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CHEMICAL COMPOSITION OF AMPHIBOLES FROM ROCKS OF INTERMEDIATE COMPOSITION FROM NEOVOLCANICS IN CENTRAL SLOVAKIA

(Fig. 1—6)

Abstract: The paper is dealing with evaluation of chemical analyses of amphibole phenocrysts from intermediate andesites and ignimbrite. The chemical parameters show that the amphiboles belong to the group of lime and sublime amphiboles into the field of magnesium and ferrous amphiboles. In graphic figures is presented relation of amphiboles to coexisting minerals and to the parent rock.

Резюме: В работе подается расшифровка химических анализов амфиболовых фенокристаллов из среднеосновных андезитов и из игнимбрита. Химические параметры показывают, что амфиболы относятся к группе кальциевых и субкальциевых амфиболов. На графических изображениях показано взаимоотношение амфиболов и совместно существующих минералов с материнской породой.

In the last decade the interest of professional public is getting on chemical composition and relations between coexisting minerals in eruptive rocks and on conditions of their crystallization. One of the most important rock-forming mafic minerals is amphibole. Chemical composition in neovolcanic rocks depends on composition of magma and conditions of crystallization. For instance, the content of Ti in amphibole can be a measure of the temperature of crystallization for fulfilment of certain preconditions. A higher content of aluminium testifies to entering aluminium into octahedron groups under high temperatures, where it substitutes silicon. Very interesting can be the relations of mg-parameters with coexistence of pyroxenes and amphiboles because higher mg-values prefer higher temperatures of crystallization. From these aspects I studied chemical composition of amphibole phenocrysts in some andesites of central Slovakia and in ignimbrite of various mineral associations. They are: garnet-amphibole: locality Breziny (1), Šiatoroš (5); garnet-hypersthene-amphibole-biotite: locality Bukovinka (4); hypersthene-amphibole-augite: locality Babiná (2, 2a), Podzámčok (3); hypersthene-amphibole-biotite: locality of ignimbrite Obyce (6, 6a), and andesites — Kozelník (7), Dekýš 8), Veľká Lehota (9). The content of amphiboles in these rocks varies within the limits of 5.6—12 %. The chemical parameters I have studied on the basis of classical silicate analyses of separated amphibole grains and from microprobe analyses.

In table 1 are summarized the analyses of amphiboles also with values recalculated to elementary lattice. With each analysis I also quote the mg-value recalculated according to Niggli's parameters.

The values recalculated to 24 (OH) show that the analysed amphiboles are not equal according to their chemical composition. Their composition depends on the chemical composition of crystallizing solution and on various physical-chemical influences during the crystallization process of amphibole.

In the scheme presented by B. E. Leake (1968) for composition and names of lime and sublime amphiboles with contents of Si, Ca+Na+K, mg and Ti values for

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Table 1

	1	2	2a	3	4	5	6	6a	7	8	9
SiO_2	42,05	46,68	42,20	46,65	48,90	42,41	45,32	43,64	44,60	44,30	41,95
TiO_2	2,01	3,30	1,90	1,90	1,00	1,62	—	1,97	1,70	1,73	0,82
Al_2O_3	7,85	7,89	16,1	6,01	12,57	11,35	8,08	9,46	9,80	8,95	9,07
Fe_2O_3	12,08	14,79	4,8	22,68	12,22	15,23	16,95	15,32	3,62	4,84	23,16
FeO	10,14	9,33	9,7	6,89	9,47			2,53	12,00	13,19	7,00
MnO	0,40	0,32	—	0,26	0,44	3,68	0,29	0,03	0,40	0,12	0,12
MgO	15,11	8,09	11,7	6,24	5,91	13,79	12,06	11,42	11,30	10,51	7,39
CaO	4,01	5,83	10,1	5,10	4,60	9,81	10,63	10,90	10,10	9,09	5,01
Na_2O	1,75	1,50	2,1	1,60	1,55	1,83	1,42	1,51	2,60	2,28	1,58
K_2O	0,40	0,65	0,1	0,80	0,40	0,62	0,91	0,68	0,40	0,79	0,26
P_2O_5	0,52	0,09	—	0,25	0,40	—	—	0,20	0,40	0,11	0,02
H_2O^+	2,95	1,41	1,8	1,10	1,56	—	—	0,69	—	1,90	1,25
H_2O^-	0,08	0,48	0,3	0,34	0,27	—	—	0,20	—	1,08	0,45
F^-	—	—	0,005	—	—	—	—	0,26	—	0,20	—
Sum	99,35	100,36	100,905	99,82	99,29	100,34	95,67	98,96	96,92	99,09	98,08
Si^{+4}	6,240	7,494	6,076	7,042	7,128	6,510	7,222	6,400	6,659	6,726	6,479
Al^{+4}	1,364	0,506	1,924	0,958	0,872	1,490	0,778	1,600	1,341	1,274	1,521
Al	—	0,978	0,814	0,111	1,291	0,566	0,591	0,039	0,387	0,330	0,120
Ti	0,223	0,395	0,205	0,218	0,114	0,184	—	0,217	0,190	0,197	0,092
Fe^{+3}	1,355	1,792	0,520	2,574	1,331	—	—	1,707	0,407	0,553	2,697
Fe^{+2}	1,257	1,252	1,168	0,870	1,156	1,955	2,258	0,310	1,499	1,675	0,899
Mn^{+2}	0,053	0,039	—	0,036	0,052	0,480	0,038	0,004	0,050	0,015	0,009
Mg^{+2}	3,334	1,936	2,512	1,405	1,278	3,153	2,860	2,497	2,516	2,379	1,696
Ca^{+2}	0,633	1,002	1,558	0,835	0,718	1,614	1,816	1,713	1,616	1,479	0,825
Na^{+1}	0,499	0,462	0,586	0,471	0,438	0,544	0,439	0,429	0,753	0,671	0,473
K^{+1}	0,071	0,125	0,037	0,163	0,070	0,110	0,191	0,127	0,076	0,153	0,046
P^{+5}	0,071	0,019	—	0,027	0,052	—	—	—	—	—	0,009
Ca + Na + K	1,203	1,589	2,181	1,469	1,226	2,268	2,446	2,269	2,445	2,203	1,344
Na + K	0,570	0,587	0,623	0,634	0,508	0,654	0,630	0,556	0,829	0,824	0,519
mg	0,56	0,39	0,60	0,29	0,34	0,57	0,56	0,56	0,56	0,52	0,21

Explanations to table 1:

1 — Amphibolic andesite with garnet. Separated amphiboles. Analysed by E. Sůrová, GÚDŠ, 1967. Published: J. Forgáč — E. Karolusová 1972. 2 — Hypersthene-amphibole-augitic andesite. Separated amphiboles. Analysed by E. Sůrová, GÚDŠ, 1967. Unpublished. 2a — Hypersthene-amphibole-augitic andesite. Separated amphiboles + marked are the values obtained by microprobe analysis. Anal. by P. Jakeš, Canberra, 1970. 3 — Hypersthene-amphibolic-augitic andesite. Separated amphiboles, analysed by E. Sůrová, GÚDŠ, 1967. Published: E. Karolusová 1971. 4 — Hypersthene-amphibole-biotite-andesite. Separated amphiboles. Anal. by E. Sůrová, GÚDŠ, 1967. Published: E. Karolusová 1972. — 5 Amphibole-garnet andesite. Analysis by microprobe. Anal. Zd. Kotrba — E. Karolusová, Research Institute of Iron Metallurgy — GÚDŠ, 1969. Unpublished. 6 — Hypersthene-amphibole-biotitic ignimbrite. Analysed by microprobe. Anal. Zd. Kotrba — E. Karolusová, Research Institute of Iron Metallurgy — GÚDŠ, 1969. Unpublished. 6a — Hypersthene-amphibole-biotitic, ignimbrite. Anal. by P. Jakeš, Canberra, 1970. 7 — Hypersthene-amphibole-biotitic andesite, analysed by microprobe. Analysed by P. Jakeš, Canberra, 1970. 8 — Hypersthene-amphibole-biotitic andesite. Separated amphiboles. Analysed by P. Jakeš, Canberra, 1970. 9 — Hypersthene-amphibole andesite ± biotite ± garnet. Separated amphiboles. Analysed by E. Sůrová, GÚDŠ, 1967. Unpublished.

the elementary lattice, the analysed amphiboles occupy a wide area within the field of magnesium amphiboles and in the field of ferrous amphiboles (fig. 1). As typical magnesium amphiboles appear those from the locality Šiatoroš (5), from ignimbrite of Obyce (6), andesite of Kozelník (7) and Dekýš (8). The amphiboles from the andesite of Breziny (1) as well as the second analysis from ignimbrite of Obyce (6a) appear as tschermakite amphiboles. Wholly into the field of tschermakite came analysis (2a) from Babiná, carried out by P. Jakeš (1970). It is characterized by an enormously low value of Si.

The second group form analyses, which in their values fell under the group of ferrous amphiboles (ferroamphiboles). Typical ferro-amphiboles are phenocrysts of amphiboles from the localities Podzámčok and Bukovinka. They show high values of Fe with comtemporaneously low Al value and almost the lowermost values of Ca+Na+K. Extreme values represents the analysis of amphiboles from Babiná (2) (ferroactinolite hornblende) and the analysis of amphiboles from Veľká Lehota (9) (ferrotschermakite-hornblende), which shows the highest value of Fe^{+3}. The majority of studied amphiboles are in association with other rock-forming minerals, mainly with orthopyroxenes. Mutual relation of amphibole-pyroxene is expressed in the following diagrams. In fig. 2 is expressed relation between Al^{VI} and the weight % of Al_2O_3 in hypersthenes. For comprehensible reasons analyses 1 and 5 as well as 9 are not plotted in the diagram because in this rock hypersthenes are wholly chloritized and therefore have not been

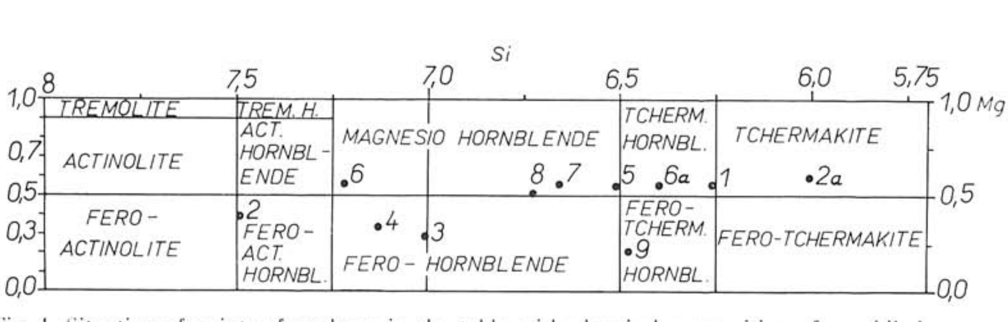

Fig. 1. Situation of points of analyses in the table with chemical composition of amphiboles.

analysed. In diagram — fig. 2 amphibole from the locality Podzámčok (3) appears with little aluminium content. An approximately equal enrichment in Al indicate the analyses of amphiboles from Babiná (2, 2a). Most aluminium contain amphiboles from the localities Obyce (6, 6a), Kozelník (7), Dekýš (8) and Bukovinka (4). At the latter the highest contents of aluminium are present also in orthopyroxenes. From the recalculations of values and their mutual position in the diagram is evident that the crystallizing rock from Bukovinka contained very high aluminium contents and consequently formation of garnets was not sufficient for their swallowing; in the course of crystallization of other phenocrysts aluminium substitutes Si-ions in tetrahedrons and so alumohypersthenes enriched in Al and Al-rich amphiboles originate (E. Karolusová 1972).

In the rocks from Kozelník (7) and Dekýš (8) garnets are not found. A higher proportion of aluminium is evident in orthopyroxenes, which are present as alumohypersthenes, as well as in amphiboles, where they substitute Si-ions.

Different relations between coexisting amphiboles and orthopyroxenes express Niggli's mg-values represented in diagram — fig. 3. The plotted values are concentrated in two small fields, in which the lower ones (analyses 2, 3, 4) are lower than the trend of relations published by B. E. Leake (1968). According to our present-day knowledge they are amphiboles from older andesites (in contrast to andesites 6, 7, 8) representing larger extrusive bodies. The graph shows that in these amphiboles Niggli's values are lower with almost equal values of mg in orthopyroxenes. This relation of Niggli's mg-value in amphiboles and orthopyroxenes cannot be expressed in the case of the amphibole from the locality Veľká Lehota (9) because in the rock the orthopyroxenes are completely chloritized.

In four cases amphiboles are associated with garnets. The relation of Niggli's mg-values in amphiboles and garnets is expressed in fig. 4. Distribution of the points is very similar to that published by B. E. Leake (1968). Lower values of mg in garnets correspond to lower mg-values in amphiboles. This is in accordance with up to present studies (E. Karolusová 1972) of garnets in garnet andesites, showing the almandine constituent to be highly predominating in our garnets. The presence of

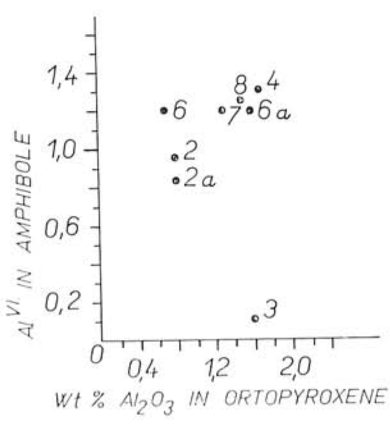

Fig. 2. Ratio of Al^{VI} in amphibole and weight per cent of Al_2O_3 in coexisting orthopyroxenes.

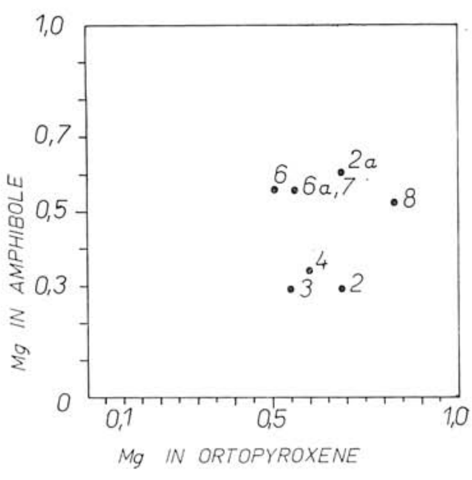

Fig. 3. Ratio of Niggli's values of mg in amphiboles and coexisting orthopyroxenes.

amphiboles and of an approximately equal low Niggli's mg-value may testify to an approximately equal concentration of Mg-Fe-Mn oxides in crystallizing magmatic solution. Only in andesites from Breziny (1) and Šiatoroš (5), where in the course of crystallization formation of pyroxenes did not take place, Niggli's values of mg are higher in amphiboles. These relations provide quite a new view in the petrography of the mentioned two garnet andesites and also explain the causes of formation of such an impoverished series of crystallization as garnet-amphibole without pyroxenes. The temperature of crystallization of these amphiboles was probably higher than in other analysed cases.

Relation of amphiboles to parent rocks is expressed in two diagrams. In diagram — fig. 5 are shown relations Na_2O/K_2O in amphiboles and their parent rocks. In our case all the points are in the field lime-alkaline rocks. In diagram 5 alkaline rocks are below to the line K = 1. According to the plotted points the amphiboles from the localities Kozelník (7), Breziny (1) and Veľká Lehota are more alkaline than their parent rocks. An increase of alkalii against the parent rock is also visible in other amphiboles from the andesites of Dekýš (8), Bukovinka (4) and Šiatoroš (5). A slight increase of alkalii is also evident in two bodies of andesite, situated near to each other geographically, from the localities Babiná and Podzámčok. Equalization of these ratios of alkalii in amphibo-

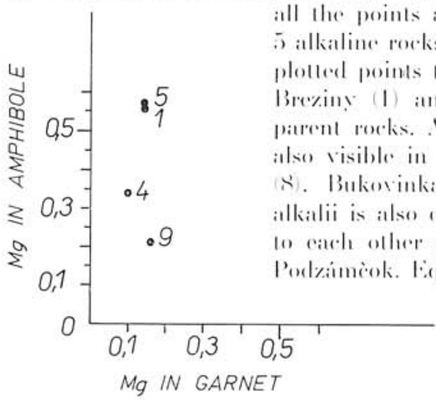

Fig. 4. Ratio of Niggli's mg-values in amphiboles and coexisting garnets.

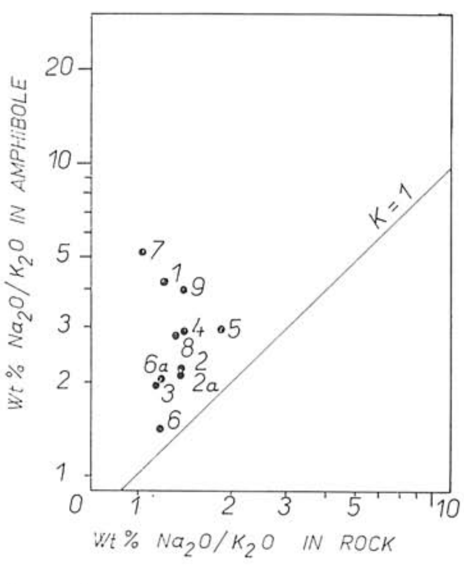

Fig. 5. Ratio Na_2O/K_2O in amphibole and Na_2O/K_2O in parent rocks.

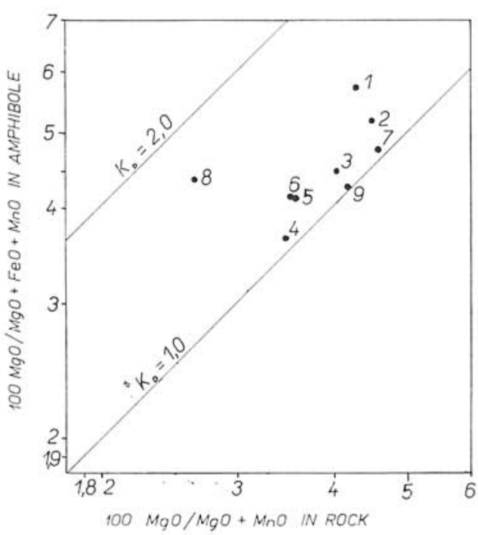

Fig. 6. Ratio 100 MgO/MgO + FeO + MnO in amphiboles and 100 MgO/MgO + FeO + MnO in parent rocks.

les and parent rocks is observed only in the analysis of amphiboles separated from intermediate ignimbrites of the locality Obyce. The analyses by microprobe display higher contents of alkalii.

In evaluation of the ratios Na_2O/K_2O in amphiboles and their parent rocks is remarkable that bodies in geographically near position show also similar values of these elements in the diagram. Similar values are also to be seen in the next diagram (fig. 6), where relations of 100 $MgO/MgO+FeO+MnO$ in amphiboles and their parent rocks are indicated. This relation shows that amphiboles from Breziny have most magnesium from the examined amphiboles; their Niggli's value of mg is higher than mg in parent rock. An almost equal ratio of mg values show analyses of amphiboles from Podzámčok (3), Bukovinka (4), Veľká Lehota (9), Kozelník (7). In the analysis from the locality Dekýš (8) amphiboles appear to have a higher magnesium content than the parent rock.

The presented evaluation shows that chemical composition of amphibole phenocrysts in rocks of intermediate composition depends on chemical composition of crystallizing magmatic solution and on physical-chemical conditions in the course of crystalization. Our intermediate rocks show a higher proportion of aluminium (K. Karolus 1964) and therefore it is most surprising that the studied phenocrysts of amphiboles have also a higher proportion of Al. As important appears information on aluminium amphiboles, which have formed in the garnet andesite from Bukovinka (4). Crystallization of garnets, formation of alumohypersthenes and alumoamphiboles testify to a high excess of aluminium in this andesite. Another new fact is establishing of a high mg-value in amphiboles associated with garnet in those cases when after crystallization of garnet pyroxenes did not form but immediately amphibole with high mg-value crystallized (Breziny, Šiatoroš), obviously at higher temperatures of crystallization. In the ratio of Niggli's mg-values the group of the so called older andesites is distinctly distinguished from the „younger" ones. With other ratios this distinguishing is not distinct. Geographical proximity is manifested in evaluation of alkalii. The geological and geographical position is reflected in very near positions of points in the corresponding graphs.

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REFERENCES

FORGÁČ, J. — KAROLUSOVÁ, E. 1972: Poznámky k doterajšej terminológii mladých vulkanických hornín. Geol. práce. Správy (Bratislava), 58, p. 201—213.

JAKEŠ, P. 1970: Analytical and experimental geochemistry of volcanic rocks from island arcs. Manuscript. Archív ČSAV, Praha.

KAROLUS, K. 1964: Petrografia a petrochémia slovenských neovulkanitov. Manuscript. Archív GÚDŠ, Bratislava.

KAROLUSOVÁ, E. 1968: Petrografia a petrochémia niektorých andezitov. Manuscript. Archív GÚDŠ, Bratislava, 122 p.

KAROLUSOVÁ, E. 1971: Study of changes in chemism of some rock-forming minerals by aid of microprobe on the example of andesite body. Geol. zborn. Slov. akad. vied (Bratislava), 22, No. 2, p. 313—330.

KAROLUSOVÁ, E. 1972: Andezit z kameňolomu Bukovinka. Geol. práce. Správy (Bratislava), 59, p. 69—86.

LEAKE, B. E. 1968: A catalog of analyzed calciferous and subcalciferous amphiboles together with their nomenclature and associated minerals. Spec. Paper, Bolder Colorado, No. 98, p. 1—210.

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