Advances in Regional Geological and Metallogenic Studies in the Carpathians, Balkans, Rhodope Massif and Caucasus (Romania, Serbia, Bulgaria and Georgia)

A field conference

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FIELD GUIDE

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Content

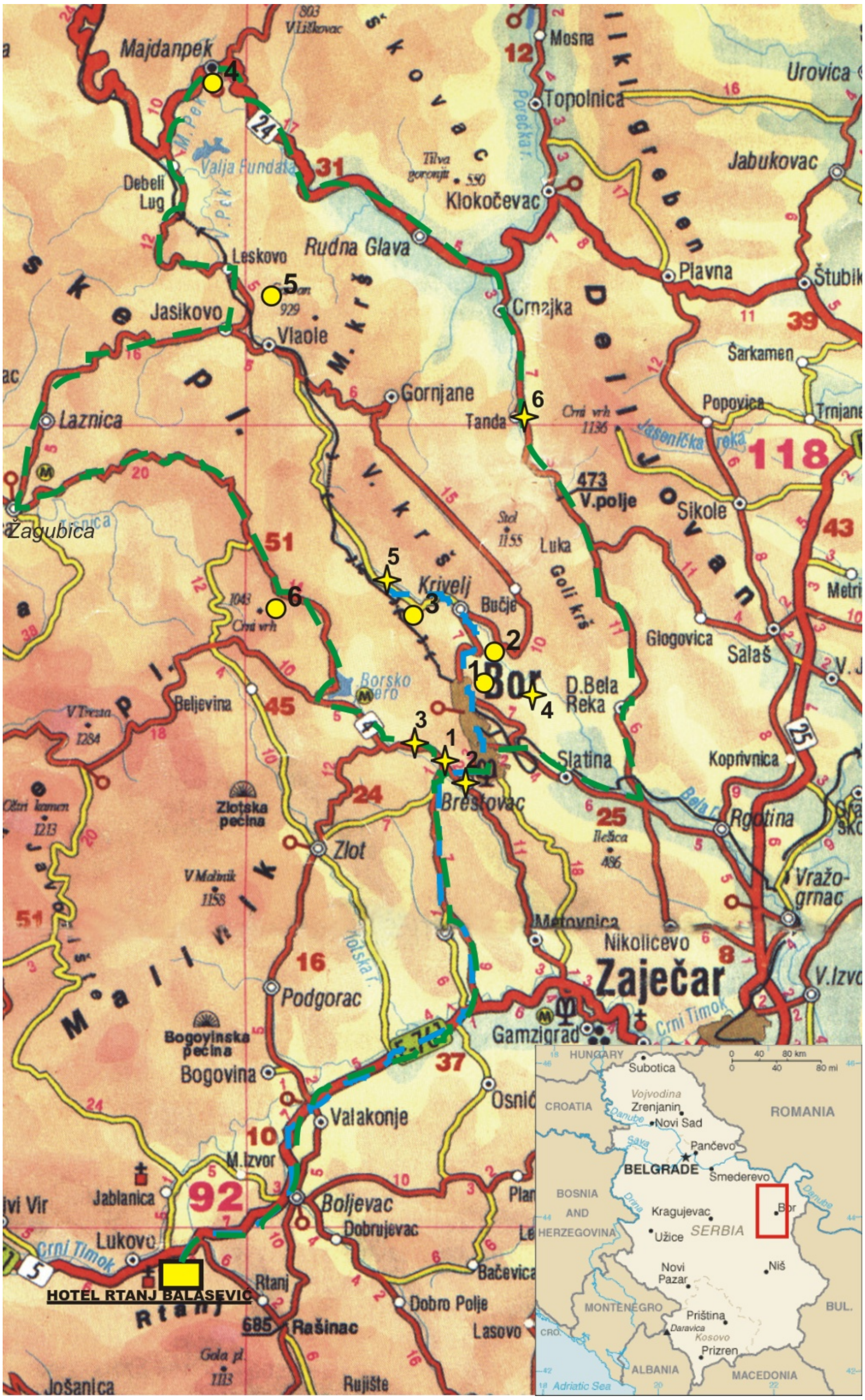

Figure 1. Geographic/road map of Eastern Serbia with with field trip observation points (field stops). Red numbers along the roads mark length of the roads in km.

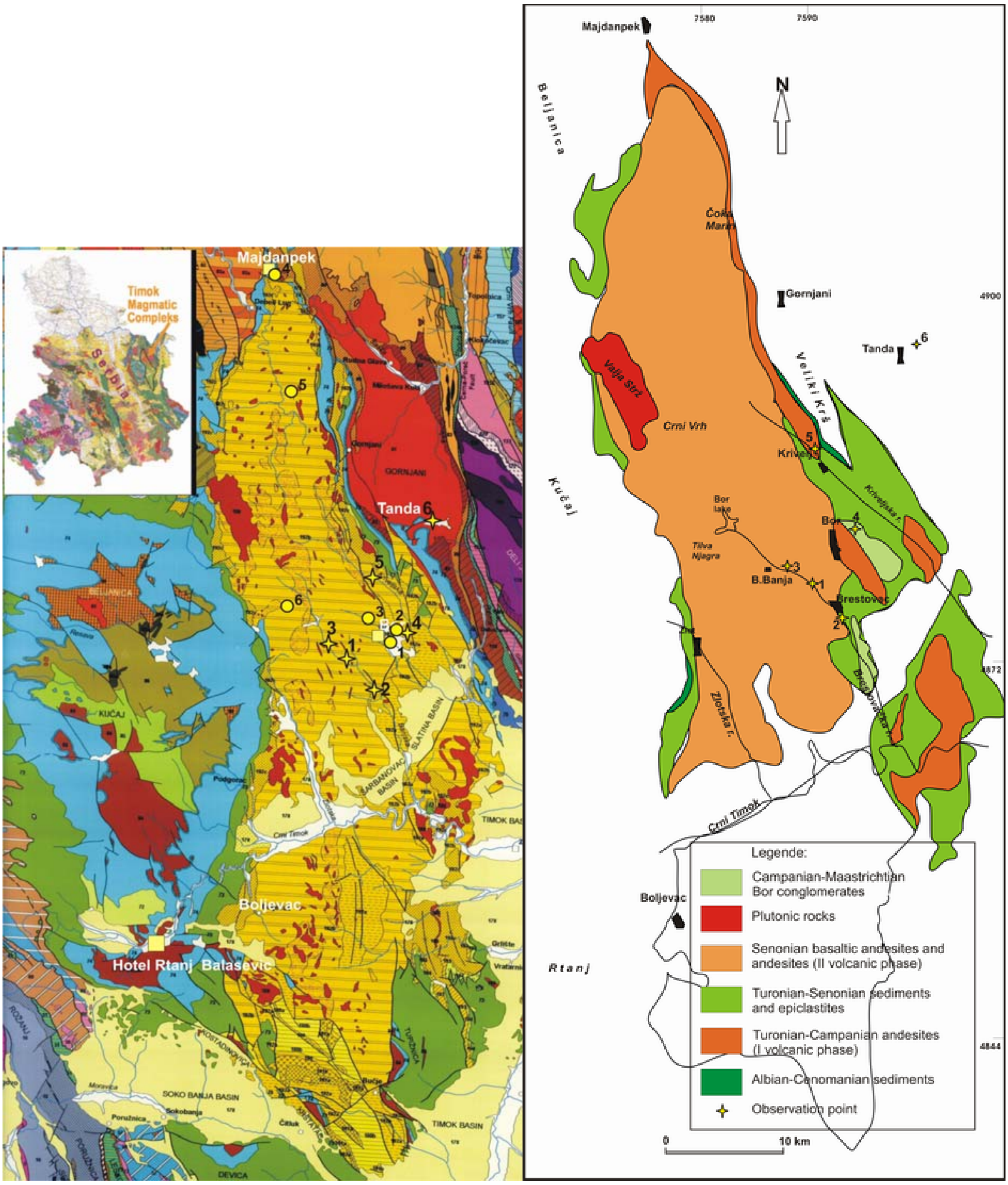

Figure 2. Geological map of the part of Carpatho-Balkanides (modified after Krautner and Krstić, 2003). Sketch of the geological map of the TMC with field trip observation points (field stops).

PLAN OF THE ROUTES

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- 1 The Bor deposit (panorama view)
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- 3 The Mali Krivelj-Cerovo ore field
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- 6 Granitoid of Gornjane, road cut toward Majdanpek near the Tanda village
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- 3 Road cut southeastward from Brestovačka Banja

Note: It is not possible to visite all ore deposits from the list. Which deposits will be observed will depand of actual conditions at the deposits (mining works, local road, weather conditions, etc.).

INTRODUCTION

The Bor-Srednjegorie metallogenic zone extends from Lilieci-Linbcova and Bozovici in the north (Romania), over Bor (Serbia) to Burgas (Bulgaria), proceeding into Black sea and Tracia in Turkey. It is over 600 km long, and from 0.5 km in the north, to 80 km wide in its eastern sector.

At the teritory of the Serbia the Bor-Srednegorie metallogenic zone (Bor metallogenic zone *senso stricto*) is associated with a rift-greben environment, where volcano-intrusive complexes are developed, but the polygenic volcanics of central type development prevail.

Geological setting

The Bor-Srednjegorie metallogenic zone is related with a subduction-setting, resulted from subduction of the Jurassic oceanic crust beneath the Eurasian plate, following the closure of Neothetys.

While the concept of subduction of the Jurassic oceanic crust is, more or less, generally accepted, a distinct disagrement arises on the direction of subduction. Some geologists (Radulescu, Sanulescu, 1973; Herz, Savu, 1974) assumed that in the domain of South Carpathions and the Transilvanian basin, oceanic crusts subducted westwards. Bogdanov (1977) suggested southwards movement of the basaltic layer, from the Moesian platform, beneath the Srednegorie. On the other hand, many geologists related the Upper Cretaceous +/- Paleocene igneous activity in the Bor-Srednegorie zone with subduction resulting from the consumption of oceanic slab of the Vardar zone (Dewey et al., 1973; Boccaletti et al., 1974; Janković et al., 1974, 19771, 1977b; Aiello et al., 1977; Hsu et al., 1977; Boyadziev, 1979; Nachev, 1993).

The westward subduction of oceanic crust, folowing the closure of the western basin is possible in the domain of the Apuseni Mts, northwards of the ophiolites of the Drocea Mts, but the volcano-plutonic complexes and ore deposits of the Bor-Srednegorie metallogenic zones are more likely associated with eastward subduction from the Vardar zone, and northward subduction from the Aegean-Izmir zone.

Magmato-tectonic features

The Bor-Srednegorie metallogenic zone and related ore deposits associate with the Upper Cretaceous +/- Paleocene multistage igneous complexes, and located within a narrow basin of rift-graben structure, filled by sedimentary and volcano-sedimentary rocks, mainly of the Upper Cretaceous age. This basin is, at present, 0.5-80 km wide and over 600 km long. It can be traced from Majdanpek in the north, to the Black sea in the east. The ore mineralization northwards of Majdanpek is related to a regional dislocation which reaches into southermost part of Banat (the area of Lilieci-Lubcova), while in the area of Srednegorie, the basin continues into Black sea.

In the Bor metallogenic zone *senso stricto*, the volcano-intrusive complexes are represented by the volcanic, volcano-sedimentary and plutonic rocks. They derived from subcrustal, contaminated magma(s) - Karamata, Djordjević (1980). The $^{87}Sr/^{86}Sr$

ratios range from 0.707 to 0.712 %o. The calc-alkaline series is prevalent with respect to tholeitic rocks.

The volcanic rocks formed within three stages during Upper Cretaceous. They are of andesitic composition, whilest dacite occurs sporadically. The plutonic granitoids belong to the composite complexes (from gabbro to diorite, monzonite and granodiorite). The Upper Cretaceous volcano-sedimentary formation spreads over the whole sector, proceeding into Srednegorie.

The igneous activity lasted from 105 my through 65 my, but locally up to 60 my (Janković et al., 1998).

Associations of the elements

The associations of the elements concentrated in the ore deposits is a specific metallogenic feature of the Bor-Srednegorie zones. The major and trace elements are:

- Major elements: Cu, Au, Mo, Fe (Py) +/- Pb-Zn
- Trace elements (recoverable): Se, PGE, Ag, Cd
- Trace elements (unrecoverable): W, Sn, Bi, Sb, As, (Ba)

The principal associations of elements are classified as follows:

- Cu, Au, Mo +/- Ag, PGE (porphyry copper)
- Cu, Pb/Zn, Fe (Py), Au/Ag +/- Se, Bi, Sb (massive sulphide)
- Cu, Au, Fe (Py), As +/- W, Sn, Se, Sb (cupriferous massive sulphide/replacement)
- Fe-S (masive pyrite)
- Cu, Fe(Py) +/- Mo, Bi, W (skarn)

The longitudinal zoning of the distribution of associations of elements can be displayed as follows (from north to south and southeast-east):

- Majdanpek: Cu, Mo, Au/Ag, Fe (Py) +/- PGE, Pb/Zn (porphyry)
- Coka Marin: Cu, Pb-Zn, Fe (Py), Au/Ag (massive sulphide)
- Bor: Cu-Fe (Py), Au, As +/- Se, Sb, W, Ag (massive sulphide)
  Cu-Au +/- Mo, Ag (porphyry copper)

Morphogenic types of the ore deposits

Although associated with predominantly calc-alkaline complexes, the ore deposits of the Bor metallogenic zone s.s., display some specific features. This is mostly due to different magmato-tectonic environments in which ore mineralization took place.

The copper and gold are the dominant metals; the base metal ores are sporadically of the economic significance. The copper deposits contain often high grade ore and significant tonnage.

The endogenous ore deposits of the Bor-Srednegorie metallogenic zone belong to volcanogenic, plutonic, and volcano-sedimentary groups.

The most prominent types of metallic mineral deposit of the Bor ore zone are (Jankovic, 1989; Jankovic, 1990a, 1990b):

- Porphyry copper deposits /PCD/. Subtypes:

- o PCD hosted by multistage composite plutonic granitoid complex /type: Valja Strž/,
- o PCD related to high-level dyke swarms above plutonic body /type: Veliki Krivelj, subtype: Cerovo-Cementacija/;
- o PCD associated with high sulphidation massive sulphides (subvolcanic type) /type: Bor- Borska reka/ and
- o PCD related to an initial rift fault structure /type: Majdanpek/);

- Hydrothermal cupriferous pyrite deposits of massive sulphide and stockwork-impregnation type of mineralization (type: Čoka Dulkan, Tilva Mika, etc.)
- Hydrothermal massive base-metal sulphide deposits (type: Tenka);
- Hydrothermal massive Cu-Pb-Zn-Au sulphide deposits (type: Čoka Marin);
- Hydrothermal vein deposits (Cu, Pb-Zn and Au) (type: Kraku Bugaresku);
- Skarn deposits (Fe-oxides, Pb-Zn, Cu) (type: Valja Saka, Potaj Čuka) and
- Epithermal gold deposits both of high and low sulphidation type (Kuruga, Zlaće, etc.).

Location map of the significant deposit of the Bor metallogenic zone is presented in Figure 1.

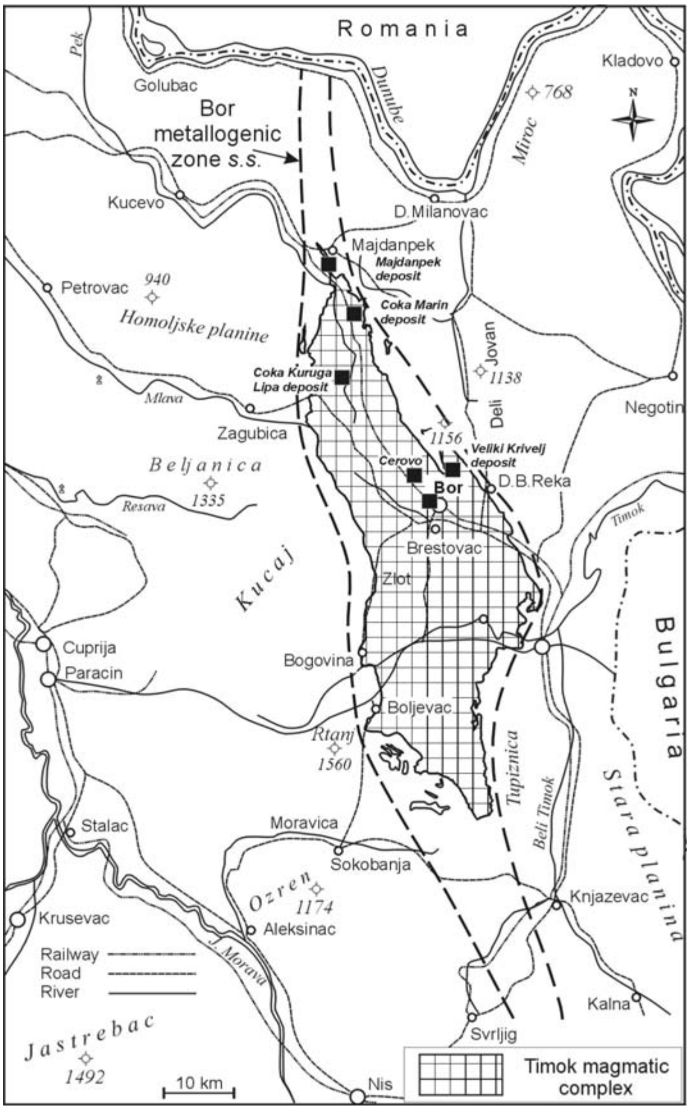


Figure 1. Location map of the significant ore deposits of the Bor metallogenic zone.

DESCRIPTIONS OF THE ORE DEPOSITS

Field stop 1 (Panorama view) : The Bor deposit

The Bor Cu-Au deposit was formed in upper-Cretaceous andesites in the form of a zone, whose length is about 5 km and width up to several hundred meters. It cosists of a large number of the orebodies which are grouped in the central part of the deposit, accompaied as by satellites by numerous smaller ore bodies (Fig. 1A, B). Those, this deposit belongs to the porphyry copper type of the deposit, associated with massive Cu-pyrite orebodies. Vertical interval of ore mineralization is very variable and the largest dimensions, by depth, reaches the group of Central ore bodies, over 2 000 m. Mineral potential of The Bor deposit, as a whole has been estimated as 7 millions tons of copper contained in the ore with cut off grade of 0.1 %Cu, and about 300 tons of gold, mainly bound to sulphides. However, majority of the deposit has been exploited (Fig. 1C).

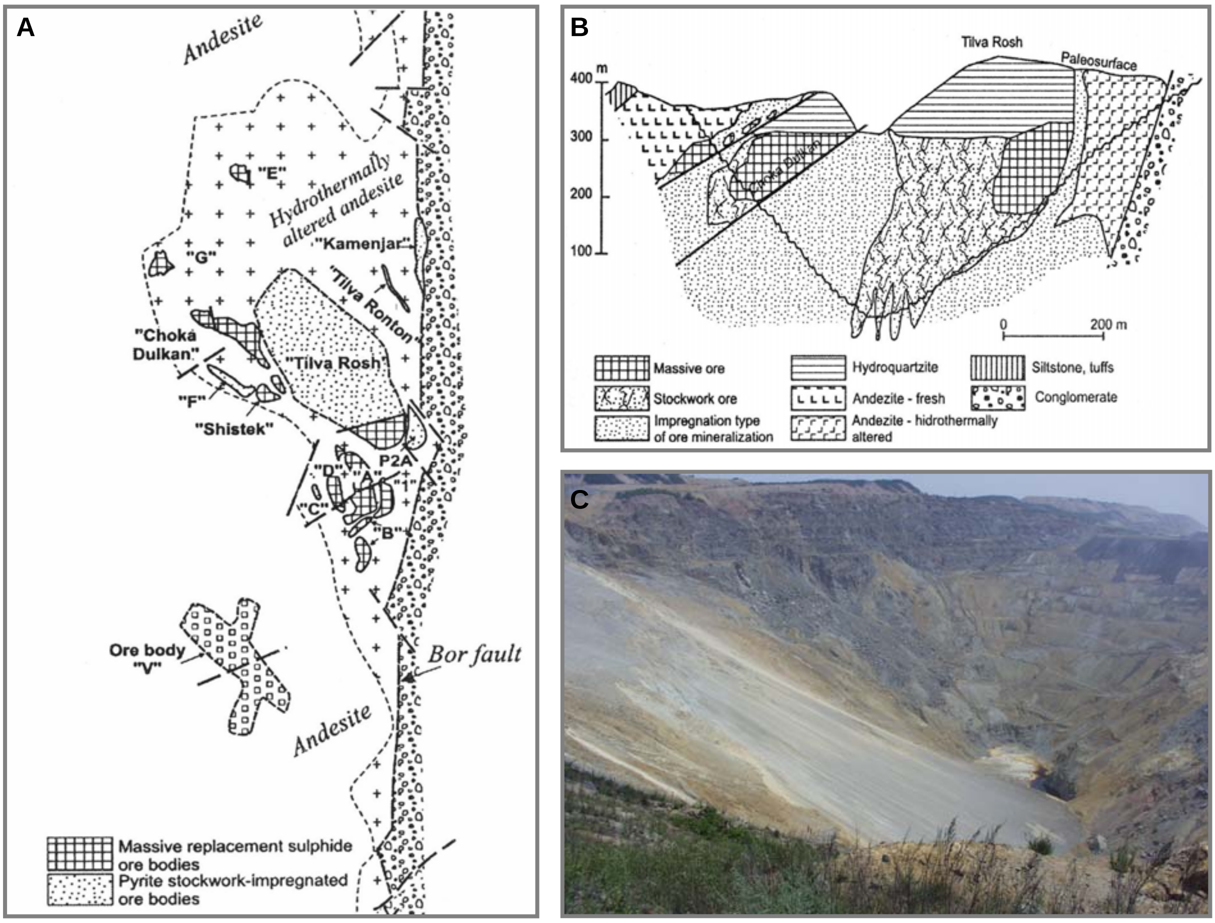


Figure 1. A. Schematic distribution of the ore bodies in the Bor deposit. **B.** Cross-section of the geological section through the central ore bodies of the Bor deposit. **C.** Open pit of the Bor deposit.

Shape and size of the orebodies: The most common morphostructural types of orebodies are pipes with elongated horizontal cross-section (iregularly cigar-shaped bodies, mineralization along fractured zones - vein-type /Fig. 2/, and disseminated mineralization in hydrothermal breccia. Strong post-ore movement displaced the orebodies.

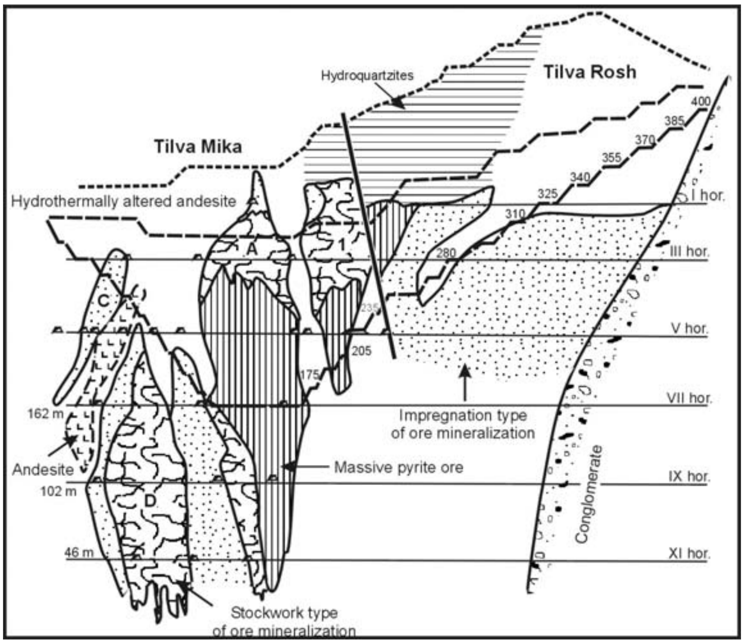


Figure 2. The Tilva Mika orebodies.

Mode of mineralization: The deposit consists of massive sulphide volcanogenic cupriferous pyrite mineralization and stockwork as well as stockwork-disseminated mineralization. Massive sulphide ore consists of high concentrations of fine-grained pyrite (often 60-70%) and copper minerals containing high contents of metal such chalcocite, covellite and enargite.

The rate of copper concentration in massive ore is often 3-6%, locally even higher, and 1-3 g/t gold.

Massive mineralization often grades, both laterally and vertically, particularly downwards, into a stockwork type where sulphides are confined to a fracture set irregularly developed in hydrothermally altered andesite. The concentrations of copper often displey a zonal pattern due to decreasing copper contents from the central part of orebody towars its margin (Fig. 2).

The disseminated type of mineralization is the most common one in the lower parts of the Central group of orebodies, with dominance of pyrite, bornite and chalcopyrite.

The distribution of mineralization types in the Central group of orebodies is characterized by a distinct zoning. Massive ore is confined into the upper parts of orebodies grading transitionally into stockwork, locally into disseminated mineralization. A system of subparallel thin veins, mostly 0,1-0,3 m wide, with or without disseminated mineralization, is developed in the lowermost part of some orebodies such as Tilva Roš. In some orebodies, such as Čoka Dulkan, massive ore is dominant troughout the orebody.

The size of major orebodies (Tilva Roš, Čoka Dulkan and Tilva Mika) varies, at different levels, between 2.000 m^2 and 130.000 m^2 (Tilva Roš). The vertical extension of massive sulphide mineralization is mostly 200-800 m, except in Tilva Roš where it exceeds 800 m.

Porphyry copper mineralization is related to hydrothermally altered hornblenda-biotite andesite intruded by quartz diorite porphyry dykes (Borska reka deposit, Fig. 3). The vertical extension of porphyry copper mineralization exceeds 1.400 m (beneath the massive sulphide mineralization).

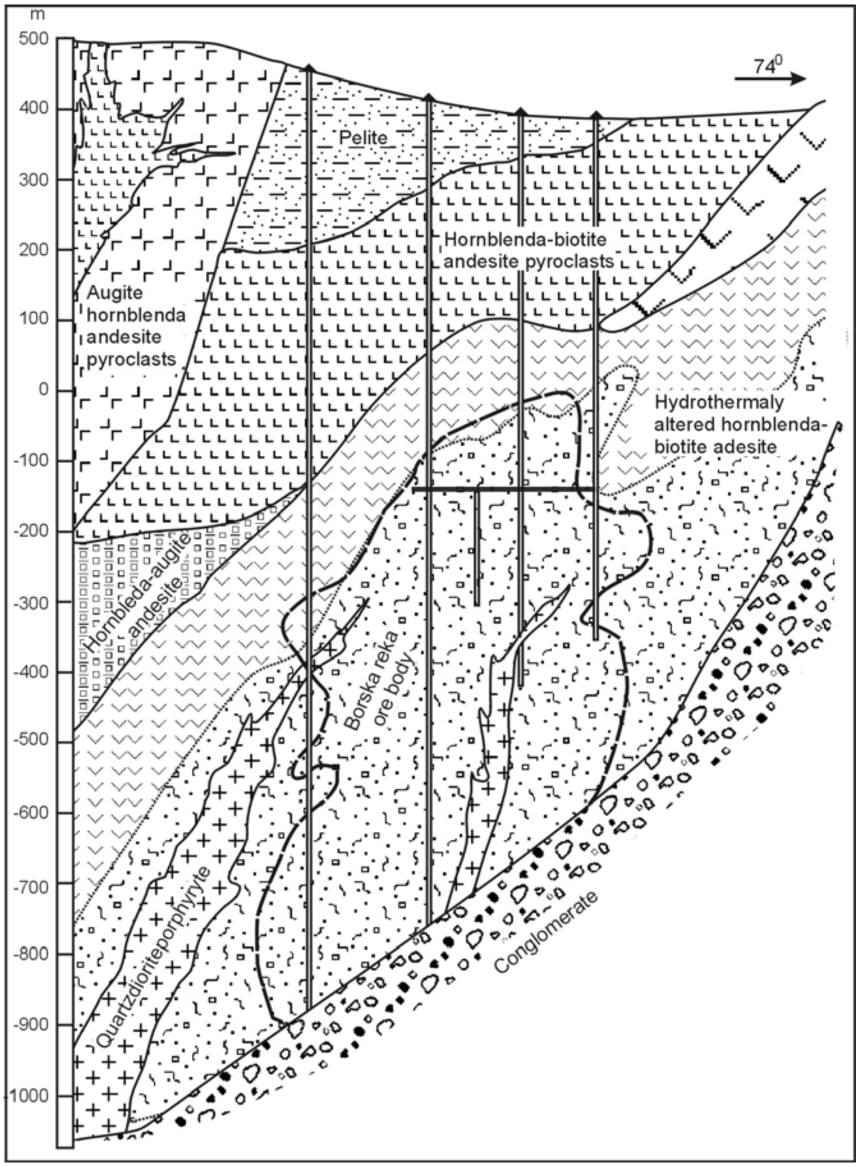


Figure 3. The Borska reka porphyry copper deposit.

The total reserves is 650 Mt: 0.61% copper, 8.5% sulphur, 0.25 g/t Au, 2 g/t Ag, 36 ppm Mo and 1.7% magnetite in the 0.3% Cu cut-off grade.

Porphyry mineralization reaches by its topmost levels to the depth of about 400 m below present terrain surface. Interval of ore mineralization along the dip exceeds 1400 m. The highest levels with copper-bearing mineralization are located below the lowest depth reached by exploration drilling so far. The length of mineralization, along the dip, has not been completely defined.

The Borska reka deposit belongs to the group of medium size volcanic-hydrothermal stockwork- metasomatic- impregnation (porphyry) copper deposits. The form is angled cone with the base towards NW. It strikes in the direction NW-SE with the dip towards south-west at the angle of 45-50. The length of ore body is 1410 m (level K-395) and width about 360 m in average.

Hydrothermal alteration - Mineralization is associated with potassium silicate alteration, and to a propylitic assemblage with widespread illite and chlorite. In the uppermost parts of the Borska Reka deposit advanced argillic alteration coupled with intense pervasive silicification, marking upwards grading into transition zone of above developed high sulphidation mineralization.

Geologic environment of occurrence of ore mineralization has been made of hydrothermally altered andesites and their pyroclastites. Deposit contours are mainly artificial and up to the level K-315 have been determined based on chemical assays. In this part of deposit, eastern boundary is almost vertical and western, hanging-wall side, very steep. Below the level K-315, deposit almost completely overthrusts Bor fault, i.e. Bor conglomerates. Deposit contours are defined towards the East and the North-West, while towards the West, they still remain open. Final drill-holes on profile towards the West, have penetrated ore mineralized intervals the thickness of which, in average, amounts to over 400 m. In that direction, deposit has not been explored to the end.

Fault structures in Borska reka deposit are most expressed structural forms. Special characteristic of tectonics is given by presence of marked dislocation of NW-SE strike, known as Bor fault, along which, volcanoclastites of first volcanic stage have been brought into contact with Bor conglomerates. The faults of strike E-W, which cross-cut Bor fault, are also observed. In deposit itself there are located numerous fractures and fissures, mainly filled with alteration products and sulphide minerals.

Mineral composition of porphyry copper mineralization is very complex: the main components are magnetite (1%), hematite, rutile, leucoxene, pyrrhotite, pyrite, chalcopyrite, bornite, molibdenite, covellite, chalcocite, digenite and petrogenic minerals. The most extensive are pyrite and chalcopyrite, subsidiary bornite, chalcocite and covellite, while other minerals (pyrrhotite) occur included in pyrite. Oxides of titanium and iron are accessory components of the host rocks. The minerals are fine-grains and simple grown. Pyrite and chalcopyrite are mostly coarse grained. In the uppermost part of the Borska Reka deposit small partches of massive sulphides were revealed by diamond drilling. The gangue minerals are quartz and widespread anhydrite, and minor calcite, sporadically barite as well.

Characteristic ore aggregates are: 1) with dominant pyrite and a) drop-like inclusions of chalcopyrite and pyrrhotite and b) chalcopyrite, c) chematized magnetite, d) rutile, e) covellite and 2) with dominant chalcopyrite and a) bornite and chematized magnetite, b) hematized magnetite. Most widely distributed structures of the ore minerals in the Borska reka deposit are metagrained, veinlet, allotriomorphous grained, cataclazes, cementative, corrosive and degradation of solid solutions.

Chalcopyrite is enriched in Au (from traces to 900 ppm – identified by microprobe), Se (50-800 ppm) and Ga (up to 1.000 ppm) – from Janković (1990).

Ore types - In the deposit Borska reka, the following basic types of ore have been observed: impregration-metasomatic, vein-fissures-fractures and nests.

Mode of mineralization - During formation of the Borska reka deposit, the several particular succession has been expressed in deposition of ore minerals. It is manifested by development of two basic stages with several phases and sub-phases of mineralization (Jelenkovic et al. 2002).

In the first, pre-ore stage, which has conditionally been called alteration, pyrite has been formed, accompanied by rutile. After that, it was formed the ore stage with the following dominant mineral associations: (1) pyrrhotite-chalcopyrite-1 (valeriite), (2) pyrite, (3) pyrite-chalcopyrite-2, (4) chalcopyrite-3-magnetite, (5) pyrite-bornite, (6) covellite-digenite; stage III-cementacion: (1) bornite, chalcocite and covellite.

Within ore stage, which is most significant from the aspect of ore mineralization formation, the following stages are expressed: (a) ore stage –1 with sub-stages : (a) which is represented by pyrrhotite, cubanite, valeriite, pyrite, chalcopyrite, bornite and enargite as dominant minerals, then sub-stage (b) with cubanite, valeriite and pyrite.

Then, oxide stage-1 has been formed, which is consists of magnetite, most probably hematite as well, ore stage-2, represented by pyrite, chalcopyrite and bornite; oxide stage-2 (magnetite and probably rutile) and finally, supergenetic stage in which cementation sub-stage is separated with chalcocite and covellite and oxidation sub-stage with minerals limonite and getite.

Field stop 2 : The Veliki Krivelj ore deposit

The Veliki Krivelj ore field is located about 3 km to the north of the town of Bor. The geological setting of the ore field is fairly simple. The environment of mineralization (approximately 4.5 x ~1 km in size) consists predominately of rocks of I phase volcanic activity: hornblende andesite, hornblende-biotite andesite and their pyroclasts, hornblende-biotite dacite, augite-andesite as well as interbeds of pellite (marls, tuffs, tuffates). Skarn and marble occur as minor occurrences. The rocks of the I phase volcanic activity are intruded by quartzdioritic dikes associated with hydrothermal alteration of copper (Aleksic, 1966; 1969; 1979).

The Veliki Krivelj porphyry copper deposit is located in the zone formed predominantly from hydrothermally altered andesite rocks, over 1.5 km long and maximal with of 700 m (average width is 400 m) and which dips towards SW. Position of this zone is controlled by a longitudinal fault of the NW-SE. Vertical mineralization interval is larger then 800 m, where exploration works have not reached the lowest levels of the ore mineralization. The deposit has an oval shape in horizontal cross-section, elongated in the direction NNW-SSE, while in cross-section it has a shape of a more or less an isometric body (Fig. 4). Significant characteristic of the ore deposit is that with the increase of depth there is no decrease of copper grade in the orebody.

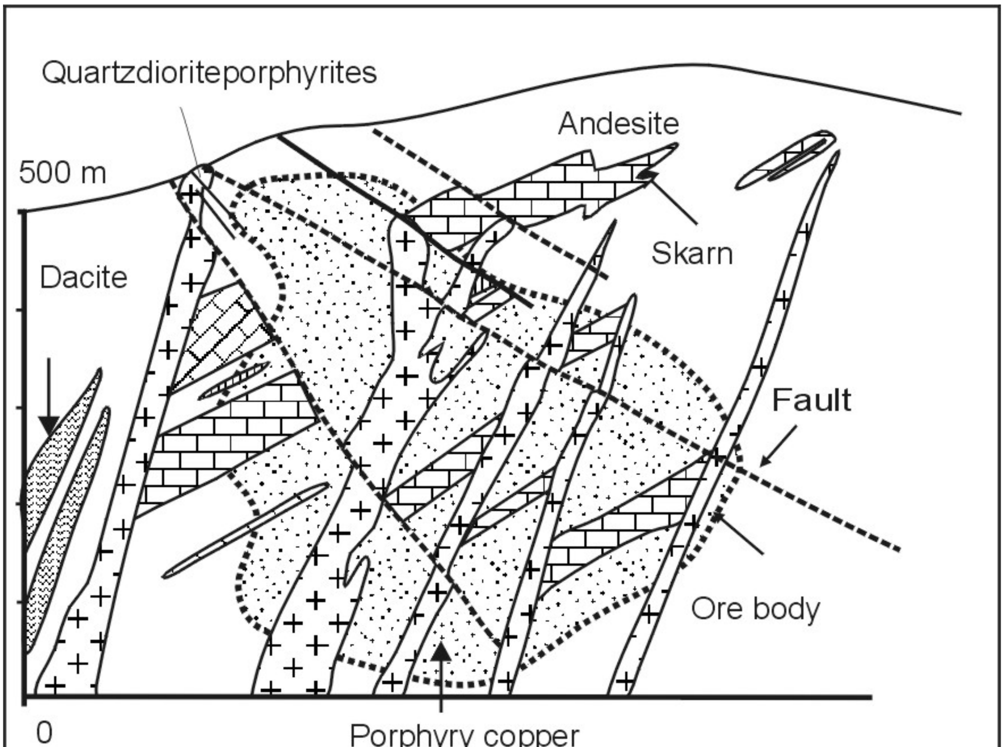


Figure 4. The Veliki Krivelj porphyry copper deposit.

Transition from ore mineralized to weakly mineralized or barren hydrothermally altered rocks is gradual, except the easter boundary of the ore body which is tectonic, i.e. along which by post ore tectonic stage nineralization of Veliki Krivelj deposit has been overtrust on the series of sandstones and limestones.

The most common lithological members in the deposit are autometasomatic and hydrothermally altered hornblende-andesites, hornblende-biotitic andesites and their pyroclasts (agglomerates, breccia and tuffs), but in terms of the genesis of the deposit the most important are dikes and quartzdiorite porphyries (Ognjanovic, 1976; Miskovic, 1979; Kozelj, 1984). Their intrusion caused intense tectonization of surrounding volcanics that made possible fluid circulation. Characteristic features of dikes are the extensive dissemination of ore minerals (with predominance of pyrite and chalcopyrite) and the high degree of alteration (central parts are relatively fresh, the rim parts are completely hydrothermally altered). The structures are subophitic (intergrown plagioclases with parallel twinning lamellae; with xenomorphic quartz in the interspaces; biotite and chlorite, seldom pyrophyllite and sericite, as well as small xenomorphic grains of feldspar) and porphyroidal plagioclase phenocrysts, biotite and hornblende composed of hydrobiotite, II generation plagioclase, seldom pyrophyllites, sericite and flaky chlorite (Đorđevic, 1980).

The host rocks were altered by the hydrothermal fluids during the pre-, sin- and post-ore phase. Alteration is supported by the presence of rupture system developed during the final stages in formation of the Timok magmatic complex. Systems of NW-SE and NNW-SSE strikes dominate along with numerous lower order cross-cutting dislocations of E-W and NE-SW strikes.

A specific feature of the environment of mineralization in the wider region of the Veliki Krivelj deposit is the facies of hydrothermal alteration (Karamata, Đorđevic et al., 1981). They are of high in extent and intensity due to the pre-ore autometamorphic alteration of rocks and the intense hydrothermal activities during the pre-, sin- and post-ore phase. The dominant are regional propyllitization and pyritization, subordinate biotitization, minor sericitization, pyrophyllitization and chloritization, seldom feldspatization. Hydrothermal alteration related to mineralization are consisting of: 1) Si-K metasomation accompanied by sericitization and silicification, 2) sericitization accompanied by silicification, locally biotitization and argyllization, 3) chloritization accompanied by carbonitization, seldom epidotization and weak silicification, 4) extensive pyritization and 5) zeolitization (laumontite). They are present in all lithological members in a manner that biotitization and silicification predominate near quartz diorite porphyrites, but argyllization, sericitization, epidotization, chloritization and calcitization further away (Jelenkovic et al., 2000, 2002).

As a rule, silicifications always accompanies biotitization, sericitization, kaolinization, feldspatization and pyrophyllitization. The most extensive alteration facies is zeolitization. Partly it is associated with depletion of K, Na and Ca from petrogenic minerals as well as sulphatization characterized with replacement of earlier calcitized plagioclase by anhydrite and gypsum veinlets.

Mineral association of the Veliki Krivelj deposit consists of magnetite (up to 2-3%), hematite, rutile, sphene, leucoxene, illmenite, pyrhotine, cubanite, valerite, pyrite (up to 5%), marcasite, chalcopyrite, bornite, molybdenite (50-150 ppm Mo), sphalerite, galena, Au-Ag phases, marcasite, enargite, tetrahedrite, siderite, covelline, chalcosine, malachite, azurite and limonite; the gangue minerals are quartz and minor calcite, barite, siderite, and, exceptionally fluorite.

The ore is characterized by very low gold contents; the mean value 0.07 g/t is the lowest gold content in all porphyry deposits of the Bor metallogenic zone. We emphasize that the Veliki Krivelj deposit is situated near Bor copper-gold deposit (a few kilometers), and the both deposits are of the same or similar age, both related to the same (?) magma. The interpretation of such a phenomena is still open.

Mineral resources of the “Veliki Krivelj” deposits are: > 540 Mt Cu ore @ 0.35% Cu, 0.068 g/t Au.

Structural-textural varieties of ore - The investigations carried out so far, determined the following varieties of minerals in terms of the amount of their concentration in the individual lithological members: impregnation-metasomatic, impregnation-lode-like-vein, vein (locally) and nest type. In terms of their structural characteristics dominate grain like (idiomorphic and xenomorphic) cataclastic, cementing and corrosive structures.

With respect to the economic types of ore the following mineral assemblages were distinguished in the Veliki Krivelj deposit: (i) pyrite-chalcopyrite and (ii) pyrite-chalcopyrite-oxide consisting with sub-types a) pyrite-chalcopyrite-magnetite and b) pyrite-titanium, then (iii) sphalerite-galena-pyrite with two sub-types: a) sphalerite-chalcopyrite-pyrite and b) sphalerite-galena-pyrite ± barite and luzonite. The predominant pyrite-chalcopyrite type of ore is composed of pyrit (3.69%), chalcopyrite (0.68%), chalcosite (<0.01%), covelline (0.03%), bornite (0.01%), molybdenite (0.01%), gold (<0.01%), electrum (<0.01%), magnetite (0.58%), hematite (<0.01%), rutile (0.06%), leucoxene (0.01%), limonite (0.01%), cuprite (0.01%), native copper (<0.01%), malachite (0.01%), waste (94.95%) - the total of 99.99% (Zaric et al., 1997). It is recognized two varieties: a) as individual pyrite and chalcopyrite grains (chalcopyrite-bornite aggregates were noticed), and b) aggregates with drop-like chalcopyrite inclusions in pyrite grains.

The main ore parageneses with economically significant (dominant) mineral types are: pyrite-chalcopyrite (± pyrrhotine, carbanite, seldom bornite, etc.) and chalcopyrite ± bornite, quartz, pyrite, molybdenite, Au-Ag phase.

The formation of the mentioned parageneses took place in the relatively high sulphur fugasity, followed by magnetite. This mineral group is known as paragenesis 3: chalcopyrite-magnetite, rutile III, Au II.

The following ore paragenesis in this deposit is polymetallic - sphalerite-galena and pyrite with drop-like separation of chalcopyrite in sphalerite. Its formation took place in low temperature conditions. Then follows the non-ore paragenesis composed of quartz, barite, calcite and fluorite

In upper levels of mineralized area oxidation zone is developed up to 30-50 m below terrain surface. Beneath this zone there is located the zone of secondary sulphide enrichment, whose wertical interval amount to 30 m (sometimes even 70 m). Intervals of these zones (oxidation and cementation) are conditioned by locally present tectonics. A large number of minerals formed both in the oxidation and cementing zones after deposition of primary mineral paragenesis.

Apart from porphyry copper mineralization, on a modest scale, there occur in the deposit skarn paragenesis in which chalcopyrite is a dominant copper mineral accompanied by pyrite.

Mining of the Veliki Krivelj deposit has started in 1982 and is still underway, where the open pit has reached the level +125 m.

Field stop 3 : The Mali Krivelj-Cerovo ore field

The Mali Krivelj – Cerovo ore field is located 10 km to the NW from the town Bor. It extends from Coka Curili and Kriveljski kamen in the south, goes over the village Mali Krivelj (in the central part of the ore field) to Balaconja in the nort. Central part of the ore field contains hydrotermally altered zone Mali Krivelj – Cerovo about 10 km long and 1-2 km wide (Fig. 5).

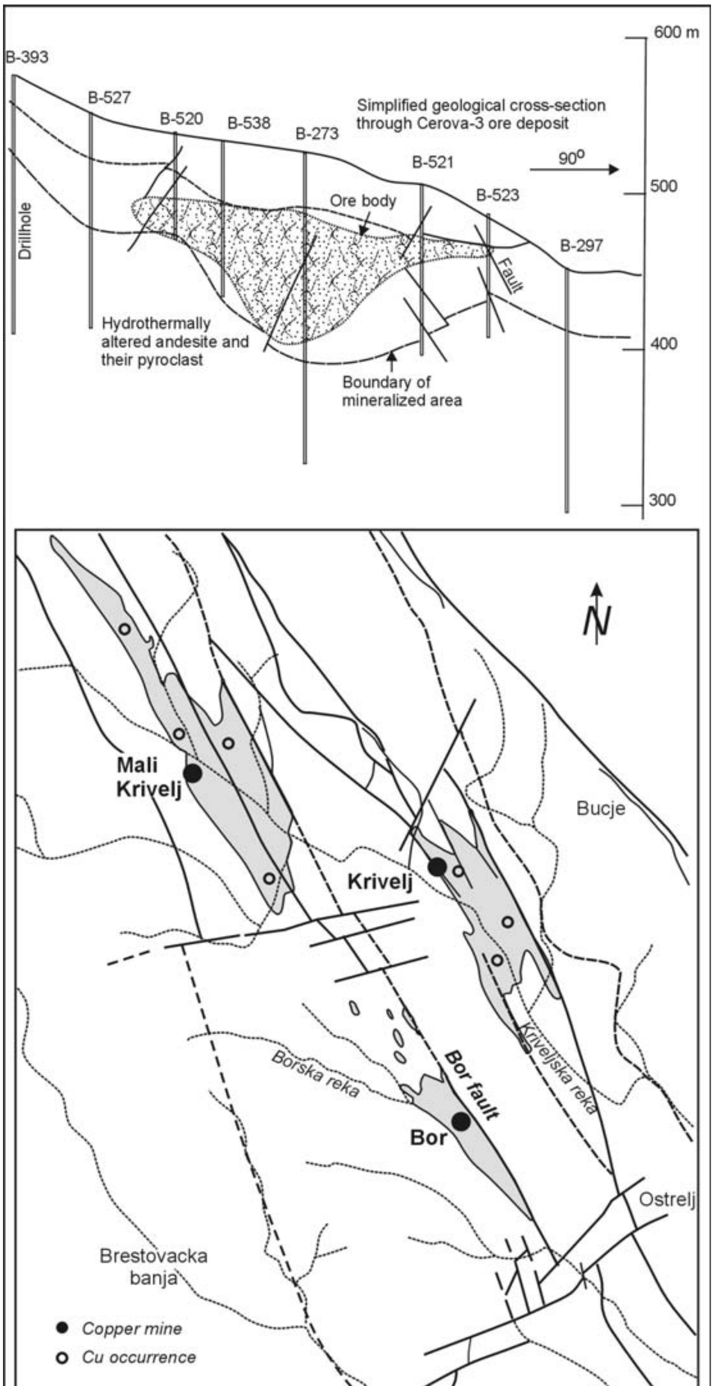


Figure 5. The position of hydrothermally aletered zone of the Mali Krivelj-Cerova area and simplified geological cross-section of the Cerova-3 ore deposit.

Wider area of copper deposit in ore field Mali Krivelj-Cerovo is made of sediments of Lower Cretaceous, hydrothermally altered volcanic-sedimentary, intrusive rocks of Upper Cretaceous and alluvial sediments. Tectonic structure of the ore zone is a complex one. In the wider area of the deposit it is represented by the system of depth dislocation of the strike NW-SE and younger system of the strike NE-SW. Both systems are accompanied by numerous cross-cut and diagonal faults. This zone may be considered as the extension of Bor zone, where near Tilva Njalta the large Bor fault brances into tree faults out of which two are markedly expressed.

From the aspect of ore mineralization of special interest are hydrothermal alterations of surrounding ore mineralized rocks. They are represented by intensive kaolinization and pyritization and are frequently accompanied by limonitization, chloritization and silification.

The Cerovo ore deposit

Specific variety of porphyry copper mineralization of the Veliki Krivelj type is copper mineralization in ore field Mali Krivelj-Cerovo. As a difference from deposit Veliki Krivelj, in which there are clearly expressed ore mineralizations with quartz-diorite-porphyry dykes, this is more assumed in this case.

There are several ore deposits – ore bodies in the Mali Krivel – Cerovo ore field: Cerovo-Primary ore deposit is located in the far northern part of the ore field, then deposit Drenovo, Cementacija-2 and Cementacija-3. In south-eastern part of the ore zone there is a deposit Cementacija 1 which is currently being mined. All mentioned deposits are of porphyry type with poor copper mineralization and clearly expressed zone of secondary sulphide enrichment. Copper mineral resources in these deposits are estimated to 20,1 Mt of Cu-ore with 0.68% Cu, 0.07 g/t Au, 1.5 g/t Ag /Cementacija 1/; 19 Mt of Cu-ore with 0.36% Cu, 0.08 g/t Au, 1.1 g/t Ag /Cementacija 2/; 0.9 Mt of complex oxide-sulphide Cu ore in oxidation zone with 0.37% Cu, 0.3 g/t Au, 1.8 g/t Ag /Cementacija 3/ and 6.5 Mt of sulphide copper ore in the zone of secondary sulphide enrichment with 0.34% Cu, 0.11 g/t Au, 1.8 g/t Ag /Cementacija 1 and 2/. Based preliminary calculation for Cemantecija 4 deposit, copper resources are 4.5 Mt with 0.35% Cu.

At the deposit Cementacija 1 in 1992 mining of copper ore has started which is still underway and the open pit has reached the level +395 m.

Facies of hydrothermal alterations show vertical and horizontal zonality of distribution as well as significant differences as regards extensity and intensity of occurrence. The basic characteristic of the deposit, as opposed to the majority of other deposits within Bor metallogenetic zone, is the occurrence of transformation of ore minerals in supergenetic conditions. Accordingly, one may observe the following alterations facias:

Immediately beneath terrain surface there is an oxidation zone with weakly expressed sub-zone of oxide enrichment. Beneath this zone, in central parts of the deposit, there is present a complex of alterations facias among which dominant are silification, chloritization, sulphatization and kaolinization. Apart from these, in the same area there are developed other forms of alterations with predominancy of sericitization and carbonization, while albitization, feldsparization, epidotization and neo-biotitization are observed only locally.

One of dominant alterations facias is silification. It is of a general strike NW-SE and accompanies the strike of wedging of quartz-diorite-porphyrites. Silification is accompanied by chloritization, sulphatization, chloritization, kaolinization, sericitization and locally feldparization.

Basic characteristic of parent rock in which mentioned structures are developed is relatively retained primary structure with numerous veins of quartz, quartz-anhydrite and quartz-anhydrite-calcite with or without sulphide Cu-Pb-Zn. Minerals from plagioclase groups are partially to completely altered and transformed into anhydrite, clay group minerals, sericite and more rarely calcite. Hornblende is intensively chloritized and partially calcified with separation of anhydrite and to a lesser degree vermiculite and pyrophylite. It is characteristic that in hornblende one may observe metasomatically formed pyrite. Biotite is rare and partially or completely replaced with sericite or chlorite.

From central parts or ore mineralized zone towards periphery (laterally), in the domain of distribution of pyroclastites of hornblende-andesites, silification weakens gradually. In certain parts of the deposit it is completely absent on the account of increased chloritization. In mentioned parts of ore field, it is regularly accompanied by kaolinization, carbonization, sulphatization and more rarely sercitization, albitization, epidotization. Locally, along the rim, one may observe zeolitization. In this part of mineralized zone, plagioclase group minerals are partially to completely altered by kaoline material, calcite or sericite. The basic rock mass is silificated, weakly sulphatized and kaolinized.

Copper deposits in ore field Mali Krivelj-Cerovo are of very similar mineralogical characteristics with expressed differences as compared to deposit Veliki Krivelj. Mineralogical composition is made of the following: titano-magnetite, magnetite, ulvospinel, ilmenite, chematite-martite, rutile, sphene, leucoxene, pyrite, pyrrhotine, chalcopyrite, brnite, cubanite, sphalerite, galenite, tetrahedrite, native gold, marcasite, freibergite, digenite, covelline.

Generally observed, two ore types may be differentiated in deposits: (i) impregnation-metasomatic type of poor ore and (ii) vein-fracture-fissure-(stockwerk) type of ore mineralization.

Common characteristic of both ore types is the presence of pyrite and chalcopyrite as dominant minerals where in type 2, locally, there may be observed concentrations of sphalerite and galenite. In secondary sulphide enrichment zone there is located chalcopyrite, which is partially corroded and transformed into digenite and covelline and in certain pyrite grains it is possible to observe covelline coats.

For the majority of deposits, it is characteristic that the following zones may be differentiated:

Oxidation zone - It is characterized by remainder of hard soluble copper compounds rich in oxygen. From alterations dominant is kaolinization and limonitization (quartz-limonite veins coated by fine-scaled sericite with the occurrence of gypsum). The basic mineral of this zone is limonite which occurs in the form of coatings, powdery or grain clusters, then chematite, magnetite and rutile. From copper minerals there are distributed cuprite, formed by transformation of secondary and partly primary copper minerals, then tenorite, malachite and rarely sericite, chalcanite and chrysocola. Observed as a whole, this zone is characterized by a low copper content (rarely above 0.1% Cu).

Secondary sulphide enrichment zone represents the part of the deposit most rich in copper. Ore mineralization is represented by dissemination and clustering of ore minerals in the zone of intensive kaolinization and weaker chloritization, the intensity of which is increased with the depth. Mineral composition of the zone is made of chalcosine formed from chalcopyrite and pyrite, then covelline which frequently occurs with chalcosine but is less distributed and mainly formed by transformation of chalcopyrite, pyrite and magnetite. Molibdenite, sphalerite and galenite are rare. Transfer from oxidation zone to secondary sulphide enrichment zone is sharp.

Secondary sulphide enrichment zone transfers in depth into primary mineralization zone. In this zone, as opposed to other hydrotheramal alterations, kaolinization is more weakly expressed. Apart from that, there occur chloritization, silification, sericitization and others. The most significant minerals in this zone are pyrite, chalcopyrite, sphalerite and rarely molibdenite.

Detailed investigations of the genesis of copper deposit "Cerovo" have not been carried out. Due to similarity of ore mineralization with other copper deposits of the same type in Timok magmatic complex, general conclusions about the genesis of these porphyry deposits may be applied also to deposits in ore field Mali Krivelj-Cerovo.

In deposit itself, by exploration drilling from terrain surface, dykes have been established of intensively autometasomatically altered quartz-diorite-porphyrites, partially mineralized by copper. Based on available data, it has been established that they are subvertical with a steep dip towards the S-E. Apart from quartz-diorite-porphyrites, in several drill-holes there have been observed shorter intervals of dacites, i.e. dacite-andesites, which are hydrothermally altered and weakly mineralized.

Primary pyrite-chalcopyrite ore mineralization has been formed in complex physical-chemical processes during hydrothermal activity. Presence of high-temperatutre mineral forms (magnetite, rutile, high-temperature pyrite and pyrrhotine), i.e. medium to high-temperature (pyrite, pyrrhotine, chalcopyrite and bornite), low-temperature (sphalerite and galenite), as well as different forms of occurrences of the same minerals, indicate multi-stage character of hydrothermal activity with changes of characteristics of pressure gradient, temperature, pH and Eh of solutions.

Several stages of hydrothermal activities are indicated also by various forms of occurrences of pyrite and chalcopyrite mineralization, as well as occurrences of alterations of surrounding mineralization rocks. Control factors of sulphide copper mineralizations are structural and magmatic. Structural one is represented by numerous faulting zones with accompanying compression and tension fractures, along which intrusive rocks have been wedged mainly of quartz-diorite-porphyrites. Magmatic factor is represented by occurrences of intrusions of quartz-diorite-porphyrites in relation to which there occur hydrothermal ore bearing solutions. As a separate entity, in the immediate vicinity of Cerovo deposit, there may be differentiated partially mineralized skarns, skarnoids and hornfels as well.

Field stop 4 : The Majdanpek ore field

The Majdanpek ore field is located in the far northern part of the Timok magmatic complex. In central part of the Majdanpek ore field Majdanpek copper deposit is located.

Until 1962, the Majdanpek deposit was a mine of massive pyrite and limonite (Jankovic, 1990). Since 1962, this a large porphyry copper deposit was mining by open pit with annual output of 12-14 Mt. The reserves exceeded 800 Mt of ore, containing 0.4-0.8% Cu, and 0.25-1 g/t Au (the mine operation started with ore grade of 0.82% Cu and close to 0.8 g/t Au). Apart from copper, the deposit had significant reserve of massive pyrite (about 15 Mt), and few million tons of lead zinc ore (grade 7% Pb+Zn). Pyrite contains 3-15 g/t Au. In the highest level of the porphyry copper mineralization high concentration of gold (1 g/t) is recognized; its concentration decreases downwards to 0.25 g/t in the depth of 300 m. Downward keeps the same rate of concentration for a vertical interval of over 1 km.

The Majdanpek deposit consists of several type of ore mineralization – the dominant porphyry copper mineralization, massive sulphide pyritic orebodies, skarn magnetite mineralization, and lead-zinc sulphides orebodies of massive replacement and hydrothermal vein types. All of them are related to the same structure, developed in multistage processes (Janković, 1990; Spasov, 1965; Donath, 1952).

The Majdanpek deposit was formed along a very narrow (up to 300 m wide) and 5 km long zone between the Jurassic limestone and the Cambrian granite-gneiss. This zone was intruded by minor dykes and subvolcanic intrusive bodies of andesite, and sporadical dykes of quartz diorite porphyry, which may indicate a larger pluton at depth (Fig. 6).

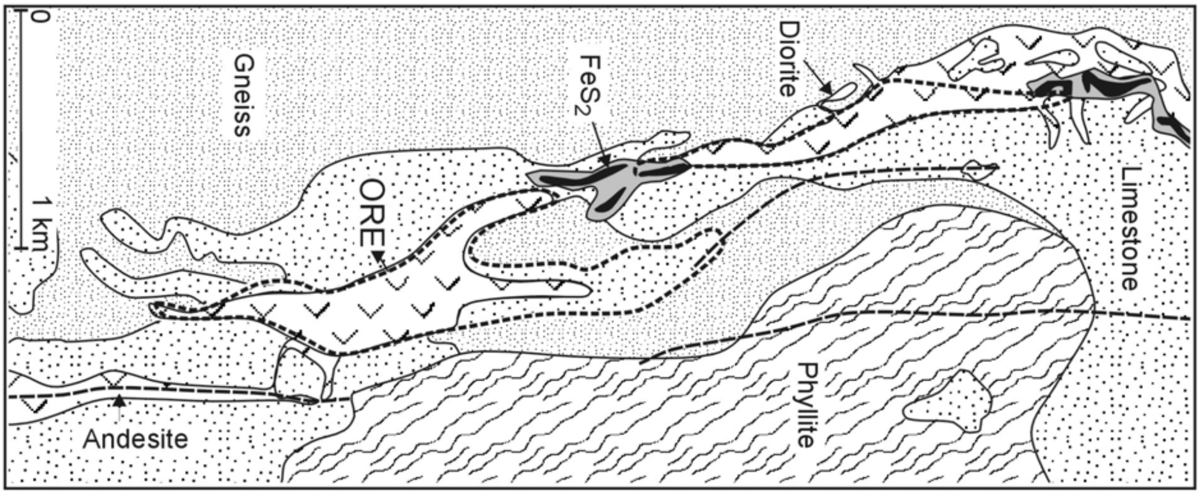


Figure 6. Geological map of the Majdanpek porrphyry copper deposit.

Copper deposit Majdanpek is divided into two mining areas: “Northern Area” and “Southern Area”. Maximal length of ore mineralized zone in “Northern Area” has been measured at the level + 335 (1300 m), at the maximal width of 200 m (average width is about 150 m). Along the depth, the zone “Northern Area” has been traced by exploration works to the length of about 500 m. The lower contour of the ore body has not been defined. However, the decrease of copper content has been observed. General strike of the ore zone is NW-SE.

Review of ore bodies

In Majdanpek deposit, currently, mining activity proceeds in two areas: Southern Area and Northern Area, in which all so far discovered ore bodies of different mineralization types are located:

Ore bodies of Southern Area. Mining field Southern Area is located to the S-SW from Majdanpek at the distance of about 500 m. It contains the largest ore body of Cu-Au porphyry mineralization "South Area" and ore body of massive Cu-Au-Ag pyrite mineralization "Knez Lazar".

Ore body "Southern Area": Porphyry copper deposit "Southern Area" - Majdanpek is the largest one in Majdanpek ore field. Bearing in mind its dimensions at presently uncovered area, the lowest open pit benches, as well as data from exploration drill-holes, it may be concluded that it contains significant ore reserves with incompletely established quality.

Ore body "Southern Area" is spatially localized in hydrothermally altered andesites, gneiss-granites and gneisses of amphibolite facia. In hanging wall of deposit to K+200m andesites have been predominant rocks in direct geological structure of the ore body, in order that, with the increase of depth, their percentage contribution should be diminished. On their account, contribution of gneiss-granite has been increased. As a difference from andesites, which, under the influence of hydrothermal ore-bearing solutions to a lesser degree and surface degradation, have been disintegrated, gneiss-granites as rock complexes are characterized by larger hardness due to higher content of silicium and represent a more stable operating environment. Eastern part of "Southern Area" consists of rocks from the group of green shales-phyllites. Observed from the point of view of distribution of ore mineralization, these rocks may be considered barren. Their basic characteristic is the presence of narrow dykes of serpentinites and metadiabases as well as numerous quartz veins with sulphides of Cu, Pb and Zn with gold. These rocks are considered eastern rim of the deposit Majdanpek- "Southern Area".

Southern part of deposit, which is called also Coka Muskal is represented by limestones Sweiz. In central portion of deposit, between limestones of the east and west, there is located a narrow dyke of andesites. Its wedging has been accompanied by intensive tectonization, fracturing and comminution of limestones, which has enabled movement of ore-bearing gas-liquid fluids and formation of smaller ore bodies of irregular form as well as of nest-like-veinlet concentrations of ore minerals made of dominant pyrite and chalcopyrite.In southern part of deposit Majdanpek-"Southern Area", there may be observed also the presence of scams, which have been formed at the contact between Upper-Cretaceous andesites and titono-valendian limestones. Scams are always mineralized but have smaller dimensions. Their thickness does not exceed a few meters.

Apart from magnetite, pyrite and chalcopyrite, they regularly contain sphalerite and galenite. Porphyry copper deposit Majdanpek -"Southern Area" has an approximately prismatic shape. Its longer axis, oriented in the strike N-S is more than 2000 m, while the width of the ore body ranges between 270 and 350m (mean width is 300 m). This dimension has been measured at the level (E+ 110). With the increase of depth there occurs gradual decrease of the width of ore body "Southern Area". At the level E-100 to which depth ore reserves have been explored, width of the ore body varies between 250 and 170 m. With the depth there is observed the decrease of copper content and according to the data from Mine Geological department, in Majdanpek deposit, it is considered that it ends in the funnel shape with the center between VII and VIII profile. Vertical interval of occurrence of ore mineralization in porphyry copper deposit Majdanpek -"Southern Area" is about 800 m, from the highest level + 600 to the lowest assumed level-200 (Fig. 7).

By analysis of previously mentioned data, which refer to morphological characteristics of the ore body Majdanpek- "Southern Area", a conclusion may be drawn that it is sub-vertical. Contours of the ore body towards the East and West are defined, while towards the North (Dolovi 2 and central ore body "Northern Area") and the South (Concentrator plant of Copper Mine Majdanpek, RBM) this is not the case. The ore body in this direction significantly narrows down, but mineralization continuity is present. The level of exploration of the ore body is not the same in all its parts. A part of the ore body between 17 and 19th profile towards Coka Muskal has not been explored to the end.

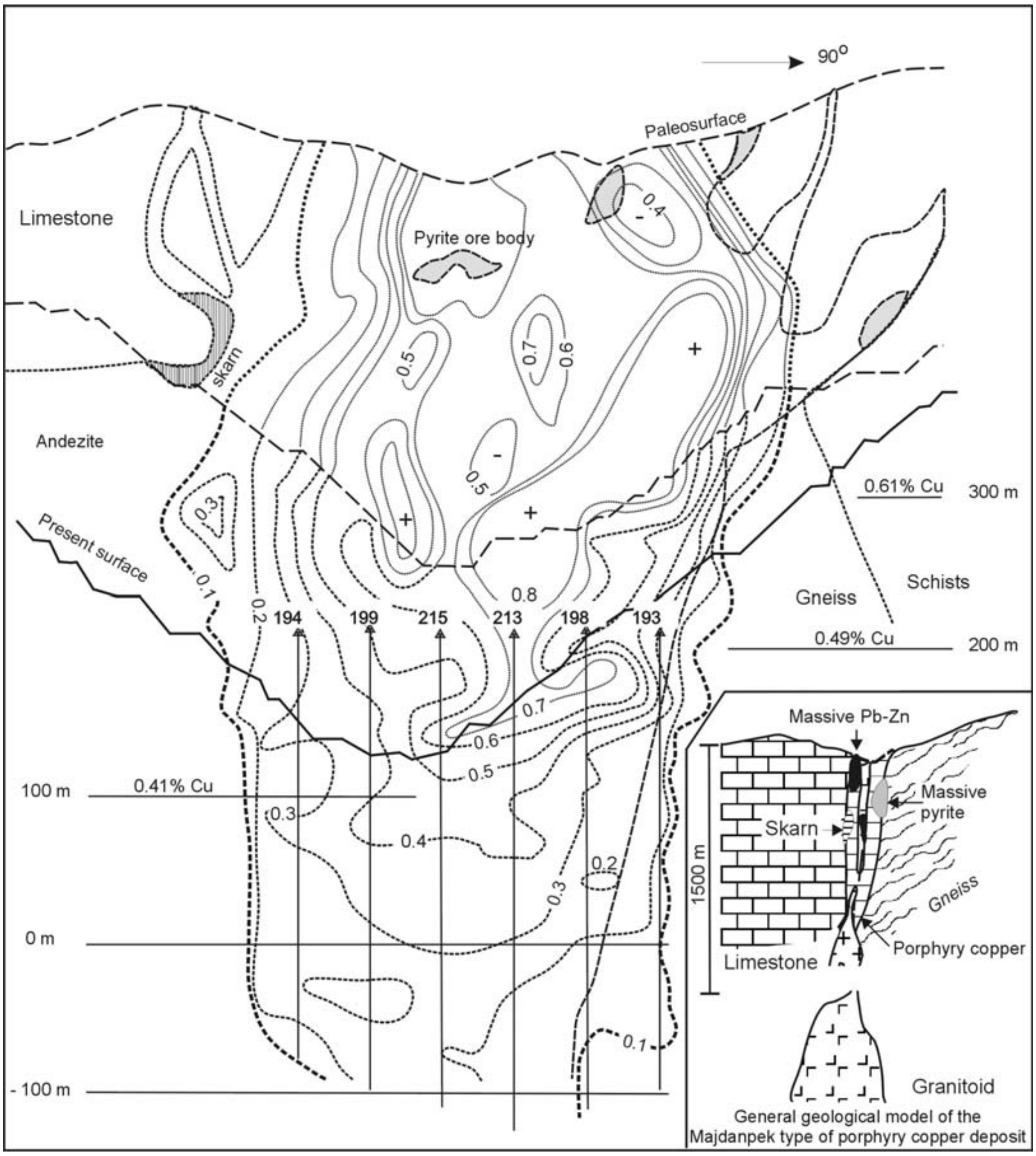


Figure 7. Geological cross-section through Majdanpek – the South Revir copper deposit.

Copper and gold contents are different in stockwerk and impregnation mineralization types and decrease with the increase of depth. In higher levels (above level K+200 m) in stockwerk fields Cu ranges from 1-8% (mean value about 1.5% Cu), while gold occurs in grades from 0.5-5 g/t (mean 0.8 g/t) and in deeper levels (below level K+200 m) copper contents range between 0.8- 3% (mean about 1 % Cu). Impregnation ore type is characterized by copper contents between 0.7-1 % (mean about 0.4% Cu) , while gold grades range from 0.1-0.8 g/t (mean 0.25 g/t). Apart from that, there are significant contents of molybdenite, which in the zone K+200 -K+530 occurs in concentrations of about 40 g/t. In these molibdenites high concentrations of rhenium are present, especially in low-temperature varieties and they range from 0.2-1.2%. Apart from these useful components, ore contains also platinum, palladium and selenium.

Due to reconstruction of the open pit, mining activity proceeds only in the far southern part of the ore body at the locality Coka Muskal.

Cu-Au-Ag pyrite ore body "Knez Lazar". This ore body is located in southern part of porphyry ore body "Southern Area", at the depth of about 400 m. It is of the shape of irregular lens and is located in tectonically fractured marble limestones at the contact with hydrothermally altered amphibolic-biotite andesites. Ore mineralization is controlled by fracturing structures of the strike N-S, more rarely NNE-SSW. Two types of ore mineralization have been established: massive-sulphide with contribution of pyrite in the amount 20-28% and vein-impregnation, which occurs in rim parts. Dominant copper mineral is chalcopyrite and to a lesser degree there are present covelline and chalcosine as well. From other ore minerals, there have been established: magnetite, chematite, pyrrhotine, meljenkovite, arsenopyrite, bornite, tetrahedrite, sphalerite, galenite and native gold.

Gold-quartz veins - Apart from gold, which in Majdanpek deposit has been defined within the scope of porphyry copper mineralization, in the same area and within the scope of the series of green shales facia as well as in gneisses of amphibolite metamorphism facia, there have been established occurrences of gold-bearing quartz veins. They have been observed in relicts of old mining works in the area Velike Livade and Kovej (K+460 and K+415, T. Spasov, 1961). By investigation of the samples from the stock-pile, in relicts of these veins, there have been established gold contents ranging from 3.05-6.5 g/t and silver from 17-30 g/t. According to the data from IBB RTB Bor: "one quartz sample analysis, which has been taken from washing water before the undercut Kovej, has given the content of Au of 800 g/t and Ag of 2900 g/t". By later exploration works which have been undertaken during 1989 and mining activity which has been directed to the extension of the open pit "Southern Area", there has been encompassed a part of old undercuts in the locality Kovej. At that time, it has been established that gold-bearing quartz veins, in the length of approximately 300 m have not been mined and based on assay results of 12 samples from the level K+425, which have encompassed gold-bearing quartz veins, the following contents of precious and accompanying ore metals have been established: 12.349 g/t Au, 116.554 g/t Ag, 5.32 % Pb and 2.43% Zn.

By additional geophysical investigations, which have been undertaken during 1993 in the locality Stacion, the presence of Au-Ag quartz veins has been indicated in crystal shales of amphibolitic facia and rocks of green facia. Detailed geological works have not been undertaken. It has been established that veins have the strike NNW -SSE with the dip towards the East at the angle of 50-60°. Their thickness ranges from 0.5 -3 m. According to data from Mine Geology Depatment of Majdanpek Mine, veins are located in the plane of foliation of chlorite-sericite shales and phyllites and comprise the area whose dimensions are approximately 1500 x 250 m. It is assumed that along the dip they may be followed in the interval of about 250 m, between the level K+350 and K+600.

Ore reserves have not been calculated and according to preliminary estimates, it is assumed that they amount to about 50 000 to 100000 tons with 18 g/t Au and 50 g/t Ag.

Ore bodies of "Northern Area". Mining field Northern Area is located about 1 km N-NW from Majdanpek and this field contains: polymetallic-gold deposit "Tenka" (Tenka-l, Tenka-2 and Tenka-3), porphyry, i.e. stockwerk-impregnation ore body "Dolovi-l" and "Central ore body", massive-sulphide ore body "Dolovi-2" and Cu-pyrite ore body "Stari Dusan" and limonite ore body "Blansard".

Polymetallic-gold deposit "Tenka". This deposit is located in the far northern part of "Northern Area" of copper deposit Majdanpek. It comprises the area of irregular trapezoid form, whose strike is N-S, longer side about 650 m, while shorter side ranges from 150 -250 m. Polymetallic sulphide mineralization is spatially limited to the western part of ore mineralized zone.

Deposit Tenka consists of several ore bodies of complex morphology among which dominant are ore veins, columns, lenses and nest-form ore bodies. Control factor of their position consists of tectonized zones of contact of volcanic rocks of Upper Cretaceous with structures of Jurassic age.

In more strongly tectonized zones (breccias) along which movement of ore-bearing fluids have been easier, there has occurred formation of smaller ore bodies of irregular morphology of stockwerk-impregnation ore mineralization type. Polymetallic, as well as Cu-pyrite ore mineralization has been deposited in scarned limestones, tectonic breccias and partly in andesites. The area around massive-sulphide mineralization is filled with stockwerk-impregnation and vein form mineralization with occurrences of barren limestone inclusions.

Massive-sulphide mineralization is regularly found in limestones, when the boundary towards surrounding rocks is sharp and in tectonic breccias when it is in combination with smaller veins and veinlets. In andesites, most frequently occur veinlets, more rarely veins. In brecciated limestones, mineralization has been deposited in existing cavities and fractures, cementing limestone fragments.

Observed from economical pint of view, of special interest are the following ore bodies: Tenka-1, northern ore body; Tenka-2, southern ore body and Tenka-3, which makes the eastern part of productive zone. These ore bodies are different in morphological characteristics, partly in mineralogical characteristics and contents of useful components.

Ore body "Tenka-l" has the form of ore column which dips steeply towards the West. Along the strike, by exploration works it has been followed in the length of about 300 m. Ore mineralization is represented by fragments of sphalerite mineralization in tectonic breccias and narrow strips in massive pyrite.

Ore body "Tenka-2" has a lens form. Thickness of the ore body is variable. It ranges from a few meters up to 20 m, locally even up to 30 m. Strike of the ore body in the length of about 150 m is N-S up to NNW-SSE and it is identical to the strike of regional dislocation which passes through Majdanpek. Ore body is made of massive pyrite in which sphalerite is deposited in the form of jets and narrow strips. As compared to ore body Tenka-l, it is characterized by lower contents of zinc and lead and higher contents of sulphur, gold and partly copper. Based on results of investigations done so far, it is assumed that ore body Tenka-2 has been formed as a result of deposition of lead and zinc mineralization in previously formed massive Cu-pyrite ore body, so that in its domain the boundary between polymetallic and Cu-pyrite mineralization is not clearly defined.

Ore body "Tenka-3" is located in the eastern part of productive zone. It is represented by Cu-pyrite mineralization type with subordinate contribution of lead and zinc sulphides. Ore body is formed in tectonized zones of contact between limestones of Starica and Upper-Cretaceous volcanites and partly in limestones, i.e. hydrothermally altered andesites. As regards mineral composition, ore body Tenka-3 represents a conglomerate consisting of massive pyrite bodies (pyrite content from 60-90%), magnetite ore bodies in scams and vein-impregnation masses of copper mineralization in andesites. Post-ore tectonics have moved certain parts of ore body Tenka-3 so that sometimes fragments of massive sulphides may be observed or scam mineral paragenesis in altered andesites where vein-impregnation and porphyry copper mineralization are dominant.

Mineral composition of deposit Tenka ore is made of numerous mineral species out of which widest distribution have rutile, pyrite, marcasite, pyrrhotine, chalcopyrite, bornite, digenite, sphalerite, galenite, enargite, tetrahedrite, tenantite, native gold, pezite and lindstrumite. Among these dominant are the following ore minerals: pyrite, sphalerite, chalcopyrite, galenite and bornite. Grouped into ore types according to the level of concentration of ore minerals and their structural-textural characteristics, the following types may be differentiated: 1. Pyrite(and marcasite)-sphalerite-massive ore type with pyrite-sphalerite grain variety; 2. Pyrite-chalcopyrite ore type in which increased concentration of bornite is present; 3. Pyrite, massive ore type; 4. Sphalerite-pyrite ore type with enargite.

One of characteristics of Tenka ore is gold content which is multiply (about 5x) higher that gold content in Northern Area. In the area of Tenka ore bodies, gold is present as independent or in the form of aggregates with lindstrumite and hesite-pezite. It has been established in sphalerite, chalcopyrite then between cataclized fragments of recrystallized pyrite and to a lesser degree in gangue. Gold distribution is not uniform.

Generally observed, from terrain surface towards deeper levels of Tenka deposit, the following zones have been separated with predominant mineralization types:

Oxidation zone is located at terrain surface in the form of a narrow strip close to limestones of Starica and its largest portion has been degraded by erosion. Depth of this zone has been variable but has not exceeded 35 m. Most represented mineral is limonite and subordinately there are present azurite, malachite, native copper, cesurite, smithsonite, jarozite, cuprite.. Presence of gold and silver has been proven by chemical analyses. Oxidation zone is developed also along particular fault zones when it occurs in the form of pockets. Main minerals are chalcosine, covel line, bornite and idaite.

Primary sulphide mineralization zone is economically interesting and represents the area that is currently mined. It is made of pyrite, sphalerite, galenite, chalcopyrite,enargite and luzonite as dominant mineral species.

Ore body "Dolovi-1" , porphyry ore body Dolovi-I is located in western part of Northern Area of Majdanpek deposit. Geological environment of occurrence of ore mineralization consists of intensively hydro-thermally altered, predominantly silificated, chloritized, epidotized and argyllitized hornblende-biotite andesites and rocks of gneiss complex. Apart from these, in ore body domain there occur also rocks of amphibolitic metamorphism facia, which consist of amphibolic gneisses, rarely amphibolites. These rocks are penetrated by dykes of Upper-Cretaceous amphibolic-biotite andesites and quartz-diorite-porphyrites. In ore body there may be observed a large number of fracture-fissure systems of different spatial orientation as accompanying structures of fault zones whose thickness ranges from 1-100 m, but can not be undoubtedly determined.

In horizontal cross-section ore body is of a rough oval shape with slight elongation in the strike NNW-SSE. Longer axis of ore body measured at the level E-485 is approximately 430 m, while its maximal width of 140 m has been measured at the level E-470, while average thickness of ore body is 24 m. Ore body dips mildly towards the North and the deepest level of mineralization is 174 m. Copper mineralization in ore body Dolovi-I occurs in the form of ore- mineralized veins, veinlets and impregnation ore mineralization type. Its distribution in ore body is not homogenous but it is possible to observe zones with higher concentrations of ore minerals and parts which have their lower concentrations. Most intensive copper mineralization of pyrite-chalcopyrite type is limited to central part of deposit. Transfer towards surrounding rocks is gradual.

Mineral composition of ore body Dolovi-I is relatively simple. Basic ore minerals are pyrite, chalcopyrite, magnetite and chematite while gangue minerals are represented by petrogenetical minerals of surrounding rocks in which ore mineralization is localized.

"Central ore body" is a stockwerk-impregnation ore body and is located in central part of production field. It is controlled by fault structures of strike NNW-SSE, along which dykes of amphibolite-biotite andesites and quartz-diorite-porphyrites have been wedged into gneisses.Ore body has the form of elongated ellipsis (1500 x 150 m) .The highest parts of ore body are located at the level K+450 m and vertical mineralization interval is about 600 m. In higher levels around this ore body, in contact zone between andesites and limestones, smaller polymetallic and massive-sulphide copper ore bodies are zonally distributed.

Ore mineralization occurs in the form of impregnations of veins and stockwerk fields with the network of quartz-pyrite-chalcopyrite veins. Dominant copper mineral is chalcopyrite and apart from this there are also repres ented magnetite, chematite, pyrite, arseno-pyrite, marcasite, bornite, tetrahedrite, molibdenite, sphalerite, galenite and native gold. From hydro-thermal alterations in ore body domain there are present silification, biotitization, sericitization, K-feldsparization and in periphery parts also chloritization, carbonization and epidotization.

Close to ore body there is developed an oxidation zone (mean thickness about 25m) and sporadically cementation zone (mean thickness 5m). As compared to ore mineralization of ore body Southern Area, in this ore body there are increased contents of magnetite (1-2%) and pyrite (mean 5%), while molibdenite content is low. Mean copper content in ore body is 0.45% and gold 0.4 g/t.

Cu-pyrite massive ore body "Dolovi-2" is located to the North-West from Majdanpek, i.e. to the West from open pit Northern Area and to the South-East from ore body Dolovi-I. Maximal length of ore body is 250 m, width about 70 m and the strike of ore mineralized zone is N-S to NNW-SSE.

In geological structure of ore body Dolovi -2 participate the following:double-mica gneisses, Jurasic limestone and Upper-Cretaceous volcanites. In lateral distribution of mineral associations forming this ore body there is observed a certain regularity. Namely, in the zone located to the East from limestone reef porphyry copper mineralization has been established with gold in silificated andesites which is a part of ore body Northern Area, ie. Its western boundary. In the zone of western contact of limestones and andesites there is located a large number of metasomatic, massive pyrite ore bodies, scam-magnetite bodies as well as zones in which polymetallic mineralization is present.

Metasomatic massive-pyrite ore bodies are of smaller dimensions and they occur in the form of lenses, nests, irregular clusters and sub-vertical veins. From sulphide minerals, apart from pyrite (from crystal to gel forms), there occur chalcopyrite, sporadically sphalerite.

Magnetite mineralization in the form of veins and irregular zones occurs in skarnoids of variable thickness.

Polymetallic mineralization is located in marbled limestones, breccia zones, scarnoids and more rarely in silificated andesites, It occurs in the form of irregular clusters, lenses, nests and smaller veins. Main zinc mineral is sphalerite.

To the West from contact zone there occurs Cu-pyrite mineralization in whose scope, based on sulphur content, three conditionally separate zones have been established: I-massive-sulphide type, where sulphur content is higher than 15%, 2-stockwerk type with sulphur content from 10-15% and 3-impregnation-stockwerk mineralization type with sulphur content of 5-10%. Copper contents in mentioned mineralization types ranges from 0.2% in impregnation-stockwerk type to 1.0% in massive-sulphide type. Main ore minerals are pyrite (from crystal to gel form) and chalcopyrite, which are deposited in silificated, epidotized and partly kaolinized and chloritized andesites.

Cu-pyrite mineralization, further away towards the West, transfers into porphyry mineralization type which is deposited in hydro-thermally altered anbdesite and double-mica gneisses. It is characterized by low copper content up to 0.2%. Main ore copper mineral is chalcopyrite. Gold contents in mentioned mineralization types show positive correlation with copper, i.e. sulphur. The highest are in sulphide mineralization (0.2-1 g/t) and the lowest in porphyry (below 0.2 g/t).

By ore microscopic investigations of samples the following ore minerals have been determined: pyrite, chalcopyrite, sphalerite, Ti-Fe oxides (chematite, magnetite, rutile, limonite, ilmenite), pyrrhotine, chalcosine, bornite, galenite, covelline, molibdenite, marcasite, tenantite(?) and gold. From non-ore minerals observed are calcite and quartz. Ore body "Stari Dusan". Copper mineralization in this ore body is limited to tectonized contact zone between andesites and limestones as well as to andesites. In one portion, it occurs also in gneisses. It is represented by pyrite and chalcopyrite as dominant mineral species. Mineralization of the same type is known also in contact zones of a limestone block, which is located in the western part of open pit. It is represented by scam ore mineralization type with massive-sulphide and vein-lens type of ore mineralization.

Common characteristic of ore bodies is a high level of tectonization, i.e. the presence of numerous ore mineralized fractures and fissures as accomnpanying systems of fault structures whose apparent thickness ranges from 6-15 m. By macroscopic analysis, two mineralization types have been established in ore body: first is spatially limited to veins and lenses with chalcopyrite as the main copper mineral and is located in hydro-thermally altered andesite and partly in limestones, while the second is represented by polymetallic Pb-Zn mineralization type-galenite, sphalerite and magnetite in scams.

Ore body "Stari Dusan", in horizontal cross-section, has the form of an elongated, deformed lens whose strike is NNW-SSE. Longer axis of ore body measured at the level E+410 has the dimension 230 m and thickness, which is variable, ranges from 10-28 m (average 16 m). According to data from Geology department of Majdanpek Mine, maximal width of ore body is 28 m, which is measured at the level E+395.

Observed from hanging wall contour of ore body, which is represented by cut-off-grade of 0.2%Cu, the average depth of ore body is about 50 m. Along the dip, by drilling, ore body is followed up to 90 m. Ore body dips towards the East in accordance with the contact of andesites and limestones. Observed along the strike, the depth is increased in the direction of the North.

Basic minerals in ore body Stari Dusan are pyrite, chalcopyrite, sphalerite, galenite, magnetite, pyrrhotine and chematite. Most widely represented is pyrite which occurs as independent impregnated in basic rock mass, then in the form of bindings with chalcopyrite and pyrrhotine and in the form binding with chalcopyritye and sphalerite. In particular cases, in the form of inclusion, it is possible to observe in it fine-grained forms of Fe-Ti oxides. Most represented copper mineral is chalcopyrite. It is mainly formed by metasomatic means but is also found in the form of fillings of smaller fracture-fissure systems. It is usually in association with pyrite, sphalerite and needle-like chematite. It frequently includes pyrite crystals. It suppresses pyrite and itself is suppressed by younger sphalerite. Sphalerite and galenite are usually found together in the same type of hydro-thermally altered rocks and in the zone of scarned surrounding rocks, usually with chalcopyrite and pyrite. Observed from quantity point of view, sphalerite is dominant. Magnetite and chematite occur in associations with pyrite, chalcopyrite and sphalerite. They have a subordinate occurrence frequency similar to Fe- Ti oxides.

Limonite ore body "Blansard". In production field Northern Area of copper deposit Majdanpek there is located a large number of limonite ore bodies as well as limonite occurrences. Some of these bodies have been mined in the past due to high copper content, which has amounted even up to 28%.

Limonite ore body Blansard is located in eastern part of production field. Ore body consists of several irregular lenses of porous limonite ore, which are located along tectonic zone of the width 50 m and strike N-S. This zone is located at the contact of Upper-Cretaceous limestones and the series of biotite-muscovite gneisses and quartz-muscovite proterozoic shales. Along this structure there has been wedged smaller penetrations of amphibolic andesites and in the zone of their contact with limestones, there have been formed massive Cu-pyrite and polymetallic ore bodies. Under the influence of surface waters rich in oxygen, which have sunk along the system of faults and fractures, Cu-pyrite ore bodies have been transformed into limonite ore bodies with carbonate and oxide copper minerals (malachite, azurite, cuprite), chalcopyrite and native copper. As cementation ore at the boundary between limonites and relicts of Cu-pyrite ore bodies, there occur also covellite and chalcosite.

The highest parts of ore body Blansard are located at the level K+560 m and the lowest at the level K+450 m. In explored part of ore body, between level K+450 and K+525, before the start of development of open pit, there have been established proven ore reserves of Q= 1 105495 t with the content Fe=45.42% and Cu=0.40%.

In the past, analyses for gold and silver have been rarely done, so that only by exploration works in 90-ties of the last century it has been established that in higher parts of ore body Blansard (between level K+550 m and K+485 m) there exist increased contents and that their distribution is not uniform and that they decreases with the depth. Mean grades at level K+540 m to K+520 mare Au=3.1 g/t and Ag=10.7 g/t.

Field stop 5 : The Coka Marin ore deposit

The Coka Marin deposit, located south of Majdanpek in the Vlaole-Jasikovo ore field, Bor metallogenic zone (Jankovic, 1990a), is an example of a polymetallic massive sulphide deposit.

Polymetallic mineralization (Zn-Cu±Pb-Au-Ag) occurs in Upper Cretaceous andesites. The hanging wall consists of a volcano-sedimentary series (hematite pelite, interbedded tuffs and volcanic breccias), with hydrothermally altered andesite and andesitic breccia forming the footwall (Fig. 8). The advanced argillic alteration (alunite, diaspore) pyritization, silicification, sericitization are a direct product of the hydrothermal mineralization (Zivkovic, 1987). The orebodies occur as irregular elongated lenses resembling stratiform type of mineralization (Jankovic, 1990). Three types of ore are recognized: massive, stockwork, and disseminated. Massive ore contains up to 3% Cu, 5-8% Zn, and up to 1% Pb; the content of pyrite exceeds 60%.

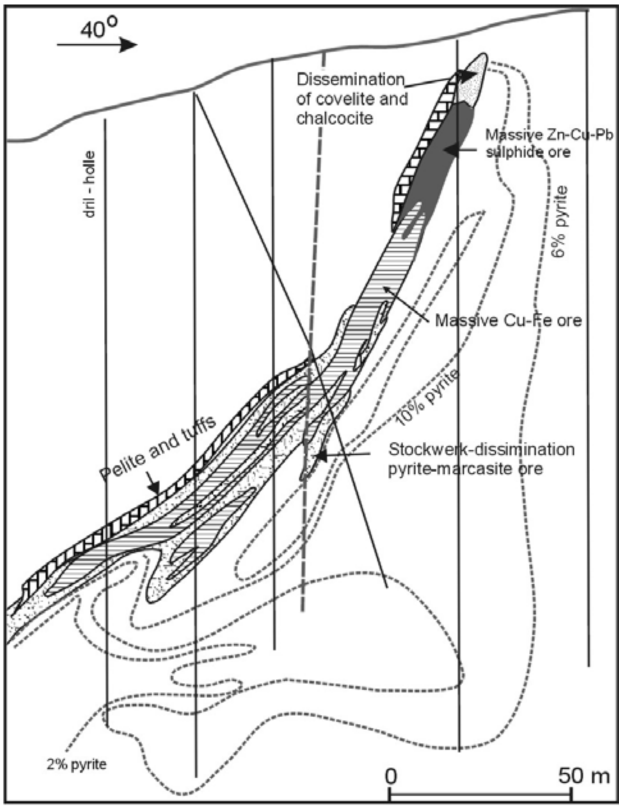


Figure 8. Cross-section of the Coka Marin deposit.

Mineral associations are comprised by pyrite, gell-pyrite, minor pyrrhotite, marcasite, enargite, luzonite, chalcopyrite, with minor bornite, native gold, sphalerite and galena, and Pb-Sb sulphosalts. Stannite, cassiterite and bravoite occur sporadically. Most of the minerals are thought to be derived from colloidal hydrothermal solutions. The gangue minerals include quartz, minor barite, anhydrite, siderite, calcite, and very rarely fluorite. The spatial distribution of the pyrite-copper minerals association, and the pyrite-sphalerite-galena-chalcopyrite association is characterized by a zonal distribution pattern. Gold is a significant constituent of the ore. Gold occurs in its native state and/or in association with sulphides (chalcopyrite, enargite, tennantite, and pyrite). The highest gold concentrations lie between the zone of advanced argillic alteration in the hangingwall, and the silicified, kaolinized and carbonatized andesitic breccia in the footwall. Gold values over a 35 m interval defined by the advanced argillic and siliceous facies ranges from 4.6 g/t to 23 g/t (average 13.2 g/t) and is associated with 159 g/t silver, 0.6% copper, 7.4% zinc, and 2.25% lead. The copper concentrate contains (Zivkovic, 1990): 7.7 g/t Au, 352 g/t Ag, 23 g/t Pt, 252 g/t Te, 186 g/t Ge, 78 g/t Ga, 50 g/t Mo, 203 g/t Sn, and 1.000 g/t Se.

Transport and deposition of gold took place in a typicaly acid-sulphate hydrothermal environment. Hydrothermal ore-forming fluids transported gold as bisulphide complex and deposition of gold occurred in response to secondary boiling and changes in pH. These physio-chemical changes resulted in a decreasing of solubility of gold-bearing complexes when the ore-forming solutions reached the hydrothermal breccias where the bulk of the gold was deposited.

Field stop 6 : The Crni Vrh ore field

The Crni Vrh ore field is located in the western part of the Timok magmatic complex. The basic ore component in the majority of deposits and occurrences of mineral raw materials in the Crni Vrh ore field is copper. Gold is most frequently related component to copper while in some bodies it occurs as the chief ore component. Deposits and occurrences of ore mineralization are localized along the northeast, eastern, southeast and partly western edges of the plutonic complex. They predominantly occur in the andesites of the second volcanic phase and their pyroclasts. Along the edges of the plutonic complexes, there are places of skarn-type mineralization which sometimes contain magnetite or galenite-sphalerite paragenesis next to copper.

In the area of Crni Vrh, in addition to relatively fresh plutonites, hornblende pyroxene andesites and their pyroclasts there are two spacious zones of hydrothermally altered rocks that contain ore mineralization in places, too.

With regard to the conditions of origin, all deposits and occurrences of copper with gold being the related ore component in Crni Vrh ore field are classified into the following genetic and morphostructural types of ore mineralization:

1. Deposits and occurrences of copper with related gold mineralization and
2. Deposits and occurrences of gold with or without copper, lead and zinc mineralization.

The first type of mineralization includes:

- porphyry copper deposits,
- hydrothermal-volcanogenic deposits of copper and
- skarn deposits of copper, magnetite and lead-zinc.

The second type of mineralization includes:

- epithermal deposits and occurrences of gold highly sulfidized and
- epithermal deposits and occurrences of gold of low sulfidization.

The Lipa ore deposit

The first geological explorations of the Lipa deposit started on the eve of the Second World War when pyrite mineralization with small galenite quantities was identifed. They were renewed in 1950 and completed by 1954. Exploitation started in 1958. Until 1967 when the mining was suspended most of the deposit was exploited (about 75%), Figure 9.

Given as percentage, over 60% of the total area that belongs to the greater surroundings of Lipa deposit are hydrothermally altered rocks. This zone starts west of the Lipa River in the brooks of Ogasu Kurugu, lower course, Ogasu Dumitri, Ogasu Rosu, then proceeds east from the Lipa river in the brooks of Ogasu Kolc, Ogasu Ilija, Ogasu Madalic, to the slopes of Coka Fresen. According to the intensity and type of hydrothermal alterations, the rocks in the Lipa surroundings are: 1- silicified, alunitized, kaolinized and limonitized (hydroquartzites), 2- silicified, pyritized and kaolinized, 3- kaolinized and pyritized, 4- chloritized, epidotized, calcitized and weakly pyritized and 4- zeolitized rocks.

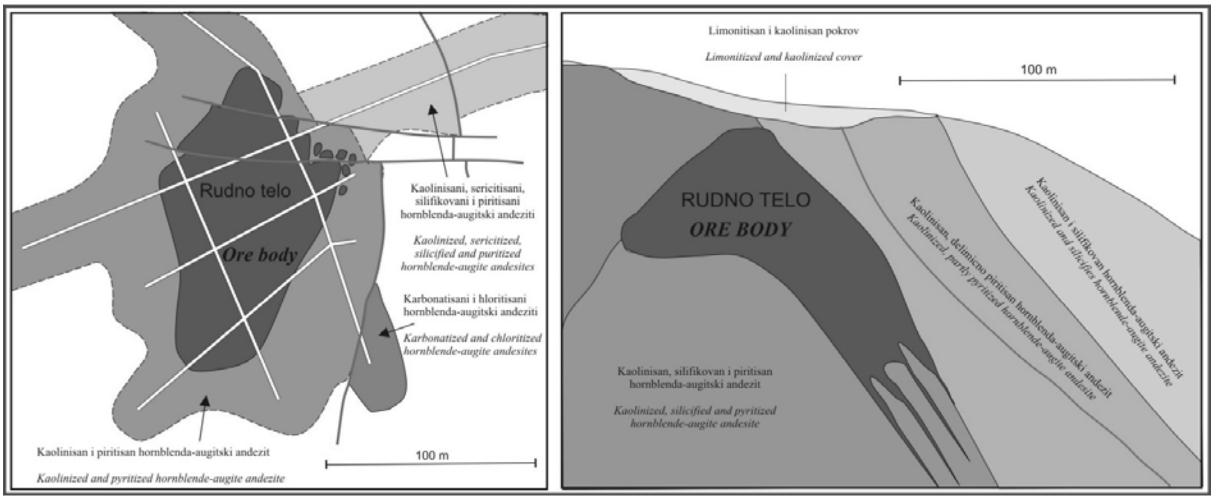


Figure 9. Geological plan and cross-section of the Lipa ore deposit.

The greater surroundings of the Lipa deposit is highly tectonized. Earlier investigations identified pre-ore, syn-ore and post-ore tectonics. Faults of the order(longitudinal faults) striking NNW-SSE coincide with general strikes of regional structures and represent main supply channels for hydrotherms. The most prominent are the faults of the Lipa River and the Kuruga-Kupinovo fault. Younger generations of faults lie at the right or other angles to structures of the first order.

The Lipa deposit and its close surroundings is made of hydrothermally altered hornblende-augite andesites. The predominant type of alteration is alunitic-diaspore facies of hydrothermal alteration reporesented by secondary quartzites. Laterally in the direction of the ore body towards the surrounding rocks, the zone of secondary quartzites continues into the zone in which sericitization, kaolinization, sulfatization and propyilization predominate. In some places in the deposit and at its flanks the presence of porous quartz was noticed. Gold occurs in hydroquartzites in the form of impregnations in concentrations of up to 2 g/t.

Kaolinization and limonitization predominate on the ground surface and its immediate surroundings. The origin of kaolinization is a descendent result of parent rock weathering in exogenous conditions. It builds a roof up to 14 m thick on the ground surface. It is important because it has safeguarded the ore deposit from oxidation processes. Individual analysis of kaolinite cover pointed to gold presence in the concentrations of 0.3 g/t Au to 1.9 g/t Au. Limonitization is the consequence of pyrite disintegration. Propylization is mostly represented by chloritization. This kind of alteration primarily attacked femic minerals in rock (amphiboles and other). This alteration facies, which has not any particular importance for ore mineralization is associated with pyrite of the first generation.

The most prominent structural element is a fault of 26-206^0 strike, 59-75^0 dip to ESE that intersects the ore body. In the northeastern part of the deposit the fault arches towards north and dips at 58^0 towards East. This fault was activated many times and represented the structural control of the vertical movement of mineralized hydrothermal solutions. In the postmineralization period the ore body suffered from partial breakate. The related structures perpendicular to the strike of the main fault were limited in space and had no effect upon additional deformation of the ore body.

The investigations cut into polymetallic quartz veins with galenite, sfalerite, pyrite, tetrahedron and chalcopyrite in several placed. The strike was North-South.

Morphology of ore bodies - From the aspect of gold the massive-sulfide deposit of the Lipa copper belongs to epithermal mineralization of high sulfidation type. The ore body (mineralized area) is in the form of stock with irregular physical distribution of gold. It consists of main and minor related ore bodies. The main ore body in the form of stock is 150 m long, 80 m wide and its dip was followed for about 100 m. The eastern limit of the main ore body is tectonic. In the other parts of the deposit, ore mineralization gradually passes into surrounding rocks.

Physically, gold mineralization has some larger spread than copper mineralization and covers the area in the immediate surroundings of massive sulfides with porous quartz. Gold mineralization lies 14 m under the ground surface.

Mineral composition - The most frequent minerals in the deposit are gel-pyrites and copper sulfides with major gold share. The oldest and the most frequent mineral of copper in the main mineralization phase is enargite accompanied with varying luzonite concentrations. Enargite occurs in several generations. In some places it pushes the hydrothermally altered andesite, pyrite and melnikovite. Younger enargite lies in the binder in ore fragments and is most frequently accompanied by barite.

The ore in the Lipa deposit is massive to breccia by structure. The matrix for breccia is enargite. It is joined with barite in some places.

Ore reserves - Total ore reserves were about 1,000,000 tons with 1.10% Cu; 13.285% S; 0.43% As; 3-6 g/t Au and about 20 g/t Ag.

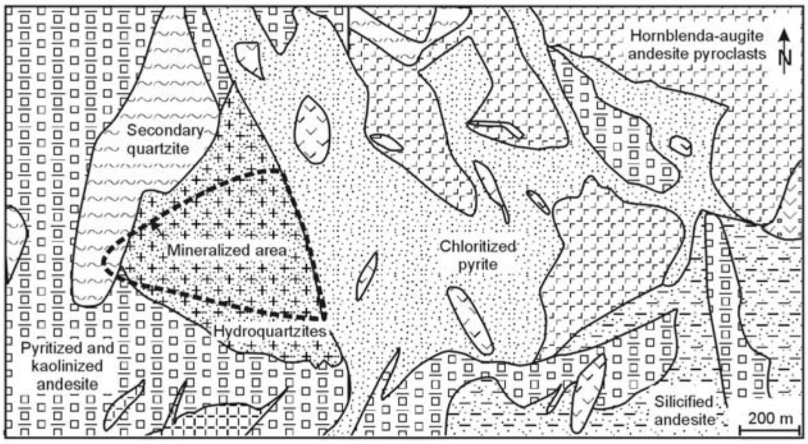
Gold occurs in variable concentrations. The central sections of the deposit contain 3-6 g/t Au and about 20 g/t Ag, while the peripheral sections contain about 0.7 - 1.5 g/t Au and about 10 g/t Ag.

The Kuruga ore deposit

In the geological structure of the Coka Kuruga deposit predominate hydrothermally altered rocks of andesite composition. Predominating among them are zones of hydroquartzites then zones of silicified, alunitized, pyritized and kaolinized andesites of secondary quartzite type, zones of chloritized and poorly altered andesites and unaltered (fresh) andesites.

If the vertical section is considered, then gold bearing hydroquartzites (porous quartz) with minerals from clay groups, then alunite and rarely rutile and scorodite lie on the top of the ore bearing Au/Cu structure in Coka Kuruga. The hydroquartzites are of breccia or relict-breccia texture. Breccia fragments are mostly represented by quartz, rarely, limonite, rutile and scorodite. Gold is of submicroscopic sizes present in quartz and limonite (Fig. 10).

Hydrothermally altered andesites lie in the immediate vicinity of the copper ore body of enargite type. Predominant facies of hydrothermal alteration are silicification, alunitization, pyritization and kaolinization. When considered from gold aspect, particularly important is alunite-kaolinite type of alteration as it indicates the presence of gold mineralization of high sulfidation type.



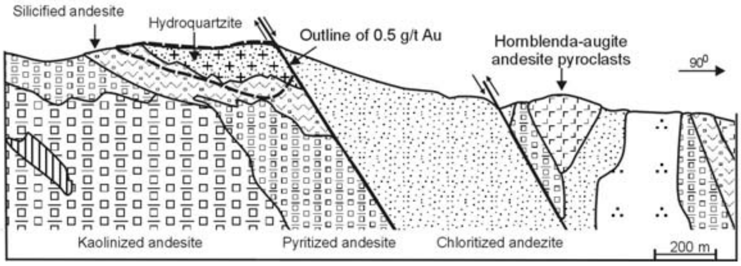


Figure 10. Geological plan and cross-section of the Kuruga deposit.

Alunitization in the area of Coka Kuruga occurs in form of minor accumulations and rarely alunite veins. It is accompanied with fine grained xenomorphic quartz, rarely, chalcedony. Kaolinization manifests itself by plagioclase turning into minerals from kaolin group (kaolinite, dickite, diaspore). Diaspore is often encountered in the form of individual crystals of minor crystals or local accumulations.

In hipsometric parts of ore bearing structure of Coka Kuruga also lie hydrothermally altered andesites. They are more intensely altered, predominantly sulfatized, silicified, kaolinized and pyritized than in the higher ground. A major share in this zone belongs to gypsum, rarely anhydrite. It occurs in the form of veins up to 1 cm thick and accummulations of irregular fields.

Silicified, pyritized, kaolinized and chloritized andesites represent the argilitic alteration facies and occur as a halo around the secondary quartzite facies. There is a zone of chloritization around them (peripheral propylite zone). Chloritization is often associated with calcitization and epidotization of femic minerals.

Volcanism in the greater area of the Coka Kuruga deposit is partly subaeran by type. Lavas were relatively poor in water so that the intensity of convection hydrothermal system probably was modest in scale. Judging by the analysis of external features, it can be assumed that in the period of volcanic activity the analyzed space has the characteristics of a flattaned volcano, pulsation in character. Hydrothermal breccia frequently occuring in the periphery and in the deep sections of the assumed volcanic systems are proofs of periodic explosive character.

In the domain of the Coka Kuruga ore bearing structure mine preceding tectonic processes are particularly important. They opened routes for rock intrusion and later circulation of hydrothermal solutions. Vertically penetrating hydrothermal fluids and permeability of surrounding andesites enabled the widening of hydrothermally altered zones more in the vertical direction and less in the horizontal direction. Funnel like shapes of hydrotermal alteration facies reflect the change of physical-chemical characteristics of the solutions with the distance increasing from the supply channel and the drop of reactive intensity with surrounding rocks.

Morphology of ore bodies - The Coka Kuruga gold and copper deposits consists of two ore bodies of different morphostructural characteristics. In the north of the mineralized area there is the "northern" massive-sulfide ore body of copper that passes into stockwork impregnating ore variety. In this type of mineralization increased gold content of epithermal type occur together with copper. The ore body is localized in the depth of about 40 m from the actual ground surface. Its dip was followed to the depth of 120 m. Vertical mineralization interval is about 80 m. Based on preliminary, non-systematic investigations, the following mean contents of useful components were determined: 0.9% Cu, 2 g/t Ag and 1 g/t Au.

In the southern part of the ore mineralized area there is the so-called „southern ore body". It is made of porous hydroquartzite of lense shape in which epithermal gold mineralization of high sulfidation (ore bearing hydroquartzite) lies in the form of impregnations. A portion of porous silica later recristallized and formed monoquartzites.

Hydroquarzite contain 0.84 g/t Au and 3.08 g/t Ag on average. Increased gold concentrations (>2 g/t Au) were noticed particularly in the areas with fine grains of quartz (1-5 mm) and silica binder as matrix. These area are in the form of pseudolayers and relatively little present. The gold bearing hydroquartzites overlie alunitized and pyritized hydroquartzites with diaspore.

The relations among the charactersitic ore elements indicate that changes of physical and chemical properties of hydrothermal solutions were more pronounced in the area of gold bearing massive suilfide mineralization than in hydroquartzite. For this reason, increased gold concentrations were not noticed in the section with hydroquartzites, which is explained to be the consequence of sudden saturation of mineralized solutions with gold, silver, copper, arsenic and separation in the form of solid phases in the deeper portions of the terrain. Because of enargite the most frequent copper mineral, arsenic concentrations are markedly increased and amount to 0.25% for massive-sulfide part and 0.18% for stockwork-impregnation art of the mineralized area.

Mineral composition **-** The mineral composition in Coka Kuruga is relatively simple. The most frequent mineral is pyrite and enargite of copper minerals. In addition to them the ore association constitutes chalcopyrite, sfalerit, scorodite, malahite, cuprite, coveline and chalcocite. The most frequent minerals in the barren rocks are quartz and barite.

Pyrite predominates in massive-sulfide type of ore mineralization (about 24% of the total mass of ore minerals). In the stockwork-impregnation type of mineralization the same mineral constitutes about 14% of the total quantity of ore minerals. In addition to solitary grains and aggregates, pyrite sometimes aggregates enargite grains or petrogenic minerals from the surrounding rocks which may point to its metasomatic origin.

Enargite is the most frequent copper mineral in the deposit. It occurs in the form of isolated pillar like crystals, then seams or ireegular fields, monomineral or in association with barite. Enargite crystals frequently push pyrite and silicate minerals. Enargit is substituted by tetrahedron and tenantite in some places along the periphery.

The presence of gold in the deposit of Coka Kuruga is not fully defined. It is assumed that is occurs as "invisible", in gold bearing pyrites, sulfides and minerals in barren rocks (barite, quartz) and alloyed with silver. It usually occurs as dispersed or rarely in crystal shapes of octahedron to 10 micron in size. It most frequently occurs in the form of electrum.

The geochemical associations of the main ore elements in the Coka Kuruga area are represented by the association of Cu+As+Sn+Ag, then Cu+Mo+As, Cu+As+Sn and Mo+As. Increased silver contents lie in connection with secondary quartzites and anomalies of arsenic and molybdenum often overlap. Increased concentrations of barium and mercury were noticed, too.

Under the influence of exogenous agents a portion of the ore mineralization close to the ground surface was exposed to supergenic transformations. Primary sulfide minerals were mostly transformed into limonite and scorodite. The copper minerals formed were malachite, cuprite and native copper. One of the most frequent minerals is malachite that occurs in the form of coatings and films.

Ore reserves - Ore reserves in the deposit of Coka Kuruga were derived from the data collected before 1984 In 1986 a study on hydroquartzite ore reserves in the Coka Kuruga deposit was prepared (Copper Institute, Bor) and the estimated reserves quoted were: Category A – 722,741 tons, Category B – 588,787 tons, Total A+B = 1,311,528 tons.

DESCRIPTIONS OF THE GEOLOGICAL PROFILES

Field stop 1. Crossroad near Brestovac

Hyaloclastic and autoclastic deposits of pyroxene- and amphibole-bearing basaltic andesites (Senonian volcanic phase) cut by a peculiar albite trachyte dyke. The whole sequence is apparently covered by resedimented hyaloclastites but their outcrops can be found along the road towards Bor. Hylaoclastic deposits have many primary features such as elements of a jig-saw puzzle structure, the presence of pseudopillows or lava lobefeatures, etc. A zircon U/Pb analysis on albite trachyte gave two ages of 81.79±0.54 and 82.27±0.35 Ma. Basaltic andesite breccias have not yet been dated.

Figure 1. Albite trachyte dyke of a pale pinkish color intruding greyish basaltic andesite volcaniclastic rocks. Relics of a lava lobe (A) found within the hyaloclastic rocks, showing partially fragmented glassy margins (full arrows); in the upper right-hand part of the photo subangular fragments formed by hyaloclastic fragmentation can be seen (B); dashed arrow shows an incompletely broken hyaloclastitic fragment.

Field stop 2. Section along the road in the Brestovac village

The section is situated within the exploration area of the SEE, which is here engaged in exploration of low epithermal Au-Ag mineralization as well as occurrences of Pb-Zn-Cu ores. The volcanic rocks which host the mineralization are represented by coherent and volcaniclastic facies of hornblende andesites and marly sediments containing Lower Senonian microfauna. The first outcrop of the section shows hydrothermally altered andesites and that is the place where the SEE makest its exploration drillings. These rocks show evidence of intensive hloritization, epidotization and weakly developed pyritization, silicification and carbonitization. Along the section, the altered rocks are subsequently followed by the Lower Senonian marly sediments after which fresh hornblende andesites occur. The fresh andesite volcanic rocks may be followed up to the end of the section.

Field stop 3. Road cut southeastward from Brestovačka Banja

The first section shows partially to totally grusified lava flow facies of pyroxene andesite composition. The volcanic rocks contain boulders and fragments of pinkish granitoid rocks of most probably Variscan age (Figure 2). The following section reveals remnants of autobrecciated lava flow facies of pyroxene-hornblende andesite (Senonian volcanic phase).

Figure 2. Small fragment of pinkish granitoid rock in to the grusified pyroxene andesite lava flow.

Field stop 4. Section along the transportation conveyer

At the site a series of Bor conglomerates, microconglomerates and sandstones can be seen. The clastic rocks are poorly sorted and contain rounded fragments which grain size ranges from several milimeters to a few tens of centimeters. The fragments are polymikt in character. According to the present of remnants of microfauna and nanoflora these sediments are interpreted as Upper Senonian – Maastrichtian in age. These sediments represent the youngest facies of the Timok Magmatic Complex since they cover all the primary and resedimented volcanic facies. Due to reverse faulting the conglomerates are disposed to the same level with mineralization and this relationship can be observed in the Bor open pit.

Figure 3. Poorly sorted “Bor” conglomerates with rounded fragments which grain size ranges from several milimeters to a few tens of centimeters. The fragments are polymikt in character.

Field stop 5. Sections along the road cut Krivelj-Mali Krivelj

At the first section crop out hornblende-biotite andesites which appear as lava dome or cryptodome facies. There is columnar to platy jointing to be seen at the outcrop (Figure 4). These volcanics belong to the First volcanic phase. They were dated by U/Pb zircon analyses and revealed the age of 84.26±0.67 Ma. In the continuation, along the road, there re several outcrops of brecciated andesites of the same composition. They were interpreted as lateral facies of the same dome/cryptodome.

Figure 4. Columnar to platy jointing in to the hornblende-biotite andesitic lava dome/cryptodome. Brecciated andesite lateral facies of the lava dome/cryptodome.

Field stop 6. Granitoid of Gornjane, road cut towards Majdanpek near the Tanda village

Deleon et al. (1965) reported a Carboniferous age (277 Ma) for these granitoid rocks. This massif is situated in the wide area of the Gornjane village. The presence of granodiorite and quartzmonzonite facies has been reported. However, the most important facies are reddisch syenite and quartz syenite facies found near the village of Tanda. The granitoid rocks show characteristics of I-type granitoids ('I' refers to igneous source) according to the classification of Chappel and White (1977). Analogous rocks occur as fragments of various size, sometimes as boulders, within the volcanic rocks of TMC (Field stop 3).

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