Geologica Macedonica, Vol. **22**, pp. 9–16 (2008)
GEOME 2 ISSN 0352 – 1206
Manuscript received: April 3, 2008 UDC: 552.323 : 550.8 (497.723)
Accepted: November 6, 2008

Original scientific paper

NEW DATA ON THE HYDROTHERMAL ALTERATIONS IN THE PLAVICA DEPOSIT (EASTERN MACEDONIA)

Orce Spasovski, Vojo Mirčovski

The "Goce Delčev" University, Faculty of Natural and Technical Sciences,
Goce Delčev 89, MK-2000, Štip, Republic of Macedonia
orce.spasovski@ugd.edu.mk

A b s t r a c t: The data presented in the paper were obtained based on analyses carried out on samples collected from various depths along the entire length of drill-hole no. 4. The drill-hole was the last one made in the area of the Plavica deposit by the Rio Tinto Company.

The samples analyzed point out the presence of subvolcanic to volcanic rocks, presumably dacites and dacite-andesites, that can be distinguished based on the presence of primary quartz. An exception is sample no. 6 which, most probably, represents one of the vein rocks.

The alterations seen under a microscope include silicification (with several quartz generations), argillitisation, sericitisation, epidotisation, K-metasomatism and, presumably, zeolitization.

X-ray examinations determined the alterations as follows: silicification, alunitisation, argillitisation, sericitisation, K-feldspatisation, fluoritisation, propylitisation and hematisation.

Key words: Plavica deposit; hydrothermal alterations; dacites; andesites; ignimbrites; drill-hole; microscopic examinations; x-ray examinations

INTRODUCTION

The Plavica deposit is situated in the eastern parts of the large Kratovo–Zletovo volcanic district, some 5 km north from Probištip. It is located in the middle parts of the Plavica volcanic apparatus which is charcaterized by complex composition and intense hydrothermal alterations of the volcanic rocks in an area of more than 6 km^2.

From metallogenetic point of view, the Plavica deposit occupies the central parts of the Kratovo–Zletovo ore region.

The polymetallic mineralization of the Plavica deposit and the wider vicinity have been subject matter of investigation and exploitation as early as the Roman period. Intensive investigations and exploitation activities were carried out from 1936 to 1941. Systematic geophysical and geochemical investigations including large drillings with distance between points were carried out from 1977 to 1979.

Data regarding the structural-geologic and metallogenetic characteristics of the deposit can be found in the works of Мијалковиќ and Пешиќ (1966), Стојанов (1974 and 1980), Иванов and Денковски (1978 and 1980), Ракиќ (1978), Мудриниќ (1986), Богоевски and Ракиќ (1985), Серафимовски (1990) et al.

The deposit is well investigated and studied. It can be said that it is an important polymetallic copper deposit.

SURROUNDING ROCKS

The geological composition of the immediate vicinity of the Plavica–Zlatica deposit consists mostly of volcanic and volcanogene-sedimentary rocks whose determination is difficult (particularly in the central parts of the deposit) due to the large presence of hydrothermal alterations. However, the

large number of lithostratigraphic and petrologic examinations discovered that the geological composition of the deposit consists of ignimbrites, stratified volcanic tuffs and breccias, dacite-andesites and their pyroclasts most often occurring as intrusions (Figs. 1, 2).

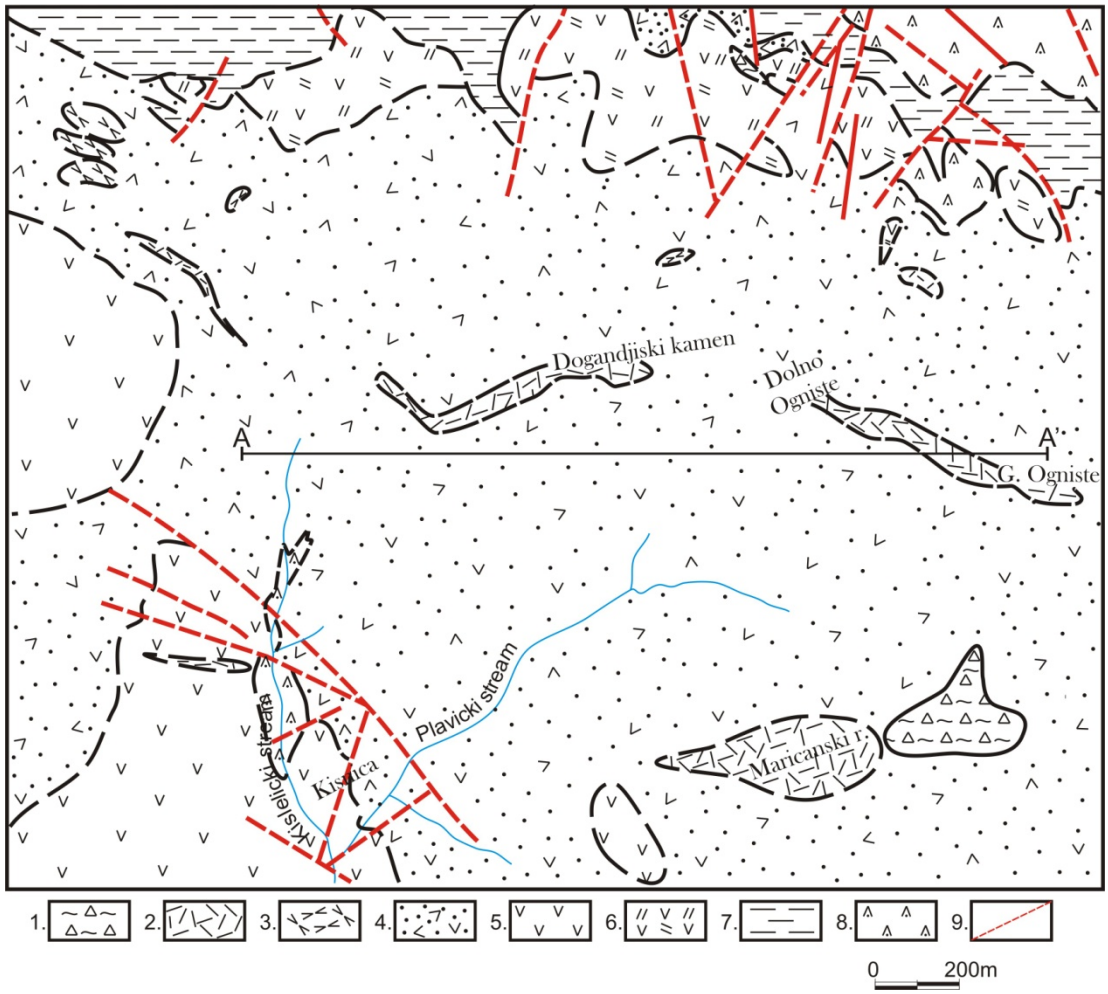

Fig. 1. Geological map of the Plavica deposit (Denkovski, 1977).
1 – Deluvium, 2 – secondary quartzites, 3 – quartzlatites, 4 – hydrothermally altered volcanics, 5 – altered dacite-andesites, 6 – propylitized dacite-andesites, 7 – stratified tuffs, 8 – ignimbrites, 9 – fault structures

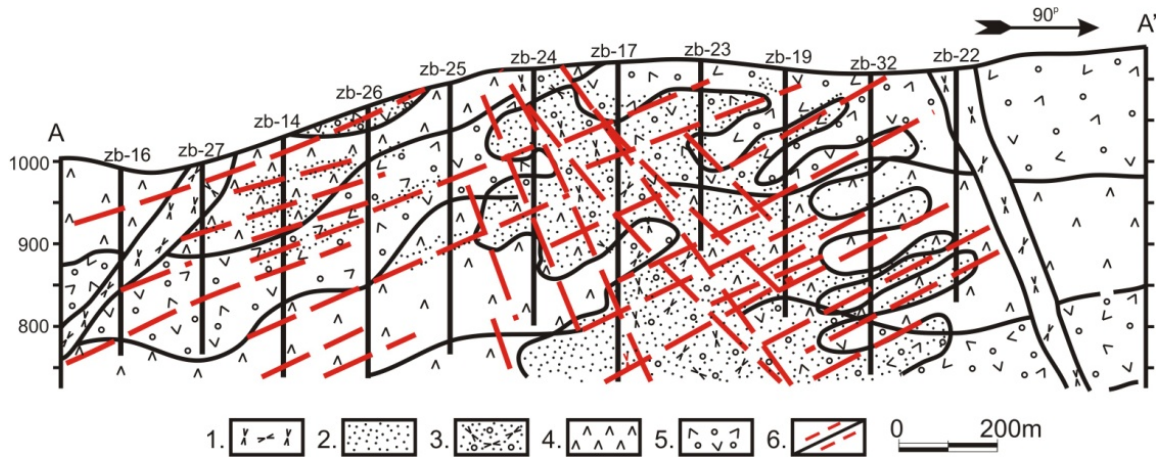

Fig. 2. Geological cross-section of Plavica (Serafimovski (1990).
1 – Quartz-latites (fresh), 2 – Si-mineralization, 3 – quartzlatites (dacites) hydrothermally altered, 4 – dacite-andesites (hydrothermally altered), 5 – volcanic tuffs and agglomerates (hydrothermally altered), 6 – fault structures

HYDROTHERMAL ALTERATIONS

One of the most important characteristics in the Plavica deposit is the abundance of hydrothermal alterations that can be found in an area of 6 to 8 km^2. They have been studied before, but not in a systematic manner. The volcanic rocks that were mainly auto-hydrotactically propylitized were also affected by hydrothermal alterations. Hydrothermal alterations are most commonly found in the middle parts of the Plavica caldera as tectonically the most altered.

Investigations and examinations carried out so far determined a large number of hydrothermal alterations. The most important are silicification, sericitisation, propylitisation, argillitisation, adularisation, kaolinisation, alunitisation, turmalinisation etc. Zonal pattern can often be seen in individual alteration types, sometimes occurring discontinuously or irregularly distributed.

Hydrothermally altered rocks are whitened and macroscopically are hard to determine. Macroscopically they can be distinguished only if they contain primary quartz which allows us to say that the rock was dacite or quartzlatite.

Silicification is best pronounced along fissures that can be followed in large areas. Silicification is accompanied by alunitisation, kaolinisation, sericitisation, pyrophyllitisation etc. The most pronounced silicification zone is that between Dolno Ognište and Gorno Ognište with WNW – ESE extension.

RESULTS AND DISCUSSION

The data presented in the paper were obtained from analyses carried out on samples taken from various depths along the entire drill-hole no. 4 (Tab. 1). The drill-hole was the last drilled in the area of the Plavica by the Rio Tinto Company.

T a b l e 1

Depth of samples collected from the core of drill-hole no. 4

Sample No.	Box No.	Depth of drill-hole (m)
1	1	2.30
2	9	27.50
3	20	70.0
4	23	82.0
5	41	152.0
6	47	170.0
7	54	194.0
8	65	232.0
9	69	246.0
10	78	280.0
11	81	289.0

Samples used to make thin sections are rather intensely altered; in some parts of the thin sections relics of primary rock can not be seen.

Samples analyzed show the presence of subvolcanic to volcanic rocks (most probably dacite and dacite-andesites) that are recognizable based on the presence of primary quartz. An exception is sample no. 6 which is probably taken from a vein rock.

Alterations seen under a microscope include silicification (with several quartz generations), argillitisation, sericitisation, epidotisation, K-metasomatism and, most probably, zeolitization.

Figure 3 shows silicification and sericitisation with no visible relics of primary rock. In picture 3b a lot of vugs can be seen as relics of the places where primary minerals were located. The shape of the free spaces allows us to assume that feldspars were located there. Feldspars often occur as relics and metasomatically replaced by alunite.

Figure 3c shows silicification present as fine-grained quartz as complete replacement of the primary rock mass. Iron oxides are often intergrown with the rock mass (Fig. 3d) most commonly accompanied by silicification and argillitisation. Iron oxides often occur in association with larger quartz aggregates and pigmentise the silicium in the rock.

Figure 3 shows minerals of ring radial structure and according to their microscopic characteristics they can be classified as zeolites. X-ray examinations have not been carried out on the ring radial structures since the quantity of the material is not sufficient enough for investigations. Microscopic studies did not determine any mineral resembling epidote (Fig. 3f). However, x-ray examinations carried out later indicated that it was alunite. The sample often contains silicification with poorly pronounced kaolinisation.

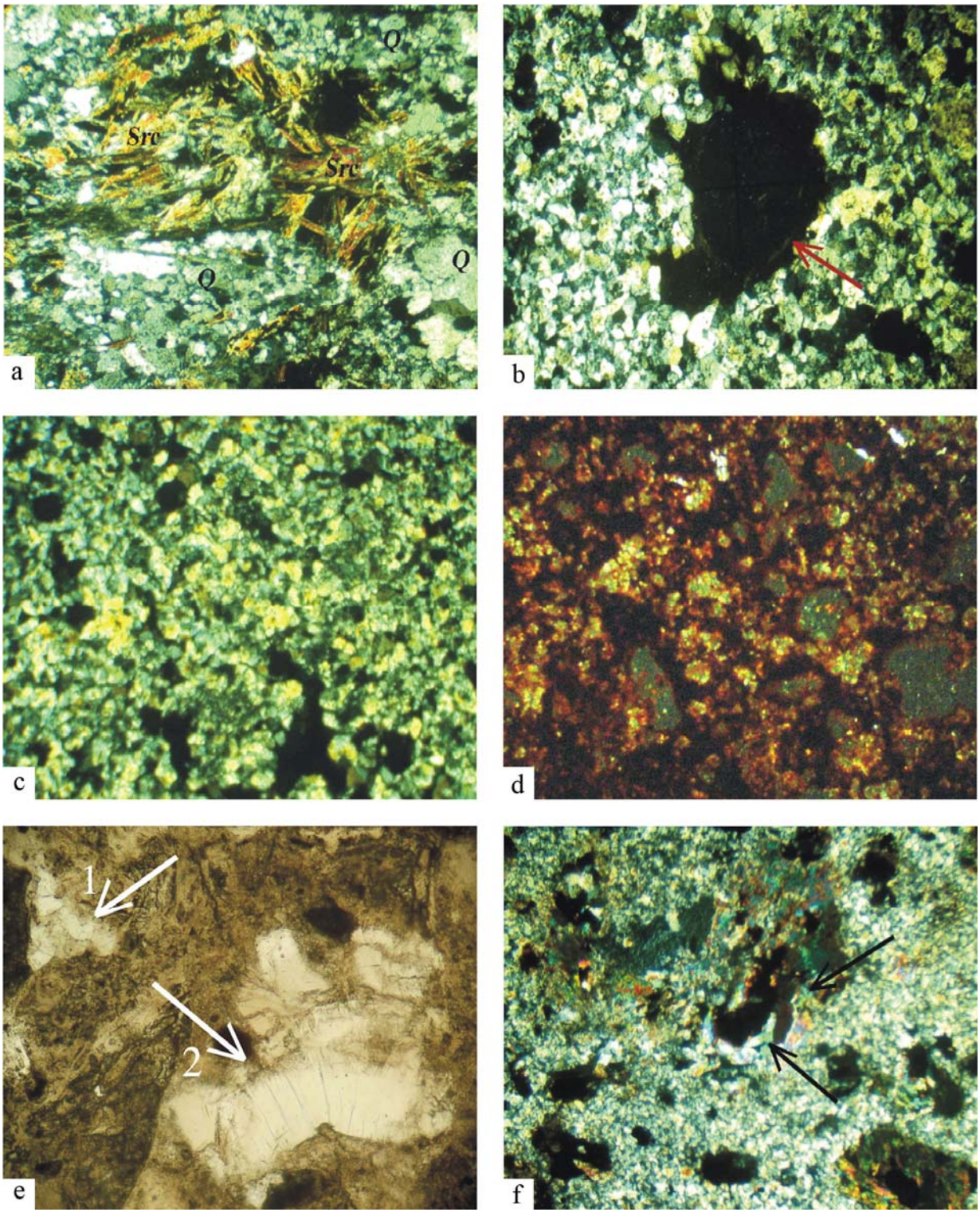

Fig. 3 Micropictures of core samples from drill-hole no. 4 of Plavica
a) Detail of pronounced sericitisation and silicification; b) an illustration of vugs formed due to leaching of individual minerals; c) silicification of rock with fine-grained quartz; d) intergrowth of rock with Fe-oxides; e) an illustration of part of zeolites (arrows 1 and 2), f) an illustration of epidotisation (shown as arrows).

The x-ray analyses carried out on samples from drill-hole 4 determined the minerals such as quartz, alunite, jarosite, feldspar, montmorilonite, kaolinite, fluorite and hematite (Table 2). The table shows that no big difference was revealed regarding their occurrence to depth. Only bigger occurrence of alunite relative to quartz can be seen in the deeper parts.

T a b l e 2

Minerals obtained by x-ray diffraction analysis carried out on samples of drill-hole no. 4, Rio Tinto

Sample No.	Depth of drill-hole (m)	Discovered minerals
5	152.00	quartz, alunite, jarosite, feldspar, fluorite?
6	170.00	quartz, alunite, fluorite? and hematite?
8	232.00	quartz, alunite, jarosite, feldspar, fluorite? and montmorilonite?
10	280.00	alunite, quartz, kaolinite, jarosite and feldspar

X-ray diffraction analyses carried out on samples taken from sample no. 5 are shown in Fig. 4. The figure shows that the values read from sample no. 5 correspond to quartz, alunite, jarosite, feldspar and fluorite. The most common mineral is quartz, whereas alunite occurs in high contents, and fluorite is uncertain since data for its determinations are insufficient.

The radiograph shown in Fig. 5 made it possible to read values that correspond to the minerals as follows: quartz, alunite, hematite and fluorite. It is clear that in this sample the minerals are the same as those found in sample 5, the only difference being that hematite was determined instead of feldspar. Quartz is the most common mineral as an indicator that silicification processes had a dominant role and that fluorite and hematite are hypothetical.

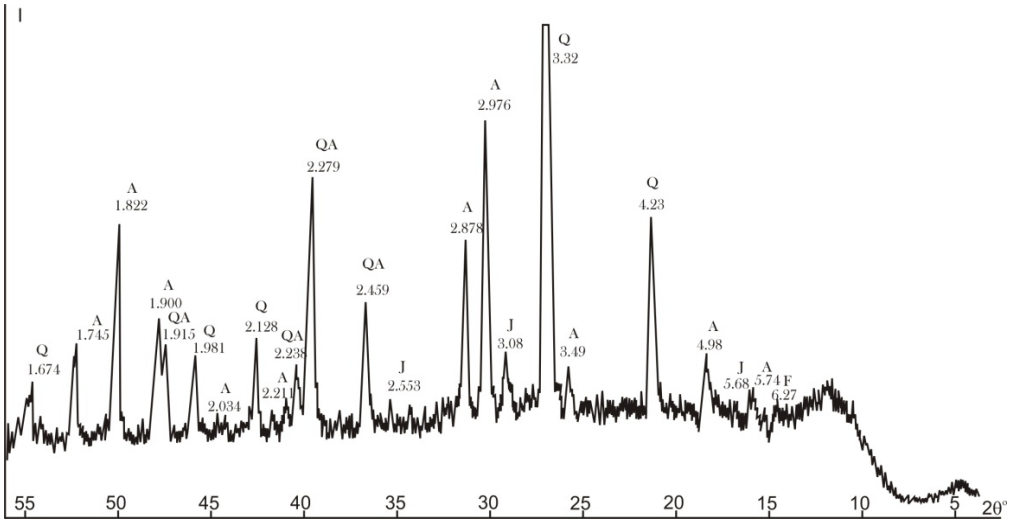

Fig. 4. Radiograph with results of x-ray analysis carried out on sample 5.
Q – quartz, A – alunite, J – jarosite, F – feldspar, f – fluorite

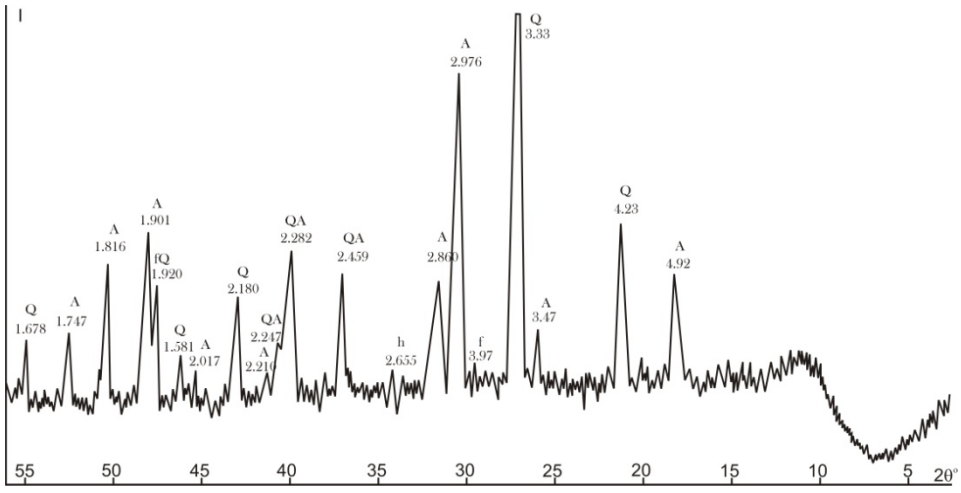

Fig. 5. Radiograph with results of x-ray analysis carried out on sample no. 6.
Q – quartz, A – alunite, h – hematite, f – fluorite

The radiograph shown in Fig. 6 shows values that correspond to the same minerals determined in sample 5 (quartz, alunite, jarosite, feldspar, fluorite and montmorilonite). This sample, unlike sample 5, shows the presence of montmorilonite. Here, like in the earlier samples described, fluorite and montmorilonite are hypothetical.

The radiograph (Fig. 7) which shows the results of x-ray analysis carried out on sample no. 10 yields values that correspond to and point out the presence of the minerals as follows: alunite, quartz, kaolinite, jarosite and feldspars. The results obtained show that the most abundant is alunite, the next most common being quartz.

Unlike earlier samples, minerals in this sample are equally well confirmed.

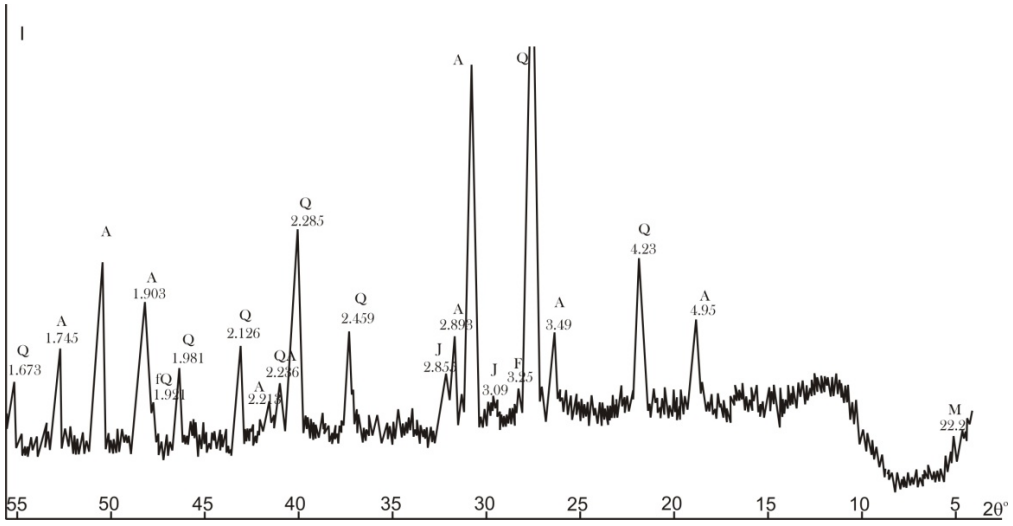

Fig. 6. Radiograph with results of x-ray analysis carried out on sample 8.
Q – quartz, A – alunite, J – jarosite, F – feldspar, f – fluorite, m – montmorilonite

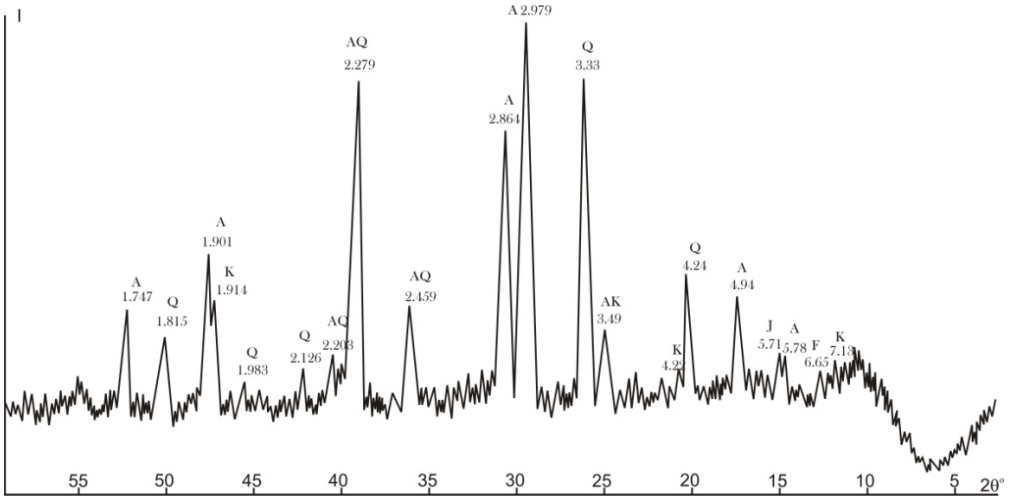

Fig. 7. Radiograph with results of x-ray analysis carried out on sample 10.
Q – quartz, A – alunite, K – kaolinite, J – jarosite, F – feldspar

The hydrothermal alteration in the Plavica deposit is of zonal pattern. Several zones can be distinguished that either cover or follow one another. An inner zone can be distinguished with secondary quartzites and alunite. The alunite is either part of the zone separating it into two subzones or goes out into the outer zones. Close to the zone of secondary quartzites there is a discontin-

ued zone of potassic metasomatism (adularisation, albitisation, hydrobiotitisation and silicification) to which the outer zone of hydrothermal alterations is added.

Silicification outside the secondary quartzites is more or less spread all over the altered zone. Still, outside the outer zone it is less abundant and disappears.

CONCLUSION

Based on the investigations carried out on the hydrothermal alterations in the Plavica deposit so far, including those of the present author, the following conclusions can be made:

The hydrothermally altered rocks were whitened and can not be ascertained macroscopically. Macroscopically they can be distinguished only if they contain primary quartz which allows us to say that the rock was dacite, dacite-andesite or quartzlatite.

Hydrothermal alterations are of zonal pattern and several zones can be distinguished that either cover or follow one another.

Hydrothermal alterations are found most in the middle parts of the Plavica caldera as tectonically most faulted. In the deeper parts of the deposit, in the propylitisation zone, the mineralization is absent, but increases in the secondary quartzite zone, in the silicification, alunatisation and in the potassic metasomatism.

In the outer zone of the hydrothermal alterations vein mineralization was found that goes outside the area under investigation. It is characterized by high contents of lead, zinc, barium, uranium and other minerals.

Plavica is a hydrothermally stock-work impregnated deposit with some traces of porphyry copper deposits.

The studied samples of rocks obtained from drill-hole 4 in the Plavica deposit, drilled by the Rio Tinto company are characterized by fairly intense hydrothermal alterations. Some of the alterations have been confirmed by microscopic and x-ray diffraction analyses.

The analyses carried out on samples collected from drill-hole 4 made it possible to determine the following alteration types: silicification, alunitisation, argillitisation, sericitisation, K-feldspatisation, fluoritisation, propylitisation and hematisation.

REFERENCES

Богоевски, К., Ракиќ, С., 1985: *Геолошке карактеристике лежишта Златица–Плавица*. Стр. фонд „Силекс“, Скопје.

Иванов, Т., Денковски, Ѓ., 1978: Геологија на металогенетскиот јазел Плавица–Златица во кратовско-злетовската област. *IX Конгрес геол. СФРЈ*, стр. 565–570, Сарајево.

Иванов, Т., Денковски, Ѓ., 1980: Хидротермални алтерации во порфирското лежиште Плавица–Златица во кратовско-злетовската вулканска област. *Симпозиум алтерација стена и минерала, 100 год. Геол. школе у Србији*, Београд.

Мијалковиќ, Н., Пешиќ, Д., 1966: Геолошке и петролошке карактеристике СИ дела кратовско-злетовске области. *Реферати VI саветовања геолога Југославије*, део II, стр. 158–170, Охрид.

Мудриниќ, Ч., 1986: Ретки и племенити метали у Cu полиметаличном лежишту Плавица–Златица (Источна Македонија), *XI Конгес геолога Југославије*, Тара.

Ракиќ, С., 1978: Неке структурне особености полиметаличног орудњења у злетовском рудном пољу, *IX Конгрес геол. СФРЈ*, стр. 565–570, Сарајево.

Серафимовски, Т., 1990: *Металогенија на зоната Леце–Халкидик,* Докторска дисертација, РГФ, Штип.

Стојанов, Р., 1974: Минералошки состав на околурудните измени на Плавица во злетовско-картовската област. *VIII југословенски геолошки конгрес*, кн. 5, стр. 42–54, Љубљана.

Стојанов, Р., 1980: Вулканската купа Плавица, полиметалните минерализации и околурудните промени во неа. *Симпозиум алтерација стена и минерала, 100 год. Геол. школе у Србији*, Београд.

Р е з и м е

НОВИ ПОДАТОЦИ ЗА ХИДРОТЕРМАЛНИТЕ ПРОМЕНИ ВО НАОЃАЛИШТЕТО ПЛАВИЦА (ИСТОЧНА МАКЕДОНИЈА)

Орце Спасовски, Војо Мирчовски

[1]Универзитет „Гоце Делчев“, Факултет за природни и технички науки, Гоце Делчев 89, МК-2000 Штип, Република Македонија
orce.spasovski@ugd.edu.mk

Клучни зборови: наоѓалиште Плавица; хидротермални алтерации; дацити; андезити; игнимбрити, дупнатина; микроскопски испитувања; рендгенски испитувања

Податоците кои се презентирани во трудов се добиени врз основа на анализа на примероци земени од различни длабочини надолж целиот интервал од дупнатината број 4. Оваа дупнатина е последна издупчена на подрачјето на наоѓалиштето Плавица од страна на компанијата Рио Тинто.

Анализираните примероци укажуваат на присуство на субвулкански до вулкански карпи, најверојатно дацити и дацито-андезити, кои се препознаваат само по присуството на примарниот кварц. Исклучок претставува примерокот бр. 6, кој најверојатно е претставник на некоја од жилните карпи.

Од алтерационите промени под микроскоп се забележани: силификација – со неколку генерации на кварц, аргилитизација, серицитизација, епидотизација, К-метасоматоза и веројатно зеолитизација.

Со рендгенските испитувања се констатирани следните алтерации: силификација, алунитизација, аргилитизација, серицитизација, К-фелдспатизација, флуоритизација, пропилитизација и хематитизација.