SLOVAK GEOLOGICAL MAGAZINE

Gabbroid rocks - a newly-found member of the leptyno-amphibolite complex of the Western Carpathians

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Abstract. In the Veporic Unit of the Nízke Tatry Mts. gabbroids have been found. They bear primary magmatic minerals as well as primary fabric. Till now two varieties have been discerned: (1) troctolites, and (2) two-pyroxene gabbros. Based on cumulate texture and magmatic mineral compositions gabbroids might originate as a part of differenciated (leyered?) intrusion. Characteristics and mineral composition represent analogies of leptyno-amphibolite complex gabbroids from type-localities in the Massif Central (France). The autors consider discussed LAC gabbroids as reworked lower crustal complex of magmatic origin.

Key words: gabbroids, lithology, leptyno-amphibolite complex, Western Carpathians

Introduction

An important part of the Western Carpathian pre-Alpine basement is built of the leptyno-amphibolite complex (LAC). LAC was distinguished on the basis of common occurrence of the following rock types: amphibolites, leptynites, garnet-pyroxene metabasites and metaperidotites (HOVORKA et al., 1992, 1994). LAC rocks in the Western Carpathians are, as far as their composition and metamorphism, comparable with type LAC rocks as defined by SANTELLIER et al. (1988). In the Western Carpathian LAC, gabbroids, occurring commonly on the type localities (e.g. French Massif Central), have so far not been found.

Geology

The northern part of the studied Veporic Unit in the Nízke Tatry Mts. consists, according to the geological map (KLINEC et al., 1976; BIELY et al., 1992) of rocks of the Hron Complex (KLINEC, 1966): amphibolites, garnet-muscovite-biotite paragneisses, mica schist gneisses to micaschists. On the southern slopes of the Nízke Tatry Mts. (in the valleys Temná, Krivuľa and Koleso) we found also occurrences of gabbroids. In the majority of cases they are various types of metamorphosed gabbro derivatives. In the Koleso Valley, occurrences of well-preserved gabbroid bodies have been found, the size of which does not exceed a few tens of meters. Towards their surroundings they pass into intensively metamorphosed derivatives, especially amphibolites. Based on a preliminary study, we may state that they are spatially and genetically related to the leptyno-amphibolite complex (LAC).

Petrography

Gabbroids of the Nízke Tatry Veporicum are medium-grained massive rocks of black-grey colour, with a brownish shade. They display preserved primary magmatic minerals and structures. Two petrographic types may be distinguished among them: (1) troctolites, (2) two-pyroxene gabbros.

Troctolite is composed predominantly of olivine and plagioclase, less abundant are from magmatogenic minerals orthopyroxene, clinopyroxene, ilmenite and chromspinelide. The rock has a preserved cumulate texture. The cumulate is formed of idiomorphic to hypidiomorphic olivine containing enclosed chrospinelide octahedrons. The intercumulus crystallised in the form of ophitically arranged plagioclase, along with a smaller quantity of ortho- and clinopyroxene.

Two-pyroxene gabbros have gabbroophitic texture. From magmatogenic minerals, there are represented plagioclases, ortho- and clinopyroxenes, in a lesser quantity olivines and ilmenite.

Troctolites and two-pyroxene gabbros bear sings of superimposed multi-stage metamorphic alterations. The predominant one was high-temperature hydration. It resulted in the formation of brown amphibole, from mafic magmatogenic silicates. The process took place in intergranulars and besides simple amphibole margins and grains, in the first stage of the process there formed also symplectites of clinopyroxene, amphibole and plagioclase. The subsequent metamorphic recrystallisation resulted in the troctolites and two-pyroxene gabbros in the formation of bluish-green and colourless amphibole, garnet, biotite, clinozoisite, chlorite, serpentine, iddingsite, white mica, titanite, magnetite and calcite.

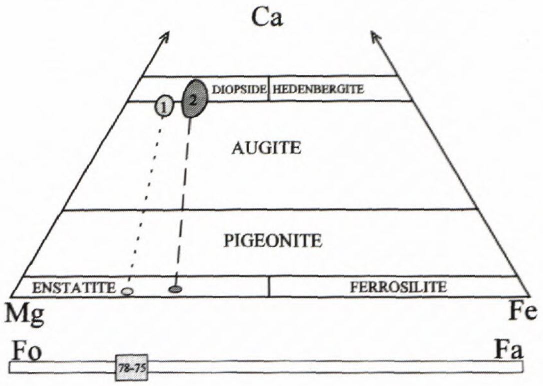

Fig. 1. Classification diagram (MORIMOTO et al. 1988) for pyroxenes of gabbroic rocks from the Nízke Tatry Mts. (Veporic Unit). 1 - clinopyroxenes from troctolite, 2 - clinopyroxenes from two pyroxene gabbro.

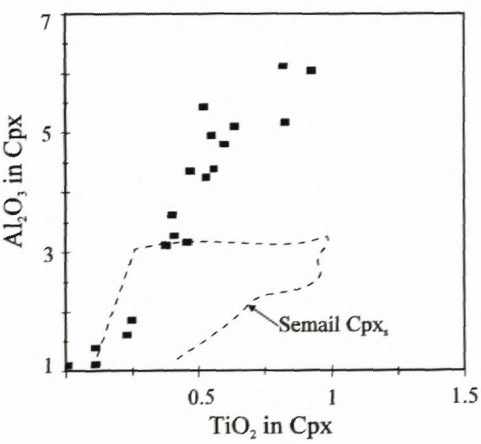

Fig. 2. Al_2O_3 vs. TiO_2 diagram for gabbroic clinopyroxenes from the Nízke Tatry Mts. Dashed field - composition of Semail Ophiolite gabbroic rocks (taken from ELTHON; 1987).

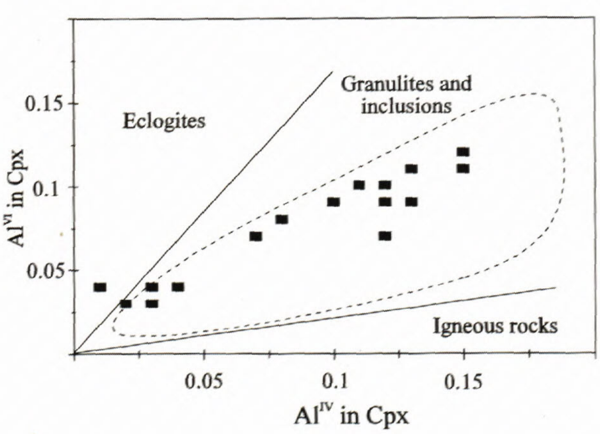

Fig. 3. Al^{VI} vs. Al^{IV} diagram for clinopyroxenes of gabbroic rocks from Nízke Tatry Mts. Dashed field - composition of clinopyroxenes from basal gabbro of Tonsina Complex (DE BARI and COLEMAN, 1989). other fields by AOKI and KUSHIRO (1968).

Mineralogy

In this study of both gabbro types, there were studied the compositions of magmatogenic olivine, orthopyroxenes, clinopyroxenes, plagioclases, chromspinelids and from metamorphogenic minerals, the composition of brown amphiboles.

The composition of olivine varies in a narrow range (Fo_{75-78}, Fig. 1). Olivines with such composition are found in oceanic basic and ultrabasic cumulates (Fo_{72-88}, ELTHON et al., 1992), but also in tholeiite layered intrusions and ocean arc gabbros (Fo_{90-40}, and Fo_{88-62}, respectively; BEARD, 1986).

Clinopyroxene in MORIMOTO´s et al. classification (1988) is with its composition on the boundary of diopside and augite (Fig. 1). Clinopyroxenes of troctolites are more Mg-rich than clinopyroxenes of two-pyroxene gabbros. In comparison with cumulates and gabbros, they contain more Fe and Ca (HÉBERT et al. 1989). The Al contents in clinopyroxenes (Fig. 2) are also increased in comparison with oceanic or ophiolite analogues. Low-Al clinopyroxenes occurring in two-pyroxene gabbros along with high-Al clinopyroxenes are suggested to be the products of superimposed metamorphic processes. The Al^{IV} vs. Al^{VI} ratio in the studied clinopyroxenes is different from clinopyroxenes of common magmatites crystallising in low-pressure conditions (Fig. 3) and they rather resemble clinopyroxenes of granulites, high-pressure xenoliths or gabbros from the basal level of the ocean arc lower crust (DE BARI and COLEMAN, 1989).

Orthopyroxene composition corresponds to enstatite (Fig. 1) and the differences in Fe-contents between orthopyroxenes of troctolites and two-pyroxene gabbros are analogous to those of clinopyroxenes.

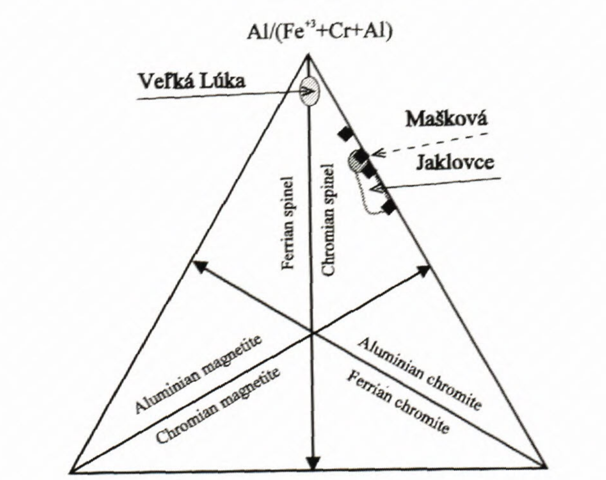

Fig. 4. Spinel from troctolite in classification diagram by Stevens (in ROJKOVIČ, 1985) Fields for peridotite xenolith spinels (Mašková), ophiolitic peridotite spinels (Jaklovce) and deuteroperidotite spinels (Veľká lúka) are ploted for comparison (data by ROJKOVIČ,1985).

The composition of plagioclase from gabbroids varies in the range of An_{62-65}, in the two-pyroxene gabbro there has been also determined plagioclase with An_{84}. The ratio between plagioclase basicity and the contents of the Fo component in olivine, which in gabbros may reflect the geodynamic setting (BEARD, 1986), is similar to tholeiite layered intrusions.

Spinel in troctolites belongs to chromium spinels (Fig. 4). Its composition resembles spines of upper-mantle origin, but it is different from spinels of oceanic rocks (Fig. 5).

Brown amphiboles which are the products of the earliest stage of the metamorphic alteration correspond, according to their composition in LEAKE´s (1978) classification, to Ti-pargasite, Ti-pargasitic hornblende to pargasitic hornblende (Fig. 6). Amphiboles of analogous composition from gabbros have been described as products of high-temperature (900-1040°) hydration by OTTEN (1984).

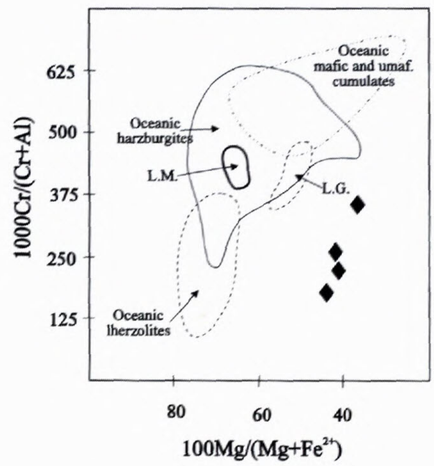

Fig. 5. Composition of spinel in a Cr/(Cr+Al) vs. $Mg/(Mg+Fe^{2+})$ diagram for troctolite with comparison to oceanic rocks. Fields from HÉBERT et al. (1989). L.M. = Macquarie lherzolites, L.G. = Gorringe lherzolites.

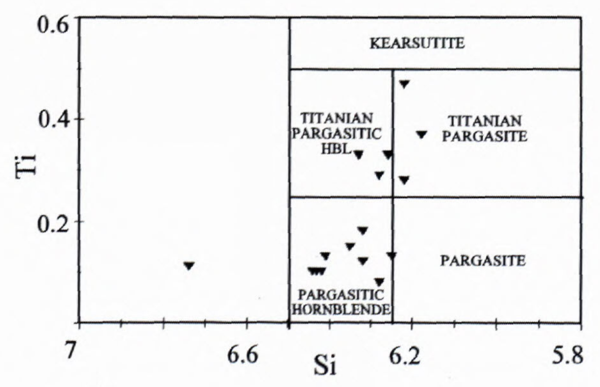

Fig. 6. Brown amphiboles from gabbroic rocks of the Nízke Tatry Mts. in classification diagram by OTTEN (1984) based on the classification of amphiboles by LEAKE (1978).

Tab. 1 Representative microprobe analyses of olivines from gabroids of the Veporic Unit (the Nízke Tatry Mts.) Structural formula calculated on the basis of 4-O

Sample	VV-100	VV-100	VV-100	VV-100
Ol. N^0	77	81	95	100
SiO_2	38.78	39.23	39.25	38.61
TiO_2	0.08	0.01	0.00	0.00
Al_2O_3	0.02	0.03	0.02	0.00
Cr_2O_3	0.13	0.03	0.01	0.07
FeO	22.09	21.93	20.49	23.63
MnO	0.32	0.30	0.00	0.48
MgO	39.95	39.59	40.87	38.54
CaO	0.00	0.06	0.00	0.00
Na_2O	0.03	0.00	0.02	0.00
K_2O	0.00	0.05	0.03	0.01
Total	101.40	101.26	100.69	101.35
Si	0.99	1.01	1.00	1.00
Ti	0.00	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00
Fe	0.47	0.47	0.44	0.51
Mn	0.01	0.01	0.00	0.01
Mg	1.53	1.51	1.56	1.48
Total	3.00	2.99	3.00	3.00
Xmg	0.77	0.76	0.78	0.74

Tab. 2 Representative microprobe analyses of clinopyroxenes from gabroids of the Veporic Unit (the Nízke Tatry Mts.) Structural formula calculated on the basis of 6-O

Sample	VV-120	VV-120	VV-120	VV-100	VV-100	VV-100
Cpx N^O	2	23	25	90	96	98
SiO_2	52.05	51.82	49.82	49.96	51.01	51.31
TiO_2	0.25	0.40	0.52	0.93	0.55	0.53
Al_2O_3	1.85	3.63	5.43	6.04	4.94	4.25
Cr_2O_3	0.11	0.19	0.51	0.73	0.65	0.57
FeO	8.46	7.79	7.59	4.98	4.00	4.16
MnO	0.32	0.31	0.23	0.23	0.16	0.13
MgO	13.65	13.80	14.28	15.07	16.41	16.31
CaO	22.14	21.12	19.01	19.87	20.11	20.45
Na_2O	0.43	0.69	0.93	1.17	1.14	0.98
K_2O	0.10	0.09	0.14	0.09	0.01	0.09
Total	99.37	99.83	98.44	99.09	98.98	98.77
Si	1.95	1.92	1.87	1.85	1.88	1.90
Al^{IV}	0.04	0.08	0.13	0.15	0.12	0.1
Ti	0.01	0.01	0.01	0.02	0.02	0.01
Al^{VI}	0.04	0.08	0.11	0.11	0.09	0.09
Al	0.08	0.16	0.24	0.26	0.21	0.19
Cr	0.00	0.01	0.02	0.02	0.02	0.02
Fe	0.27	0.24	0.24	0.15	0.12	0.13
Mn	0.01	0.01	0.01	0.01	0.00	0.00
Mg	0.76	0.76	0.80	0.83	0.90	0.90
Ca	0.89	0.84	0.76	0.79	0.79	0.81
Na	0.03	0.05	0.07	0.08	0.08	0.07
K	0.00	0.00	0.01	0.00	0.00	0.00
Xmg	0.74	0.76	0.77	0.85	0.88	0.87

Tab. 3 Representative microprobe analyses of orthopyroxenes from gabbroids of the Veporic Unit (the Nízke Tatry Mts.). Structural formula calculated on the basis of 6-O.

Sample	VV-100	VV-100	VV-120	VV-120
Opx No	108	106	26	30
SiO_2	55.16	54.60	52.37	51.97
TiO_2	0.12	0.17	0.11	0.12
Al_2O_3	1.13	1.23	0.66	0.77
Cr_2O_3	0.03	0.05	0.03	0.10
FeO	15.32	15.77	25.89	25.35
MnO	0.37	0.34	0.89	1.32
MgO	27.12	27.55	19.98	20.22
CaO	1.00	0.51	0.40	0.60
Na_2O	0.08	0.04	0.01	0.00
K_2O	0.00	0.02	0.00	0.02
Total	100.33	100.28	100.34	100.47
Si^{IV}	1.98	1.96	1.98	1.96
Al^{IV}	0.02	0.04	0.02	0.03
Al^{VI}	0.03	0.02	0.01	0.00
Ti	0.00	0.00	0.00	0.00
Fe	0.46	0.47	0.82	0.80
Mn	0.01	0.01	0.03	0.04
Mg	1.45	1.48	1.13	1.14
Ca	0.04	0.02	0.02	0.02
Na	0.01	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00
Xmg	0.76	0.76	0.58	0.59

Tab. 4 Representative microprobe analyses of plagioclases from the gabroids of the Veporic Unit (the Nízke Tatry Mts.) Structural formula calculated on the basis of 8-O

Sample	VV-100	VV-100	VV-120	VV-120
Opx No	108	106	26	30
SiO_2	55.16	54.60	52.37	51.97
TiO_2	0.12	0.17	0.11	0.12
Al_2O_3	1.13	1.23	0.66	0.77
Cr_2O_3	0.03	0.05	0.03	0.10
FeO	15.32	15.77	25.89	25.35
MnO	0.37	0.34	0.89	1.32
MgO	27.12	27.55	19.98	20.22
CaO	1.00	0.51	0.40	0.60
Na_2O	0.08	0.04	0.01	0.00
K_2O	0.00	0.02	0.00	0.02
Total	100.33	100.28	100.34	100.47
Si^{IV}	1.98	1.96	1.98	1.96
Al^{IV}	0.02	0.04	0.02	0.03
Al^{VI}	0.03	0.02	0.01	0.00
Ti	0.00	0.00	0.00	0.00
Fe	0.46	0.47	0.82	0.80
Mn	0.01	0.01	0.03	0.04
Mg	1.45	1.48	1.13	1.14
Ca	0.04	0.02	0.02	0.02
Na	0.01	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00
Xmg	0.76	0.76	0.58	0.59

Discussion

The cumulate texture of the gabbroids and differences in the mineral composition indicate that these rocks originally represented a component of a differentiated (layered?) intrusion. Data on chemical composition of the rock are not available yet. In spite of this, it we may assume that the studied gabbroids are in their composition different from analogous oceanic rocks. They probably crystallised at higher pressures than oceanic gabbroids from magma with low water content and hydrous minerals were formed in the sub-solidus stage of the incorporation of the fluid at relatively high temperatures. Further metamorphic stages are superimposed on this alteration. The petrographic characteristics and mineral composition of gabbroids from the vicinity of Heľpa are analogous to gabbros of the leptyno-amphibolite complexes of type localities in French Massif Central (c. f. Pin & Lancelot, 1982; Briand et al., 1991). They are a part of the LAC forming the northern part of the Veporic Unit. The crystallisation at high pressures, high-temperature hydration and multi-stage regression support our interpretation of the LAC as a reworked lower crustal complex of magmatic origin.

Tab. 5 Representative microprobe analyses of spinels from the gabroids of the Veporic Unit (the Nízke Tatry Mts.) Structural formula calculated of the basis of 3 cations. Fe^{+3} calculated from spinel stechiometry.

Sample	VV-100	VV-100	VV-100	VV-100
Sp. N^0	78	93	101	105
TiO_2	0.01	0.03	0.00	0.07
Al_2O_3	43.77	48.94	45.74	36.47
Cr_2O_3	22.93	16.11	19.82	30.03
Fe_2O_3	0.00	0.28	0.00	0.26
FeO	23.30	23.68	23.80	24.83
MnO	0.24	0.20	0.28	0.35
MgO	9.54	10.32	9.60	8.34
CaO	0.11	0.00	0.00	0.07
Total	99.90	99.57	99.24	100.42
Ti	0.00	0.00	0.00	0.00
Al	1.49	1.63	1.55	1.28
Cr	0.52	0.36	0.45	0.71
Fe^{+3}	0.00	0.01	0.00	0.01
Fe^{+2}	0.56	0.56	0.57	0.62
Mn	0.01	0.00	0.01	0.01
Mg	0.41	0.44	0.41	0.37
Ca	0.00	0.00	0.00	0.00

Conclusions

1) For the first time, gabbroids which are a rock member of a leptyno-amphibolite complex, have been found in the pre-Alpine basement of the Western Carpathians.

Tab. 6 Representative microprobe analyses of amphiboles from the gabroids of the Veporic Unit (the Nízke Tatry Mts.) Structural formula calculated on the basis of 23-O

Sample	VV-100	VV-100	VV-100	VV-120	VV-120	VV-120
Hbl No	92	104	111	2	21	12
SiO_2	43.41	44.00	44.29	42.57	43.93	44.01
TiO_2	4.37	3.09	2.72	1.59	1.17	0.95
Al_2O_3	13.24	12.89	13.25	14.06	13.40	13.49
Cr_2O_3	0.13	0.05	0.19	0.09	0.77	0.53
FeO	7.28	7.28	6.08	13.70	11.47	12.31
MnO	0.14	0.14	0.04	0.32	0.20	0.28
MgO	14.62	14.98	16.58	10.90	12.56	12.31
CaO	11.50	11.67	12.00	11.15	11.52	11.36
Na_2O	3.12	3.08	3.08	2.19	2.15	2.16
K_2O	0.39	0.51	0.46	0.71	0.60	0.48
Total	98.20	97.69	98.69	97.28	97.77	97.88
Si^{IV}	6.22	6.33	6.28	6.32	6.41	6.43
Al^{IV}	1.78	1.67	1.72	1.68	1.59	1.57
T site	8.00	8.00	8.00	8.00	8.00	8.00
Al^{VI}	0.45	0.52	0.49	0.78	0.72	0.76
Ti	0.47	0.33	0.29	0.18	0.13	0.10
Cr	0.01	0.01	0.02	0.01	0.09	0.06
Mg	3.12	3.21	3.50	2.41	2.73	2.68
Fe	0.87	0.88	0.70	1.62	1.33	1.40
Mn	0.02	0.02	0.00	0.00	0.00	0.00
Ca	0.05	0.04	0.00	0.00	0.00	0.00
M1,2,3	5.00	5.00	5.00	5.00	5.00	5.00
Fe	0.00	0.00	0.02	0.08	0.07	0.11
Mn	0.00	0.00	0.00	0.04	0.02	0.03
Ca	1.77	1.80	1.82	1.77	1.80	1.78
Na	0.23	0.20	0.15	0.11	0.10	0.08
M4 site	2.00	2.00	2.00	2.00	2.00	2.00
Na	0.63	0.66	0.70	0.52	0.51	0.53
K	0.07	0.09	0.08	0.13	0.11	0.09
A site	0.65	0.72	0.78	0.65	0.62	0.62
Xmg	0.78	0.79	0.83	0.59	0.66	0.64

2) Two petrographic gabbroid types have been distinguished: troctolites and two-pyroxene gabbros.

3) Based on the composition of magmatogenic minerals, the gabbroids are not analogues of ophiolite gabbros, they are similar to gabbros of layered tholeiite intrusions which crystallised at elevated pressure.

4) The gabbroid rocks underwent high-temperature hydration, with the formation of Ti-rich amphiboles and subsequent multi-stage retrograde alteration

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