Rudarsko-geološko-naftni zbornik	Vol. 1	str. 23—28	Zagreb, 1989.

UDC 553.445:552.13:622.34"311" *Izvorni znanstveni članak*

GALENA-BEARING ORE OCCURRENCES IN THE ČATRNJA DISTRICT OF TRGOVSKA GORA IN CROATIA

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Key-words: Ore minerals, Microphysiography, Intensity, Extensiveness, Sequence of mineralization, Old mines

The paper gives an account of mining operations in the Paleozoic of the Čatrnja district where mining was conducted for silver-bearing galena.
A detailed description is given of the microphysiography and the sequence of hypogenic, hypergenic and epigenetic metamorphic minerals in the Čatrnja district.

Ključne riječi: Rudni minerali, Mikrofiziografija, Intenzitet, Ekstenzitet, Redoslijed mineralizacije, Stari rudokopi

U radu je dat prikaz rudarske djelatnosti u paleozoiku područja Čatrnja gdje se rudarilo na srebronosne galenite.
Dat je i detaljan mikrofiziografski opis hipogenih, hipergenih i epigenetskih metamorfnih minerala, zatim redoslijed mineralizacije kao i intenzitet i ekstenzitet identificiranih minerala.

Introduction

The Trgovska gora (+577 m) is situated south of the town of Sisak at a distance of about 40—50 kms (Fig. 1). The area lies in the catchment area of the river Una, with the Žirovac brook as its main tributary.

In the Trgovska gora numerous remnants bear witness to mining activity in search of iron and silver-bearing lead ores in Illyrian, Roman and medieval times and in search of iron and copper ores in the time of the Austrian empire (Jurković, 1962).

The detailed geological characteristics of the Trgovska gora and a description of seven paragenetic types of ore occurrences are given in papers by Jurković & Durn (1988) and Jurković (1988).

The silver-bearing galena ore occurrences are one of seven paragenetic types of the Trgovska gora metallogenetic area. This type is represented by siderite as the main gangue mineral and by silver-bearing galena as the main ore mineral. Chalcopyrite and smaller quantities of tetrahedrite, sphalerite, pyrite and gersdorffite are subsidiary constituents. Quarz is a significant gangue mineral.

These deposits occur in the catchment area of the tributaries running into the Mali Majdan stream (the Zrin district described by Jurković & Durn, 1988), as well as in the catchment area of tributaries to the Velebit brook (Čatrnja district).

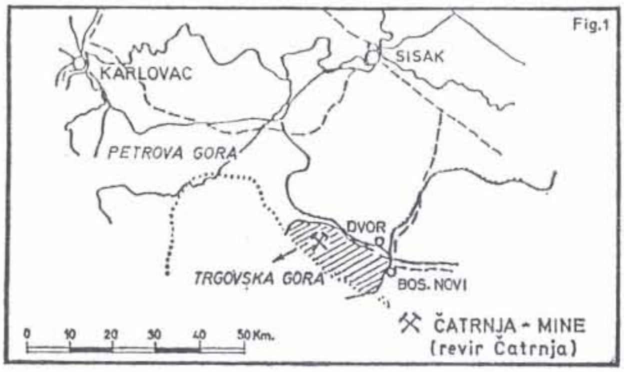
The ore-bearing district of Čatrnja

This district is situated south of the Zrin district (Fig. 2), between Pavlovo Brdo (+433 m) and Hasanov Grob (+383 m) on the north, and between Kleb (+509 m), Zarića Kosa (+435 m) and Puhovac (+353 m) on the south, stretching N—S about 2 kms. It covers the source area of the Velebit potok (8 kms long), the tributary of the Žirovac potok near the village of Trgove.

At a distance of 4,5 kms upstream from its mouth the Velebit stream receives the Jamarski brook, which flows across the northern and eastern slopes of Zarića Kosa, the north-eastern slopes of Kleb, and the southern slopes of Puhovac. Further upstream, at level +230 m., the Velebit stream is formed by the junction of four tributaries: Manašica, the Grigorijev brook, the Čatrnja brook, the Jamsko brook.

In the Middle Ages the Čatrnja and Zrin districts constituted a unique ore-bearing region where prospecting and mining for silver-bearing galena were pursued. They were not connected by underground workings, but only by superficial diggings, pits and adits on the eastern slopes of Pavlovo Brdo. We have very scanty data relating to mining activities during that period.

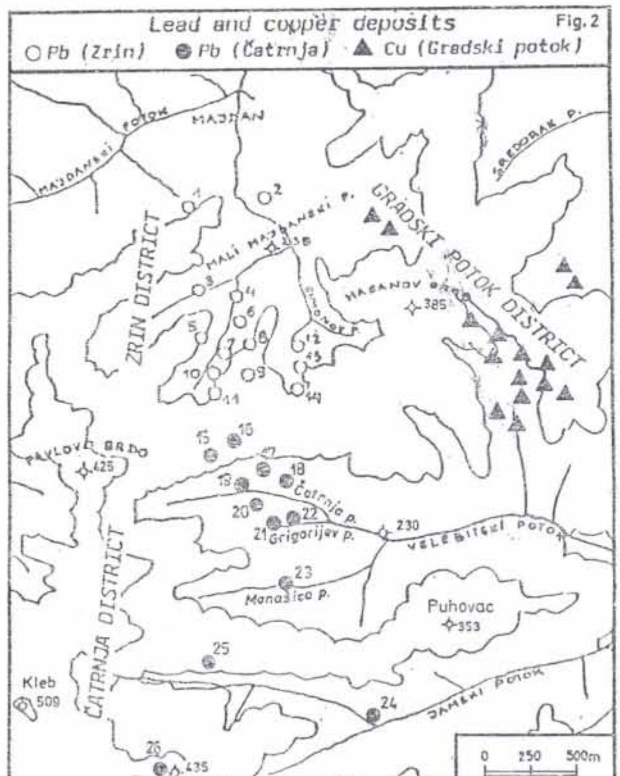
Prospecting activities were carried out in the 18th and 19th century in an attempt to link the Zrin mine to the Čatrnja mine, but when this work was suspended it was still 200—250 meters short of the proposed junc-



tion, some 80—100 meters below the deepest medieval workings.

The medieval operations were highly intensive, both as regards prospecting and exploitation, operations in more recent times have had an almost exclusively exploratory character, with ore being extracted only from prospecting sites.

Mineralisation is concordantly deposited in Paleozoic (Carboniferous) shales, siltites and grauwacke sandstones, running generally in a NNW—SSE direction with a donward gradient towards ENE.



15. UPPER JAMARSKO ADIT 16. JAMARSKO SHAFT 17. LOWER JAMARSKO ADIT 18. FERDINAND ADIT 19. ČATRNJA ADIT 20. ANA ADIT 21. UPPER JUSTEMBERG ADIT 22. LOWER JUSTEMBERG ADIT 22. LOWER JUSTEMBERG ADIT 23. MANAŠICA ADIT 24. LOWER JAMSKO ADIT 25. UPPER JAMSKO ADIT 26. DRAŠ.JE

Siderite is the main mineral of the ore occurrences in the ore-bearing district of Čatrnja, quartz is next in quantity after siderite, locally in equal quantity. With the naked eye we were able to observe galena, chalcopyrite, pyrite, tetrahedrite; sphalerite and gersdorffite only by microscope.

Historical Data

The geographical location of prospecting operations in the Čatrnja ore-bearing district during the period from 1772 to 1910 is best illustrated by old mining maps by Wojtanek (1772), Szedelmy (1845) and Reithofen (1910). Data concerning particular mining operations, especially the Ferdinand mine workings, are to be found in publications and surveys by Lipold (1856), Andrian (1868), Hauer (1870), Vukasović (1879), Kišpatić (1901), Reuter (1910) and Andrejević (1922). These sources record that the ore-bearing bodies are deposited concordantly in Carboniferous schists running NNW—SSE, declining towards the ESE, that the deposits are in the form of flat lenses lying parallel to each other, that the ore occurrences are very uneven along their extension, very poor, almost sterile sections giving way to richer and thicker stretches. The ore is sideritic, with a fair amount of quartz. Amongst sulfides, silver-bearing galena is the most plentiful, followed by chalcopyrite, then tetrahedrite and sphalerite.

Tućan (1908) published an analysis of the siderite from Jamski potok, and in a later article (Tućan, 1941) mentioned some of the minerals of the Ferdinand, Justemberg and Manašica mines. Tetrahedrite is mentioned by Zepharovich (1859), along with chalcopyrite and galena. There is also a note to the effect that the firm »Trgovski mines and foundries« extracted 83,5 tons of lead ore in the period between 1857 and 1874.

An account of individual mine workings

In the area of the Čatrnja stream, from which the district derives its name, and which is the most northerly component of the Velebit watercourse, on the slopes of Pavlovo Brdo, there is situated the Jamarsko group of workings. *The Upper Jamarsko adit* (no 15 on Fig. 2) is located at level +310 m. and extends N 15° W, following the lode at a depth of 30 m., with a cross-cut intersecting a 20 m. wide mineralized zone with a series of thin ore-bearing »Lagergängen«. From this cross-cut *the Jamarsko shaft* (no 16) was constructed to the west for ventilation purpose, reaching the surface of the site at +325 m. From the workings at no. 15 a gallery 20 m. long was constructed which linked these workings with the *Lower Jamarsko adit* (no 17) at the level +295 m. This adit was 250 m. long, reaching the ore-bearing zone after 120 m. and following it for 130 m. in the NNW—SSE direction of its extension. The adit cut through four ore-bearing zones, three relatively major zones at 80 to 90 m. along the adit, and the main ore-bearing zone at 120 m. The lode was very irregular the stratified seams were very thin, thicker and more ample only here and there. In places a system of thin veinlets formed the ore-bearing zone. Attempts were made by means of short inclines and raises (the longest 15 m.) to reach the Ferdinand adit, but a junction was not achieved.

The most important prospecting work carried out in the Austro-Hungarian period was the *Ferdinand adit* (no. 18) at level +250 m., 210 m. long, running N 40° W. Its terminal point cut through a lode extending N 20° W and ran with it for about 80 m. At 175 m. along the adit a cross-cut was constructed which also cut through the ore-bearing zone at a distance of 20 m. The quality of mineralisation was tested by additional cross-cuts to east and west. A junction with the Lower Jamarsko adit was not accomplished. The Ferdinand adit showed the existence of deep mineralisation extending through 75 m., from elevation +325 to +250 m. All the evidence suggests that the ore-bearing zone in the workings described here represents an extension southward of the workings from the Zrin district (Alexander, Leopold, Franciska).

On the left bank of the Čatrnja brook two adits called the *Čatrnja adits* (no. 19) were constructed, one at elevation +270 m., the other at +280 m., at outcrops of galena ore deposits. There are no written records of these.

On the opposite, right bank of the Čatrnja brook, the *Ana adit* (no. 20) was excavated, 50 m. long, irregular in its alignment and traversing minor ore seams. It was desired to explore the further extension of mineral deposits in a southerly direction by means of this adit.

On the Grigorijev brook, the central tributary of the Velebit watercourse (Fig. 2), there are two adits: the *Upper Justemberg adit* (no. 21) at elevation +260 m., and the *Lower Justemberg adit* (no. 22) at elevation +255 m. The first was constructed before 1772, the second was later. Prospecting was carried out on two ore-bearing zones running in a NNW—SSE and NW—SE direction with a decline to the NE. The length of the adits was 40 m. The working confirmed that the mineralisation ran parallel to the schistosity of the wall-rocks. The siderite ore was liberally sprinkled with galena, locally with chalcopyrite, and here and there also with tetrahedrite, sphalerite and pyrite. Sulfides are for the most part bound to silicified parts of the siderite. The seams are irregular, frequently splitting up into reticulated complexes, but there are also conjuctions of veinlets, thicker sections rich in ore.

Further to the south, in the valley of the Manašica brook, the most southerly component of the Velebit watercourse (Fig. 2), there are the remains of ancient mine workings which continue across a spur towards the Grigorije brook. Particularly prominent is the *Manašica adit* (no. 23) at elevation +250 m., which is recorded on the oldest mining maps by Wojtanek from 1772 and Szedelmy from 1845 as exploratory works for silver-bearing galena. According to R e u t e r (1870), the adit, 40 m. long and running NW—SE, was pursuing an ore-bearing zone with a dip towards the NE.

In the catchment area of the Jamsko brook, which enters the Velebit stream beside the village of Stambolije, there are a number of outcrops of galena ore which were explored by means of two short adits, the *Lower Jamsko adit* (no. 24) at level +220 m., and the *Upper Jamsko adit* (no. 25) at +260 m. The former is situated halfway between Puhovac and Zarića Kosa, while latter is in the upper part of the catchment area on the left side of the Jamsko brook. The former was constructed before 1772, latter after that date.

The southernmost exploratory workings, *Orašje* (no. 26) were situated on Zarića Kosa (+435 m.) and there were amongst the oldest prospecting sites for silver-bearing galena developed in the Austro-Hungarian period; they are entered on Wojtanek's map of 1772. The ore-bearing tract runs N—S.

Paragenesis

A detailed microscopic examination of thin ground and polished sections from the ore occurrences in the Čatrnja district revealed the following hypogenic and hypergenic minerals (Fig. 3):

Hypogenic minerals: pyrite I, siderite I, pyrite II, quartz II, gersdorffite (korynite), sphalerite (marmatite), chalcopyrite II, tetrahedrite I, tetrahedrite II (freibergite), galena.

Metamorphic minerals: siderite II, hematite.

Hypergenic minerals: anglesite, chalcocite, covellite, goethite, lepidocrocite, malachite, azurite.

INTENSITY AND EXTENSIVENESS OF HYPOGENIC AND HYPERGENIC MINERALS IN THE ČATRNJA DISTRICT ORE OCCURRENCES

Fig. 3

HYPOGENIC MINERALS	I	E	HYPERGENIC MINERALS	I	E
PYRITE I (pirit I)			ANGLESITE (anglezit)		
SIDERITE I (siderit I)			CHALCOCITE (halkozin)		
PYRITE II (pirit II)			COVELLITE (kovelin)		
QUARTZ II (kvarc II)			GOETHITE (getit)		
GERSDORFFITE (gersdorfit)			LEPIDOCROCITE (lepidokrokit)		
SPHALERITE (sfalerit)			MALACHITE (malahit)		
CHALCOPYRITE II (halkopirit II)			AZURITE (azurit)		
TETRAHEDRITE I (tetraedrit I)			METAMORPHIC MINERALS	I	E
TETRAHEDRITE II (tetraedrit II)			SIDERITE II (siderit II)		
GALENA (galenit)			HEMATITE (hematit)		

Sl. 3 Intenzitet (I) i ekstenzitet (E) minerala u paragenezama rudnih pojava područja Čatrnja

M i c r o p h y s i o g r a p h y

H y p o g e n i c m i n e r a l s :

Pyrite I is a very rare mineral; it appears as individual microscopically small rounded grains in siderite I.

Siderite I is the main mineral in all the microscopically investigated specimens (on average from 70 to 90 % of the ore mass); only here and there quartz II matches the quantity of siderite. Siderite I is in the form of large crystals, with very clear to perfect rhombohedral cleavage,very high bireflection and anisotropic effects. Some specimens show brown or reddish-brown colour from dust-like inclusions of hematite. Deformation by tectonic action caused locally cataclased structures and recrystallites of fine grained siderite II. Siderite is often replaced by quartz II, sulfides and sulfosalts, especially beautiful replacement structures are those formed by galena (sieve-like or insular structures of siderite). In some specimens oxidization of siderite I into goethite follows along the plane of cleavage; this phenomenon is more markedly visible in tectonically deformed parts of siderite I. The analysis made by Tućan (1908) of coarse-grained siderite from Jamarsko potok showed: 80,72 % $FeCO_3$, 1,32 % $MnCO_3$, 3,81 % $CaCO_3$, 2,14 % $MgCO_3$ and 11,58 % insoluble matter.

Pyrite II is observed in strongly silicified parts of siderite I as small corroded grains, locally associated with younger gersdorffite; in one polished specimen we observed a few relatively larger idiomorphycally developed crystals of hexaedric habit.

Quartz II is, after siderite I, the most abundant mineral in the ore paragenesis and it is present in all polished specimens. It replaces siderite I at cleavage planes, fissures and the edges of siderite I grains, creating micro-grain systems and scattered small masses and »plages« (open spaces, cavities, interstices) filled with younger minerals. It is itself replaced by later crystallized sulfides and sulfosalts. Quartz II is a bearer of corroded pyritic grains and especially of gersdorffite in the form of corroded micrograins or idiomorphically developed hexahedric crystals (ϕ 10—30 microns).

Gersdorffite (korynite) — Ni, Fe, Co) As S is observed in the majority of ore samples, but often only by microscope in polished specimens, very rarely by the naked eye as silver-white to steel-grey masses with metallic lustre. Polishing properties are perfect. Cleavage ∥ (100) is also perfect. The polishing hardness is considerably higher than those of sphalerite, chalcopyrite, tetrahedrite, galena, but much lower than that of pyrite. Reflectivity is high, white in colour, contrasted with blue-white galena it shows a cream tinge. In cedar oil not distinctly lowered. Isotropic. The grain size is of microscopic dimensions, mostly idiomorphic with (100) and (111) or slightly corroded crystals (in quartz composed of individual crystals of a diameter of 10 to 30 microns) or as small droplets and isometric masses in galena. Very often it is associated with chalcopyrite, less often with tetrahedrite, and is replaced by them. In quartz it is mostly idiomorphically developed, in chalcopyrite, tetrahedrite and especially in galena very often more or less corroded. The sequence established by the cases of replacement indicate that gersdorffite crystallizes in the same phase as quartz II and pyrite II. Ore samples from the Čatrnja adit and from the Ferdinand adit showed traces of Ni by chemical analyses.

Sphalerite is found only in a fifth of the polished specimens, mostly of a microscopic dimension, rarely observed by the naked eye. Usually associated with chalcopyrite and tetrahedrite, it is replaced by them and by galena, itself replacing siderite I in the form of isolated masses. Iron-rich (marmatite), with numerous yellow, brown and dark-brown internal reflections. Locally found in larger masses of chalcopyrite in the form of corroded grains.

Chalcopyrite II is observed in all investigated polished specimens, and, after galena, is the most plentiful sulfide. In some specimens it even predominates over galena. Mostly it occurs replacing siderite I or filling the cavities (drusy space) in quartz II together with other sulfides and sulfosalts, especially with galena. Chalcopyrite II is very unequally distributed in ore specimens. Very often it is associated with tetrahedrite, less often with galena, rarely with sphalerite and gersdorffite. Masses of chalcopyrite II are irregular in form and of very different diameters. Inside bigger masses of galena there occur rounded, corroded masses of chalcopyrite II.

Tetrahedrite I is visible to the naked eye in some polished specimens. Observed by microscope, it exibits olive-green reflectivity. It occurs replacing siderite I, alone, or associated with chalcopyrite II. Tetrahedrite I is older than galena, in part somewhat younger than chalcopyrite II, but also in part coeval with it (mutual boundaries).

Tetrahedrite II is found in galena, it is a silver-bearing tetrahedrite or freibergite. This mineral is the main bearer of silver in the ore deposits of the Čatrnja district. The ore samples taken from the Justemberg and the Ferdinand adits showed very strong traces of Ag by chemical analyses. It occurs in the form of microscopically small rounded grains or irregular corroded relicts inside galena. Often it is associated either with chalcopyrite II or with gersdorffite.

Galena is the main sulfide mineral of all ore occurrences in the Čatrnja mining district; only in few specimens is it subordinate to chalcopyrite II. The distribution of galena is very irregular from one specimen to another in the different ore deposits. To the naked eye it is observed associated with chalcopyrite

II, sometimes with tetrahedrite I. It is a very coarse-grained mineral. It replaces siderite I along cracks and cleavage planes, forming very instructive irregular masses, nests, veinlets. In some crystals triangular pits following the cube-planes are visible. Galena fills the drusy spaces in larger masses of quartz I. It is a bearer of small rounded grains and masses of tetrahedrite II, rarely of chalcopyrite II and very rarely of gersdorffite. It is the younger mineral of the paragenesis. Chemical analyses of ore specimens taken from the dump of the Justemberg adit showed 12,.14 % and 8,43 % Pb, and one specimen from the Ferdinand adit 3,85 % Pb.

Metamorphic minerals:

Siderite II is observed in cataclased and milonitized parts of ores. In those parts of siderite I which have been affected by fissures and cataclases locally these processes brought about recrystallization into fine-grained aggregates of siderite II, some of those spatially and optically aligned, orientated.

Hematite is formed by hematitization of siderite I in the form of dust-like microscopic and submicroscopic inclusions. This phenomenon causes red-brownish internal reflections (»Braunspat«); it arose probably during the last orogenic phase in Tertiary.

Hypergenic minerals:

Anglesite is a product of the incipient phase of oxidation which develops along cleavage cracks of the galena.

Chalcocite and *covellite* are products of the oxidation of chalcopyrite II in lamellae ‖ (111), or, to a lesser extent, of tetrahedrite I.

Goethite is the most abundant hypergenic mineral; it is primarily a product of oxidation of siderite I, then of siderite II, but also to some extent of other Fe-bearing minerals (in such cases together with *lepidocrocite*).

Malachite and *azurite* arose by the weathering of Cu-bearing minerals (chalcopyrite and tetrahedrite).

All the polished specimens were taken from the lower levels of the Čatrnja district which have been affected only by the incipient phase of oxidation. The ores from the upper levels have been oxidized to a significant degree.

Sequence of mineralization

The oldest mineral is pyrite I in the form of corroded grains of microscopic dimensions inside siderite I and quartz II.

The crystallization of coarse-grained siderite I represents the main phase of mineralization. It is often of reddish-brown color (Braunspat) from finely dispersed hematite dust.

The next phase is the phase in which quartz II crystallizes as the main mineral after siderite I.

The crystallization of quartz II in the form of veinlets, nids, nests and larger or smaller irregular masses is accompanied by small amounts of pyrite II and gersdorffite.

The next step is the phase of sulfides and sulfosalts: sphalerite, chalcopyrite II, tetrahedrite I and, finally, galena with the exsolutions of tetrahedrite II (freibergite).

The hypogenic minerals underwent diagenetic and anhymetamorphic processes (Variscan and Pyrenean orogenesis): crystallization, strains in the minerals, optical anomalies, cataclasis, recrystallization of siderite I into small-grained siderite II, hematitization of siderite I etc. Hypergene processes arose in the Tertiary.

The genesis of silver-bearing deposits in Trgovska gora has been discussed in papers by Jurković & Durn (1988) and Jurković (1988).

Received: 3. XI. 1988.
Accepted: 6. II. 1989.

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Olovne rudne pojave u području Čatrnja u Trgovskoj Gori, Hrvatska

I. Jurković

Rudno područje Čatrnja je južni nastavak orudnjenja u rudištima Zrin i Franz detaljno opisanih u radu Jurković & Durn (1988). Mineralizacija se javlja u izvorišnom dijelu Velebitskog potoka koji nastaje spajanjem Čatrnja, Grigorije, Manašica i Jamsko potoka.

U srednjem vijeku rudna područja Zrin i Čatrnja predstavljali su jedinstveno područje na kojem se vadila olovna ruda i iz nje koristilo srebro za kovnice novca u Gvozdanskom. Radovi nisu bili podzemno povezani jer se radilo raskopima, niskopima i slijepim oknima nepravilnih oblika. U doba Austro-Ugarske (XVIII i XIX stoljeće) izrađen je niz istražnih potkopa ukupne natkopne visine od 75 m, neki međusobno povezani niskopima i uskopima. Eksploatacije nije bilo, vadilo se samo rudu iz istraga. U članku je dat kratak opis rudarskih radova iz prošla dva stoljeća navedenih pod brojevima 15—26 ucrtanih na slici 2.

Istrage su pokazale da se mineralizacija javlja u karbonskim sedimentima: šejlovima, siltitima, grauvaknim pješčenjacima, konkordantno slojevitosti tih stijena, općeg pružanja NNW—SSE s padom na ENE.

Glavni mineral u paragenezi je krupnozrnat siderit, često u vidu »Branuspata« zbog submikroskopski finog praha hematita. Po količini slijedi kvarc koji potiskuje siderit duž romboedrijskih ploha kalavosti ili sistema prslina i pukotina kristalizirajući u vidu žilica, gnjezdašca, manjih ili većih masica unutar siderita. Istdobno se kristaliziraju neznatne količine pirita i gersdorfita. Slijedi glavna faza sulfida i sulfosoli: sfalerit → halkopirit → tetraedrit → galenit s frajbergitom.

U postmineralizacionoj fazi, u toku mlađih orogeneza tektonska naprezanja dovode do lokalne rekristalizacije siderita u mikrozrnati rekristalizat siderita II te hematizacije siderita.

U tercijeru je došlo i do zamjetljivih hipergenih procesa u najgornjim dijelovima rudnih pojava i do stvaranja prvenstveno getita, u manjoj mjeri anglezita, halkozina, kovelina, malahita, azurita, lepidokrokita i sl.

U članku je dat detaljan mikrofiziografski opis svih identificiratnih minerala, redoslijed izlučivanja te intenzitet i ekstenzitet pojavljivanja minerala.