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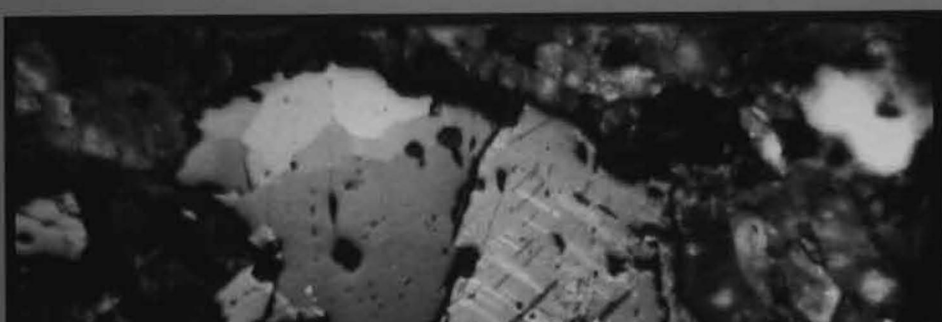

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IRON MINERALIZATION RELATED TO THE PALEOZOIC GRANITOIDS IN THE CUREV RID LOCALITY (EASTERN MACEDONIA)

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Abstract: The latest field and laboratory investigations carried out on the occurrences of Fe mineralization in the vicinity of Curev Rid offered new understanding about this Paleozoic granitoid mineralization. Microscopic and electronic microprobes made possible a more complex understanding of the features of the major ore minerals. The investigations discovered the composition of the major minerals and obtained data about the contents of microelements by monomineral tests on magnetites or their geochemical characteristics. The most important ore textures and compositions were determined for the first time making possible the determination of the sequence of ore mineralization as well as the genetic type of this ore occurrence.

Key words: ore occurrence; ore minerals; structures; textures; magnetite; hematite

INTRODUCTION

The Curev Rid Fe occurrence is situated southwest of Gubenek some 12 km southwest of the town of Berovo. Several research workers have investigated the occurrence and its surrounding: Rakicevic et al. (1969), Rakičević and Kovačević et al. (1973) when compiling the pages for Strumica, Štip and Delčevo. Dumurdžanov (1977) carried out detailed investigations and studies during the explorations for iron carried out in Eastern Macedonia from 1975 to 1978. The metallogeny was studies by Spasovski and Serafimovski (1998).

GEOLOGICAL CHARACTERISTICS

Data obtained in the geological mapping and earlier investigations determined Precambrian metamorphic rocks, Riphean-Cambrian metamorphic rocks and Tertiary-Quaternary sediments (Fig. 1).

Precambrian metamorphic rocks

Precambrian occurrences can be seen in the northwest and west of the terrain present as high degree metamorphic rocks with gneisses, micaschits, amphiboles and amphibolite schists.

Gneisses predominate in the Precambrian complex. During magmatic intrusions in the Serbo-Macedonian mass gneisses were affected by many phases of feldspatization and other metasomatic processes. These processes of regional metamorphism and metasomatic processes had an enormous effect on the mineralogical and textural-structural characteristics of the gneisses.

Several varieties of gneisses were formed, depending on the influence of the magmatic processes. Striped two-mica gneisses that can be seen in the north of the terrain are written in the map. They are grey, medium to coarse-grained with striped or augen texture as well as lepidoblastic or porphyroblastic composition. They are made up of quartz, potassium feldspar, plagioclase, muscovite and biotite. Garnet and epidote occur as accessory minerals.

Feldspars are present as microcline and twinned or untwinned albite and oligoclase grains. Muscovite occurs as primary mineral in gneisses, whereas biotite occurs on account of muscovite due to metasomation carried out by granitoids.

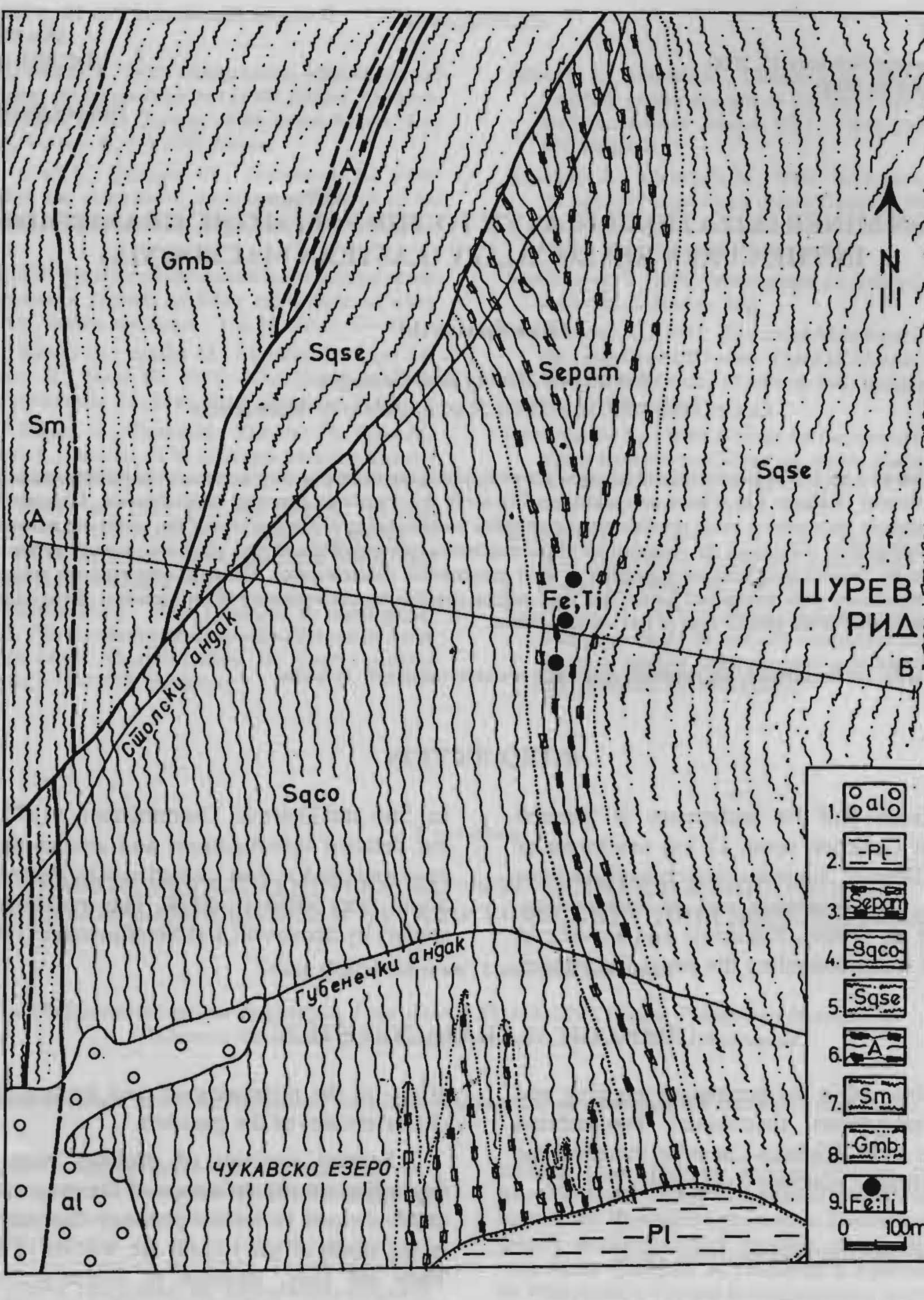

Fig. 1. Geological map of the Curev Rid locality (after Dumurdžanov, 1977, modified by Spasovski, 1998).
1. Alluvial sediments, 2. Pliocene sediments, 3. epidote-chlorite-amphibole schists, 4. quartz-sericite-chlorite schists, 5. quartz-sericite schists and metasandstones, 6. amphibolites and amphibole schists, 7. micaschists, 8. gneisses, 9. ore occurrences

Micaschists occur as an elongated stripe in the western part of the terrain and their relationship to gneisses is gradual. In some places the rocks were affected by feldspatization and locally turn into gneiss-micaschist and gneisses. They are fine- to large-micaseous, grey with schistose texture and lipidogranoblastic structure. They are made up of quartz, muscovite and garnet.

Amphibolite and amphibole schists are rare in the area and occur as lenses and thin stripes concordantly overlying the gniesses and are in tectonic contact with the Ripheap-Cambrian complex. Amphibolites and amphibolitic schists are green to dark-green, medium-grained, seldom fine-grained, poorly to intensely schistose (amphibolic schists). They are made up of hornblende, epidote, coisite and chlorine. Quartz, titanite and biotite occur as accessories.

Riphean-Cambrian rocks comprise most of the terrain and they are in tectonic relationship to the Precambrian occurrences. Field investigations and laboratory studies distinguished the major lithological such as quartz-sericite schists and metasandstones, quartz-sericite-chlorite schists and epidot-chlorite-amphibole schists.

Quartz-sericite schists and metasandstone rocks are fairly developed and occur in the eastern part of the terrain as larger masses, as well as in the north-western part as smaller masses. Schists are grey to light grey, fine-grained and intensely folded made up of quartz, sericite and chlorite of varying amounts, containing also epidote and seldom amphibole as accessories.

Epidote-chlorite-amphibolite schists are very common in the terrain. They are dark-green, fine- to medium- size grained, poorly to significantly schistose with non-metablastic composition. They are composed of amphibole, epidote and chlorite as well as titanite, quartz, magnetite and limonite as accessories.

The Tertiary and Quaternary sediments. The Pliocene sediments are widespread in the south part of the terrain. The transgressively overlie rocks of older complexes.

General characteristics of mineralization

The Curev Rid Fe magnetite mineralization is related to Paleozoic granitoids. It was dug with five shallow shovel cuts. The mineralization occurs as a mineralized quartz vein crosscutting epidote-chlorite-amphibole schists in NNE-SSW direction. The terrain in which the Paleozoic magnetite mineralization occurs is rather covered. Earlier diggings and decomposed surface materials indicate that the vein is of small size. It can be seen that the 40 cm thick vein occasionally disappears. Mineralization occurs as compact ore and quartz mass injected into the ore as striped texture (Fig. 2).

Chemical analyses of this magnetite mineralization yielded fairly high iron contents of 61.56% Fe and 0.23% TiO_2. Low-grade ore contains 33.70% Fe and 0.27% TiO_2.

Data clearly indicate that iron contents are variable, whereas those of TiO_2 are almost constant.

Minerals present

Microscopic examinations carried out yielded a simple mineral composition. Magnetite occurs as major mineral accompanied by hematite and limonite. Pyrite can be found in small amounts.

Fig. 2. Microphotograph of schistose to folded quartz-sericite-chlorite schist (crossed nicols)

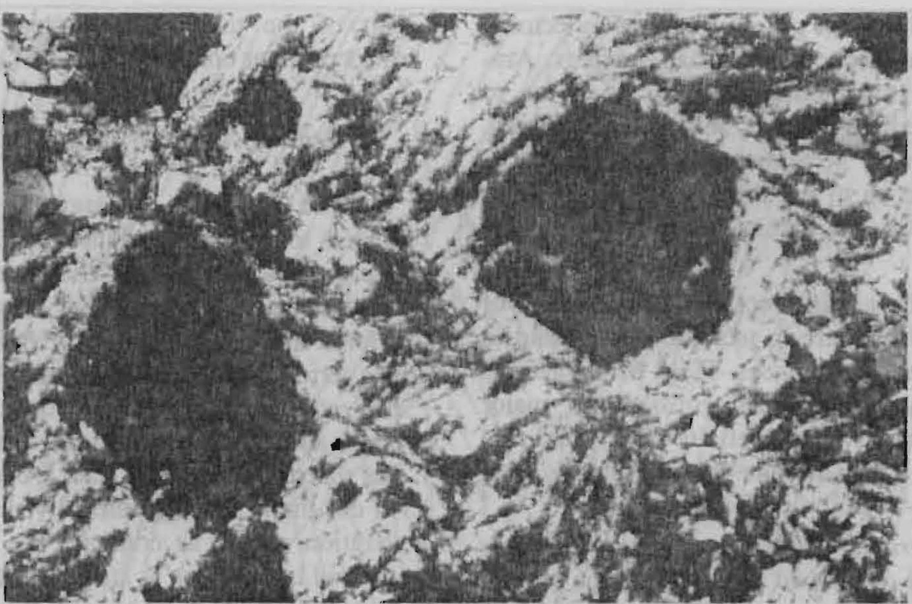

Fig. 3. Microphotograph of quratz-sericite-chlorite-garnet schists (crossed nicols)

Magnetite is the most common mineral comprising most of the mineralization. It occurs as large and irregular grains largely affected by martitization process. Martitization develops from the periphery to the middle parts, occurring also along cleavage directions as very small acicular shapes. Hematite and limonite often accompany magnetite.

Hematite is the second most common mineral occurring as irregular grains or as elongated lathy shapes. Hematite and magnetite comprise the major mineralization in the occurrence. Hematite is economically insignificant being only an addition to the mineral composition. The rim parts of magnetite are affected by martitization process. Martite also develops along cleavage directions as small acicular forms. Martitization is strongly pronounced with some grains. Only magnetite grains are visible in such cases.

Limonite is rare occurring as very small veinlets, or in rare cases replacing pyrite.

Pyrite can be found in some places only as small and irregular grains. Replacement by limonite can be seen with some pyrite grains due to exogene processes.

Magnetite composition

Oxide minerals, their phase composition and their relationships are used in the explanation of the genesis of the parent complexes (most commonly in gabroic rocks), but also in the determination of oxide processes that prevailed during the mineralization.

Magnetite structure makes possible the isomorphic replacement of iron by several elements such as Ti, V, Cr, Mg, Mn, Al, Ni, Co, Zn, Cu Ge and Ga. Si and Ca are present as admixtures. In terms of its geochemistry, of particular importance are data about the distribution of titanium, vanadium, chromium, magnesium, cobalt and nickel.

These elements and their concentrations in magnetites in intrusive rocks depend on the type of magma. So, magnetite can be used to explain the affiliation of development of parent complexes and the estimation of the prospects of the complex.

The results of the chemical examinations (6 microprobe analyses and 5 atomic absorption and 2 neutron activation) clearly demonstrated the manner and regularity of distribution.

The chemical composition of magnetite was determined by electronic micro probe. The results are shown in Table 1. The elements occurring as admixtures in magnetites were determined by atomic absorption and neutron activation. The results are shown in Table 2.

Table 1 shows that a small number of analyses have been carried out that offer initial information about the composition of the mineral. Six analyses indicate that the major component parts of magnetite are constant and that Cr, Mn and Ti are present as admixtures. Magnetites analysed indicate close values to those published.

Table 1

X-ray structural microanalyses of magnetite of the Curev Rid locality (in %)

Elements	1	2	3	4	5	6
Fe	74.35	75.75	71.09	74.20	71.70	74.83
Ti	0.09	0.06	0.07	0.05	0.11	0.00
Mn	0.22	0.23	0.26	0.25	0.00	0.24
Mg	0.00	0.00	0.00	0.00	0.00	0.00
Al	0.00	0.00	0.00	0.00	0.00	0.00
Si	0.16	0.00	0.00	0.00	0.00	0.00
Cr	0.14	0.12	0.15	0.14	0.12	0.17
Ca	0.00	0.00	0.00	0.00	0.00	0.00
O	20.52	21.86	20.55	21.43	20.67	21.59
Σ	95.48	98.02	92.12	96.07	92.60	96.83

Note: Analyses were carried out in the Geological Institute, Bratislava, the Slovak Republic. Analyst Konečný.

Table 2

Contents of admixtures in monomineral magnetites (in g/t)

Elements	1	2	3	4	5
Fe (%)	68.92	68.21	68.11	68.25	66.79
Ti	218.9	333.1	359.9	261.6	246.1
Ni	10.95	16.54	15.16	14.84	17.26
Co	9.53	19.19	17.75	11.39	12.21
Cr	5.58	23.92	24.69	4.99	2.26
Mn	534	459	582	696	661
Ag	0.13	4.95	0.04	0.02	0.04
Cu	13.71	19.18	18.21	16.46	8.86
Zn	76	72.9	89	163.7	104.2
Pb	82.29	26.76	29.87	125.8	199.5
Cd	6.62	3.37	5.62	2.54	8.66

Note: Analyses were carried out in the laboratories of FGM in Štip by AES ICP method.

Titanium occurs as the most significant typomorphic element. Its concentration includes granitoids, iron-bearing granitoids, gabro-diorites and divided intrusions into titanium-bearing gabros. Magnetite is characterized by fairly low TiO_2 contents amounting from 0.05 to 0.11%. Mn contents are also low amounting from 0.22 to 0.26%. High contents have been found for Cr from 0.12 to 0.17%.

In order to obtain a full understanding of the contents of admixtures tests of monomineral magnetites were carried out by AES ICP method. The results are shown in Table 2. The table shows that magnetites are relatively pure with no significant concentration of admixtures. Elements display permanent concentration. Most of them, however, occur in insignificant amounts.

Ni and Co occur as the most common accompanying elements in magnetites with 10.95 to 17.26 g/t Ni and 9.53 to 19.19 g/t Co that is very common for magnetites. The contents of Pb, Zn and Cd are also fairly high. Those of Pb from 26.76 to 19.99 g/t, Zn from 72.9 up to 163.7 g/t, and those of Cd within 2.54 and 8.66 g/t. Chromium also shows increased concentrations in magnetite. In these analyses, however, it yielded relatively low contents from 4.99 to 24.69 g/t. The contents of Mn, which yielded 459 to 696 g/t Mn, are also worth mentioning. Titanium does not largely concentrate in magnetite, although it is a common accompanying component part in magnetites. The numerous accompanying component parts do not comprise their own minerals but occur in the crystalline lattice of magnetite where they increase Fe^{2+} or Fe^{3+}.

The admixtures present in magnetites are within the normal. Contents of lead and zinc show increased amounts most probably due to their metallogenetic relationship to the complexes within the Serbo-Macedonian massif.

Ore textures and structures

A structural-textural characteristic of the mineralization has been insufficiently studied. This paper aims to give a more detailed and systematic description of the ore structures and textures. Macroscopic and microscopic examinations distinguished several morphological and morphogenetic types of textures and structures.

Striped texture is characterized by alternative appearance of dark magnetite and light quartz stripes (Fig. 4). Magnetite in light stripes is small-grained, very fresh and isolated.

Massive texture is characterized by local increased concentrations of magnetite. Thus, in some parts there are massive magnetite mineralizations alternating stripes of magnetite and quartz.

Fig. 4. Striped magnetite mineralization in Paleozic granitoids

Two kinds of replacement developed in various degrees have been established in the Curev Rid ore occurrence.

Corrosive replacement is carried out along fine textural-structural directions in magnetites (cleavage directions, rims of twinning, micro cataclases) by hematite (martite) (Fig 5b). Narrow rims and stringers of martite develop around the magnetite grain and the aggregate in the replacement, whereas the rims are bent or jagged. The newly developed mineral develops as vein-like and vein-grid-like shape in the magnetite groundmass. This replacement results in the formation of corrosive and striped textures. Morphological structures are metagrained and acicular corrosive.

Pseudomorphic replacement leads to the development of a new mineral or mineral aggregate that receives the shape and structure of the mineral replaced. An example of pseudomorphic replacement is that of magnetite into martite that takes place from the rim parts of magnetite grains. The borders between magnetite and the newly developed mineral are rather bent and jagged.

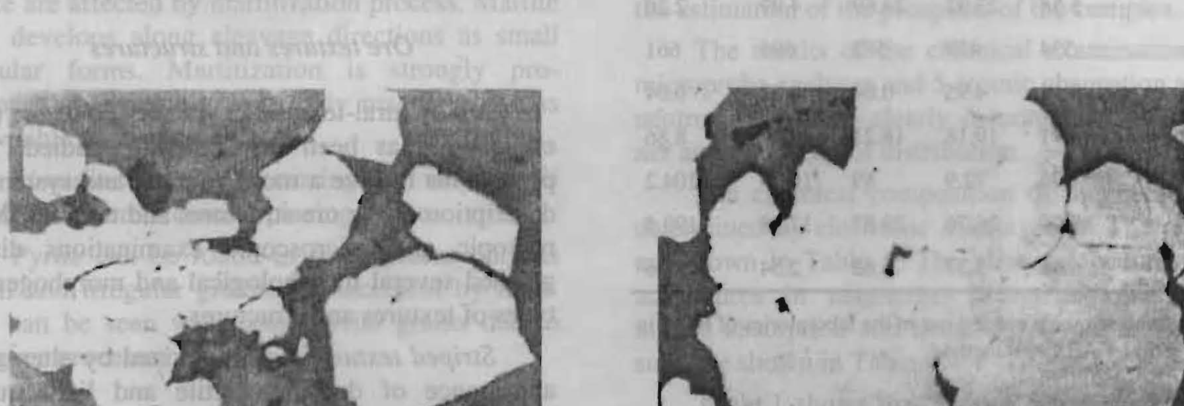

Fig. 5. Structures of pseudomorphic (a) and corrosive (b) replacement:
a) hiidiomorphic and alotriomorphic completely martitized magnetite grains, b) alotriomorphic magnetite grains (grey) and corrosive development of hematite along cleavage directions (white)

Genetic characteristics

Based on the manner and the environment of the occurrence, the mineralization can be associated with pegmatite phase of intrusion of the Delcevo granitoid. Pegmatite type of magnetite mineralization is very common in nature. However, economically significant occurrences are not known.

CONCLUSION

Taking in consideration the results of investigations carried out so far and the results obtained in the investigations in the Curev Rid iron-bearing ore occurrence the following conclusions can be drawn:

– Magnetite-hematite mineralization in the vicinity of Curev Rid is genetically related to the Paleozoic granitoids, but it intrudes epidote-chlorite-amphibole schists.

– The mineralization occurs sporadically as a 150 m long and 40 cm thick quartz vein.

– Examinations carried out on the chemistry yielded high iron contents. The compact magnetite ore contains 61.56 % Fe, and the low grade ore 33.70 % Fe.

– Based on the occurrence mode and its surrounding the authors come to the conclusion that the mineralization is genetically related to pegmatite phase of intrusion of the Delčevo granitoid.

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Резиме

МИНЕРАЛИЗАЦИЈА НА ЖЕЛЕЗО ПОВРЗАНА СО ПАЛЕОЗОИСКИТЕ ГРАНИТОИДИ НА ЛОКАЛИТЕТОТ ЦУРЕВ РИД (ИСТОЧНА МАКЕДОНИЈА)

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Клучни зборови: рудна појава; рудни минерали; структури; текстури; магнетит; хематит

Имајќи ги предвид севкупните резултати од досегашните истражувања, како и резултатите добиени со нашите испитувања извршени во најново време, може да се констатира дека на подрачјето на Цурев Рид е откриена магнетитско-хематитска минерализација, генетски поврзана со палеозоиските гранитоиди, но таа ги пробива епидот-хлорит-амфиболските шкрилци. Магнетитско-хематитската минерализација настапува во вид на кварцна жила со должина од околу 150 метри, со моќност од околу 40 cm, која наместа се појавува и наместа се губи. Со хемиските испитувања се утврдени значително високи содржини на железо. Компактната магнетитска руда содржи 61,56 % Fe, додека посиромашната руда содржи 33,70% Fe. Врз основа на начинот и средината во која се појавува, сметаме дека минерализацијата од оваа појава генетски е поврзана за пегматитската фаза на интрузијата на делчевските гранитоиди.