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POLYMETALLIC SULPHIDE OCCURRENCES IN THE UPPER PALEOZOIC COMPLEXES OF NORTHEASTERN MONTENEGRO

POJAVE POLIMETALNIH SULFIDA U GORNJOPALEOZOJSKIM STIJENAMA SJEVEROISTOČNE CRNE GORE

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Key words: Upper Paleozoic, stratiform and stratabound Fe, Cu, Zn, Pb sulphide ore occurrences, isotope composition of lead and sulfide sulphur, NE Montenegro

Abstract

In the NE Montenegro, in the area Mt. Javorje and in the surrounding of the towns Bijelo Polje, Mojkovac, Ivangrad (Berane), Murino, Plav and Konjusi (Konjuhe) there are numerous small ore occurrences of pyrite and subordinately pyrrhotite with few per cent of Cu-, Zn- and Pb-sulphide in the small quantity of quartz and carbonate gangue minerals in Upper Paleozoic deposits. Different opinions considering the age of this ore occurrences exist in the literature of Montenegro: Upper Paleozoic or Middle Triassic. This study has revealed that most of this ore occurrences are of Permian age. Such statement relies on the discovery of Lower-Middle Permian fossils, on the specific occurrence of intercalated conglomerates, coarse grained sandstones and recrystallized limestones in the immediate vicinity and on the frequent stratiform (concordant) form of the occurence of ore and magmatic lenses and layers, or on the stratabound occurrences of ore impregnations and veins, respectively.

It was concluded that all Pb-Zn ore deposits of Montenegro were derived from the same magma. It gave in three successive pulsations Permian small ore occurrences in early rift stage, larger Lower Triassic ore occurrences in the intermediate rift stage and the largest Middle Triassic Pb-Zn ore deposits in the main rift stage. This hypothesis is based on the isogenetic character of Pb^{204} and on the uniform values of endogene sulphide sulphur S^{34} of galena and pyrite in the ore deposits of all three stratigraphic horizons. The important indicator is permanent presence of Cu minerals, what is typical for Paleozoic ore deposits of whole Dinarides.

Ključne riječi: Gornji paleozoik, stratiformne i stratabound Fe, Cu, Zn, Pb sulfidne pojave, izotopne analize olova i sumpora, SI Crna Gora

Sažetak

U SI dijelu Crne Gore, u području planine Javorje i okolini gradova Bijelo Polje, Mojkovac, Ivangrad (Berane), Murino, Plav i Konjusi (Konjuhe) nalaze se u gornjepaleozojskim naslagama brojne male pojave pirita, podređeno pirotina s najviše nekoliko postotaka Cu, Zn, Pb sulfida u malo jalovine kvarca i nešto karbonata. U crnogorskoj literaturi podijeljena su mišljenja o starosti tih pojava: gornjopaleozojska ili srednjotrijaska. Ova studija je pokazala da je većina tih pojava permske starosti. Taj stav se oslanja na nalaz donjo-srednjo permskih fosila, na specifičnu pojavu interkalacija konglomerata, krupnozrnih pješčenjaka i rekristaliziranih vapnenaca u neposrednoj blizini te na vrlo čest stratiforman (konkordantan) oblik pojavljivanja rudnih i magmatskih leća i slojeva, odnosno na stratabound pojave rudnih impregnacija i žila.

Zaključeno je da su sva Pb-Zn ležišta Crne Gore porijeklom iz iste magme iz koje su se u tri uzastupne pulzacije stvarale u ranoj riftnoj fazi u permu male rudne pojave, zatim u riftnoj međufazi donjeg trijasa veće rudne pojave i konačno u glavnoj riftnoj fazi srednjeg trijasa najveća Pb-Zn orudnjenja. Ta hipoteza se bazira na izogenetskom karakteru izotopa olova Pb^{204} i na istovrsnim vrijednostima izotopa endogenog sulfidnog sumpora S^{34} galenita i pirita u ležištima sva tri stratigrafska horizonta. Važan indikator je permanentna prisutnost Cu minerala što je karakteristika paleozojskih ležišta cijelih Dinarida.

Brief description of Montenegro Paleozoic

Due to the lack of fossils, great dispersion over the terrain, and significant lithological similarities, it was possible to conduct only partial stratigraphic analysis of certain Paleozoic deposits.

In the Kotor-Budva (Antonijević et al., 1969) and Bar-Ulcinj (Mirković et al., 1978) sheet areas, as far as Paleozoic deposits are concerned, only **Permian** sediments (schists, marls, marly limestones) occur as secondary blocks and fragments (non-mineralised) in the Anisian flysch. Paleontological explorations were conducted by Kochansky-Devidé (1951-53, 1958a, 1958b), Kostić-Podgorska (1958, 1965), and Pantić (1963).

Paleozoic deposits are mainly concentrated in northeastern Montenegro (Fig. 1).

The Paleozoic clastic and carbonate sediments are the oldest formations discovered in Montenegro. These sediments are mainly distributed in the marginal parts of Bjelasica, Komovi and Prokletije mountains, then in the Lim river region and its tributaries, in the Tara river valley, between Mojkovac and Kolašin and in Turiak and Lisa mountains (Mirković, 1984).

Đurđanović (1973) discovered conodonts of the **Ordovician - Upper Silurian (?)** age in the Tamnjačka river, area Plav.

The oldest **Silurian-Devonian** rocks were discovered on Mt. Čakor, in the Rožaje sheet area (Mojsilović and Baklaić, 1984) and their age was determined by Antonijević et al. (1970) and Kostić-Podgorska (1961). The rocks are made up of quartz-sericite schists, quartz sandstones, fine-grained conglomerates and alevrolites.

Devonian was found northwestern of the town Bijelo Polje, in the upper Grančarevska Rijeka river, then near Pavino Polje, in the Kićavnica river mixed with Carboniferous and Permian sediments (Mirković, 1976; Živaljević et al, 1984). Middle Devonian was paleontologically confirmed in the Paleozoic of Mt. Prokletija (Kostić-Podgorska and Pantić, 1972). Devonian rocks are made up of phyllites and quartz-mica sandstones, with intercalations of sandy limestones passing gradually into Carboniferous deposits.

Devonian-Carboniferous deposits, although non-fossiliferous, were identified by analogy with Mt. Čakor rocks of the same type (quartz-sandstones, alevrolites, quartz siderite schists, quartz-calcite schists, fine-banded quartz-ferruginous schists), locally with lenses of limestones and conglomerates (Živaljević et al, 1982; Mirković, 1972). On the basis of fossils, Mojsilović and Baklaić (1984) identified Devonian-Carboniferous deposits on Mt. Čakor (Rožaje sheet), in the bed of the Sušica, at upper Ibar and in the river Bukuljska Rijeka.

On the basis of new foraminiferal genus Klubovella, Mirković (1980) discovered **Lower Carboniferous** on Mt. Mušnica.

Middle Carboniferous was found by Kostić-Podgorska (1962) who identified corals from the Paleozoic deposits in the Pb-Zn mine Brskovo.

Carboniferous (undivided) was discovered in the area Pljevlje (Janjina area) (Mirković and Pajović, 1980), in the area Žabljak (Živaljević et al, 1989), in the area Rožaja near Turjak, Štedim, Rožaje, rivers Dolovska Rijeka and Ribarića Rijeka (Mojsilović and Baklaić, 1984), as well as in a small area of Bijelo Polje sheet area (Živaljević et al, 1984). Carboniferous consists of phyllites, clayey schists, schistose sandstones, and quartz and mica sandstones with small intercalations of sandy limestones and conglomerates.

Carboniferous-Permian is the most widespread in the area Bijelo Polje (Živaljević et al, 1984). It is made up of meta-sandstones, various types of schists with rare lensoid beds of limestones and conglomerates. In the beds of rivers Ljubovića, Grančarevska Rijeka and Lipnica, there was submarine magmatic activity with effusions of **quartz-keratophyre** and **quartz-diorite** with **cornites** in the form of small concordant bodies or thin (<2m), discordant, stratabound veins. Carboniferous-Permian deposits in eastern Montenegro were first discovered by Simić (1938), and confirmed later by Kochansky-Devidé and Herak (1960).

In the Tara Valley on its right bank, **Lower and Middle Permian** was found by Kochansky-Devidé and Milanović (1962) based on identification of fusulinides and algae (Sakmarian and ev. Artinskian). On the left bank the upper part of the Lower Permian was identified. It is very important to emphasize that the fossils of the same age (285 Ma - 265 Ma) were found in the rocks near Gornja Rakita ore occurrence (No 12) .

Lower and **Middle Permian** were discovered in the vicinity of the town Andrijevica, lying over fossiliferous deposits of Middle and Upper Carboniferous. They are composed of marine littoral-neritic sediments (sandstones, schists with subordinate limestones, dolomitic limestones, dolomites and conglomerates) (Živaljević et al., 1982).

Upper Permian was paleontologically proved by Simić (1934) in Nikšićka Župa, by Pantić (1958) in the Boan Valley, by Ercegovac (1974) near Pašina Voda and by Pešić et al. (1980) in Nikšićka Župa. Small surfaces of Upper Permian sandstones and schists with limestone beds were identified in the area Šavnik (Kalezić et al., 1973).

Permian (Permotriassic) covers large areas of Janjina, Javorje, Bučje and Pljevlja on the geological map Pljevlja (Mirković, 1974; Mirković and Pajović, 1980). It was mapped as Permotriassic (quartzites, mica-sandstones, lithoclastic sandstones, alevrolites, phyllites, clayey schists with limestone lenses and conglomerates). Sediments are shallow-marine. The presence of carbon and conglomerates indicates local lifting. Paleontological examinations include those of Kostić-Podgorska (1966) on corals of Sjerogošte (river Tara), of Živaljević (1970) on the fossils of Mt. Bjelasica and of Mirković (1986) on the microfacies of the Nikšićka Župa.

In his short presentation, Mirković (1984) provided a detailed spatial distribution of the Devonian-Carboniferous (DC), Carboniferous (C), Carboniferous-Permian (C, P) and Permian deposits (P), accompanied by description of lithology. The greatest extent of Paleozoic deposits of NE Montenegro may be found on the brim of Mts. Bjelasica, Komovi and Prokletija, then in the valleys of river Lim and its tributaries, in the Tara Valley and in the vicinity of Mojkovac, as well as on Mts. Turjak and Lisa.

In the course of 1985-1986, the Paleozoic sediments from the northern part of Mt. Bjelasica were explored micropaleontologically. The discoveries, subsequently separated and presented in the work of Mirković (1988), included certain biofacies from **Cambrian, Ordovician-Silurian, Lower Devonian, Middle Devonian, Upper Devonian, Lower Carboniferous, Middle Carbonifero-**

us, Upper Carboniferous, Lower Permian and **Middle Permian**. The positions of the examined samples, as well as a very different, complex stratigraphic individual bio-facies are shown in Fig. 2.

Polymetallic sulphide ore occurrences located in the Upper Paleozoic rocks of the NE Montenegro

These occurrences are concentrated in six small or bigger ore districts (Fig. 1 and Fig. 2): **I Javorje Mt.** with ore occurrences Nos 1 and 2 (Fig. 3); **II Bijelo Polje** with ore occurrences Nos 3, 4, 5, 6, 7, 8 (Fig. 4); **III Mojkovac** with ore occurrence Nos 9,10,11, 12 (Fig. 5); **IV Ivangrad (Berane)** with ore occurrences Nos 13,14, 15, 16, 17 (Fig. 6); **V Konjusi (Konjuhe)** with ore occurrences Nos 18, 19, 20, 21, 22, 23 (Fig. 7) and **VI Murino-Plav** with ore occurrences Nos 24, 25,26, 27, 28, 29, 30, 31, 32, 33 and 34 (Fig. 8).

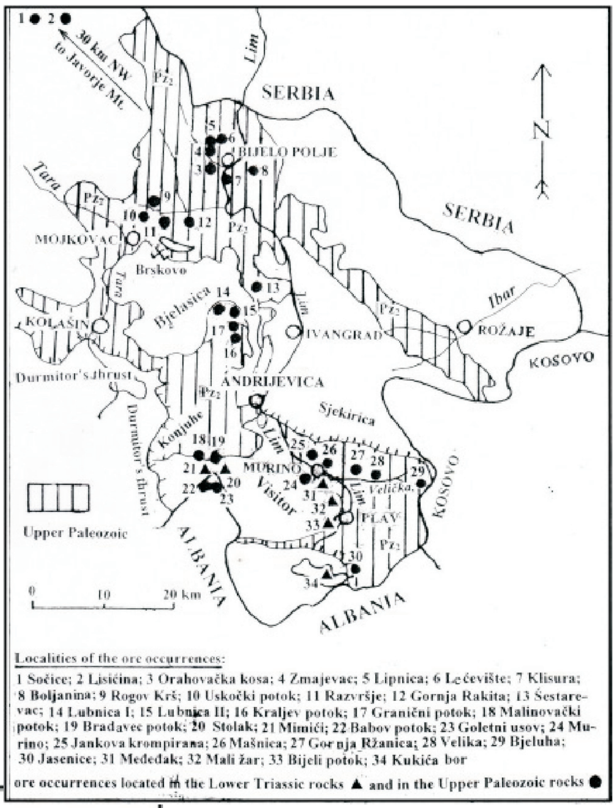

Figure 2 Distribution of the iron, copper, zinc and lead sulphide ore occurrences in the area of the North-Eastern Montenegro. I. Jurković synthesized on the basis of the published data

Slika 2. *Distribucija Fe, Cu, Zn i Pb sulfidnih rudnih pojava u SI Crnoj Gori. I. Jurković sintetizirao na temelju publiciranih podataka*

I Ore district of the river Poblaćnica

The Mt. Javorje representing in the structural sense an anticline is situated 10-20 km northernly from the town Pljevlja (Mirković & Pajović, 1980). The oldest rock outcrops in the core of the anticline are Devonian phyllites, mica sandstones, and quartz sandstones with intercalations of limestones containing conodonts. They gradually pass into Carboniferous schists and sandstones characterized by intercalations of limestones containing conodonts. This sequence is mapped on the geological map Pljevlje (Mirković &

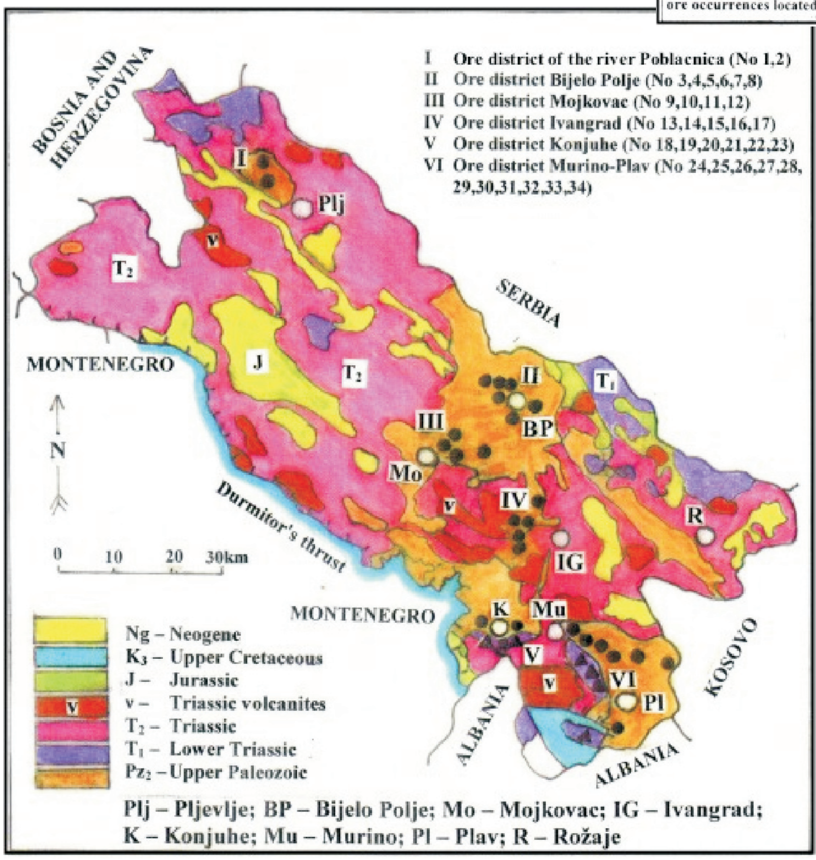

Figure 1 Simplified geological map of NE Montenegro with polymetallic (Fe, Cu, Zn and Pb) sulphide ore ocurrences: ● in the Upper Paleozoic rocks and ▲ in the Lower Triassic rocks (made by I. Jurković on the data of basic geological maps and published papers)

Slika 1. *Pojednostavljena geološka karta SI Crne Gore s polimetalnim (Fe, Cu, Zn i Pb) sulfidnim rudnim pojavama u stijenama gornjeg paleozoika (●) i stijenama donjeg trijasa (▲). Napravio I. Jurković na temelju geoloških karata i publiciranih radova*

Pajović, 1980) as Devonian-Carboniferous. Carboniferous deposits outcrop northeasternly from Mt. Javorje, in Janjine area (Fig. 3).

Devonian-Carboniferous deposits of Javorje are surrounded on geological map Pljevlje by Permian-Triassic (PT) deposits. On the basis of discussion which author of this paper had with the geologist A. Ramovš from Ljubljana in Sarajevo 1988 is Permo-Triassic in Fig. 3 substituted by $P_{1,2}$ (Lower-Middle Permian). Permian sediments consist of quartzites, muscovite sandstones, lithoclastic sandstones, alevrolites, muscovite schists, phyllites, argilites with limestone lenses (Pcl) and quartz conglomerates (Pco). The fauna in limestones is of Permian age. Conglomerate occurrences point to the orogenic activity.

On the Mt. Javorje near the hamlet **Sočice** - No 1 and **Lisičina** - No 2 occur in sandstones narrow veins up to 10 cm thick and 2 m long consisting of quartz, pyrite and some galena.

Mineralogical occurrences of gypsum inside of Permian clastites have been found in the **Butova and Poblaćenice area**.

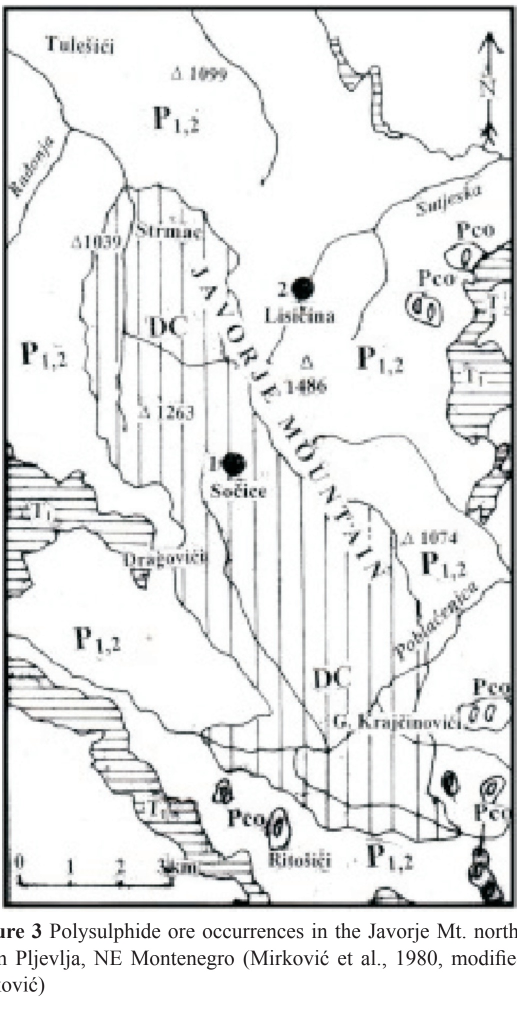

Figure 3 Polysulphide ore occurrences in the Javorje Mt. north of the town Pljevlja, NE Montenegro (Mirković et al., 1980, modified by I. Jurković)

Slika. 3. *Polisulfidne rudne pojave u planini Javorje, sjeverno od grada Pljevlja, SI Crna Gora (Mirković i dr., 1980, modificirao I. Jurković)*

II Ore district Bijelo Polje

Due to the covered terrain and lack on fossils the biggest part of the Paleozoic rocks has been mapped as Carboniferous-Permian (C,P) rocks (Živaljević et al., 1984). The oldest rocks are small outcrops of Devonian gray and black schists and limestones, clayey sandstones and phyllites in the beds of the river Kićavnica (Pavino Polje) and river Grančarevska Rijeka (Mirković, 1976).

Upper Carboniferous (C_3 and uppermost parts of C_2), represented by stratified and massive limestones with algae and foraminifers, were found only on the mouth of the Dobrinjski Creck into the river Lim and more southernly in the village Metanjac (Fig. 4).

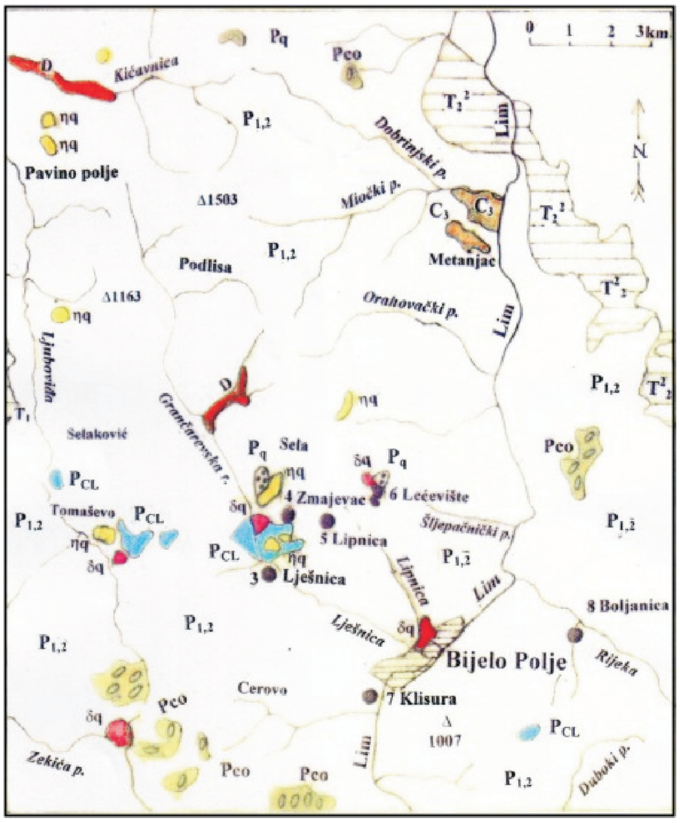

Figure 4 Polysulphide iron deposits in the area of the town Bijelo Polje, NE Montenegro. Geology is taken from the geological map Bijelo Polje (Živaljević et al., 1984)

Legend: ηq = diorite, diorite-porphyrite; δq = keratophyre, Pco = intercalation of quartz-conglomerate and coarse-grained sandstone; Pcl = recrystallized limestone; Pq = cornite; D = Devonian; $C_{2,3}$ = Upper Carboniferous; $P_{1,2}$ = Lower-Middle Permian; T = Triassic; ● = ore occurrences.

Slika 4. *Polisulfidne rudne pojave na području oko grada Bijelo Polje, SI Crna Gora.Geologija je preuzeta iz geološke karte Bijelo Polje (Živaljević i dr., 1984)*

Legenda: ηq = diorit, diorit-porfirit; δq = keratofir, Pco = proslojci kvarcnih konglomerata i krupnih pješčenjaka; Pcl = rekristalizirani vapnenac; Pq = kornit; D = devon; $C_{2,3}$ = gornji karbon; $P_{1,2}$ = donji-srednji perm; T = trijas; ● = rudne pojave.

Metasandstones, and schist with rare limestones (Pcl) and conglomerate lenses (Pco) mapped on the geological map (Bijelo Polje sheet) as Carboniferous-Permian deposits (C,P), were changed by author of this paper in the Fig.4 on the basis of paleontological data into Lower-Middle Permian. In the $P_{1,2}$ sediments occur small outcrops of keratophyre (δq), quartz keratophyre (qδq), diorite (ηq) and quartz-diorite (qηq).

Magmatite occurrences have been found at the following localities: (1) at the confluence of rivers Lipnica and Lim, 420 m upstream; (2) at the confluence of rivers Zekića Rijeka and Ljuboviđa, 250 m upstream, (3) 750 m NE of the position 2; (4) on the left bank of the Ljubovida river, in the village of Jabučno; (5) westernly of Bijelo Polje, in the right tributary of the Lješnica creek (Barički potok); (6) in the brook that flows from Sela into the Lješnica creek; (7) in the bed of Lješnica creek (Vranjski krš); (8) at upper part of Šljepašnički Potok brook; (9) at Tomaševo, in Čokrlije; (10) at the spring of Šljepašnički Potok brook (Gočanin, 1933; Stijović, 1972; Živaljević, 1974; Dubak, 1974; Dubak 1980; Pajović, 1980; Živaljević et al., 1984).

The most magmatic outcrops are small bodies, varying in thickness from 0.7 to 2 m and in length from few meter up to about ten meter. The greatest outcrops are situtated between the village Sela and the creek Lješnica (magmatic body having length of 500 m), in the village of Jabučno (magmatic body with the dimensions of 250 x 120 m), and along 800 m long creek Šljepašnički Potok. Quartzkeratophyres and keratophyres are about equally numerous as quartzdiorites and diorites, but keratophyres have greater dimensions. All outcrops are more, less or completely wheathered (pyritized, calcitized, rarely kaolinized). The occurrences of small garnet-pyroxene-epidote skarns (Lećevište (Laćevište), No 6 on the Fig. 4) are observed too.

Živaljević (1974) provided an exhaustive outline of discovered and studied ore occurrences in the vicinity of Bijelo Polje. He also used results of Vujanović's (1972, 1973) and Dubak's (1974) ore-microscopic investigations, as well as the results of Šuković & Bulatović's (1973) chemical analysis and the spectral analysis carried out at the Copper Institute in Bor (Dubak, 1974).

Lješnica, Orahovačka Kosa - No. 3. In the schists of the tributary of the creek *Lješnica*, numerous quartz veinlets and lenses up to 10 m long and 0.5 m thick were discovered, with *pyrite, galena, sphalerite*, *pyrrhotite, chalcopyrite*, *tetrahedrite and bournonite* (Dubak, 1977). According to Pajović (1980) the occurrence is of the stratiform type **Orahovički greben** (**No. 3a**) . In quartz sandstones, 750 m SE of the occurrence No. 3, there are mineral occurrences with *pyrrhotite, pyrite* and *chalcopyrite*, *pyrite + marcasite*, and one Ni-Co sulphosalt. In the proximity of **Orahovačka Kosa** (**No. 3b**), discordant hydrothermal *quartz-calcite* veins with very little *sulphides* are visible (Pajović, 1980). In the bed of the creek **Barički Potok - No. 3c**, a right tributary of the Lješnica creek, on **Mt Majna gora**, on the right bank of the river Ljubovida, ore samples taken from quartz conglomerates contain *galena, chalcopyrite* and *sphalerite*.

Zmajevac - No. 4. Around 400 m downstream from the source of the creek Zmajevac, in the calcschist of several meters thickness, Živaljević (1974) investigated impregnations, veinlets, and stockworks of very extensive character and presented the following paragenesis: *quartz with a little pyrite, galena, sphalerite, chalcopyrite,* and *tetrahedrite* occlusions in *galena* and *sphalerite*. In addition, *up to 20 ppm of Ag* was found. Pajović (1980) believed that this occurrence is of syngenetic type.

Lipnica - No. 5. In the upper stream of the creek **Lipnica**, an ore occurrence very similar to that in the Zmajevac creek was found (Živaljević, 1974). According to Pajović (1980), it consists of stratiform *pyrite* beds and lenses with a very little *pyrrhotite, sphalerite, galena* and *quartz.*

Lećevište (**Laćevište**) - **No. 6**. Živaljević (1974) stated that **at the confluence of two Matov Creeks** into creek **Šljepašnički Potok**, as well as **along this creek**, in the silicified limestones and calcschist, there is a pyroxene skarn bounded to the Upper Paleozoic keratophyre with *pyrite, pyrrhotite, chalcopyrite, valeriite, chalcopyrrhotite, marcasite, sphalerite* and *galena*. Dubak (1974, 1977) was of the opinion that this was quartz diorite of Triassic age. Pajović (1980), favouring the opinion that there were diorites and quartz-diorites Triassic in age. Pajović et al. (1982) claimed these eruptives to be of unknown age.

Klisura - No. 7. At Klisura location, 1.5 km SW of Bijelo Polje, on the right bank of the river Lim, there are *sphalerite* as dominant sulphide, and subordinate *galena* and *chalcopyrite*.

Boljanina (**Boljanica)** - **No. 8**. In the right leg of the brook Votnički Potok, nearby the **village of Boljanina (Boljanica)**, mica-quartz schists and quartz-conglomerates are mineralised (Živaljević, 1974). Mineralisation takes the form of dispersed impregnations, veinlets, lenses, containing *pyrite, sphalerite, chalcopyrite* and trace of *gold*. According to Pajović (1980), this deposit belongs to the group of stratiform impregnation deposits.

III Ore district of Mojkovac

Ore district of Mojkovac is shown in Fig. 5.

In **Rogov Krš - No. 9**, according to Pajović (1980), a stratiform impregnation type of mineralisation was developed in the series composed of coarse-grained sandstones and conglomerates with *pyrite* as the dominant mineral.

In the **Uskočki potok - No. 10**, extensive mineralisation formed in the several meter-thick sericite-carbonate schists. These are syngenetic veinlets and impregnations, while discordant veinlets with *pyrite, chalcopyrite, sphalerite, galena, tetrahedrite* are rare. *Pyrrhotite* and *arsenopyrite* are very rare. Residue of banded texture in the carbonate matrix may be discerned in the ore.

In **Razvršje - No. 11**, a stratiform type of *pyrite* lenses and beds is developed, with a varying quantity of polymetallic sulphides: *pyrrhotite, sphalerite, chalcopyrite, galena* and *tetrahedrite*, very rarely *arsenopyrite*. The main gangue mineral is *quartz*; *carbonates* are very subordinated.

Gornja Rakita - No. 12 contains a stratiform impregnation type of mineralisation in the series of sandstones and schists (interbedded veinlets, more rarely discordant veinlets intercalations) with *pyrite, sphalerite, galena, chalcopyrite, tetrahedrite, quartz* and *calcite*.

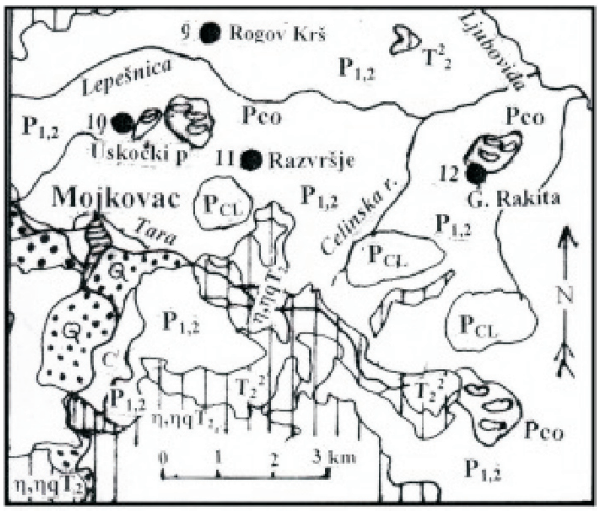

Figure 5 Polysulphide iron ore occurrences in the area of the town Mojkovac (NE Montenegro). Geology is taken from Živaljević et al. (1982). Positions of ore occurrences are marked by I. Jurković

Slika 5. *Polisulfidne željezne rudne pojave u području oko grada Mojkovca (SI Crna Gora). Geologija je preuzeta od Živaljević i dr. (1982). Pozicije rudnih pojava je označio I. Jurković*

IV Ore district of Ivangrad (Berane)

Ore occurrences are situated in the eastern part of Mount Bjelasica, 6 to 10 km NW and W from the town of Ivangrad (Berane) **(Fig. 6)**.

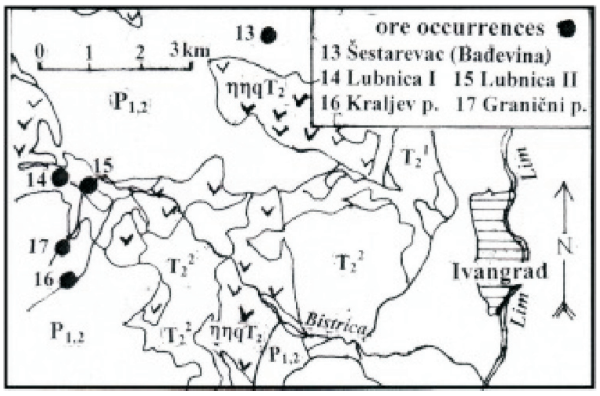

Figure 6 Polysulphide iron ore occurrences west of the town Ivangrad (Berane) in NE Montenegro. Geology is taken from Živaljević et al. (1982). Positions of the ores are marked by I. Jurković

Slika 6. *Polisulfidne željezne rudne pojave zapadno od grada Ivangrad (Berane) u SI Crna Gora. Geologija je preuzeta od Živaljević i dr. (1982). Pozicije ruda označio je I. Jurković*

All ore occurrences were investigated and described by Vujanović (1953). According to Vujanović (1953) the occurrences are of plutonic hydrothermal origin and Triassic in age. They are not genetically bounded to Triassic porphyrites. Magmatic intrusions opened only channels for ascension of therms. All mentioned ore occurrences are situated in the Lower (P_1) and Midle (P_2) Permian deposits (sandstones and schists as dominant constituents, intercalated with limestones (Pcl), dolomites and conglomerates (Pco)). Fusulinides, algae, corals characterize these marine littoral neritic $P_{1,2}$ sediments (Živaljević et al., 1976).

Vaćevine (Bađevine), Šestarevac (Šestarovac) - No. 13. At this position, near the village of **Šestarevac**, four short (<10 m) and thin (0.5 m) massive pyrrhotite ore lenses, concordantly inserted in black argillites were found. *Pyrrhotite* with *chalcopyrrhotite* lies at the contact of sandstones and black argillite, while *pyrite* is found near salbands. The ore contains little *chalcopyrite, chalcopyrhotite*, *sphalerite* and *galena*, as well as *quartz* as the gangue mineral (Pajović, 1980).

At **Lubnica I - No. 14**, there is a very small lense of massive *pyrite* with a little *galena* and *sphalerite*, very little *chalcopyrite*, and *quartz* as the gangue. At **Lubnica II (No 15),** there is an occurrence of *pyrite* with a little *chalcopyrite* in the *quartz* gangue.

Kraljev potok - No. 16 contains mineralisation in black argillite, in the form of a bed with weathered *pyrrhotite* (*pyrite + marcasite*), *pyrite, red sphalerite* (with inclusions of *pyrrhotite*), and a little *chalcopyrite* in *pyrrhotite* and *sphalerite*.

Granični Potok - No. 17 is an stratiform deposits of short (up to 10 m) and thick (up to 0.5 m) lenses and beds of *pyrite* with a little *chalcopyrite* and rarely other polymetallic sulphides (*sphalerite, galena, arsenopyrite, pyrrhotite*), situated in argillites.

V Ore district of Konjusi (Konjuhe)

The ore district of Konjusi (Konjuhe) is shown in Fig. 7.

The village of **Konjusi (Konjuhe)** lies 5 km SW of the town of Andrijevica, near the Albanian border. The northern part of the terrain, in the Perućica river valley, is covered by clastites of Upper Paleozoic age (P_{Z2}) (Dubak, 1980; Živaljević et al., 1982) or according Mirković's (1984) opinion of Lower-Middle Permian age ($P_{1,2}$). In their lower waterways, the creeks flowing northwards from the south to north into the Perućica river, such as **Stolak, Mimići, Bradavec (Bradovec), Babov** and **Malinovački Potok,** are partly covered by Upper Paleozoic ($P_{1,2}$), partly by Verfenian (T_1^2) limestones and partly by Verfenian (T_1^1) clastites. They include quartz-chlorite and quartz-sericite schists, and quartz-muscovite sandstones/conglomerates. Further south, there is a series of Middle Triassic (T_2) limestones, dolomites and intrusions of diorite-porphyrite, quartz-diorite porphyrite and gabbrodiorite. Magmatites are concentrated in the area of **Goletni Usov** and the upper waterway of **Babov Potok**.

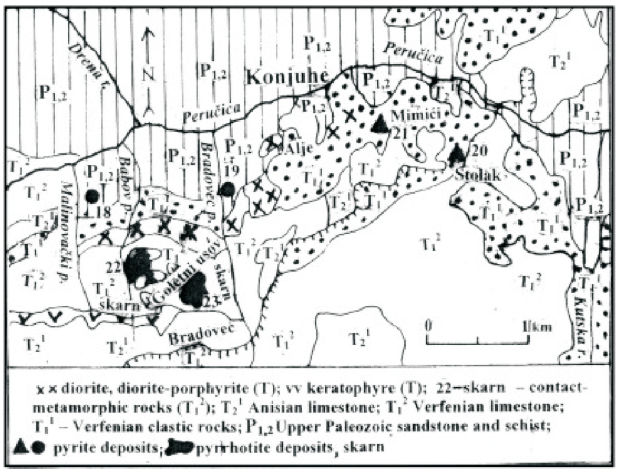

Figure 7 Pyrite and pyrrhotite deposits in the Konjuhe area, NE Montenegro (after Dubak, 1980, modified by I. Jurković)

Slika 7. *Piritska i pirotinska ležišta u području Konjuhe, SI Crna Gora (prema Dubaku, 1980, modificirao I. Jurković)*

The first study on the Konjusi (Konjuhe) ore occurrences was made by Vujanović (1952), as part of the prospecting project covering the areas of Andrijevica, Murino and Plav. According to Vujanović (1952), the ore mineralisation is hydrothermal and metasomatic, caused by ascension of Triassic hydrotherms after a porphyrite intrusion. The main ore mineral is *pyrite* (more in clastites) or *pyrrhotine* (mainly in *porphyrite*). The gangue minerals are *quartz* and *calcite*. *Chalcopyrite*, occurs in small quantities, while *sphalerite, galena, tetrahedrite, arsenopyrite* and *bournonite* are subordinate constituents.

Dubak (1980) was the first explorer who in the area of Konjusi (Konjuhe) recognized two totally different paragenetic, morphological and genetic types of ore mineralisation. The older type of ore mineralisation is found in the Upper Paleozoic ($P_{1,2}$) and Verfenians clastites (T_1^1). These include the occurrences in **Stolak - No 20** (Zarić, 1971) and **Mimići - No 21** creeks, as well as in the lower streams of **Bradavec - No 19** (Dragović et al., 1965) and **Malinovački Potok - No 18** creeks. Mineralisation occurs in the form of small lenses, short beds, irregular bodies, often concordant to neighbouring clastites, with exceptionally sharp margins but without any signs of hydrothermal alterations. *Pyrite* (finegrained, Ø 0.1-0.6 mm or dispersed Ø up to 80 µm) is the dominant mineral (90 % of the ore mass). It is followed by the ever-present *chalcopyrite*, whereas *pyrrhotite, sphalerite,* and *tetrahedrite* are very subordinate, and *hematite, arsenopyrite, electrum, gold*, and *TiO_2 minerals* very rare. *Quartz* and *calcite* are the main gangue minerals. In Dubak's opinion (1980), the Konjusi (Konjuhe) pyrite deposits are syngenetic deposits in the P_{Z2} and T_1 clastites. Any genetic association with distinct magma could not be verified.

The younger type of mineralization is found as skarns in the Lower Triassic rocks. There are garnet-pyroxene skarn, garnet skarn, garnet-epidote skarn, epidote skarn, rare vesuviane-garnet skarn, garnet-amphibole skarn and marble. The biggest skarn ore body has an surface of 500 m^2 and the depth of 70 m. The best locations are **Babov Potok - No 22** and **Goletni Usov - No 23**. Mineralization occur also in the diorites.

The paragenesis is rich, more than that in the $P_{1,2}$ and T_1^1 clastite, it is typical for subvolcanic hydrothermal deposits. *Pyrrhotite* is the predominant mineral constituent. Other minerals are *sphalerite, tetrahedrite, chalcopyrite, galena, stannite, pyrite, marcasite, arsenopyrite, magnetite, bismuthinite, bismuth, electrum, graphite, bournonite, cerussite, valeriite, cubanite, garnet, pyroxene, epidote, amphibole, vesuviane, calcite, sericite, chlorite and quartz* (Rakić, 1969; Pavlović, 1964; Maksimović 1968; Vujanović, 1959, 1973; Dubak, 1980).

VI Ore district Murino – Plav

The ore district Murino-Plav is shown in Fig. 8.

According to Đokić et al. (1970), Đokić et al. (1976), Rakić and Zarić (1970), Pajović et al. (1973), Živaljević (1976) and Pajović and Čepić (1977) on the right bank of the river Lim from Murino to Plav and in the area of Velička, terrain is built up of Carboniferous-Devonian deposits. They consist of mica-schists and sericite schists, with subordinate quartz schist, mica and quartz sandstone The limestone lenses are rarely intercalated in sandstone and schists. Spilites are very rare too. According to mentioned authors northern and eastern margins of the Mt. Visitor, on the left bank of the river Lim, are build of Lower Triassic quartz conglomerate and sandstones characterized by many Cu-, Pb- and Ag sulphides. Chemical analyses gave: Pb > 1%, Zn to 1.83 %, Cu to 0.56 %, Ag to 16,5 g/t and Au to 1.5 g/t. Particularly interested are quartz-tetrahedrite veins containing >100 g/t Ag.

Živaljević (1976) considers that Lower Triassic rocks are partly Permo-Triassic in age. Pajović et al. (1982) state that the Paleozoic rocks in the Plav area represent P,C and D deposits instead D,C_1. The first investigations were published by Vujanović (1952), and followed by Đokić et al. (1976), Pajović (1980) and Pajović et al. (1982).

Murino - **No 24**. An adit follows a *calcite vein with pyrite* and a little *chalcopyrite* (weak exolution *of sphalerite*), *sphalerite* and *galena* (Vujanović, 1952). According to Pajović (1980), this is a hydrothermal type of ore mineralisation in discordant *quartz-carbonatic veins* with sulphides.

Jankova Krompirana - **No 25.** This locality is situated on the right bank of the river Lim, 1 km from Murino. In the sericite and quartz schist, intersected by calcitic veinlets, there are *bedded pyritic veins* with ore impregnations between them. Gangue contains *quartz* and *calcite*. *Chalcopyrite* is in traces. According to Pajović (1980), the deposit belongs to the stratiform type of bedded and lensoid pyritic mineralisations, with a little *chalcopyrite* and only rarely with other polysulphides.

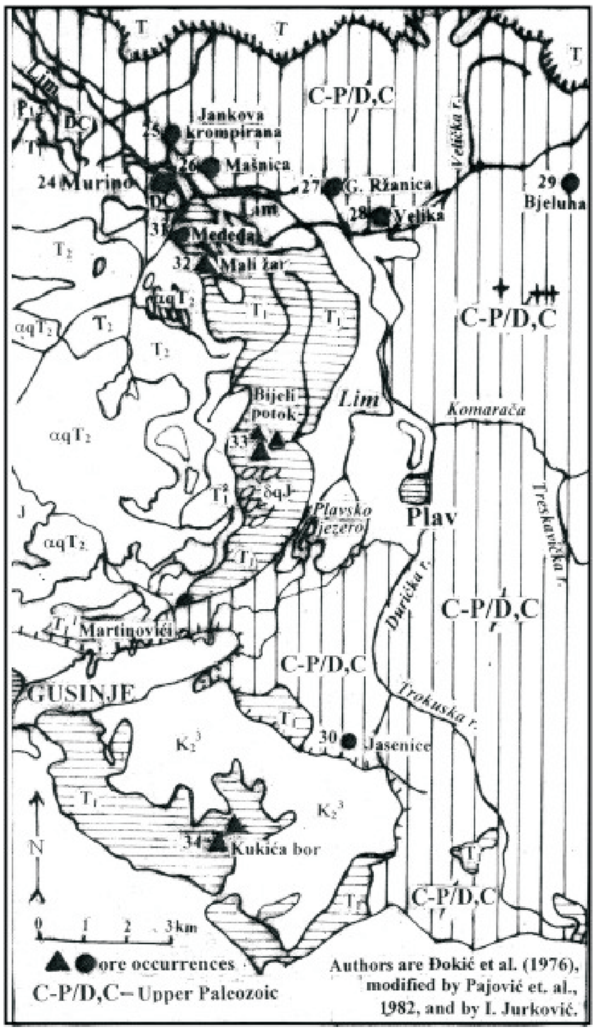

Figure 8 Distribution of the ore occurrences located in the Lower-Triasic rocks (▲) and in the Upper Paleozoic rocks (●) in the area Murino and Plav (sheet Gusinje, NE Montenegro)

Slika 8. *Raspodjela rudnih pojava smještenih u donjotrijskim stijenama (▲) i gornjopaleozojskim stijenama (●) u području Murino i Plav (list Gusinje, SI Crna Gora)*

Mašnica - No 26. The ore mineralisation is located on the SW slopes of Mt Sjekirica. 1 km NE from Murino on the right bank of the river Lim, in quartzite and quartz-schist. It consists of several lenses (ten meters long) with *pyrite* and some *chalcopyrite* with *quartz* and it was investigated by short adits.

Gornja Ržanica - No 27. According to Vujanović (1952), in the quartz schist bed being 20 cm thick, there are visible impregnations of *pyrite*. In Pajović's opinion (1980), this is a discordant hydrothermal type of *pyrite* veins, 3-10 m long and up to 0.5 m thick, locally with some *chalcopyrite* and only rarely with *pyrrhotine*. Occasionally, these veins are interbedded. At this locality, Pajović (1980) also mentions occurrences of massive stratiform beds and lenses of *pyrite* and *pyrrhotite.*

Velika - No. 28 Velička Potok creek iron deposit found in 1976. is an *iron hat* identified in sericitic schist, containing relicts of strongly *limonitised pyrite* with a little *chalcopyrite*. Approximately 500 m upstream from the confluence of the rivers Velika Rijeka and Lim, in the schistose phyllitic sandstone, there is a *bedded calcitic vein* 15 cm thick. The main ore mineral is *chalcopyrite*, while *pyrite* is found next to salbands.

In 1977, in the vicinity of the village of **Bjeluha - No. 29**, in a series of quartz sandstones and conglomerates, bed of *pyrite* 100 m long and 2 m thick (with some exsolutions of *chalcopyrite*) was discovered (Antonijević et al., 1968). Very rarely occur little *sphalerite*, *galena*, *arsenopyrite* and *pyrrhotite too*. *Quartz* is the main gangue and carbonates are subordinated. The type of deposit found in Bjeluha was identified by Pajović (1980) as a stratiform type bounded to the submarine hydrothermal activity in Upper Paleozoic. As a variety, there are parts of the Bjeluha deposit with several polymetallic sulphides. In Bjeluha, according to Pajović (1980), there are also *hydrothermal carbonate* or *carbonate-quartz veins* with *sulphides* in the form of rare dispersions and nests.

Jasenice - No. 30, near to the Albanian border is an small pyrite deposit.

Međeđak - No 31. Several *iron hats* were identified in schists, as skeletons with porose *limonite* and *quartz*, as well as with relicts of *limonitised pyrite* (Vujanović, 1952).

Mali Žar - No 32. According to Vujanović (1952), at Mali Žar **(No 32)** locality, there is a 20 cm-thick *pyrite* bed with a little *chalcopyrite* and a very little *sphalerite* (without exolution *of chalcopyrite*), and with *quartz* gangue.

Bijeli Potok - No 33. It is the most important ore occurrence on the eastern part of the Mt. Visitor. Mineralization is located inside 400 m thick, Lower Triassic series consisting of quartz-conglomerates, quartz-sandstones, quartzites, quartz-sericite, chlorite-sericite and sericite schists (Đokić et al., 1976). Ore occurs as a) pyrite impregnations with *sphalerite, chalcopyrite, tetraedrite* and *galena*; b) *pyrite* impregnations with a little of *chalcopyrite*; c) *pyrite* impregnations with very small quantites of *galena* + *sphalerite*. Some ore samples gave 16.5 g/t Ag and 1.5 g/t Au. Tetrahedrite veins have 13-1000 g/t Ag, 350-450 g/t Cu and cca 1% Zn. Additionally, some samples gave 680 g/t Bi.

Kukića Bor and **Memina Mt. - No 34.** According to Vujanović (1952) in this deposit two types of ore were revealed: a) *pyrite* veins in calcschist with a little of *pyrrhotite*, b) *bornite* veins (>10 cm thick) with *chalcpyrite* grains or plages and rarely with rombic *chalcocite, covellite* and *malachite*. Ore contains up to 18 g/t Ag, 1400 g/t Cu and 1.5 g/t Au. Ore reserves are very small (Đokić and Živaljević, 1967).

Critical look back at last results of investigations and unsolved scientific problems with discussion

1) Parageneses of pyrite (± pyrrhotite) deposits with some Cu-, Zn-, Pb-, and Fe-sulphides

Pyrite is dominant mineral (up to 90% of ore mass). Pyrrhotite is usually subordinate, being more abundant in Lješnica (No. 3), Gornja Ržanica (No 27), Mali Žar (No 19) and in skarn Lećevište (Laćevište) (No 6). Chalcopyrite is present in all ore occurrences. Beside it Cu-Sb tetrahedrite bearing Au and Ag occurs locally and in Kukića Bor (No 34) there are also bornite and chalcocite. Three types of chalcopyrite can be distinguished: chalcopyrite without exsolutions (mesothermal type), chalcopyrite with exsolutions of sphalerite ± pyrrhotite (meso-katathermal type) and chalcopyrite occuring as fine exsolution in sphalerite and pyrrhotite grains (katathermal type). Among other sulphide sphalerite is the most frequent, galena is more subordinate and arsenopyrite is rare. Deposits having more pyrrhotite contain «bird eyes» structure of secondary pyrite and markasite. Additionally, in skarn Lećevište (Laćevište) (No 6) occur very subordinate chalcopyrrhotite, bournonite, valeriite, cinnabar and typical silicate skarn minerals, among which the most significant are pyroxene, garnet and epidote.

It should be pointed out that copper is typical element of Hercynian, Upper Paleozoic metallogenic epoch. This has been proven by numerous copper deposits being associated with Upper Paleozoic strata in Dinarides. The examples of such deposits are: a) Upper Carboniferous siderite deposits with chalcopyrite in Jesenice and in Vitanje in Slovenia, (Drovenik et al., 1980); b) Upper Perm «red bed» deposits of chalcopyrite and bornite in Škofja (Drovenik et al., 1980); c) Permian siderite deposits with chalcopyrite in Rude in the vicinity of Samobor (Šinkovec, 1971); d) Carboniferous-Permian quartz-siderite occurrences with chalcopyrite in Pecka in Petrova Gora (Jurković, 1958); e) Carboniferous quartz-siderite deposits with chalcopyrite in Gradski Potok in Trgovska Gora (Jurković, 1989); f) Middle-Upper Carboniferous siderite deposits with chalcopyrite in Sinjakovo in Jajce (Vasiljević, 1972); g) Upper Devonian Au-Ag-Hg tetrahedrite deposits in Kreševo and Gornji Vakuf (Jurković, 1957); h) Upper Permian «red bed» deposits of chalcopyrite and chalcocite in Ustiprače, Southeastern Bosnia (Kulenović, 1987).

The permanent presence of chalcopyrite in all polymetallic sulphide occurrences associated with Lower-Middle Permian strata of northeastern Montenegro, and additionally local occurence of Cu-Sb tetrahedrite, bournonite, bornite, chalcopyrrhotite, chalcocite and valeriite is an important indicator of Upper Paleozoic age of this deposits.

2) Morphology of polymetallic sulphide occurrences in northeastern Montenegro

Most authors neither studied systematically the forms of the polymetallic sulphide occurrence nor worked out the systematics of morphological types. Dubak (1980) studying the deposits in Konjusi (Konjuhe) (SW from Andrijevice) was first who noticed the difference between the pyrite deposits in Upper Paleozoic (Pz_2) and Lower Werfenian clastites, which are layered or lensed and inserted concordantly into surrounding rocks composed of pyrrhotite irregular stockwork occurrences in skarns of Upper Verfenian limestones (T_1^2) and Anisian limestones (T_2^1). The first systematics of ore occurrences has been published by Pajović (1980) which is here presented in simplified form: 1. stratiform deposits including: a) massive lensed and layered bodies of pyrite or pyrite and pyrrhotite with subordinate Fe-, Cu-, Zn- and Pb-sulphides and b) impregnations, singenetic layered veins and stockworks associated with definite stratigraphic horizons of quartz conglomerates and coarse sandstones or packages of sandstones and schists; 2. diagonal hydrothermal pyrite veins with subordinated polymetallic sulphide; 3. pyroxene skarns mit polysulphides (Lećevište (Laćevište), No 6).

Such division seems to be correct except for the 1b) deposits, which present the classical stratabound type of deposits originated most likely by regional metamorphosis of remobilisated primary stratiform deposits.

3) Chemical composition of ore

Polymetallic sulphide ore in Paleozoic strata in northeastern Montenegro may be regarded as pyrite ore and as ore of nonferrous metals (Cu, Zn and Pb). Impregnation- and vein types of pyrite ore are economically worthless. The content of pyrite in massive ore type is very high (90-95% of ore mass) but the ore bodies are very small, so they are out of bilance. The biggest ore body is Bjeluha (No 29) with dimensions 100 x 2 m. More significant are great Triassic deposits in Montenegro, such as Šuplja stijena, Brskovo, Žuta Prla and others having considerable reserves of pyrite ore.

Considering nonferrous metals, primary chemical criterion is the content of copper, zinc and lead in terms of percentage. The most data are collected in ore area Bijelo Polje (Živaljević, 1974) in fact in Lješnica deposit (No 3), whose ore contained up to 2.25 % Pb, up to 1.25 % Zn, up to 0.14 % Cu, up to 15 g/t Ag and trace of Au. In deposit Orahovački greben (No 3a) ore grade up to 1 % Zn, up to 0.43 % Pb and up to 0.085 % Cu. In the ore of deposit Barički Potok (No 3b) it was estimated up to 0.354 % Pb, up to 0.824 % Cu and 0.351 % Zn. The ore of deposite Majna Gora consisted up to 0.24 % Pb, up to 0.02 % Cu and up to 0.58 % Zn. In the deposit Zmajevac (No 4) it was found up to 3.71 % Pb, up to 1.18 % Zn, up to 0.08 % Cu and up to 20 ppm Hg. In the ore occurrence Lipnica (No 5) it was up to 0.06 % Cu, up to 0.57 % Zn and up to 0.04 % Pb. In the occurrence Klisura (No 7) it was found up to 0.35 % Pb, up to 3.44 % Zn and up to 0.044 % Cu. The ore occurrence (Boljanina) Boljanica (No 8) consisted of 0.12 % Pb, up to 0.36 % Zn and up to 0.044 % Cu.

Đokić et al. (1976) gave partial data from the deposits at the eastern side of mountain Visitor. Their ore contained up to 1.83 % Zn, less than 1 % Pb, up to 0.56 % Cu, up to 1.5 g/t Au, and up to 16.5 g/t Ag. In the deposits with tetrahedrite as main sulphide mineral it was found up to 100 g/t Ag. The most interesant data are from the localities Zmajevac, Klisura and Visitor. All other ore occurrences are less worth or are out of bilance. The deposits having increased content of Au-Ag tetrahedrite may have locally economical significance.

4) Isotope composition of sulphide sulphur

Pajović et al. (1982) have been published isotopic sulphur values of 75 samples of polymetallic suphides. From these, 23 samples were from ore deposits located in Paleozoic strata and 52 samples from Triassic ore deposits. The sulphur isotopic analyses have been performed in Ljubljana by Pezdič et al. (1981) on galena (49 samples), pyrite (23 samples), pyrrhotite (2 samples) and sphalerite (1 sample).

The results of isotopic measurement shown in Table1 indicate that $\delta^{34}S$ values in all 75 sample from deposits located in Paleozoic and Triassic rocks range within a -4.52 to +5.91 ‰ interval, with mean value close to +1.52 ‰.

The sulphur isotopic analyses have revealed that the **sulphur is of endogene origin** and that during the migration the isotopic values remained homogeneous. The enrichment of heavy sulphur isotope in all ore occurrences on the mountains Ljubišnja and Visitor and in the deposit Bjeluhi explained Pajović et al. (1982) by activity of high-temperature hydrothermal solutions. They explain two different sulphur isotopic values in Velička rijeka by different sulphur sources.

The most likely interpretation is that **sulphur and metals** of all Upper Paleozoic and Triassic polymetalic sulphide deposits of NE Montenegro **originate from unique deep magma source** giving three pulse of magma which have formed pyrite ± pyrrhotite ± Cu, Zn, Pb sulphide deposits. for conventional technologies.

Table 1 Isotopic composition of sulphides

Tablica 1. *Izotopni sastav sulfida*

Geological time	Ore deposit	Mineral	Number of minerals	$\delta^{34}S$ ‰
Ore deposits from Paleozoic strata	Lješnica (No 3)	galena	3	-1.86
		pyrite	1	-0.70
	Uskočki potok (No 10)	galena	2	-1.24
		pyrite	1	-0.85
	Konjusi (Konjuhe) (No18-21)	galena	3	-1.80
		pyrite	3	-0.70
	Visitor (No24-27,30-34)	galena	9	+3.38
		pyrite	9	+4.04
	Velička rijeka (No 28)	galena	1	-4.92
		galena	1	+2.58
	Bjeluha (No 29)	galena	2	+4.18
Triassic ore deposits	planina Ljubišnja	galena	11	+4.41
		pyrite	3	
	planina Mataruge	galena	2	-0.32
	planina Bjelasica	galena	13	-0.32
		pyrite	4	
	planina Sjekirica	galena	2	+0.42
		pyrite	2	+0.99
		sphalerite	1	+0.45

5) Isotopic composition of lead in galenas

Pajović et al. (1982) have published isotopic lead values (Pb^{204}, Pb^{206}, Pb^{207} and Pb^{208}) in 48 galena samples. The isotopic analyses were made in Ljubljana by Pezdič et al. (1981). The overview of those 17 samples belonging to the deposits described in this work is given in Table 2.

Table 2. Isotopic composition of lead in galenas

Tablica 2. *Izotopni sastav olova u galenitima*

Geological time	Ore deposit	Number of samples	Pb^{204} (%)	Pb^{206} (%)
$P_{1,2}$	Uskočki potok (No 10)	3	1.330 – 1.383	52.25-52.59
$P_{1,2}$	Lješnica (No 3)	3		
$P_{1,2}$, T_1^1, T_1^2	Konjusi (Konjuhe) (No 18-23)	3		
$P_{1,2}$, T_1^1, T_1^2	Visitor (No 24-27, 30-34)	4		
C-P	Velička rijeka (No 28)	2		
C, P	Bjeluha (No 29)	2		

Isotope Pb^{204} ranges from 1.330 % to 1.383 % (average 1.362 %). The values are higher than those of Tertiary Pb-Zn deposits. Very similar Pb^{204} values in all deposits of northeastern Montenegro indicate **isogenetic character of the lead**. Only the lead of deposit Kozica differs stronger from others, what Pajović et al. (1982) have interpretated by the presence of rhyolite, unique magmatic occurrence in Montenegro.

Values of isotope Pb^{206} are between 52.25 % and 52.59 %. The studying of Pb^{204} to Pb^{206}/Pb^{204} ratio and Pb^{204} to $Pb^{208}/^{204}$ ratio has revealed that the oldest ore occurence is Kolijevka situated in the T_2^1 strata, whereas the youngest ore occurrence is Kozica laying in T_2^1 strata and the youngest deposit is Uskočki Potok (No 10) occurring in $P_{1,2}$ strata (Pajović et al., 1982). The mentionated lead ratios indicate that all polymetallic sulphide deposits of northeastern Montenegro are Middle Triassic. Such conslusion conflicts with Pajović's opinion (1980) who announced that remarkable number of ore deposits located in the Upper Paleozoic rocks are stratiform and consequentially of Upper Paleozoic age. In a similiar manner Dubak (1980) regarded pyrite massive ore deposits of Konjuh laying in Carboniferous-Permian deposits as syngenetic one.

Pezdić et al. (1981) have calculated for all these sulphide ore deposits the age ranging from 330 Ma (Serpukhovian) to 250 Ma (the border T_1^1/P_3 using Holmes-Houteromans model). Pajović et al. (1982) regarded this values as something higher and contradictory in the terms of geological fact.

The problem might be resolved on the assumption that unique magma existed in the depth in the time from 280 Ma (P_1 – Sakmarian) to 230 Ma (T_2^1 – Ladinian) which is characterized by the paleontological evidences. The magma evolution would comprise three temporal separated phases. The initial phase of magmatism starting in Lower–Middle Permian ($P_{1,2}$) would be relatively weak and followed by stronger magma reactivation in Lower and Upper part of Werfenian (T_1^1 and T_1^2). Finally the most intensive magmatic pulse would occur in Middle Triassic (T_2^1 and T_2^2). Such theory is supported by very similar isotope composition of sulphide sulphur and isogenetic character of the Pb^{204} isotope.

In the neighbouring Middle Bosnia (MBSM – Mid-Bosnian Schist Mts.) existed similar thermal activity giving in Bradina: diabase of Lower Permian age (P_1–Asselian; 287,8 Ma), orthogreenschist of Lower Permian age (P_1-Sakmarian-Artinskian; 268,7 Ma), orthogreenschist of Upper Permian age (P_3-Upper Permian; 247,0 Ma) and metadiabase of Middle Triassic age (T_2^2 – Ladinian; 238,4 Ma) (Pamić et al., 2004).

6) Stratigraphical position of polymetallic sulphide occurrences

Stratigraphical positions of polymetallic sulphide occurrences have been published on the geological map of NE Montenegro (1: 100 000) and commented on the basis of data known in the time of map production in the corresponding map interpreters. On the geological map sheet Pljevlja (Mirković and Pajović, 1980) ore occurrence Sočice (No 1) occurs in D,C deposits and ore occurrence Lisičani (No 2) in P, T deposits (Fig. 2, Fig. 3). All ore occurrences from No 3 to No 8 on the geological map sheet Bijelo Polje (Živaljević et al., 1980) are situated in C, P deposits. On the geological map sheet Ivangrad (Berane) (Živaljević et al., 1982) all ore occurrences in the Mojkovac area (No 9 - No 12), shown in Fig. 5, and all ore occurrences west of Ivangrad (Berane) (No 13 – No 17), shown in Fig. 6, are located in $P_{1,2}$ deposits.

On the same sheet Ivangrad (Berane), in the area Konjusi (Konjuhe) (Fig. 7) ore occurences No 18 and No 19 are situated in C,P deposits, the ore occurrences No 20 and No 21 in T_1^1 deposits and the ore occurrences No 22 and No 23 in T_1^2 deposits, subordinately in T_2^1 deposits. On the geological map sheet Gusinje (Đokić et al., 1976) the ore occurrences No 24 and No 30 occur in D,C deposits, the ore occurrences No 31, No 32, No 33 and No 34 in T_1^1 and T_1^2 deposits (Fig. 8)

Pajović et al. (1982) have published for some ore deposits modified geological profiles drawn by Kalezić. In the area of Bijelo Polje they put the ore occurrences into the Permian deposits with keratophyre and diorite; in the profile Konjusi (Konjuhe) they drew ore occurrences in Permian and in T_1^1 i T_1^2 deposits. In the area Visitor (Nos 24-27 and 30-34) they located ore occurrences in P, T_1^1, T_1^2 i T_2^1 and those occurring in area of Velička Rijeka and Bjeluha in C-P deposits. They relocated the ore deposits Malinovački Potok (No 18) and Bradavec Potok (No 19) from Upper Paleozoic (C,P) deposits into Permian (P) deposits. In the Fig. 7 they are marked as $P_{1,2}$ deposits.

Pajović et al. (1982) noticed that the geological map sheet Gusinje (Đokić et al., 1976) does not contain Permian deposits. This is in contrast with the neighbouring sheets Ivangrad (Berane) and Rožaje. Up to now the conodonts from Upper Devonian (D_3) and Lower Carboniferous (C_1) (Mirković, 1984) and from Ordovician-Silurian (?) (Đurđanović, 1973) have been determinated on the sheet Gusinje. In Paleozoic of Prokletija Middle Devonian (D_2) has been proved (Kostić & Pantić, 1972). Although there is no Permian on the sheet Gusinje Pajović et al. (1982) have put the ore occurrences Velička Rijeka (No 28) and Bjeluha (No 29) into Carboniferous-Permian (C-P), no into the Devonian-Carboniferous (D,C). This is accepted in the Fig. 8.

On the basis of the discussion in 1988 that author of this article had with the geologist A. Ramovš from Ljubljana, who led the IGCP project „Paleozoic in Dinarides“ in this time, it is concluded that the Permian-Triassic deposits (P,T?) on the geological map sheet Pljevlje are actually $P_{1,2}$ deposits (Fig. 3).

Detailed study of the geological map sheets Pljevlje, Bijelo Polje and Ivangrad (Berane) shows that ore occurrences are present only in those parts of Upper Paleozoic deposits where appear numerous intercalations of quartz conglomerates and coarse grained sandstones (Pco), then recrystallized limestone lenses (Pcl), locally magmatites and, what the most important is, fossils from $P_{1,2}$ (Sakmarian-Artinnskian) deposits in the series of sandstones – schists deposits. It is noticed that there is no ore occurrences in C_2 and C_3 deposits.

The Asturian orogeny, late in Carboniferous, between the Westphalian and Stephanian stages, were determinated with certainty in the investigated area. Mirković (1988) noticed the olistostromes and the olistolithes on the basis of discovered biofacies of different age ranging from Cambrian to Middle Permian on the northern slope of the Mt. Bjelasica.

The olistolithes are formed in the phases of abrupt tectonical movements who caused seismogravitational rockfalls. They are the expression of the consolidation phase in tectonogenesis. The olistostromes of Asturian orogeny are described in Jadar (NW Serbia), Javorje (western Serbia) and in Prača and Vlasenica (SE Bosnia) by Pešić (1980, 1982), Krstić et al. (1988) and Filipović & Jovanović (1994).

If the thesis that Fe occurrences with Cu, Zn, Pb sulphides of NE Montenegro have been derived from the unique deep magma is correct, then the ore occurrences located in Lower-Upper Permian deposits are associated with early rift magmatism and not with Triassic late rift magmatism.

Conclusions

1. All polymetallic sulphide ore deposits of NE Montenegro being located in Lower-Middle Permian, Lower Triassic and Middle Triassic sedimentary and magmatic rocks are genetically associated with **unique deep magma** and its subvolcanic differenciates (Fig. 9). Three evidences support this statement. The first and the most important evidence is **isogenetic character of lead in 48 galena samples** in ore deposits of Mt. Ljubišnja, Mt. Bjelasica, Mt. Sjekirica and Mt. Visitor being found in all three stratigraphical horizons ($P_{1,2}$, T_1^1, T_1^2, T_2^1, T_2^2). Isotope Pb^{204} ranges from 1.330 % to 1.383 % (average 1.362 %). The second evidence is **endogene origin of sulphide sulphur** being determinated in 75 isotopic analyses (45 galena samples, 23 pyrite samples, 2 pyrrhotite samples and 1 sphalerite sample). The $\delta^{34}S$ values range within a -4.52 to +5.91 ‰ interval, with mean value close to +1.52 ‰. The ranges of values are very similar in all three orehosting stratigraphical horizons pointing clearly to the same magmatic origin. The third evidence is characteristical change of trend in the content of nonferrous metals (Cu, Zn, Pb) being typical for Dinarides. This is marked by the permanent presence of Cu-bearing minerals with changeable presence of subordinate Zn and Pb in Upper Paleozoic deposits. In Lower Triassic deposits the content of Cu decreses, but the content of Pb and specially of Zn increases in ore deposits. The maximal values of Zn- and specially of Pb content are typical for Middle Triassic.

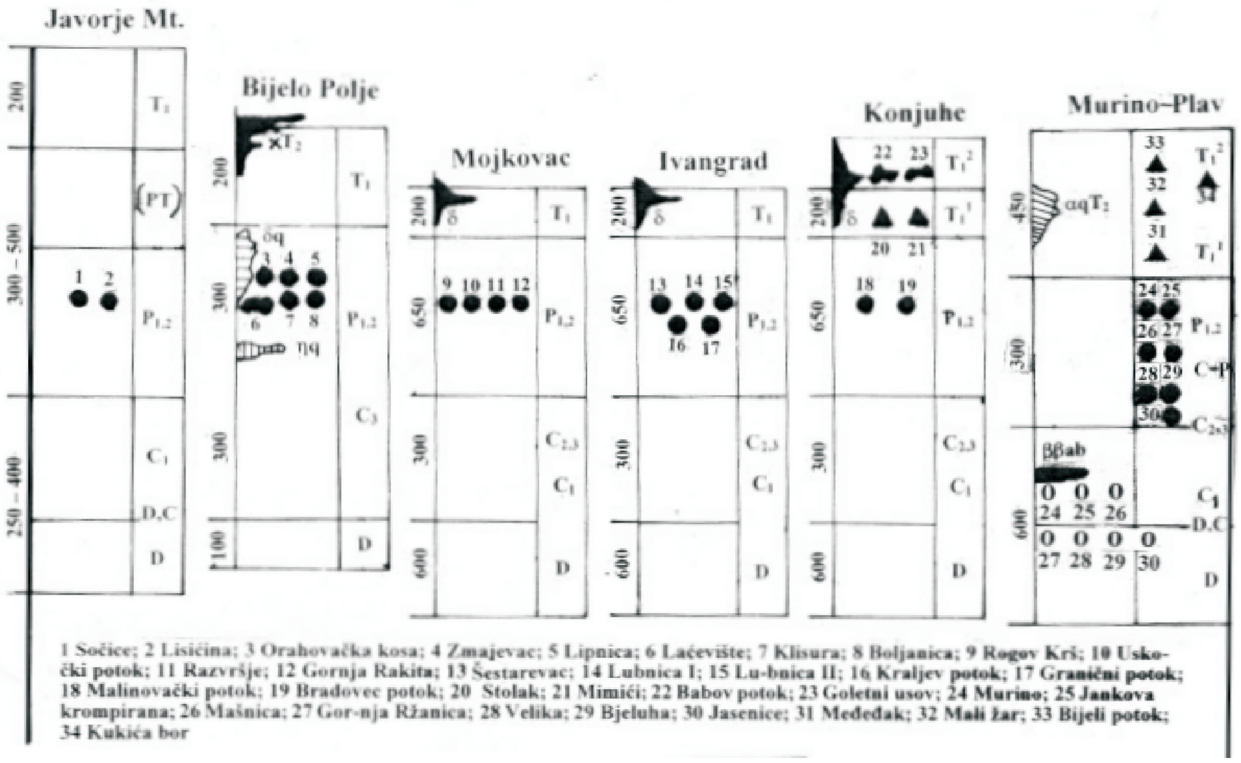

Figure 9 Age of the sulphide ore occurrences in the stratigraphic column of the NE Montenegro (according I. Jurković)

Slika 9. *Starost sulfidnih rudnih pojava u stratigrafskom stupu sjeveroistočne Crne Gore prema I. Jurković*

2. Based on the fossil evidences of few localities in the Mojkovac area the first early rifting process took place in Lower Permian (P_1-Sakmarian) and on the boarder to Lower part of Middle Permian (P_2-Artinskian). In this time, between 280 Ma and 265 Ma, the first relatively weak pulse of magma resulted in an eruption on the seafloor followed by hydrothermal activity and origin of SEDEX type of stratiform and stratabound deposits. These events were preceded by Asturian orogeny phase being determinated by discovery of olistostromes and olistolithes in Upper Carboniferous in Western and Northwestern Serbia, Eastern and Southestern Bosnia and in Mt. Bjelasica in Northestern Montenegro.

During the later stage of rift magmatism more important magma pulses tooking place in Lower and Middle Triassic gave medium-sized lead-zinc ore deposits. Finally the most intensive magmatic pulse occured in Middle Triassic (T_2^1 and T_2^2).

Upper Paleozoic polymetallic sulphide ore deposits present insignificant part of total ore deposits in Montenegro.

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