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Review
Pregledni rad

METALLOGENY OF EOCENE SYNCOLLISIONAL GRANITES OF MOTAJICA AND PROSARA MOUNTAINS

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Key words: Motajica and Prosara Mts., Northern Bosnia, Eocene syncollisional granitoids, pegmatites, greisens, quartz veins, kaolin deposits.

Abstract

The geological setting is dominated by Eocene (48.7 Ma) syncollisional granitoids in the form of a small pluton in the Motajica Mt. and in the form of numerous sills and dykes in the Prosara Mt. Microelement paragenesis of these magmatites, pegmatites, greisens and quartz veins are distinguished by U, Th, Ce, Y, P, Nb, Ta, B, Li, F, Be, Sn, Mo, W, Fe, Cu, Pb. These elements and $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ isotopic values indicate the mantle origin of magma contaminated by relatively sterile lithospheric rocks. The most probable hypothesis of such a hybrid magma formation is the "slab break-off model". Deep erosion of Motajica granitoid pluton opened its acrobatholitic and epibatholitic level with numerous, but small pegmatite deposits (beryllites, tourmalinites, emeraldites and sylexites with piezoelectric quartz). Greisenization marked by strong silicification and muscovitization affected less than 1% of pluton. It is characterized by minor and accessory molybdenite, wolframite, huebnerite, scheelite, fluorite. Hydrothermal occurrences, galena and Fe minerals have only a mineralogical significance. Economically significant are numerous autochthonous kaolin deposits formed in Pliocene-Pleistocene time.

Prosara apomagmatic granitoids, exclusively granite dykes are metallogenetically sterile.

Ključne riječi: Planine Motajica i Prosara, sjeverna Bosna. Eocenski sinkolizioni granitoidi. pegmatiti, grajzeni, kvarcne žile, kaolin.

Sažetak

Eocenski (48.7 Ma) sinkolizioni granitoidi izgrađuju Motajicu u obliku malog plutona te kao brojni silovi i dajkovi Prosaru. Parageneze mikroelemenata tih magmatita, pegmatita, grajzena i kvarcnih žila: U, Th, Ce, Y, P, Nb, Ta, B, Li, F, Be, Sn, Mo, W, Fe, Cu, Pb kao i vrijednosti $^{87}Sr/^{86}Sr$ te $\delta^{18}O$ indiciraju porijeklo magme iz omotača koja ja kontaminirana relativno metalogeno sterilnim stijenama litosfere. Najvjerojatnija hipoteza formiranja takove hibridne magme je "slab break-off model". Duboka erozija granitoidnog plutona Motajice otvorila je njegov akro- i epibatolitski nivo sa brojnim skromnim ležištima pegmatita (beriliti, turmaliniti, esmerladiti, sileksiti, s piezoelektričnim kvarcem). Grajzenizacijom je zahvaćeno manje od 1 % plutona i karakterizira je izrazita silifikacija i muskovitizacija granitoida sa sporednim ili akcesornim molibdenitom, volframitom, hibneritom, šelitom, fluoritom. Hidrotermalne pojave galenita i Fe minerala imaju samo mineraloški značaj. Značajna su u ekonomskom smislu autohtona ležišta kaolina formirana na granitoidima u pliocen-pleistocenu.

Apomagmatske granitoidne, isključivo žilne stijene planine Prosare su metalogenetski sterilne.

Introduction

Motajica mountain, 652 m, is located at the western part of Bosnia, southward from the Sava river, between the rivers Vrbas on the east side and the Velika Ukrina on the west side. **Prosara mountain** is 50 km westward, between the Una river in the west, the Jablanica rivulet in the east and the Sava river in the north. Due to only 363 m of its height it is considered to be a very low mountain (fig. 1).

Both mountains are characterized by Eocene syncollisional granitoids. Metallogeny related to them is a unique example in the Dinarides. Granitoids of Motajica mountain form a plutonic body of 50 km^2 which is intruded in contemporaneously very low, low and medium metamorphosed Upper Cretaceous and

Paleogene flysch. Approximately 150 sills and dykes up to 10 m thick were intruded simultaneously in the same Eocene metamorphic sequences of Prosara

Figure 1. Position of the Prosara and Motajica Mts.

Slika 1. Položaj planina Prosara i Motajica mountain. Eocene age of metamorphic rocks of Motajica and Prosara mountains has been proved by fossil record in low-metamorphosed rocks of the metamorphic sequence (Pantić & Jovanović, 1970), as well as by K-Ar dating in higher grade metamorphic rocks. Geological age of metamorphism and synkinematic granitoid plutonism is concordant to the age of 48.7 to 55.0 Ma obtained by Sr-isochrone dating (Pamić & Prohić, 1989; Lanphere & Pamić, 1992).

Previous research of petrogenesis and age of Motajica granitoid

Mojsisovics et al. (1880) provided the first data of geological setting of the Motajica Mt. According to these authors it consists of granite intruded in Pre-Carboniferous rocks. Metamorphic rocks and granitic pluton of the Motajica Mt. are, according to Katzer (1924; 1925), of Pre-Carboniferous, or Azoic age.

Varićak (1966) has completed a detailed investigation of Motajica. He carried out a petrological examination of granite varieties: normal granite, granite with frozen-edges, leucocratic, aplitic, pegmatitic and greisenised granites, as well as granite-porphyre veins, lamprophyres and rhyolites. They were intruded during Hercynian orogeny (Upper Carboniferous-Lower Permian) into Devonian sediments generating a contact-metamorphic belt.

New ideas of age were given by Deleon (1969) who determined the Alpine age of Motajica granite using Rb-Sr method. Pantić & Jovanović (1970) found pollen in Motajica phyllites of Upper Cretaceous and Paleogene age. They suggested the generation of phyllites by gradual metamorphism of Upper Cretaceous sediment-protolites. Labaš (1975) proved by geophysical methods that there is no granitic batholite in the broad area of Motajica, but only a few isolated granitic plutons.

Pamić & Jelaska (1975) emphasized gradual metamorphism progressing northwardly of the Cretaceous volcano-sedimentary series in the southern slope of Motajica Mt. Karamata (1976) pointed out the differences of deeper erosion level of Motajica granitic pluton compared to the very shallow Prosara erosion level.

Pamić (1977) considered Motajica metamorphic rocks to be generated by metamorphosis of Upper Cretaceous sediments, but did not document it. These rocks were defined as Senonian on the Nova kapela and Kostajnica sheets (Šparica et al., 1980; Šparica et al., 1984) considered Motajica granite to be of Lower Tertiary age, and its metamorphic belt to be of Upper Cretaceous age. There are also some opinions that different metamorphic rocks of Prosara are of Alpine age generated of Upper Cretaceous and Paleogene sediments.

Pamić & Prohić (1989) gave proof of gradual changes of Motajica Upper Cretaceous sediments under very low and low-grade metamorphic PT conditions. They identified the presence of chloritoide, staurolite and tourmaline-bearing schists and clearly noticeable metamorphic zonation. They determined a tight migmatite zone between metamorphic rocks and granite. They considered Motajica granite to be monzogranite and granodiorite, in the minor part monzodiorite and quartz-diorite considering these rocks as S-granites.

Pamić & Lanphere (1991) and Lanphere & Pamić (1992) published ages of Motajica and Prosara granitoids, dated by K-Ar, 48.7 Ma and 56 Ma respectively.

Pamić & Balen (2001) consider Motajica and Prosara magmatic rocks to be Eocene syncollisional granitoids.

Metallogenic characteristics of the main magmatic stage of the Motajica granitoids

Motajica granitoid pluton takes space of the northern and the central part of Motajica Mt. It is 11.5 km long in the east-west direction and 6.5 km in the north-south direction. On the basis of geophysical measurements (Labaš, 1975) it is considered to be a stock and not the upper part of a deep pluton (fig. 2 and fig. 3).

According to Varićak (1966), approximately 75% of granitoid area is covered by standard granite, 15% by leucocratic granite, 5-7% by aplitic granite and less than 1% by granite with chilled margins. The largest bodies of leucocratic granite followed by smaller veins of aplitic granite are located on the southern and south-western part of the granitic massif. The major aplitic granite, bodies associated with leucocratic granite are placed in the western part of the massif. The rest of 2-4% are vein granitoids: granite-porphyres, pegmatites, aplites, quartz veins, rhyolites and lamprophyres (fig. 4 and 6).

Tectonics. Very common are longitudinal steep faults. However, the most common are steep diagonal faults. There are leucocratic and aplitic granite bodies as well as granite-porphyric, aplitic, pegmatitic and quartz veins formed along these faults. These faults were channels for circulation of pneumatolytic and hydrothermal solutions.

All three granitic types have similar **essential mineral composition: quartz, microcline,** orthoclase, albite-oligoclase, biotite, muscovite. They differ in the percentage of the above mentioned components (Table 1). There are numerous **accessory components,** but not exceeding 2% of the rocks weight.

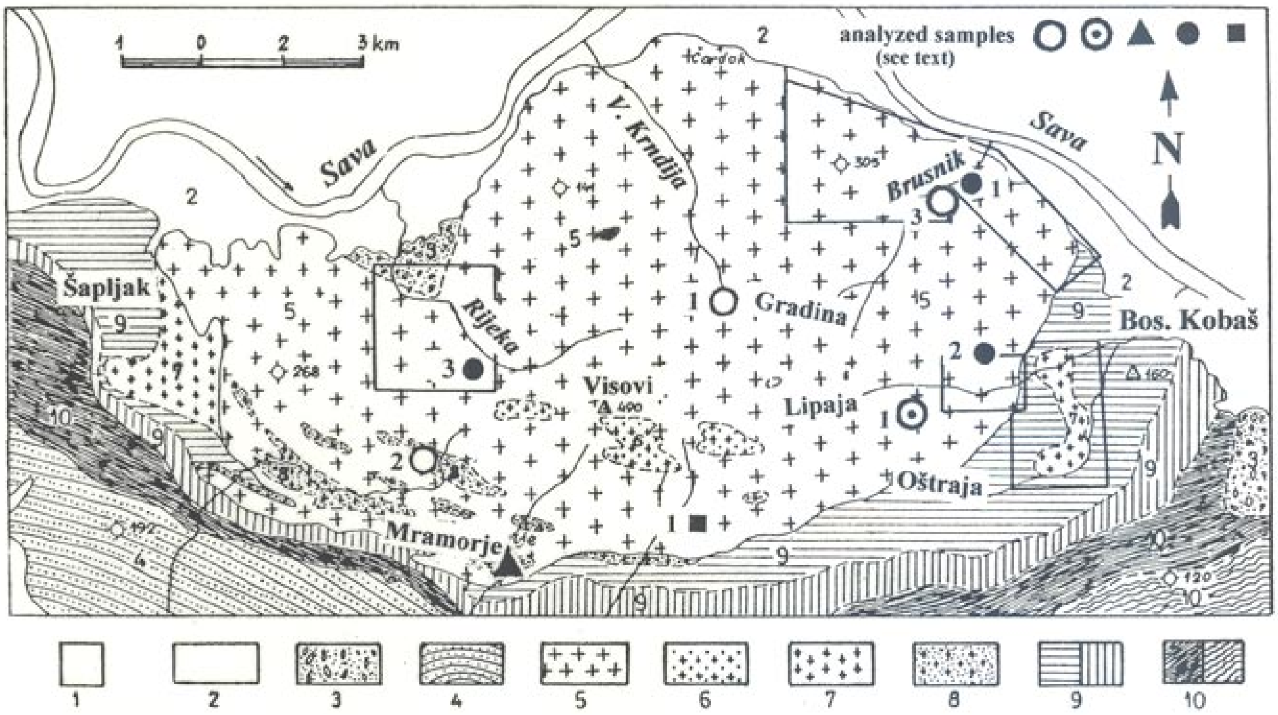

Figure 2. Geological map of the Motajica granite (Varičak, 1966; Ramović, 1976)
1 – the occurences of the kaolinized granite; 2 – Quaternary; 3 – Upper Pliocene; 4 – Upper Cretaceous; 5 – granite; 6 – graysenized granite; 7 – aplitoidal granite; 8 – leucocratic granite; 9 – contact metamorphic belt; 10 – Paleozoic schists and sandstones

Slika 2. Geološka karta masiva granita Motajice
1 – najznačajnije pojave kaoliniziranog granita; 2 – kvartar; 3 – gornji pliocen i kvartar; 4 – gornja kreda; 5 – granit; 6 – grajzenizirani granit; 7 – aplitoidni granit; 8 – leukokratni granit; 9 – metamorfiti kontaktnog pojasa; 10 – paleozojski škriljavci i pješčenjaci

Figure 3. Geological profile of the Motajica granite massif in the direction N – S (Varičak, 1966)
5 – typical granite; 6 – graysenized granite; 8 – leucocratic granite; 9 – contact metamorphic belt; 10 – Paleozoic schists and sandstones

Slika 3. Geološki profil granitnog masiva Motajice u smjeru S – J (Varičak, 1996)
5 – standardni granit; 6 – grajzenizirani granit; 8 – leukokratni granit; 9 – kontaktni metamorfni pojas; 10 – paleozojski škriljavci i pješčenjaci

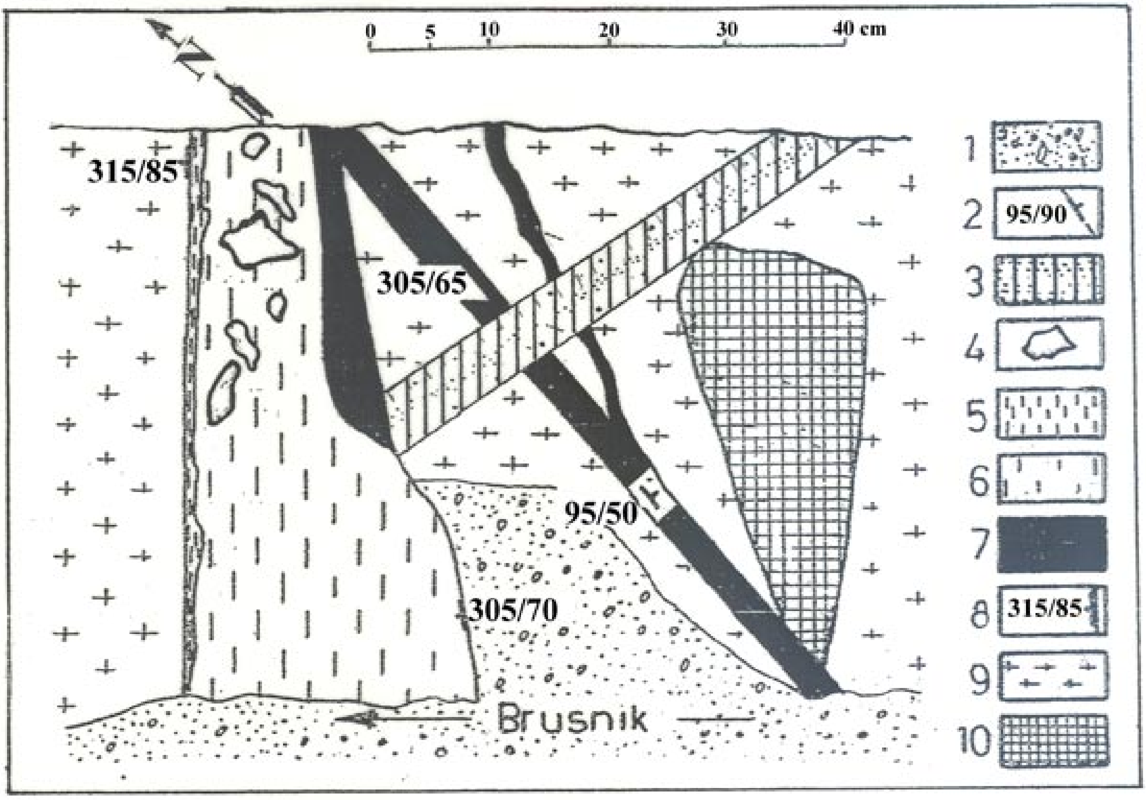

Figure 4. Profile of three types of pegmatitic veins in the leucocratic granite, lower course of the Brusnik brook (Varičak, 1966)
1 – alluvial; 2 – joint plane with its strike and dip; 3 – aplite–pegmatite; 4 – beryl; 5 – muscovite aggregate; 6 – quartz-pegmatite; 7 – pegmatite; 8 – vein wall plane with its strike and dip; 9 – leucocratic granite; 10 – contactolite enclave

Slika 4. Profil tri tipa pegmatitskih žila u leukokratnom granitu, donji tok potoka Brusnik
1 – aluvij; 2 – elementi pada pukotina; 3 – aplit–pegmatit; 4 – beril; 5 – agregat muskovita; 6 – kvarc–pegmatit; 7 – pegmatit; 8 – zidovi žila s elementima pada; 9 – leukokratni granit; 10 – anklava kontaktolita

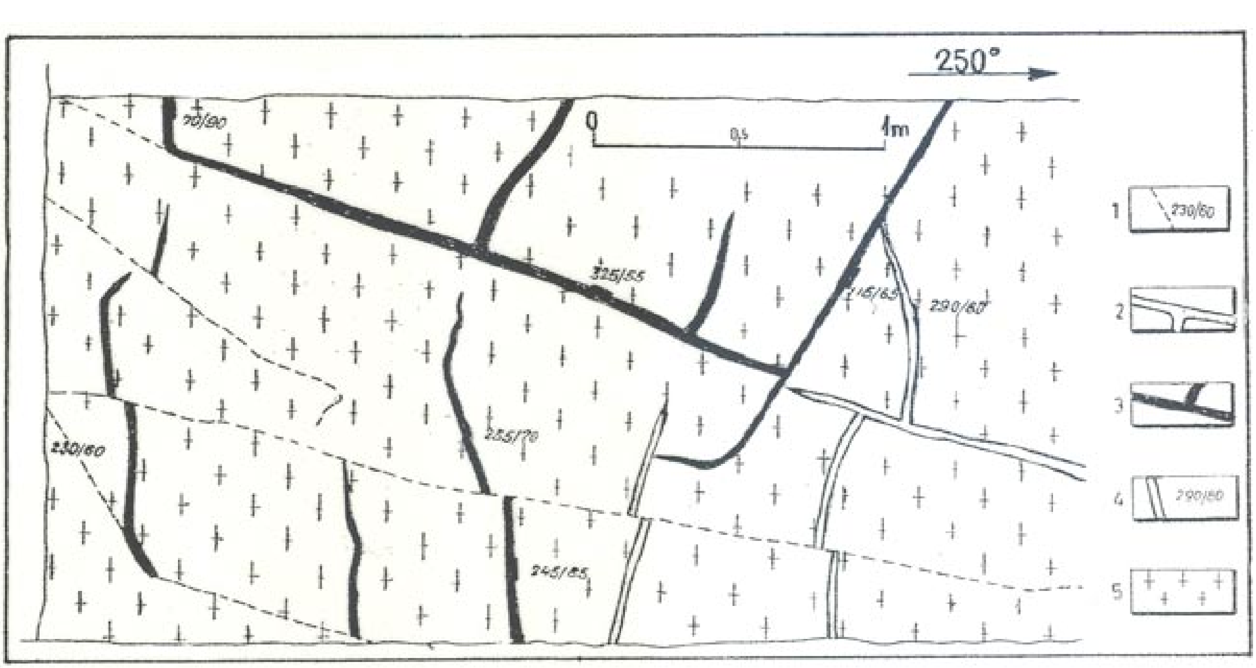

Figure 5. Network of the quartz–pegmatite and quartz veins in the kaolinized granite of the kaolin deposit Đidovi, Bos. Kobaš (Varičak, 1966)

Slika 5. Mreža žila kvarc–pegmatita i kvarcnih žila (sileksita)

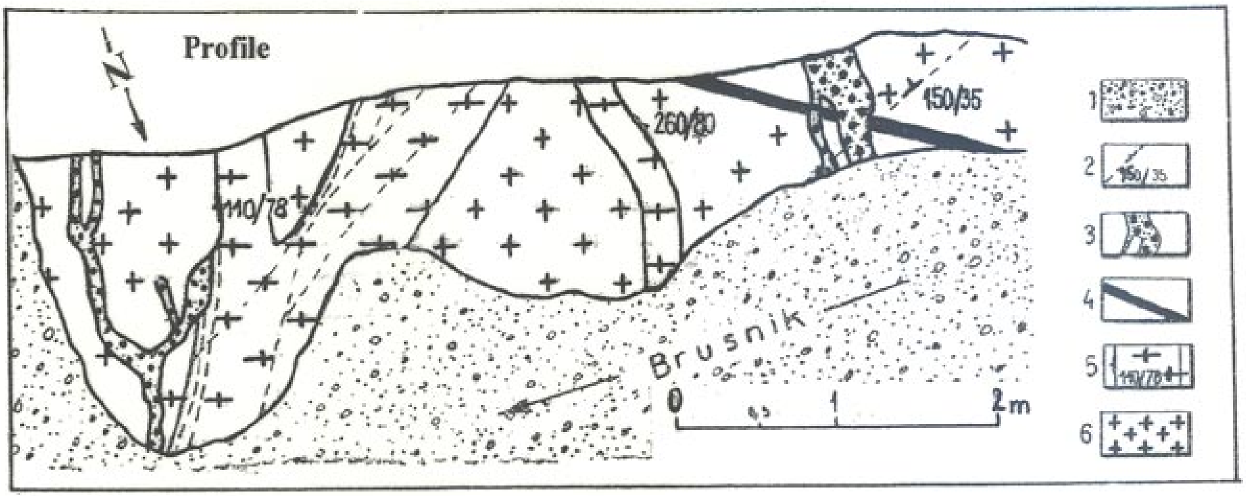

Figure 6. Leucocratic granite–aplite and pegmatite within standard granite, Brusnik brook (Varičak, 1966)
1 – alluvial; 2 – joint plane with it strike and dip; 3 – aplite; 4 – pegmatite; 5 – leucocratic granite; 6 – typical granite

Slika 6. Leukokratni granit–aplit i pegmatit u standardnom granitu, potok Brusnik
1 – aluvij; 2 – elementi pada pukotina; 3 – aplit; 4 – pegmatit; 5 – leukokratni granit; 6 – normalni granit

Table 1. Chemical and modal composition of the most typical normal leucocratic and aplitic Motajica granite samples (Varićak (1966), Đoković (1966)).

Tablica 1. Kemijski modalni sastav najtipičnijih standardnih leukokratskih i aplitskih uzoraka granita Motajice (Varičak, 1966; Đoković, 1966)

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Granite type	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	author
standard	72.11	15.60	1.32	0.45	0.55	1.79	2.65	4.55	0.69	Varićak
leucocratic	72.26	17.45	1.76	0.20	0.44	0.93	3.41	2.65	0.72	Đoković
aplitic	75.92	15.00	1.78	0.20	0.15	1.13	2.03	3.18	0.45	Đoković

Granite type	q	mk	pl	my	mu	bt	zr	ot	chl
standard	31	33	20	9.5	4.5	1.5	0.5		
leucocratic	35	16.5	33.5	-	9.0	0.5	1.0	0.5	3.0
aplitic	45	18	26.5	4.5	2.0	2.0	2.0		

Modal composition: ***q***–quartz; ***mk***–microcline; ***pl***–plagioclase (***ab***–albite, ***ol***–oligoclase); ***my***–myrmekite; ***mu***–muscovite; ***bt***–biotite; ***zr***–zircon; ***ot***–orthite-allanite; ***chl***–chlorite.

Metallogenic feature of Motajica granitoids is best expressed through the composition of accessory minerals.

Accessory minerals. Using panning of crushed Motajica granite samples Mihailović-Vlajić_(1967) determined following accessory minerals: **thorite** ($ThSiO_4$), **uraninite** (UO_3), **allanite-orthite** [(Ce,Ca, Y)$(Al,Fe)_3(SiO_4)_3OH$], **monazite** ($CePO_4$), **xenotime** (YPO_4), **corundum** (Al_2O_3) and **niobium-tantalum minerals** (Nb-Ta). These minerals were mentioned in the previous publications of Mihailović-Vlajić & Markov (1965, 1967) and Markov & Mihailović-Vlajić (1969).

Thorite is found in the river detritus of Motajica mountain by Petković (1957) who assumed it to be of granitic origin. The grain size of thorite obtained by crushed rock panning ranges from 0.1 to 3 mm, and in aplitic granite up to 1 mm. It is of green colour. Thorite crystalized in the late magmatic stage in interstitial space formed by quartz and feldspar crystals. Therefore, it is most abundant in aplitic granites, sometimes up to 4.2 vol. percentage, very rare in biotite and two-mica granite and not found at all in amphibole-biotite granite and pegmatite. It possesses xenomorphic or idiomorphic habit (Mihailović-Vlajić & Markov, 1967).

Uraninite of Motajica granites is mentioned for the first time by Mihailović-Vlajić & Markov (1965). It occurs in all the granite varieties, but less abundant in the late aplitic stage and mostly present in the part of biotite granite. Ramović (1982) provided results of radiometric prospection of Motajica Mt. showing existence of **elevated radioactivity** in some parts of granitic pluton. Gamma spectrometry showed 15-75 ppm of uranium and 20-100 ppm of thorium.

Allanite (orthite) was microscopically investigated by Varićak (1966). It is accessory in all granitic types, and zonally in granite-porphyre. Mihailović-Vlajić (1967) determined four morphological allanite types of Motajica. The most abundant is dark-brown to black with grain size of 0.1 to 0.5 mm. There is some reddish-brown xenomorphic allanite noticed in leucogranites, and brown-red xenomorphic radioactive allanite in muscovite granite containing 1750 ppm of niobium. Allanites contain 600-1200 ppm Y, approximately 1% of La, 300-400 ppm of Sc, 300-1000 ppm of Zr.

Monazite is mentioned by Mihailović-Vlajić & Markov (1965) as a rare accessory mineral in Motajica granites. Using crushed rock panning method, Mihailović-Vlajić (1967) found orange, rounded grains of 0.2-0.4 mm or pale-yellow platy or xenomorphic grains of 0.1 mm. It is more abundant in leucocratic granite.

Traces of **xenotime** in Motajica granitoids are mentioned by Mihailović-Vlajić & Markov (1965) without any location data.

Niobium-tantalum and titanium minerals of undefined composition and in small amounts as a content of Motajica granites are mentioned by Mihailović-Vlajić & Markov (1965), Mihailović-Vlajić (1967) and Markov & Mihailović-Vlajić (1969). Mihailović-Vlajić (1967) found 1750 ppm of niobium in allanite crystals of Motajica muscovite granite.

Other rare accessory minerals. In all Motajica granitic types, except in standard granite, **corundum,** is a very rare mineral. It has irregularly shaped grains of 0.2-0.3 mm in size, coloured more or less blue (Mihailović-Vlajić, 1967).

Brookite (TiO_2) is found by Mihailović-Vlajić (1967) in Motajica aplitic granite in the form of yellow and brown-yellow crystals of 0.2 mm diameter size. **Cassiterite** (SnO_2) is found by Mihailović-Vlajić & Markov (1965) in Motajica granite using crushed rock panning method. **Anatase** (TiO_2) is found in Motajica muscovite and aplitic granites. It is of platy or bipyramidal habit (Mihailović-Vlajić, 1967); Markov & Mihailović-Vlajić, 1969).

Garnet ($Me_3^{2+}Me_2^{3+}$ $[SiO_4]_3$) in Motajica Mt. magmatic and metamorphic rocks firstly noticed by Koch (1908). It appears most commonly as an accessory mineral in granite, muscovite granite, biotite-granite-gneiss. Colourless garnet is found in biotite gneiss of Hercegovački Dol (Bosanski Svinjar). All these data are also provided by Katzer (1924, 1926) and Varićak (1966).

Black **tourmaline** $(Na,Ca)(Mg,Fe^{2+},Fe^{3+},Al,Li)_3A_6(BO_3)_3Si_6O_{18}(OH)_6$ is firstly identified by Koch (1899, 1908) in pegmatitic vein of Veliki Kamen near Vlaknica. Varićak (1966) found it in many Motajica granitoid types as well as in rocks generated during the pegmatitic and pneumatolytic stage. Tourmaline also occurs as an inclusion in quartz and feldspar of biotite gneiss of Židovski potok. In Studena Voda muscovite gneiss it is red coloured. Black tourmaline occurs in the same rock associated with smoky quartz and small quantity of orthoclase in numerous thin pegmatitic veins. In Osovice stream biotitic gneiss tourmaline crystals are dark-purple. According to Trubelja & Barić (1979) crystalization of tourmaline took place in a wide temperature range. Star-shaped black tourmaline (schorl) crystalized in the late magmatic stage, short-columnar schorl during the pegmatitic stage, and various bluish, brown, green, red tourmalines are generated in the hydrothermal stage.

Mihailović-Vlajić & Markov (1965), Mihailović-Vlajić (1967) i Markov & Mihailović-Vlajić (1969) identified the following **opaque minerals: ilmenite** ($FeO{\cdot}TiO_2$), **magnetite** ($FeO{\cdot}Fe_2O_3$), **pyrrhotite** ($Fe_{1-x}S$), **chalcopyrite** ($CuFeS_2$), **marcasite** (FeS_2), **covellite** (CuS), **titanite-sphene** ($CaTiSiO_5$).

Arsenijević (1967) determined 1340 ppm of tin and 1900 ppm of niobium in titanite, 100 ppm of tin and 900 ppm of niobium in epidote, 25 ppm of tin, 40 ppm of beryllium in Motajica muscovite.

Late magmatic and postmagmatic stage of the Motajica Mt.

Vein rocks

There are numerous vein rocks in Motajica mountain. The most abundant are **granite-porphyres**, followed by **pegmatites** and **aplites** as well as **quartz veins**. There are few **lamprophyres** and **rhyolites.** Granite-porphyres are mostly located at the contact, to a lesser extent in granitoid pluton; pegmatites, aplites and quartz veins are most abundant within pluton, rarely within a contact-metamorphic belt. Lamprophyres occurre only at contact margin, and rhyolites mostly at the contactolite, considerably rare in Upper Cretaceous sediments.

The thickest veins are granite-porphyres, up to 4 m, rarely up to 5 m. Pegmatites, aplites and quartz veins reach thickness of 2 m and lamprophyres and rhyolites only up to 1 m. The longest are granite-porphyre veins, but more precise measurement is not possible due to the covered terrain. Dimensions of quartz occurrences measured in open stone-pits are reaching 100 m (probably in the form of rosary-chaplet) and 25 m along dip.

Granite-porphyres

Granite-porphyres are the vein rocks, the most abundant, the longest (hundreds of meters) and the thickest (4 to 5 m). Most of them are located at the contact belt, less often in within granitic pluton (Varićak, 1966).

Major constituents in these rocks are q**uartz, microcline, orthoclase**, mostly micro-perthite with 35 % ***an*****, plagioclase** (mostly albite-oligoclase and oligoclase, rarely albite, with 3.5 to 42 % ***an*****), allanite (orthite)** occurs rather commonly, and minor are **magnetite, ilmenite, pyrrhotite, titanite, apatite, zircon, epidote**. Accessory are: **tourmaline, beryl, scheelite, molybdenite, chalcopyrite, pyrite, hematite, rutile.**

Chemical composition of typical leucocratic granite-porphyre (Varićak, 1966) in weight percentages: 73.86 SiO_2, 15.21 Al_2O_3, 0.57 Fe_2O_3, 0.21 FeO, 0.35 MgO, 0.75 CaO, 2.93 Na_2O, 5.57 K_2O, 0.53 H_2O^+. **Modal composition:** q 36.5, mk 32, pl 21, my 7, mu 2, bt 1, zr 0.5.

These rocks contain locally increased content of chlorite, opaque minerals, epidote, and orthite (allanite). The approximate content of minor and accessory minerals is 1-5%, exceptionally up to 15%.

Pegmatites

First finding of pegmatite vein in the Motajica Mt., in ***Veliki Kamen*** granite quarry, between the villages of Vlaknica and Brusnik is described by Koch (1899). Its main minerals are **feldspar, quartz, muscovite** and **beryl,** and minor **albite, tourmaline, fluorite, talc, pyrite** and **psilomelane.** Kišpatić (1902) completed the paragenesis of this pegmatite with **heulandite** and **smoky quartz**. He examined beryl crystals by carrying out detailed goniometric measurements.

Katzer (1924,1926) accomplished the list of minerals by **garnet, hematite, stilpnomelane, galena** and **limonite**. He noticed 3 cm thick pegmatite vein in Brusnik stream consisting of quartz and short-columnar beryl crystals. Ramović (1957) described pegmatite vein wich containes **arsenopyrite, pyrite** and **molybdenite**. Nikolić (1962, 1963) mentioned two pegmatite genetic types: metasomatic which is dominant and the minor vein type. Varićak (1966) classified pegmatites according to the percentage of quartz and its grain size. The frequency percentages listed in parenthesis for a particular type: **(1) true pegmatites** (frequency 40 %) containing < 50 % of quartz, with 30-70 % quartz grains larger than 2 mm as are the true pegmatites classified: **(1a) pegmatites-aplites** (10 %) with 30-70 % quartz grains larger than 2 mm **(1b) aplites** (10 %) with < 30 % grains larger than 2 mm; **(2) quartz-pegmatites** (20 %) containing 50-90 % of quartz, with approximately 50 % larger than 2 mm; **(3) quartz-aplites** (5 %) with 50-90 % of quartz, with < 30 % larger than 2 mm; **(4) silexite** (7 %) with > 90 % of quartz and with feldspars as dominant minor minerals; **(4a) emeraldite** (3 %) with dominant muscovite as a minor mineral; **(4b) tourmalinite** (< 1 %) with dominant tourmaline as a minor mineral expressing strong pleochroism; **(4c) beryllite** (< 1 %) with short-columnar beryl as a dominant minor mineral.

Microcline pegmatite and silexite consist of microcline and accessory orthoclase. Plagioclase-pegmatites and albitized microcline pegmatites contain albite. Plagioclases are represented by albite and albite-oligoclase, and by oligoclase in plagioclase-pegmatites showing clear zonality. (***an*** component content varies from 5.5 to 24.5 %, average 12 %. There are also three chemical analyses of pegmatite carried out: (a) microcline pegmatite (Đoković, 1966), (b) albitized microcline-pegmatite (Varićak, 1966) and (c) pegmatite with numerous aplitic veins (Đoković, 1966). (Table 2)

Table 2. Chemical and modal compositions of three types of pegmatites (b, Varičak, 1966; a i c, Đoković, 1966).
Tablica 2. Kemijski i modalni sastav tri tipa pegmatite Motajice (b, Varičak 1966; a i c Đoković, 1966).

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	H_2O^+	H_2O^-	Total
a	65.28	–	22.91	1.02	0.18	trace	0.90	0.82	1.76	6.06	0.30	0.81	0.14	100.18
b	78.60	0.06	17.11	0.76	0.16	trace	0.22	1.03	5.78	1.82	0.10	0.66	0.07	100.37
c	65.35	trace	23.57	0.70	0.10	trace	0.51	0.84	3.90	4.06	0.03	0.58	0.06	99.79

Table 2. Chemical and modal compositions of three types of pegmatites (b, Varičak, 1966; a i c, Đoković, 1966) – continued.
Tablica 2. Kemijski i modalni sastav tri tipa pegmatite Motajice (b, Varičak 1966; a i c Đoković, 1966) – nastavak.

	q	mk	pl	my	mu	bt	zr	tu	chl
a	21	50	13.5	–	14.5	–	–	–	–
b	30	7	57.5	–	5.0	0.5	–	–	–
c	25.5	22.5	40.0	1.5	1.0	–	0.5	0.5	8.5

Pegmatites are recorded by Jelić (1976a) in ***Pekina Glavica, Kamenčić, Rastova Kosa*** and ***Vedeta,*** by Jelić (1976c) in ***Pavkov Jarak*** and by Ramović (1982) in ***Visovi***. Jelić (1976a) mentioned as very interesting albitized microcline-pegmatites in Brusnik-Lipaja-Šeferovići area. He also described pegmatite in Pavkov Jarak where there were mining exploration on thin-sheeted muscovite. This pegmatite, 170 m long, 4 m thick, contained 20-50 % of quartz, 30-70 % of alkali feldspar and 0-30 % muscovite with thin-sheets of 10 x 2.5 cm. Jelić (1976b) noticed "Fluoritization" phenomenon evidenced in the complex pegmatites of Brusnik area. Ramović et al. (1979) carried out prospections on numerous feldspar-bearing aplitic veins in the NW parts of Motajica Mt. Their paragenesis is beryl, tourmaline, zircon, sphene, molybdenite, pyrite and mica. Veins were characterized by enhanced radioactivity. Ramović et al. (1982) determined-obtained by crushed rock panning on pegmatite sample: 25-70 ppm **Sn**, 20-100 ppm **Mo** as well as 140-580 ppm of **Bi**. Higher tin content with trace of tungsten were recorded on the Visovi location. Trubelja & Barić (1979) and Barić & Trubelja (1984) provided a short overview of petrogenetic and opaque minerals in Motajica pegmatites.

Pegmatites, aplites and quartz bodies are very irregular: Most abundant are veins, sometimes lens-shaped veins, and rare net-shaped vein systems (fig. 4 and 5). Many pegmatites are sills expressing planar fabric. Contacts with surrounding rocks are sharp or gradual, sometimes fuzzy. There are occurrences of boudinage in pegmatites (fig. 7) noticed in the western part of the contactolite belt.

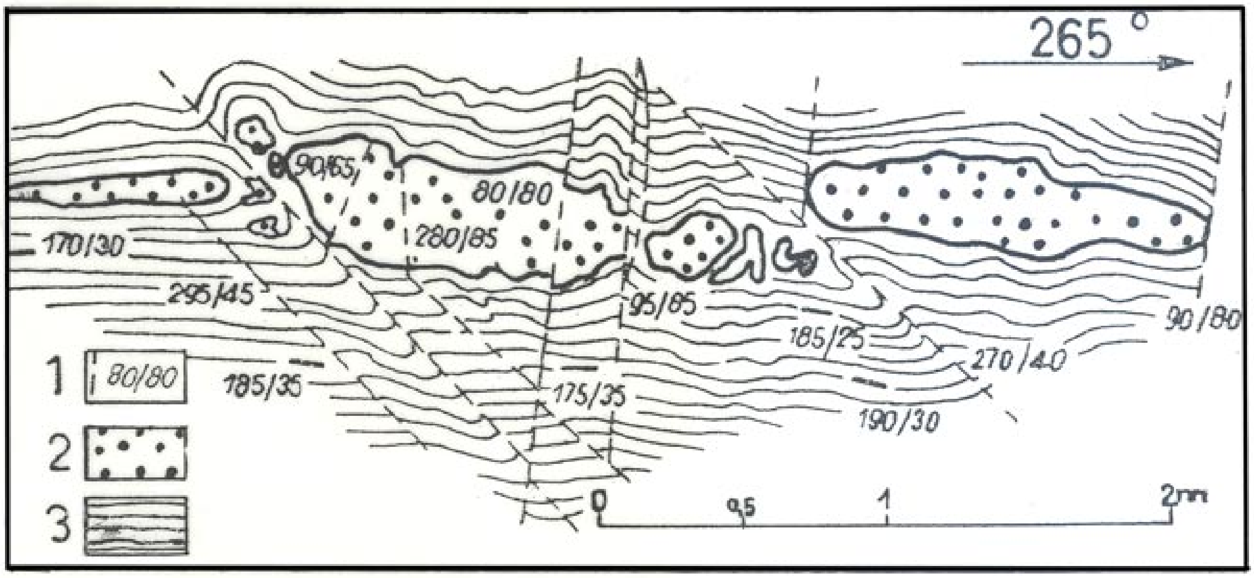

Figure 7. Pegmatite boudinage bodies in the inner contact zone, Hercegov Stol (Varičak, 1966)
1 – joint and fault planes with their strikes and dips; 2 – pegmatite; 3 – contactite rock

Slika 7. Pegmatiti u obliku budinaža unutar unutrašnjeg kontaktnog pojasa, Hercegov Stol
1 – elementi pada pukotina; 2 – pegmatit; 3 – kontaktolit

Pegmatites have zoned or homogeneous fabric, sometimes breccia-like or schist-like. Grain-size changes from very coarse-grained to fine-grained. Quartz, feldspar, mica, locally beryl, tourmaline, garnet, epidote and molybdenite are visible by naked eyes.

The most common texture is zonal, rarely homogeneous, breccia-like, miarolitic, planparallel. Banded, amygdaloidal and lensy textures are rare. Among structures the most common is hypidiomorphic with changes to panidiomorphic and panalotriomorphic. Also common structures are pegmatitic, perthitic, granophyric, cataclastic, porphyric, with other textures being very rare (Varićak, 1966).

Paragenesis: the main constituent is **quartz**, essential or accessory are **microcline, orthoclase, albite, muscovite, beryl** and **tourmaline.** The accessory constituents are **biotite, zircon, apatite, magnetite, ilmenite, titanite, epidote, garnet, molybdenite, scheelite, pyrite, rutile, hematite, pyrrhotite, and piezoelectric quartz crystals**. Secondary minerals are sericite, chlorite, clay group minerals, "limonite", psilomelane, talc, covellite.

Useful raw-materials in Motajica pegmatites are **feldspars, quartz, sheet muscovite** (exploited in Pavkov Jarak pegmatite) as well as **beryl** and **piezoelectric quartz**, the most important data of which are listed below.

Beryl ($Be_3Al_2Si_6O_{18}$) is firstly identified by Koch (1899, 1902, 1908) in pegmatite vein of Veliki Kamen granite stone-pit near Vlaknica village, Bosanski Kobaš. He noticed two beryl crystal types. The first type is represented by blue-green single crystals from 5-6 mm to 10 cm long and from 3-5 mm to 4-5 cm wide. Another aggregate type is represented by colourless beryl with short-columnar habit, from 1.5 - 2 mm to 5-6 mm in length, and 2-3 mm wide. Chemical analysis of Koch of coloured (a) and colourless (b) beryl (in percentages) are presented in Table 3.

Table 3. Chemical compositions of coloured (a) and colourless (b) beryl (Koch, 1899) of the pegmatite vein of Veliki Kamen.
Tablica 3. Kemijski sastavi obojenog I bezbojnog berila pegmatitske žile Veliki Kamen, Motajica (Koch, 1899).

a)	65.74	SiO_2	14.50	Al_2O_3	11.48	BeO	2.84	Fe_2O_3	0.32	CaO	0.45	MgO
b)	65.69	SiO_2	14.69	Al_2O_3	11.55+	BeO	2.68	Fe_2O_3	0.31	CaO	0.43	MgO

Kišpatić (1902) performed goniometric measurements on the analysed beryl crystals. Katzer (1926) found in Brusnik stream 3 cm thick pegmatitic quartz vein with 2-5 mm long beryl crystals, of short-columnar habit, mostly honey-yellow colour, with bluish crystals being rare. Barić (1960) performed very detailed optical and goniometric examinations of beryl crystals. Ristić et al. (1965) investigated beryl by spectrographic analysis identifying the presence of 0.093 % Cs, 0.1 % Li, 0.009 % Rb, up to 30 ppm Cu, and 30-3000 ppm Sr. Varićak (1966) mentioned beryl presence in quartz veins. He separated beryl-rich beryllites (fig. 4). Numerous quartz relicts on the peripheral parts of beryl crystals indicate metasomatic origin of beryl. Nikolić (1962, 1963) suggests that beryls are present in two pegmatite genetic types, as dominant metasomatic and as minor vein-type. Gojković & Nikolić (1967) found 2 g/t of uranium and 1.2 g/t thorium in green and green-blue beryls. Jelić (1976d) wrote that beryl occurrences were connected to beryllites and quartz pegmatites. Beryl-containing veins are up to 1 m thick and may contain up to 50 % of beryl. Trubelja & Barić (1979) gave a critical review of all published beryl data of Motajica Mt.

Piezoelectrical quartz is identified and described by Varićak (1976a) on the following locations: ***1. Bunarički potok; 2. Brusnik, 3. Rastova Kosa; 4. Vlaknica*** and ***5. Visovi*** (fig. 8). He determined them as genetic type 1 related to pegmatites. Quartz occurs as transparent crystals, milky quartz, smoky quartz, rose quartz, amethyst, citrine and morion. These crystals are distinguished by hexagonal habit with elongated prismatic faces, and uniform prismatic surfaces as well as with both rhombohedral faces. Crystalline quartz occurs in complex pegmatites, pegmatite-aplites as well as in pegmatitic-pneumatolytic-hydrothermal quartz vein rocks (silexite, emeraldites, beryllites) within granites and contactotites. Paragenesis consists of clay minerals and sericite. One finds up to 100 kg of crystalline quratz in some occurrences. Occurrences are mostly in the form of lenses, sometimes fracture veins.

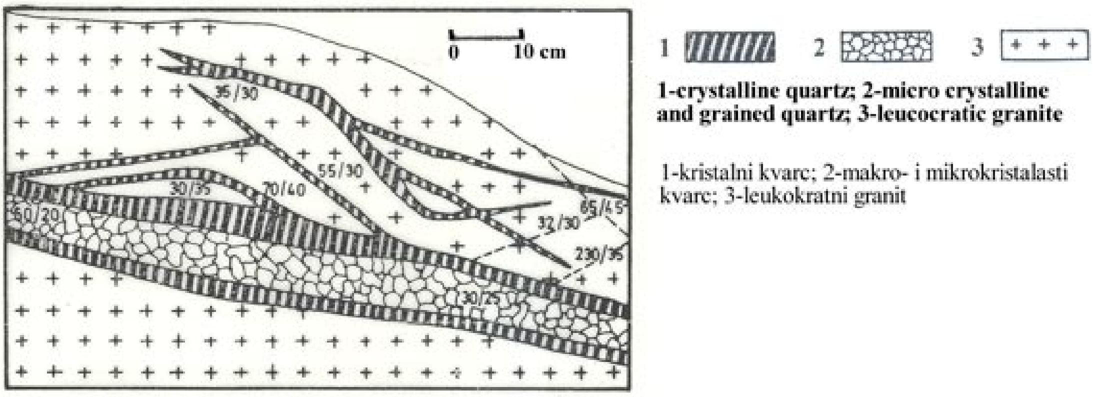

Figure 8. Piezoelectric quartz crystals on the location Visovi in the Motajica Mt. (Varičak, 1976)
1 – crystalline quartz; 2 – micro crystalline and grained quartz; 3 – leucocratic granite

Slika 8. Kristalni kvarc na lokaciji Visovi u planini Motajici
1 – kristalni kvarc; 2 – makro- i mikrokristalasti kvarc; 3 – leukokratni granit

Živanović (1976) and Trubelja & Barić (1979) reported following characteristics of quartz convenient for industrial purposes: quartz crystals should possess crystal faces from 5 cm^2 in size, or they should be meta-faceted, but physically and chemically homogeneous, with no fractures, inclusions, optical or electrical twinning or crystal parts weighting 50-2000 grams.

Quartz

There are reports by Katzer (1924, 1926) regarding quartz-vein occurrences in Motajica Mt., but most detailed ones are those issued by Varićak (1966) described in the previous chapter. Karamata (1976), Živanović (1976), Trubelja & Barić (1979) summarized results obtained earlier by Varićak.

Ramović et al. (1979) determined elevated radioactivity of quartz veins containing hematite and pyrite in kaolinized Motajica granite on the locations Grebski and Kameni Potok.

Greisenised Motajica granites

Greisenised granite is located in the few interrupted zones in the area between ***Babin Grob, Gradina*** and the area of the ***Lepenica*** river source generally spreading along the east-west direction. Greisenisation belt is 2 kms long and more than a hundred meters wide, but relatively shallow. Hence, it is considered to affect less than 1 % of granite pluton (fig. 2 and 3).

Greisenisation affected with very different intensity normal granite, leucogranite and aplitic granite.

During the pneumatolytic phase intensive silicification, muscovitisation and sericitisation of primary granitic minerals (especially of feldspars) took place. In the course of pneumatolysis, particularly during the final stages the gaseous solution, enriched in **Mo, W, Fe, Cu, Mn, S** gave rise to formation of small ore occurrences.

Greisenised granite is a fine-grained (0.1 - 0. 5mm), rarely mid-grained (1.5-2 mm) porous rock containing 60-80 % **quartz,** 10-30 % **muscovite** and **sericite**, and up to 10 % of other minerals. These are **zircon, apatite, titanite, microcline** and **biotite** relicts, **scheelite, huebnerite, pyrite**. Greisen structure is cellular to miarolitic, and texture panalotriomorphic granular with transition to hipidiomorphic texture, rarely porphyritic or cataclastic.

Greisen analysis made by Đoković (1966) gave the following results:

90.93 % SiO_2, traces TiO_2, 3.41 % Al_2O_3; 0.23 % Fe_2O_3, 0.28 % FeO, traces of MnO, 0.41 % MgO, 0.72 % CaO; 1.40 % Na_2O; 0.64 % K_2O; 0.04 % P_2O_5; 0.08 % S; 0.64 % H_2O^+, 0.08 % H_2O^-. **Modal composition**: 79 % quartz, 10 % muscovite; 9 % sericite; 2 % Fe-hydroxides and oxides.

In the course of postmagmatic pneumatolytic stage typical accessory minerals are formed: **wolframite** [(Fe,Mn)WO_4], **huebnerite** ($MnWO_4$), **scheelite** ($CaWO_4$), fluorite (CaF_2), molybdenite (MoS_2).

Wolframite in the single grain form is a very rare accessory mineral whereas **huebnerite** occurs more commonly (Mihajlović-Vlajić, 1967). These minerals were previously found by Petković (1957) in the river alluvions of Motajica mountain.

Scheelite is firstly mentioned by Mihailović-Vlajić & Markov (1965). Varićak (1966) found it in greisenised granite. Mihailović-Vlajić (1967) found very rare xenomorphic scheelite grains 0.1-0.2 mm in size in the granite sample obtained by crushed rock panning method.

Fluorite as a very rare constituent is firstly mentioned by Katzer (1924). Varićak (1966) considered it as an accessory mineral, originated during the transitional, pegmatitic-pneumatolytic-hydrothermal phase. Mihailović-Vlajić (1967) found violet fluorite crystals in the coarse-grained biotite granite. She suggested that the generation of fluorite occurred during the albitization process of Motajica granite in the late-magmatic stage.

Molybdenite is firstly mentioned by Ramović (1957) as a pegmatite constituent (Vlaknica locality), Varićak (1966) found molybdenite in granite-porphyres, pegmatites, aplites and quartz veins. The presence of molybdenite in Motajica pluton is reported by Mihajlović-Vlajić & Markov (1965) and Mihailović-Vlajić (1967).

Other hydrothermal ore occurrences

According to Katzer (1924, 1926) **galena** was found in ***Kruškovec***, southward from Bosanski Kobaš, as isolated veins and nests in limestone. Ramović (1957) described up to 10 cm big pieces of galena ore associated with **tetrahedrite, hematite, cerussite, covellite** and **goethite** in the alluvion of a small stream near ***Japaga*** village. Galena finding in the ***Kumana*** village and Krševac is mentioned by E. Ramović (1982).

Iron-ore occurrences

Katzer (1926) reported **iron-ore** occurrences northward from ***Galicijska kolonija*** in ***Jurin Jarak***, in the quartzeous rock. Jurin Jarak limonite contained 34.9 % Fe, 2.1 % Mn, 30.4 % SiO_2 and 0.5 % P. According to the report by ing. Turina, there were **limonite** blocks and **siderite** coverings near ***Presjeka - Gradina*** road in the direction of ***Ergitina Kosa***, 1 km southward from Gradina, as well as **quartz veins** with **iron minerals**.

Jovanović et al. (1979) reported few iron-ore occurrences in Motajica Mt., including limonite blocks in ***Rudina***, but without any economical value.

Mineral pigments

Varićak (1976b) wrote about some occurrences suitable as a raw material for pigments in ***Streljačka Kosa*** and ***Gavranić***. The latter location is 8.5 km south-west from Bosanski Kobaš, in the eastern part of Motajica.

Investigation of Gavranić location was carried out in the year 1967/1968, covering 15 shafts on the area of 250 x 100 m. In the year of 1957/1958 dye and lacquer factory from Male Lužine exploited 200 t of ore. Analyses of two samples provided the following chemical composition: 74.5 and 69.1 % SiO_2; 11.4 and 14.0 % Al_2O_3; 5.7 and 5.4 % Fe_2O_3; 1.1 and 1.0 % FeO; 0.1 and 0.2 % MnO, etc. Ore reserves were 250.000 t C_2 category.

Ore body has a dish-inverted shape of 250 x 100 m with maximal depth of 10 m. It is covered by 1 m thick clay and underlayered by Upper Cretaceous flysch.

Autochtonous Motajica kaolin deposits

First Motajica kaolin data in ***Brusnik*** and ***Ciganluk*** locations are provided by Katzer (1924, 1926). Ilić (1953), Stangačilović (1956, 1969) wrote about kaolin deposits, and later by Jurković & Šinkovec (1960), Grković (1961), Ramović (1976), Trubelja & Barić (1979) (fig. 2).

Ilić (1953) determined the following paragenesis of the Grebski and Kameni potok kaolin deposit: **kaolinite, albite, muscovite, quartz** and **chlorite**. According to Ilić, kaolin deposits are of hydrothermal origin.

Stangačilović (1956) carried out investigation on the ***Đidovi*** kaolin deposits. In the coarser grained kaolin fraction (0-15 micrometers) **kaolinite, illite** and **quartz** are determined, and in 0-5 micrometer fraction almost pure kaolinite is found. Other detected minerals are **orthoclase, albite, sericite, biotite, magnetite, zircon** and **limonite**. According to this author, granite kaolinization occured in a marine coastal part of Bosanski Kobaš-Brusnik area during the Tertiary transgression. After the sea-water withdrawal kaolinization continued in the swamp environment, being most intensive along contact fractures filled with hydrothermal quartz-veins.

According to Varićak (1966) the most intensive kaolinization of Motajica granite took place in the ***Babin Grob*** area in the western part of the pluton. In the northern and eastern edges of the granitic pluton there are numerous small irregular kaolinized bodies. Kaolinized parts having more than 5% of kaolin are more extended than greisenised parts. Varićak suggested that kaolinization was associated to superficial weathering without excluding some contribution of hydrothermal solutions. Ramović (1976) suggested that the role of hydrothermal solutions was significant. Support to this thesis is the presence of **galena, pyrite, sphalerite, molybdenite** and a**rsenopyrite** already reported by Ilić (1953).

Kaolin exploration activities are carried out from 1953. till 1962. In 1960. a separation of kaoline and feldspars for 30.000 t of raw-material per year is established. Jurković & Šinkovec_(1960) carried out ore reserve estimation to be 409.000 t A + B and 132.000 t of C_1 category for Đidovi deposit and 732.000 t A + B i 300.000 t of C_1 category for Grebski and Kameni potok deposit, i.e. totally 1.573.000 t. Average kaolin content was 13.4 %, varying from 3.4 % to 18 % (fig. 4 and fig. 5). Grković (1961) wrote about Đidovi, ***Filipovića Kosa*** and Babin Grob kaolin occurrences. Raw-material in Đidovi contained 12.37 % of kaolin, in Grebski and Kameni potok 9.40 %, in A-zone of Filipovića Kosa 10.37 %, and in B-zone of Filipovića Kosa 12.65 %. Technological features showed that raw-material containing more than 10% of kaolin is appropriate for high-grade ceramic production, and for ceramic in the construction industry raw-material containing less than 10 % kaolinite might be appropriate. It is determined that 58% of Motajica raw-material samples are appropriate for high-grade ceramic. Allochtonous kaolin deposits in Pliocene sediments are not found up to now (fig. 9 i 10).

Resistates

In some alluvions of Motajica mountain streams and rivers **scheelite** and **huebnerite** (Petković 1957) are found.

Prosara Mountain

Prosara mountain, 363 m high, is located in the northern Bosnia, between Una river in the west and Jablanica in the east and south-east. It is bordered by the Sava river in the north (fig. 1).

Previous research

Turina (1912) pointed out on the Slavonska Gradiška-Orahova sheet, some ten granite outcrops on Prosara mountain. Katzer (1926) described within geological map Banja Luka sheet, small granite bodies in crystalline schists of Azoic age. He considered them as marginal facies of deeper granite pluton.

Varićak (1957a) determined various schists that costitute the Prosara trunk considering them to be regionally metamorphosed rocks generated from pellitic-psamitic protholite under the greenschist facies conditions and low amphibolite facies. In the further investigations Varićak_(1957b) described **60 quartz-porphyre vein occurrences** that intruded into contemporaneously regionally metamorphosed schists during Hercynian orogeny. Karamata (1976) accepted the thesis provided by Varićak (1976b) about Hercynian age of Prosara magmatites, but considered that the shallow erosian level did not open deeper zones where pegmatitic-pneumatolitic mineral occurrences might be expected. Hence, there are only small hydrothermal quartz veins discovered. Šparica et al. (1984) determined Prosara magmatic rocks to be quartz-porphyres and granite-porphyres of Alpine age. Prosara metamorphic rocks as well as those of the neighbouring Motajica Mt. are Alpine metamorphism products of the surrounding Upper Cretaceous and Paleogene sediments.

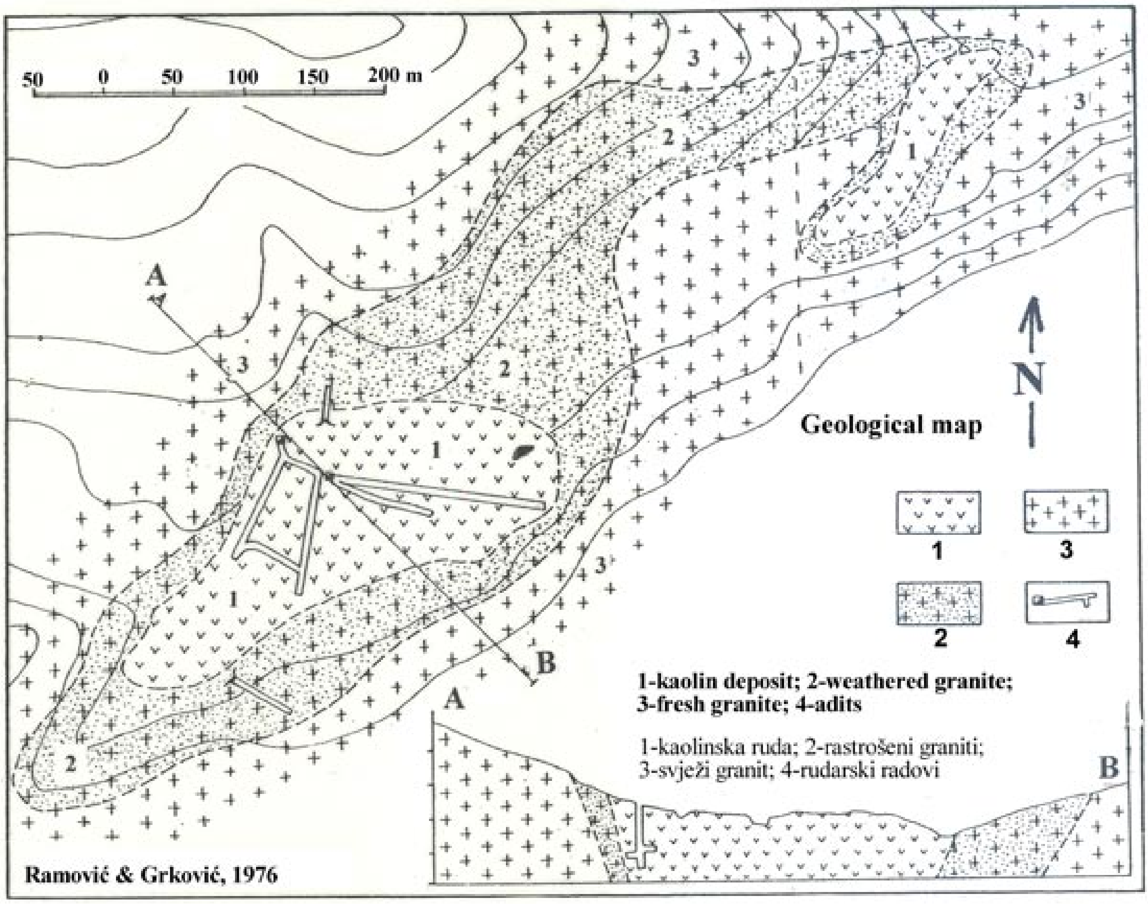

Figure 9. Kaolin deposits on the confluence of the Grebski potok and Kameni potok creecks in the Motajica Mountain

Slika 9. Ležište kaolina na sastavu Grebskog i Kamenog potoka, planina Motajica

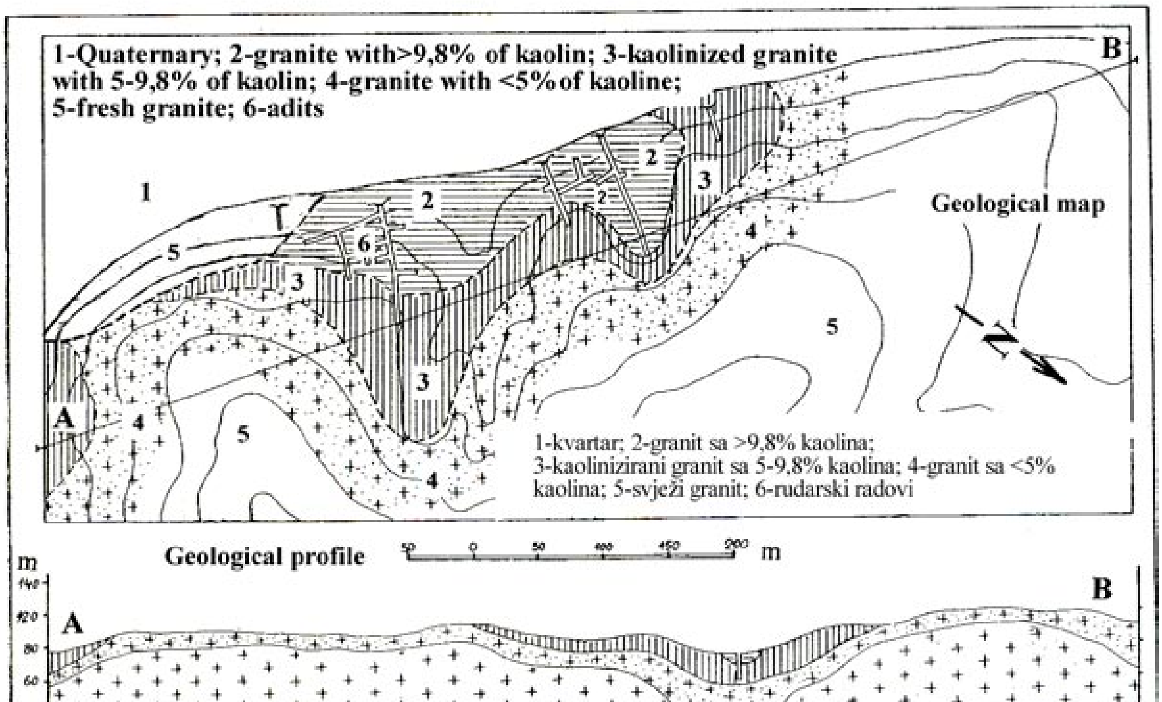

Figure 10. Kaolin deposit Đidovi in the Motajica Mountain (Jurković & Šinkovec, 1960)

Slika 10. Kaolinsko ležište Đidovi, planina Motajica

Pamić & Injuk (1988) interpreted the Prosara Mt. setting. Its middle part is constituted of various metamorphic rocks generated subsequently by the metamorphosis of Upper Cretaceous and Paleogene sediments. Metamorphic rocks are cut by **85 hypoabyssal eruptive sills**, mostly small or a few meters thick. The best exposed sills, concordantly incorporated into schists are located in the Pisarić and Joševac stream-source area. The sills are few meters thick, rarely more than 10 m. Besides dominating vein forms there are magmatic bodies of 1 km to 2.5 km long, and of 100 m wide, found on the five localities. Two bodies are located at the right coast of the upper Gašnica stream. Two bigger bodies are located in the Šibovica stream-source area in the western part of Prosara. The bigger Gašnica bodies are sills, others are stocks of smaller size (fig. 11).

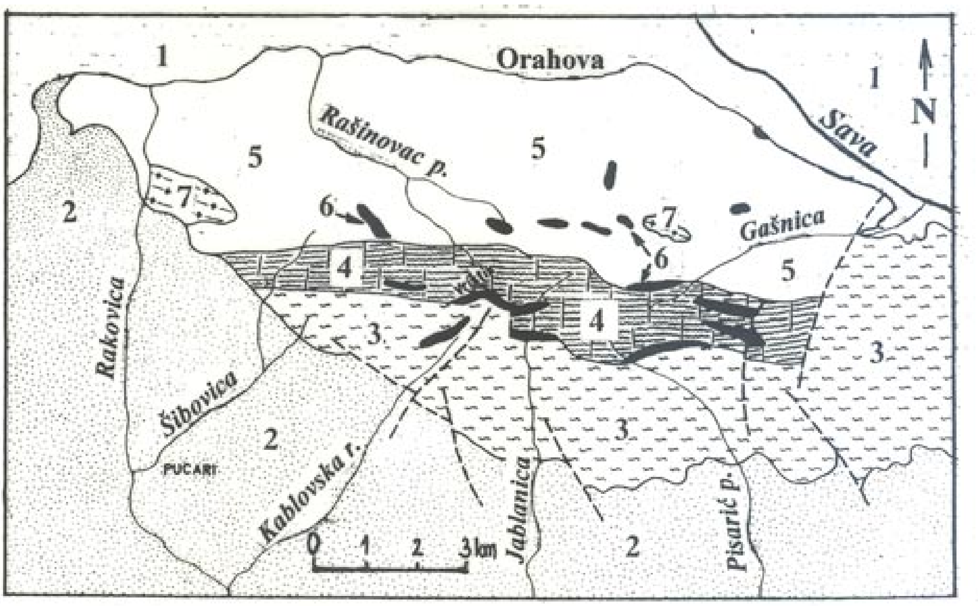

Figure 11. Geological map of the Prosara Mountain in the northern Bosnia (Šparica et al., 1984)
1 – Alluvial; 2 – Neogene; 3 – Upper Cretaceous slates and metasandstones with relics of the shales, sandstones and limestones; 4 – phyllites and green schists; 5 – gneiss and quartzitic schists; 6 – granite-granodiorite; 7 – pre – alpine gneisses and phyllonites; 8 – geological boundaries; 9 – faults

Slika 11. Geološka karta planine Prosare u sjevernoj Bosni
1 – aluvij; 2 – neogen; 3 – gornjokredni slejtovi i metapješčenjaci s reliktima šejlova, pješčenjaka i vapnenaca; 4 – filiti i zeleni škriljavci; 5 – gnajs i kvarcitični škriljavci; 6 – alpinski granit-granodioriti; 7 – predalpinski gnajsevi, graniti i filoniti; 8 – geološke granice; 9 - rasjedi

Biotite-muscovite alkali-feldspar bearing granite-porphyres of leucocratic type represent 2/3 to 3/4 of the total magmatite volume, syenite-porphyres and quartz syenite-porphyres represent 1/4 of the total magmatite volume with diorite-porphyres and quartz diorite-porphyres being subordinate (5%). Magmatites are similar to leucocratic alkali-feldspar rocks of alaskite type, i.e. to A-granites.

Pamić & Balen (2001) suggested that Eocene syncollisional granitoids are associated to the main Alpine deformation phase. There are approximately **150 dykes** noticed in Prosara mountain, up to 10 m thick, intruded into the Eocene metamorphic sequence. Eocene age of metamorphic rocks has paleontological evidence in weakly metamorphosed protholites (Pantić & Jovanović, 1970). It is also confirmed by K-Ar dating method (Pamić & Lanphere, 1991). Geological age of metamorphism and synkinematic granitoid plutonism are in concordance with the age of 48.7 to 55.0 Ma obtained by Sr-isochrone dating. Prosara granitoids are represented by varieties of alkali-feldspar granites with minor alkali-feldspar syenites and rarely occurring diorites (Pamić & Lanphere, 1991).

Dominating granite-porphyres contain 70.9-74.2 % SiO_2, 4.1 % Na_2O, 3.5 % K_2O, 0.6 % CaO. These are characterized by very low CaO and MgO content (0.2-0.5 of weight %) indicating high fractionation stage. Granitoids belong to the S-type and transitional S-type/I-type. There is some trace element content determined for Prosara magmatites (average values): 30-156 (124) ppm Ba, 51-859 (431) ppm Sr, 10-65 (17) ppm Cu, 10-52 (34) ppm Pb, 27-91 (51) ppm Zn, 17-243 (118) ppm Rb, 5-19 (9) ppm Nb, 5-65 (19) ppm Y, 0-226 (40) ppm V. High Sr and Nd (to 30 ppm) concentrations indicate typical crustal values. Among the accessory minerals, there is up to 2-3 % of opaque minerals, zircon, little apatite, rutile and rarely tourmaline.

Eocenic collisional granitoids of Prosara and Motajica comparing to other Dinaride Tertiary magmatites (Oligocene and Miocene) have the lowest $^{87}Sr/^{86}Sr$ values. They are 0.70497 for Prosara rocks. Oxygen isotopic composition ranges from 7.3 ‰ (increased upper mantle values) to 10.2 ‰ (crustal values).

Mineral occurrences

Postmagmatic changes noticed on Prosara granitoid rocks are: intensive sericitization, frequent kaolinitizaton, rare epidotization of albite; biotite deferrization with limonitization, sometimes chloritization with epidotization. These changes gave rise to secondary minerals: **sericite, kaolinite, epidote, chlorite, iron hydroxides** and **pyrite**.

There are marginal effects of contact thermal metamorphosis of the surrounding metamorphic rocks characterized by enhanced crystalinity, more frequently occurring above mentioned hydrothermal alterations. Enhanced **muscovitization** and not yet identified **opaque mineral** occurrences are only observed on Pisarić potok phyllites.

Cataclasis and mylonitization of Prosara granitoids are mostly observed at the Upper Postenjska Rijeka, Middle and the Lower Podgraska river and the Lower Rakovica river.

There are **epidote** occurrences in some Prosara granite-porphyres in the form of veins of mm-cm in size, and irregular nests. Veins and nests are filled with secondary **epidote ± quartz,** sometimes also with **albite**. In the Pisarić stream-source area, on magmatic vein and phyllite contact there are undefined **opaque minerals** observed as well as enhanced **muscovitisation**.

Metallogeny of Eocenic Granitoids of Motajica and Prosara Mountains (discussion and conclusions)

The linear Periadriatic-Sava-Vardar-Helenides magmatic belt was formed in the period of 55-29 Ma. It consists of the following magmatic associations: (1) syncollisional Eocene granitoids; (2) postcollisional Oligocene granitoids and related magmatic rocks; (3) Oligocene shoshonites and calc-alkaline volcanites with lamprophyres - with high potassium content; (4) Egger-Eggenburgian calc-alkaline volcanics; (5) Egger-Eggenburgian granitoids. Dominating rocks of Periadriatic lineament are granitoids, and of the Sava-Vardar zone dominant are shoshonites and calc-alkaline volcanites (Pamić et al., 2002).

The Sava-Vardar zone is characterized by Cretaceous-Early Paleogene turbidites intruded by the Late Paleogene magmatic associations. During the Eocene compression (55-45 Ma) the subduction of Tethys, tectonization and ophyolitic mélange obduction were completed. The Cretaceous and Early Paleogene formations metamorphosed by Alpine middle to high metamorphism were contemporaneously intruded by synkinematic granitoids (Pamić et al., 1998).

Lower and Middle Eocene syncollisional granitoids (age of 55 to 48.7 Ma as obtained by Sr-isochrone dating) are located only in the western part of the Sava segment of the Sava-Vardar zone as well as in the basement of the Panonian basin. These are Motajica granitoid pluton (48.7 Ma) made of granodiorits, monzogranites, quartz-diorites and monzodiorites as well as numerous Prosara vein granitoids (48.7 Ma) made of alkali feldspar granites and syenites and rare diorites (Lanphere & Pamić, 1992). In the eastward direction there are Oligocene granitoids of Boranja and Cer mountains (ages from 33.7 to 22.0 Ma obtained by K-Ar method).

Pamić et al., (2002) suggest that Motajica and Prosara granitoids belong to S-family, and only to a lesser extent to the transitional part between S and I families. The conclusion is based on the isotopic values of strontium and oxygen of the Motajica and Prosara granitoide. $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ isotopic values are listed below (Table 4).

Identical plutons of considerably larger dimensions are: (a) **Sithonia pluton** (age 50.1-44.6 Ma obtained by Sr-izochrone) in the Vardar zone built of granodiorites, tonalites, granites and leucogranites (D'Amico et al., 1990) and (b) **Elatia pluton,** in Greek Rhodopes (age 50.0 to 47.8 Ma obtained by K-Ar) built of granodiorites, tonalites, quartz-diorites and monzodiorites (Soldatos et al., 2002).

There are numerous hypothesis published concerning the origin of magmatic assocciations of the Periadriatic - Sava/Vardar – Helenides magmatic zone. The most probable hypothesis is the **"Slab-break-off model"** in the subducted litospheric plate in the depths of 90 - 100 km. Von_Blanckenburg & Davis (1995), Davis & von Blanckenburg (1995) and Neubauer (2002) suggest the origin of magmas of mentioned associations by astenospheric "upwelling" and border zone melting together with crustal contamination of ascending melt.

Metallogenic phases of Motajica and Prosara granitoids

Characteristic accessory minerals for the **main and late magmatic stage are thorite, uraninite, allanite-orthite, monazite, xenotime, niobium-tantalum minerals, garnet, tourmaline.** Characteristic elements are **U, Th, Ce, Y, P, Nb, Ta, B, Li (F)** and **Sn** (in titanite, epidote).

Microelement paragenesis listed, which is a part of granite, leucogranite and aplitic granite accessory minerals setting of Motajica Mt. clearly indicates the primary **mantle origin** of the initial **magma**. The original magma was subsequently contaminated what is clearly visible from $\delta^{18}O$ = 9.8-10.2 ‰ isotopic values for Motajica granitoids and $\delta^{18}O$ = 7.3-9.3 ‰ for Prosara granitoids. $^{87}Sr/^{86}Sr$ isotopic values for Motajica samples ranging

Table 4. The $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values of the Motajica and Prosara Mts granitoids (Pamić et al., 2002).
Tablica 4. Vrijednosti $^{87}Sr/^{86}Sr$ i $\delta^{18}O$ granitoida planina Motajice i Prosare (Pamić et al., 2002).

Motajica granitoids	$^{87}Sr/^{86}Sr$	$\delta^{18}O$	Prosara granitoids	$^{87}Sr/^{86}Sr$	$\delta^{18}O$
	0.70645 - 0.72024	9.8 - 10.2		0.70497 - 0.70812	7.3 - 9.3

from 0.70645 to 0.72024 and from 0.70497 to 0.70812 for Prosara samples also indicate stronger contamination effects for Motajica than Prosara. One of the significant causes of relatively small pegmatitic-hydrothermal and greisenised mineral occurrences in Motajica granitoids is the contamination of relatively sterile litospheric rocks.

Postmagmatic stage is characterized to a lesser extent by granite-porphyres and significantly by pegmatites. **Pegmatitic stage** in Motajica Mt. is the main stage of Eocene syncollisional metallogeny. The paragenesis of numerous Motajica mountain pegmatites indicates the complex pegmatites typical for I-granites. Distinctive minerals are **beryl** which is very commonly accessory or minor constituent representing in some pegmatites, i.e. so-called beryllites (10-50% of beryl) the major constituent, together with feldspar, quartz and coarse-grained muscovite. Further locally distinctive accessory minerals and minor minerals are **tourmaline, molybdenite, scheelite, pyrrhotite, garnet.** Characteristic microelements are: **Be, B, Li, F, Mo, W**. Sn, Bi, Cs, Rb, Sr, U, Th are found in the heavy fraction obtained by crushed rock panning method.

Pneumatolytic stage (greisenisation stage) is developed in the location of Babin Grob, Gradina and the Lepenica river-source area in Motajica Mt.. It is characterized by a marked silicification (60-80 % of quartz), muscovitization and sericitization (10-30 % of muscovite and sericite) as well as by the presence of **Mn, W, Fe, Cu, Mo, S** in the form of **wolframite, huebnerite, scheelite, molybdenite, fluorite, pyrrhotite, chalcopyrite.** The occurrences are very small, but are genetically significant.

Hydrothermal stage is poorly developed. During the erosion processes the cover of the Motajica pluton possibly containing low-temperature hydrothermal deposits was eroded-off. The residue are only parts with high-temperature hydrothermal quartz occurrences. A few galena, iron and copper minerals occurrences have no economical significance.

Autochtonous kaolin deposits of Motajica mountain on Brusnik, Ciganluk, Grebski and Kameni stream, Điđovi, Filipovića Kosa, Babin Grob locations with averagely 13.4 % of kaolinite and 1.5 mil. of tons of the ore represent valuable industrial raw-material. Their origin is due to the kaolinization of all Motajica granitoid types in very late Neogene-Pliocene- Pleistocene.

There are numerous small granitoid bodies, mostly small sills and only few small stocks discovered in **Prosara Mt.** intruded into Eocene metamorphic sequence. Geophysical investigations showed that these porphyric rocks are nor spatially neither genetically related to some large granitoid pluton, because there are only small plutons found geophysically in the Motajica-Prosara area.

Besides common alteration processes (silicification, sericitization, kaolinization, chloritization, epidotization and pyritization) there are found only small **veins** and **nests** built of **quartz, epidote, muscovite** and **opaque minerals**. Hypothetically possible small pluton is neither affected nor opened by the erosion.

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