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Original scientific paper

MINERALOGIC-PETROGRAPHIC CHARACTERISTICS OF THE AMPHIBOLE GABBRO OF NOVO SELO – KRIVA LAKAVICA

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A b s t r a c t: The paper deals with the mineralogic-petrographic characteristics of the amphibole gabbro of the Novo Selo, Krica Lakavica site. Investigations were carried out at the Faculty of Mining and Geology – Štip, IGEM – Moscow and the Institute for Crystallography and Petrography in Zurich.

Key words: Amphibole gabbro; amphibole; pyroxene; feldspar; zircon

INTRODUCTION

Pieces of amphibole gabbro of 5 – 25 cm in size (and variable form) can be seen in the carbonate rocks of Novo Selo – Kriva Lakavica. Various kinds of pieces were collected for analyses.

RESULTS AND DISCUSSION

Microscopic analyses conducted made it possible to discover amphibole gabbro as follows:

1. Fine-grained amphibole pyroxene gabbro,
2. Medium size-grained amphibole gabbro,
3. Coarse-grained amphibole gabbro.

Fine-grained amphibole pyroxene gabbro

Microscopic characteristics: it has grey-greenish colour. Feldspars and amphibole can be noticed with naked eye (Fig. 1).

Texture: massive.

Microscopic characteristics:

Structure: fine-grained.

Mineral composition: 35% hastingsite, 15% diopside, 30-35% plagioclase. Titanite, apatite, zircon and saussurite occur as subordinate minerals.

Hastingsite – accounts for 35% of the total mass. It occurs in grains of 0.2 – 0.4 mm in size. The grains are, in part, idiomorphic with hexagonal crosscuts. The two cleavages can be noticed easily with idiomorphic grains. Interference colours are of second order. Pleochroism ranges from quite light yellow to reddish brown. The pleochroism indicates that, most probably, it is hornblende rich in titanium. The angle of tarnish measured parallel to the crosscut (010) amounts to about 30°. All hestingsite grains are quite fresh. They do not possess traces of chemical decomposition.

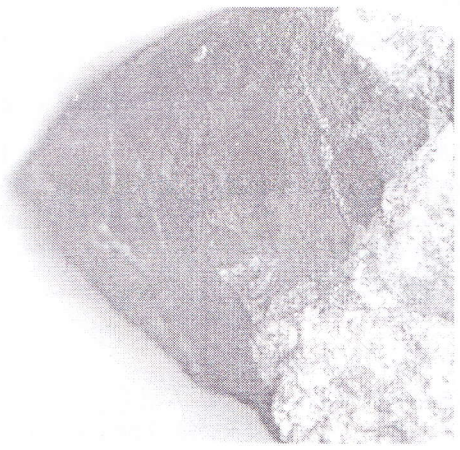

Fig. 1. Fine-grained amphibole pyroxene gabbro of the cross-section near the Štip – Radoviš road (Novo Selo – Kriva Lakavica)

Diopside – accounts to 15% of the total rock mass. Most of the grains are alotriomorphic. There are hypidiomorphic grains as well. Grains vary between 0.3 and 0.7 mm in size. Sometimes they look like porphyroblasts or like intruded in the rock. This is an indicator that diopside crystallisation took place for a long time so that in the end it filled the void spaces of the rock which are either small or large. Octagonal crosscuts with clear cleavage under the angle of 90° can also be seen with idiomorphic grains. Interference colours are of second order. All grains are without pleochroism and with pronounced relief. They are fresh; their angle of tarnish, measured at crosscuts parallel to (010), amounts to 45° – 54°.

Plagioclase – accounts for 30 – 35% of the total rock mass. The grains are xenomorphic with sharp rims. Grains are 0.1 – 0.2 mm in size. A small number of the grains are hypidiomorphic. Part of the plagioclase has been affected by decomposition. The other part is quite fresh. The process of decomposition started from the centre. Quite often grains, whose central parts are completely altered, have rims that are fresh. Sometimes chemical decomposition has developed along fissures of cleavage. Some feldspar grains are totally decomposed and transformed to fine flaky mineral – sericite.

Apatite – Based on the crystal forms and colour it can be inferred that there are two generations of apatite. The first are light yellow, others milky white. Their ration is 1:1. Milky white, according to literature data (Troger 1969, page 186), have probably come into being from gel. Colouring occurs due to contamination of other minerals. They are short columnar in shape. The plane (1011) is poorly developed.

Zircon – Two kinds of zircon can be found, pale pink and transparent. Their ratio is 2:1 in favour of transparent ones. They are less common. The characteristic feature is that none of the population has radioactive rims. This means that the two populations were poor in uranium and thorium or are relatively young.

Saussurite is also present in the rock, as well as thin and short epidote lodes. The chemical composition of the fine-grained amphibole pyroxene gabbro was determined by XRF method in IGEM, Moscow. The results are shown in Table 1.

Table 1

Chemical composition of fine-grained amphibole pyroxene gabbro of Novo Selo – Kriva Lakvica determined by XRF in IGEM, Moscow

SiO_2	48.27
Al_2O_3	14.51
Fe_2O_3	12.29
MgO	6.75
Na_2O	3.62
K_2O	0.60
MnO	0.181
CaO	9.38
TiO_2	2.647
P_2O_5	0.37
zag.z.	1.35
Total	99.96

Table 2

Contents of rare elements and rare earth elements in fine-grained amphibole pyroxene gabbro (ppm) of Novo Selo – Kriva Lakavica determined by ICP-MS in Moscow

Mo	>2	Nb	8.5
Ag	>0.5	Ta	0.57
In	>0.1	W	>0.5
Sn	2	Tl	0.07
Sb	1.1	Pb	>5
Cs	0.4	Bi	>0.1
Ba	84	Th	0.68
La	13.4	Ce	32.4
U	0.31	Pr	4.39
V	285	Nd	21.6
Cr	180	Sm	5.89
Co	35	Eu	2.10
Ni	37	Gd	6.97
Cu	28	Tb	1.29
Zn	99	Dy	7.70
Ga	19	Ho	1.51
Ge	>0.5	Er	4.65
As	11	Tm	0.699
Rb	4	Yb	4.12
Sr	709	Lu	0.595
Y	41.3	Hf	4.9
Zr	193		

Note: Analyses were carried out under the supervision of Dr. Sergej Korikovski.

Medium size-grained amphibole gabbro

Microscopic characteristics: colour is dark grey to black, in some places light brown yellowish. Amphiboles can be seen under microscope.

Fig. 2. Image of medium size-grained amphibole pyroxene gabbro collected from the right side of the Štip – Radoviš road in the Novo Selo – Kriva Lakvica

Texture: massive

Microscopic characteristics:

Structure: hypidiomorphic grain-like.

Mineral composition: 40 % tschermakite hornblende, 15 % diopside, 25–30 % plagioclase, orthoclase as well as epidote, zircon and apatite occurring as subordinate.

The structure and mineral composition can be seen in Fig. 3.

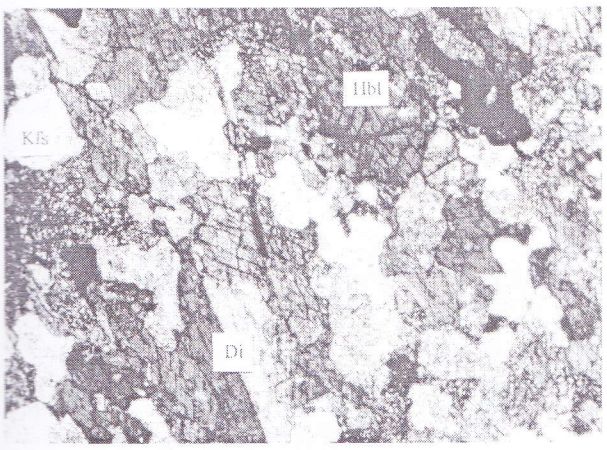

Fig. 3. Structure and mineral composition of medium size-grain amphibole gabbro of Novo Selo – Kriva Lakvica. X N magnification 6.3
Note: Kfs – potassium feldspar, Di – diopside, Hbl – hornblende

Hornblende – is the most common of the femic minerals. It accounts for 40% of the total mass. It occurs as hypidiomorphic and idomorphic grains the ratio 1:1. The grain size ranges from 0.4 to 0.6 mm. Hexagonal cross cuts can be seen with idiomorphic grains with visible cleavage. Twin pairs can be seen in the grains (Fig. 3). Interference colours are of second order. Table 3 shows the chemical composition of hornblende. Chemical analyses carried out with a microprobe indicated that they belong to the tschermakite hornblende (Fig. 4).

Table 3

Chemical composition of tschermakite hornblende in medium size-grained amphibole gabbro of Novo Selo – Kriva Lakvica determined by electronic microanalysis in ETH – Zurich. Analyst: Juger Sommerauer

	1	**2**	**3**
SiO_2	44.486	44.555	44.987
TiO_2	2.291	2.214	2.443
Al_2O_3	10.028	10.388	10.346
FeO	14.696	15.834	16.027
MnO	–	–	–
MgO	12.032	11.983	11.832
CaO	10.634	10.766	10.882
Na_2O	2.066	2.095	2.112
K_2O	0.586	0.568	0.589
Total	96.82	98.4	99.2
SiIV	6.553	6.467	6.494
AlIV	1.447	1.533	1.506
T pos.	8.0	8.0	8.0
Al	0.293	0.243	0.253
Cr	–	–	–
Fe^{3+}	0.588	0.763	0.656
Ti	0.254	0.242	0.265
Mg	2.642	2.593	2.546
Fe^{2+}	1.222	1.160	1.279
Mn	–	–	–
M1,2,3	5	5	5
Mg	–	–	–
Fe	–	–	–
Mn	–	–	–
Ca	1.678	1.674	1.683
Na	0.322	0.326	0.317
M4	2	2	2
Ca	–	–	–
Na	0.269	0.264	0.274
K	0.110	0.105	0.108
Apos.	0.379	0.369	0.383
O	23	23	23

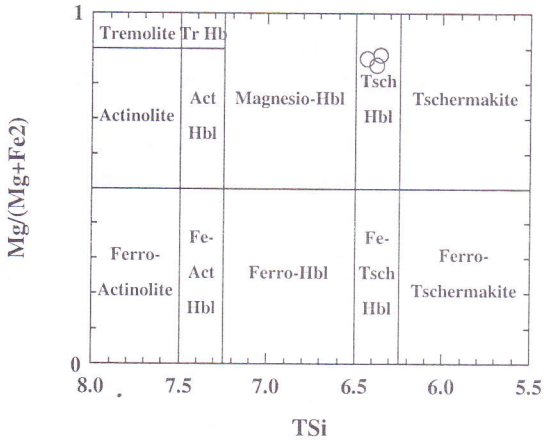

Fig. 4. Amphibolite composition of medium size-grained amphibole gabbro of Novo Selo – Kriva Lakavica shown on a diagram after the classification of Leake et al. 1997

Diopside. Unlike hornblende diopside is less common (some 15%), but it is larger in size than hornblende (Fig. 5). Grain size ranges from 0.6 to 0.8 mm. Cleavage can be seen in two directions. Interference colours are of first order. There is no pleochroism. The grains possess pronounced relief. The chemical composition of diopside is given in Table 4.

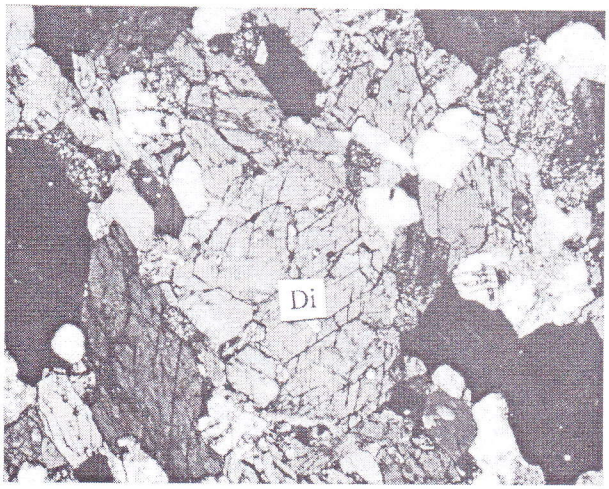

Fig. 5. Microphotograph of diopside of medium size-grained amphibole gabbro of Novo Selo – Kriva Lakavica X N, magnification 6.3.
Note: Di – diopside

Plagioclase – occurs in hypidiomorphic grains. Grain size ranges from 0.2 to 0.3 mm. Polysynthetic twins can be found (Fig. 7). A large number of grains also host zircon. The grains are fresh.

Table 4.

Chemical composition of diopside of medium size-grained amphibole gabbro hornblende of Novo Selo – Kriva Lakavica determined with electronic microanalysis in ETH – Zurich. Analyst: Juger Sommerauer

	1	2	3	4	5
SiO_2	51.14	51.57	50.06	50.41	51.03
TiO_2	0.59	0.46	0.78	0.55	0.60
Al_2O_3	5.38	3.79	5.13	4.41	4.46
Cr_2O_3	–	–	–	–	–
Fe_2O_3	–	–	–	–	–
FeO	10.23	9.18	9.70	10.09	9.30
MnO	–	–	–	–	–
NiO	–	–	–	–	–
MgO	10.54	10.85	10.28	10.52	10.68
CaO	23.10	23.39	23.42	23.38	23.32
Na_2O	0.98	0.94	1.03	0.94	0.96
K_2o	-	–	–	–	–
Total	**101.9**	**100.1**	**100.4**	**100.3**	**100.3**
SiIV	1.88	1.93	1.87	1.88	1.90
AlIV	0.12	0.07	0.13	0.12	0.10
T pos.	2	2	2	2	2
AlVI	0.11	0.09	0.09	0.08	0.10
Ti	0.02	0.01	0.02	0.02	0.02
Cr	–	–	–	–	–
Fe^{3+}	–	–	–	–	–
Fe^{2+}	0.29	0.28	0.30	0.32	0.29
Mn	–	–	–	–	–
Ni	–	–	–	–	–
Mg	0.58	0.60	0.57	0.59	0.59
Fe	0.02	-	-	-	-
Ca	0.91	0.94	0.94	0.94	0.93
Na	0.07	0.07	0.08	0.07	0.07
K	–	–	–	–	–
M_1M_2	2	2	2	2	2
O	6	6	6	6	6

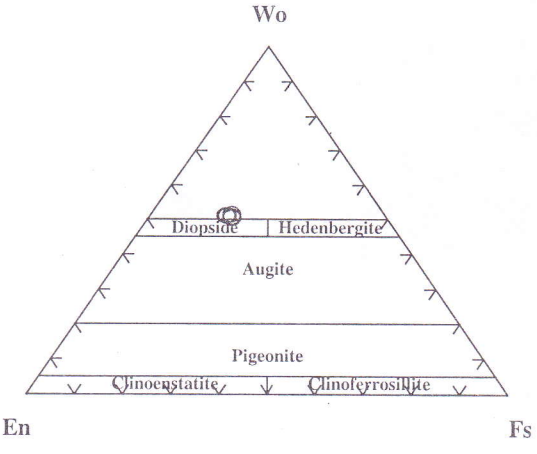

Fig. 6. Diopside composition in medium size-grained amphibole gabbro of Novo Selo – Kriva Lakavica shown in a diagram after the classification of Morimoto et. al. (1988)

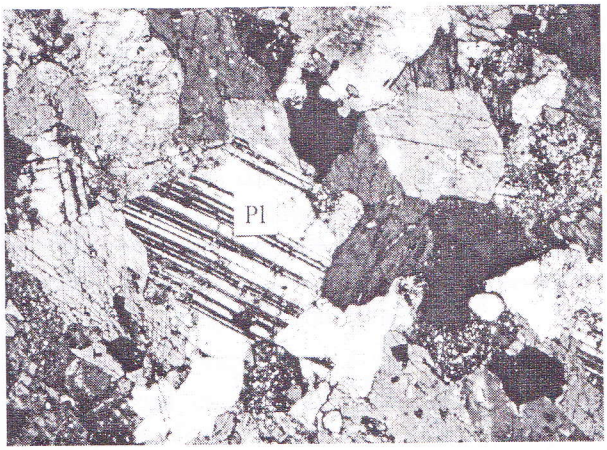

Fig. 7. Microphotograph of plagioclases in medium size-grained amphibole gabbro of Novo Selo – Kriva Lakavica shown, X N, magnification 6.3.
Note: Pl – plagioclase

K-feldspar – occurs in alotriomorphic grains the grain sizes ranging from 0.2 to 0.6 mm. The grains are pertitized in some places.

The occurrence of potassium feldspar along with basic plagioclase, pyroxene, amphibole, inclusion of plagioclase as well as its size indicate that it was formed after the crystallisation of all minerals. Formation was carried out with supplies of solutes probably rich in K_2O that affected the rock prior to consolidation.

Most common subordinate mineral is epidote. It occurs solely in veins of variable thickness.

Coarse-grained amphibole gabbro

Microscopic characteristics: colour is dark grey to black. The rock is hard and compact.

Fig. 8. Photograph of coarse-grained amphibole gabbro taken from the cross-section along the Štip – Radoviš road, the Novo Selo – Kriva Lakavica site

Texture: massive
Microscopic characteristics:
Structure: Coarse-grained.

Mineral composition: 60 % amphibole-tremolite and 25–30 % plagioclase, epidote, zircon and ilmenite occurring as subordinate.

Tremolite – accounts for 60% of the total rock mass. It occurs in xenomorphic grains. The grain size is from 0.5 to 0.9 mm. The rims of the grains are serrate. Cross cut where the two cleavages under an angle of 124° can be seen are common. Twins are common. Interference colours are of second order. Sometimes it includes apatite and zircon, in some places, however it decomposes to epidote.

X-ray imaging on tremolite was performed and the d-values obtained helped to calculate the parameters of the lattice. (Table 5 and X-ray diagram in fig. 9). The results obtained are consistent with the world JCPDS standards.

Table 5

X-ray diffraction data for tremolite in coarse-grained amphibole gabbro of Novo Selo – Kriva Lakavica.

h	k	l	d calc	d obs	2 theta calc	2 theta obs	I
0	2	0	9.043	9.100	9.773	9.711	2.3
1	1	0	8.434	8.426	10.480	10.490	67.7
1	3	0	5.095	5.112	17.389	17.334	1.4
2	0	0	4.767	4.747	18.597	18.676	3.1
0	4	0	4.521	4.516	19.617	19.642	2.7
2	2	0	4.217	4.209	21.049	21.092	3.1
1	5	0	3.382	3.386	26.330	26.301	9.2
2	4	0	3.281	3.285	27.159	27.125	28.4
3	1	0	3.130	3.128	28.492	28.515	100.0
–1	5	1	2.940	2.944	30.378	30.332	12.5
3	3	0	2.811	2.811	31.803	31.808	22.7
–3	3	1	2.742	2.746	32.631	32.580	9.6
–3	3	1	2.742	2.723	32.631	32.862	27.9
–1	1	2	2.591	2.604	34.583	34.407	12.2
2	6	0	2.548	2.544	35.196	35.251	8.1
3	5	0	2.387	2.392	37.644	37.570	11.4
–3	5	1	2.344	2.346	38.361	38.343	11.9
–4	2	1	2.332	2.337	38.571	38.483	17.8
2	6	1	2.157	2.165	41.851	41.687	14.2
2	8	0	2.043	2.049	44.307	44.173	4.3
–4	0	2	2.018	2.021	44.876	44.818	13.6
3	7	0	2.005	2.005	45.190	45.186	14.5
–4	2	2	1.970	1.970	46.042	46.015	2.1
5	1	0	1.896	1.896	47.931	47.949	9.0
–4	6	1	1.884	1.882	48.260	48.317	7.0

h	k	l	d calc	d obs	2 theta calc	2 theta obs	I
4	6	0	1.870	1.872	48.659	48.594	3.0
2	4	2	1.847	1.846	49.291	49.330	1.8
2	8	1	1.824	1.823	49.961	49.975	7.7
–5	1	2	1.752	1.754	52.167	52.093	1.8
–5	5	1	1.725	1.723	53.052	53.106	0.9
3	3	2	1.694	1.693	54.091	54.119	5.1
0	2	3	1.656	1.654	55.436	55.501	13.9
4	8	0	1.640	1.639	56.016	56.053	8.0
–2	4	3	1.622	1.622	56.695	56.698	5.7
3	5	2	1.586	1.587	58.099	58.079	10.9
–4	2	3	1.562	1.562	59.103	59.092	1.3
1	3	3	1.536	1.536	60.174	60.197	6.2
4	2	2	1.521	1.521	60.829	60.842	3.4
2	8	2	1.508	1.509	61.440	61.395	11.7
–4	8	2	1.505	1.505	61.545	61.577	0.5
2	0	3	1.472	1.471	63.121	63.144	2.8
3	7	2	1.457	1.458	63.807	63.789	5.7
0	12	1	1.444	1.445	64.460	64.434	27.4
2	4	3	1.399	1.400	66.793	66.736	0.4
–6	6	2	1.371	1.367	68.368	68.578	7.5
7	1	0	1.358	1.358	69.100	69.130	4.8
–6	0	3	1.345	1.346	69.852	69.959	2.5
–1	13	1	1.341	1.341	70.104	70.143	4.2
–5	9	2	1.324	1.324	71.147	71.156	2.0
6	8	0	1.300	1.299	72.669	72.722	3.6
6	6	1	1.280	1.282	74.009	73.827	2.2
–5	7	3	1.276	1.276	74.246	74.287	2.0

The parameters of the lattice of tremolite are:
a = 9.859 (2) Å
b = 18.134 (5) Å
s = 5.287 (2) Å
$\alpha = \gamma = 90°$
$\beta = 104.78\ (3)°$
$V = 913.9\ (3)\ Å^3$

Plagioclase – often occurs in xenomorphic grains. Hypidiomorphic grains can also be found. It accounts for 25 to 30%. Grain size varies from 0.3 to 0.5 mm. There are grains that are quite fresh and those that are completely decomposed. Fresh grains were measured with a microprobe. The results are given in Table 6.

The table shows that albite component ranges from 47.9 to 62.4%, whereas the anorthite from 36.4 to 49.4%. This leads to the conclusion that they belong to the andesine and labrador group (as shown in Fig. 14).

Table 6

Chemical composition of andesine-labrador in coarse-grained amphibole gabbro of Novo Selo – Kriva Lakavica determined by electronic microanalysis in ETH – Zurich. Analyst: Juger Sommerauer

	1	2	3	4	5
SiO_2	60.00	59.71	59.73	57.95	56.36
TiO_2	–	–	–	–	–
Al_2O_3	26.02	25.95	24.47	26.89	27.10
Fe_2O_3	–	–	–	–	–
CaO	7.75	8.06	7.43	9.51	10.01
Na_2O	6.46	6.88	7.04	5.66	5.36
K_2O	0.18	0.22	0.20	0.52	0.46
BaO	–	–	–	–	–
Total	**100.4**	**100.8**	**98.87**	**100.5**	**99.29**
Si	10.63	10.57	10.76	10.30	10.20
Al	5.43	5.41	5.19	5.63	5.78
Fe	–	–	–	–	–
Ti	–	–	–	–	–
Ca	1.47	1.53	1.44	1.81	1.94
Na	2.22	2.36	2.46	1.95	1.88
K	0.04	0.05	0.05	0.12	0.11
Ba	–	–	–	–	–
Cations	19.78	19.92	19.89	19.91	19.90
O	32	32	32	32	32
Ab	59.5	59.9	62.4	50.3	47.9
An	39.4	38.8	36.4	46.7	49.4
Or	1.1	1.3	1.1	3.0	2.7

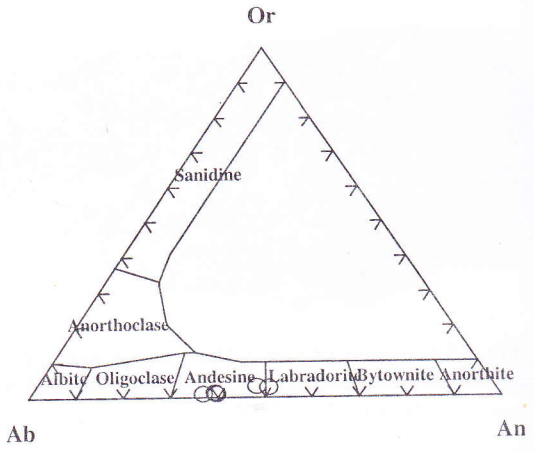

Fig. 9. Composition of feldspars in coarse-grained amphibole gabbro of Novo Selo – Kriva Lakavica shown in the diagram after the classification of Deer et al., 1972

Decomposed grains were not measured. They are all saussuritized, kaolinitized, most probably there are grains that are sericitized. This can not be said for sure since they are fairly fine-grained.

CONCLUSION

Based on data obtained during the investigations on pieces of amphibole gabbro in the carbonate rocks of Novo Selo – Kriva Lakavica the following conclusions can be drawn:

1. Fine-grained amphibole pyroxene gabbro

Mineral composition: hastingsite, diopside, plagioclase. Titanite, apatite, zircon and saussurite are common araccessories.

2. Medium size-grained amphibole gabbro

Mineral composition: tschermakite hornblende, diopside, plagioclase and orthoclase. Accessory minerals include epidote, zircon and apatite.

3. Coarse-grained amphibole gabbro

Mineral composition: predominatly amphibole-tremolite and plagioclase, epidote, zircon and ilmenite occurring as subordinate.

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JCPDS – 0010

Р е з и м е

МИНЕРАЛОШКО-ПЕТРОГРАФСКИ КАРАКТЕРИСТИКИ НА АМФИБОЛСКИ ГАБРО ОД НОВО СЕЛО – КРИВА ЛАКАВИЦА

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Клучни зборови: амфиболско габро; амфиболи; пироксени; фелдспад; циркон

Врз основа на минералошките и петрографските испитувања на стените кои се среќават во карбонатните карпи од Ново Село – Крива Лакавица се издвоени следните видови :

1. Ситно зрнест амфиболско пироксенски габро, со минерален состав: хастингсит, диопсид и плагиоклас како главни минерали и титанит, апатит, циркон и сосирит како споредни минерали.

2. Средно зрнест амфиболски габро во кој како главни минерали се среќават: хорнбленда, диопсид и ортоклас, а од споредните епидот, циркон, титанит и апатит.

3. Крупно зрнест амфиболски габро со минерален состав: тремолит, плагиоклас (андензин, лабрадор) и од споредните минерали епидот, циркон, апатит и илменит.