-ophitic, subophitic, intergranular, intersertal; while structure is homogenous. Their mineral composition is practically the same in all samples. They consist of partially to completely altered plagioclase (mainly transformed into albite), and clinopyroxene - augite (mainly transformed into chlorite, sporadically into actinolite). In the interstitial space there are mainly pumpellyte, zeolite, calcite, rarely secondary quartz. Accessory minerals are ilmenite and magnetite, while leucoxene is secondary. Mineral composition and diabase sampling locations are shown in table 3.

Table 3. Locality and mineral composition of Majevica diabase based on optical examinations

Sample	Locality	Mineral composition
M1	Marinovići	Pl, Chl Ab, Zo, Ilm, Lm, Cal
M4	G. Srebrenik	Pl, Aug, Chl, Ilm, So, Cal
M6	G. Srebrenik	Pl, Aug, Chl, Ilm, Mag, Pmp, Zeo
M9	Crveno Brdo	Pl, Aug, Chl, Ilm, Lm, Act
M20	Marinovići	Pl, Cal, Chl, Ilm, Mag
M21	Marinovići	Pl, Aug, Chl, Ilm

Pl –plagioclase, Aug -augite, Ab –albite, Chl –chlorite, Zo –coisite, Cal –calcite, Zeo –zeolite, Pmp –pumpellyte, Act -actinolite, Mag –magnetite, Ilm –ilmenite, Lm – limonite, [9].

The largest masses of diabase on the Majevica mountain are located at the site of village Crveno Brdo. Diabase also can be found in several places around the Majevica, but these rock occurrences are much smaller

Diabase sample M1 from locality of the village Marinovići (figure 4a and 4a') has plagioclases as main petrogenous minerals, which are entirely transformed. These mineral grains appear in hipidiomorphic to idiomorphic forms, which are blurred and cracked. Some of the plagioclase grains show undulatory extinction. Chlorite fills the interstitial space. Coisite and calcite occur as small secondary aggregates in the form of clusters. Accessory mineral in this sample is ilmenite. Texture of the rock is intersertal, structure is homogenous.

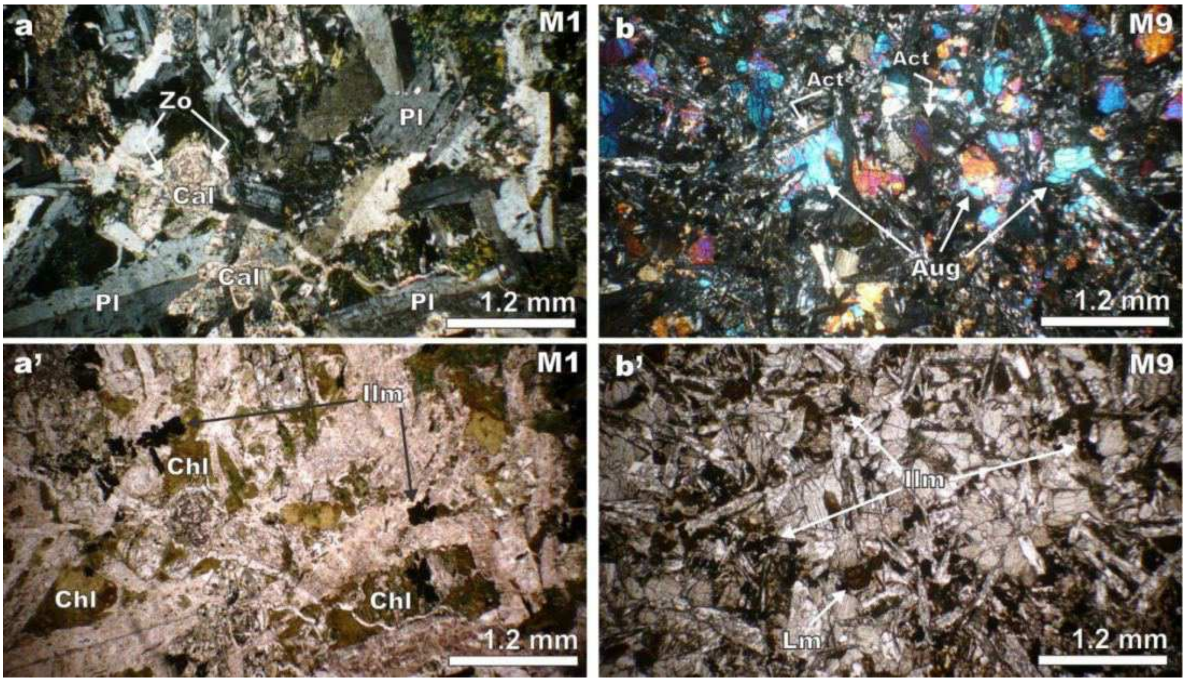

Figure 4. Micrphotographs of diabase samples M1 and M9 (XPL (a and b) and PPL (a' i b'))
Aug –augite, Cal –calcite, Zo –coisite, Act –actinolite, Chl –chlorite, Ilm –ilmenite, Lm -limonite

Diabase sample M9 form the village Crveno Brdo (figure 4b and 4b') according to the grains size belongs to medium-grained varieties. This rock has intergranular texture. Main petrogenous components in the sample are plagioclase and pyroxene. There are observed two different types of plagioclase. The first type has elongated prismatic forms, which are more alterated.

The second type of plagioclase occurs in rectangular forms, which are less alterated compared to the first type. In some parts of this thin section can be visible finely dispersed clay component after plagioclase grains. Anhedral augite grains fill interstitial space between plagioclase grains. These mineral grains are quite fresh, although in certain spots around them can be seen transformation into actinolite or chlorite. As accessory minerals in this sample appear ilmenite and limonite. Rock structure is homogenous.

AMPHIBOLE DOLERITE OF THE MAJEVICA

A term dolerite refers to rocks intermediate in grain size between basalt and gabbro and composed essentially of plagioclase, pyroxene and opaque minerals; often with ophitic texture [18]. This rock type is coarser in grains and less alterated than diabase. Appearance of these rocks was observed at two sites in Gornji Srebrenik. Sampling locations and their mineral composition are shown in table 4.

Table 4. Locality and mineral composition of Majevica dolerite based on optical examinations

Sample	Locality	Mineral composition
M5	G. Srebrenik	Aug, Hbl, Pl, Chl, Cal, Mag, Py
M7	G. Srebrenik	Aug, Hbl, Pl, Chl, Act, Cal, Ilm, Mag
M8	G. Srebrenik	Aug, Hbl, Pl, Chl, Act, Cal, Ilm, Mag, Py

Aug –augite, Pl –plagioclase, Hbl –hornblende, Chl –chlorite, Act –actinolite, Cal –calcite, Ilm –ilmenit, Mag –magnetit, Py –pyrite. [9].

In amphibole dolerite sample M7 (figure 5a and 5a') clinopyroxene augite appears in the anhedral forms whose dimensions are up to 2 mm. Interference colours of augite grains range to upper second order. Partially, edges of augite grains are transformed into actinolite and/or chlorite. Amphibole is represented by brown hornblende. Anhedral hornblende grains have a size up to 1 mm. Horblende has a characteristic brown pleochroism and two directions of cleavage that intersect at 124 and 56 degrees. According to augite relics, honblende and actinolite can be considered as products of its transformation. Relicts of plagioclase forms are only partly visible due to intense argilitic alteration. Accessory minerals are ilmenite, magnetite and pyrite. Rock structure is homogenous, while texture is nematoblastic with relicts of intergranular.

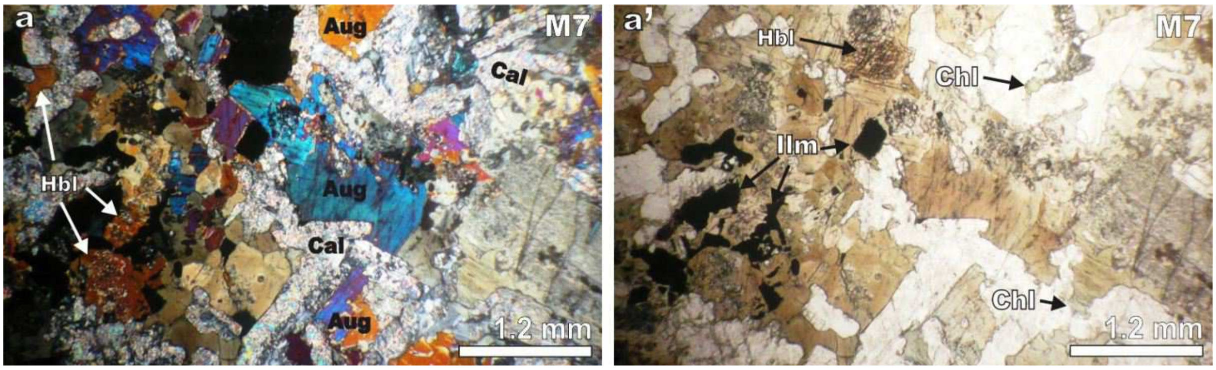

Figure 5. Microphotographs of amphibole dolerite sample M7 with prevailing nematoblastic and relicts of intergranular texture (XPL (a) and PPL)
Aug –augit, Hbl –hornblenda, Cal –kalcit, Chl –hlorit, Ilm –ilmenit

CONCLUSION

Within ophiolite melange of the Majevica, in form of larger or smaller fragments (olistolites), occur the following types of mafic extrusive rocks: spilite with its characteristic pillow forms, diabase, dolerite, metadiabase and metadolerite. Textures of mentioned rocks are ophitic, porphyritic, porphyric-ophitic, „quench", and appearance of nematoblastic texture. Structures mostly are homogenous, and amygdaloidal. By detailed observations of the terrain, it was concluded that spilite rocks significantly prevail compared to diabase and dolerite. Primary minerals of these rocks (plagioclase and clinopyroxene) were exposed to different types of physical and mechanical disintegration and chemical decomposition, of various intensity. Disintegrative changes mainly are manifested by folding and schistosity of primary minerals (clinopyroxene). Decomposition of primary minerals and groundmass was conducted in two phases. The first phase took place during solidification of basaltic lava under sea water (albitization). The second phase is a result of subduction processes and formation of ophiolite melange when some fragments are metamorphosed in conditions of very low temperatures and pressures, as has been indicated by occurrence of zeolite, pumpellyte, chlorite, epidote/zoisite and actinolite. Albitization was dominant alteration process that affected mafic extrusive rocks of Majevica. Based on occurrence of zeolite, pumpellyte and actinolite in association with epidote / zoisite it can be assumed that some of these rocks were subjected to metamorphism of very low degree that corresponds to conditions between zeolite and prehnite-pumpellyte to actinolite facies, where temperature is between 200 and 350° C and pressure is less than 2.5 - 3 kbar. In order to confirm these assumptions, research will be focused on chemical composition examinations and microprobe studies, and these will be input parameters for definition of geochemical and geodynamic characteristics. This paper enhances scant geological and petrographic informations relating to the locality.

GRATITUDE

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LITERATURE

[1] Kranjec, V. (1969). Geološka građa šireg tuzlanskog područja. Disertacija. Rudarsko-geološki fakultet Tuzla.
[2] Pamić, J. i Jelaska, V. (1975). Pojave vulkanogeno-sedimentnih tvorevina gornje krede i ofiolitskog melanža u S. Bosni i njihov značaj u geološkoj građi unutrašnjih Dinarida. II god. znan. skup. Znan. Savjeta za naftu JAZU, Zagreb. Ser. A. kj. S. 109-117.
[3] Pamić, J. i dr. (1979). Postkonsolidacione promjene u bazičnim stijenama iz ofiolitske zone u Bosni. Glas. Zem. Muzeja u BiH, Sarajevo. 18. 25-36.
[4] Pamić, J. (1976). Petrološke karakteristike magmatskih stijena ofiolitskog melanža i senonske vulkanogeno-sedimentne formacije na SZ obroncima Majevice i JZ padinama Trebovca u sjevernoj Bosni. Glas. Zem. muz. Sarajevo. U BiH. 15.5-17.
[5] Buzaljko, R. i dr. (1985). Osnovna geološka karta SFRJ, list Brčko, 1 : 100 000. RO Geoinženjering, OOUR Geoinstitut Sarajevo i Geološki zavod Zagreb.
[6] Buzaljko, R. i Marković, S. (1985). Tumač za osnovnu geološku kartu SFRJ, list Brčko, 1 : 100 000. RO Geoinženjering, OOUR Geoinstitut Sarajevo i Geološki zavod Zagreb.
[7] Čičić, S. i dr. (1988). Osnovna geološka karta SFRJ, list Tuzla, 1: 100 000, OOUR Geoinstitut Sarajevo.
[8] Čičić, S. i dr. (1988). Tumač za osnovnu geološku kartu SFRJ, list Tuzla, 1: 100 000, OOUR Geoinstitut Sarajevo.
[9] Le Maitre et al. (2002). A Classification and Glossary of Terms, Recommendations of tne International Union of Geological Sciences, Subcomimission of the Systematics of Igneous Rocks. Cambridge University Press. ISBN 0-521-6615-X.
[10] Whitney L.D. & Evans W.B. (2010). Abbreviations for names of rock-forming minerals. American Mineralogist. Volume 95, pages 185 – 184.
[11] Flett, J.S. (1907). Petrography of the igneous rocks. In: W.A.E. Ussher (Editor), The Geology of the Country around Plymouth and Liskeard. Memoirs of the Geological Survey. England and Wales. London. Sheet 348, p.1–147.
[12] Brongniart, A. (1827). Classification et caracteres mineralogiques des roches homogenes et heterogenes. Levrault, Paris. 144pp.
[13] Tröger, W.E. (1938). Spezielle Petrographie der Eruptivgesteine. Eruptivgesteinsnamen. Fortschritte der Mineralogie, Kristallographie und Petrographie. Jena. Vol.23, p.41–90.
[14] Radukić, G. i dr., (1990). Proučavanje pumpeliita iz ofiolitne zone Bosne. XII Kongres geologa Jugoslavije. Ohrid.
[15] Brongniart, A. (1807). Traite elementaire de mineralogie. Deterville, Paris. Vol.1, 564 pp.
[16] Tröger, W.E. (1969). Spezielle Petrographie der Eruptivgesteine. Ein Nomenklatur - Kompendium. mit 1. Nachtrag. Eruptivgesteinsnamen. Verlag der Deutschen 4.2 References 203. Mineralogischen Gesellschaft, Stuttgart. 360 pp. + 80 pp.
[17] Streckeisen, A. (1976). To each plutonic rock its proper name. Earth Science Reviews. International Magazine for Geo-Scientists. Amsterdam. Vol.12, p.1–33.
[18] D'Aubuisson de Voisins, J.F. (1819). Traite de geognosie. Levrault, Strasbourg. Vol.2, 665 pp.