Rochovce metagabbro: Elemental and isotopic contamination by Late Cretaceous granite (the Western Carpathians)

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Abstract: The drilling into the body of hidden granitic intrusion near Rochovce village revealed (Klinec et al., 1979) the location of approximately 100 m thick body of dark metamorphosed gabbroidic rocks directly above the Cretaceous Rochovce granite. The compiled petrographic, geochemical and isotopic data support the arguments about the autochthonous, pre-granite position of Rochovce gabbro above the Rochovce Late Cretaceous granite. The intrusion of granite caused not only the gabbro penetration by aplitic veinlets, but significantly influenced its former material (mineral, chemical) and isotopic compositions. The impacts of contamination processes were selective. They resulted mainly in the extreme enrichment of metagabbro by Rb and LREE. The isotopic composition of strontium $(^{87}Sr/^{86}Sr)_{76}$ in gabbroid after the granitic contamination generally corresponds with its original composition, but the isotopic composition of Nd is significantly lowered. As a result of contamination, the isotopic characteristics of Nd and Sm/Nd ratio in gabbro copy those of underlying granite. This is the reason, why these data cannot be used as characteristic end-member in geochemical considerations about interaction (mixing) of mafic and acid magmas during the genesis of Hercynian granitoids of the crystalline basement of Western Carpathians. The geological, structural and partially also petrographic data allow to limit the lower age of investigated gabbroidic body with the age of Hercynian granitoids intrusions in Veporicum (350 – 300 Ma) and upper age with Alpine (Cretaceous) tectonic processes – the Cretaceous intrusion of Rochovce granite. The $^{40}Ar/^{39}Ar$ dating of amphiboles yield the age of origin of newly formed amphiboles in gabbro during the contact metamorphic recrystallization caused by intrusion of Rochovce granite and suggests the complete loss of accumulated radiogenic $^{40}Ar^*$. The age of amphibole from metagabbro 75.9 ± 1.8 Ma represents an independent proof of intrusion age of Rochovce granite.

Key words: Veporic unit, Rochovce, Alpine granite, metagabbro, elemental and Sr, Nd isotope interactions

Introduction

The existence of hidden granitoid intrusion has been supposed in the area of southeastern boundary of the Kohút zone of Veporicum and at its tectonic contact with Gemericum already earlier (Vrána, 1964a). The drilling works at the end of the 1970´s (borehole KV-3, Klinec et al., 1979) proved the presence of granitoid body with supposed Alpine age, appearing in the approximate depth 700 m. The appox. 100 m thick body of dark metamorphosed gabbroidic rocks is located above this so-called Rochovce granitic body. This article aims to evaluate geochemical and isotopic data from gabbro and granite and to determine whether the present data are usable for the conception of mutual geochemical (and isotopic) interaction of both bodies.

Brief summary of former works

The geological setting of the Pre-Alpine units in the wider area of the Rochovce village is complicated with the hidden Alpine granitic intrusion forming contact aureole with biotite, cordierite, occasionally also with andalusite (Klinec et al., 1980; Vozárová, 1990). Petrographic, mineralogical and geochemical characteristics of the Rochovce granite differ from granitoids of Veporicum and Gemericum (Határ et al., 1989). The Upper Cretaceous age of this body was proved by two independent zircons U-Pb datings - 82 ± 1 Ma and 76 ± 1.1 Ma (Hraško et al., 1999; Poller et al., 2001). Directly above the Rochovce granite the approximately 100 m thick body of dark metamorphosed gabbroidic rocks is located (borehole KV-3). The drilling works have shown, that in the basal part of the gabbroidic body the weak Ni-Co-(Cu) mineralization is present (Ivanov, 1981, 1983). In the past this finding led to more detail studies, concerning the petrogenetic, metallogenetic and metamophic topics. The metagabbro genesis and its relation to granite is interpreted by various authors differently. The differences preferably concerned the reasons of metagabbro metamorphic changes, including evaluated P-T conditions. Some authors prefer the Hercynian regional metamorphism (Krist et al., 1988; Korikovskij et al., 1989), others suppose the metamorphism of the body to be a result of the heat from underlying Cretaceous granitoid intrusion (Kantor & Rybár 1979a; Ivanov 1981, 1983). Hovorka (1983) connects the origin of mineral neoblasts and mainly the metasomatic replacement of amphibole by biotite with the thermal effect of underlying granite; the temperature increase in the granite exocontact he estimated to 550-600 °C.

Slovak Geol. Mag., 10, 4 (2004), 263 – 276

According to Krist et al. (1988) and Korikovsky et al. (1989), the protolith – subalkaline, biotite–pyroxene-amphibole gabbro was metamorphosed in conditions of garnet zone of epidot-amphibolite facies (T = 440 – 450 °C, medium pressure conditions) during Hercynian regional metamorphism, coinciding with the metamorphic conditions of basic rocks (amphibolites) of the complex of Hladomorná dolina valley (sensu Vrána, 1964b). Krist et al. (l.c.) supposed the tectonic contacts of granite with gabbro, because no evidences of contact metamorphism by granite were found in the gabbro.

No special attention was paid to the age of metagabbro in above cited works, despite the geological indications (Ivanov, 1981), that it is younger in comparison with phyllites and micaschists of the Hladomorná dolina valley (Lower Paleozoic-Devonian; Klinec & Planderová, 1981, resp. Slatviná Formation of the Upper Carboniferous age according to Vozárová & Vozár, 1982) and older than the intrusion of Rochovce granite. The Carboniferous age of the gabbro was supposed by Ivanov (1983). Kantor & Rybár (1979b) published the K/Ar ages from amphibole, resp. biotite of the metagabbro 82 resp. 75 Ma, being interpreted as a product of temperature influence of the Rochovce granite on gabbro.

2. Geological position of metagabbro

The metamorphosed gabbroidic body is a constituent of the lower part of rock sequence being in the past regarded as the migmatitized part of crystalline basement, resp. aplitoid granites without adequate categorization. After the reevaluation of drilling material we regard these rocks to be the Hercynian granitoids, and mainly granodiorites of Vepor type and their aplitoid varieties, which suffered the Hercynian as well as Alpine regional deformation and recrystallization.

Accordingly, in the drilling profile the gabbroidic body is located in the underlier of complex of metagranitoids of Vepor type and directly in the contact with Rochovce granite (Fig. 1). The question about mutual relation of these two bodies was until now not unambiguously answered. As we document in the further text, the overlying rock complexes including the metagabbro alone, are penetrated with subvertical veins of granite-aplite (Fig. 2A), being derived from underlying granite and oriented relatively perpendicularly to mineral lination (most probable of Alpine age) of metagranitoids and metamorphites and penetrating into the brittle structures without more distinct interactions with rocks. Part of the body expresses also older granitization process (Fig. 2B), probable relating with the uppermost thermal reworking of gabbroid, accompanied with production of leucotrondhjemitic aplitic veins and bulges. The coarse-grained xenoliths of overlying metagabbro are present in granitic matrix of the uppermost part of granite (Fig. 2C). They differ from the microgranular enclaves found in granite (Hraško et al., 1998). The age of emplacement of gabbro into the recent position in the overlier of granite is therefore pre-granitic and not post-granitic, as suppose Krist et al. (1988). The relation of metagabbro and overlying metagranitoid probable resemble the relation of Hercynian

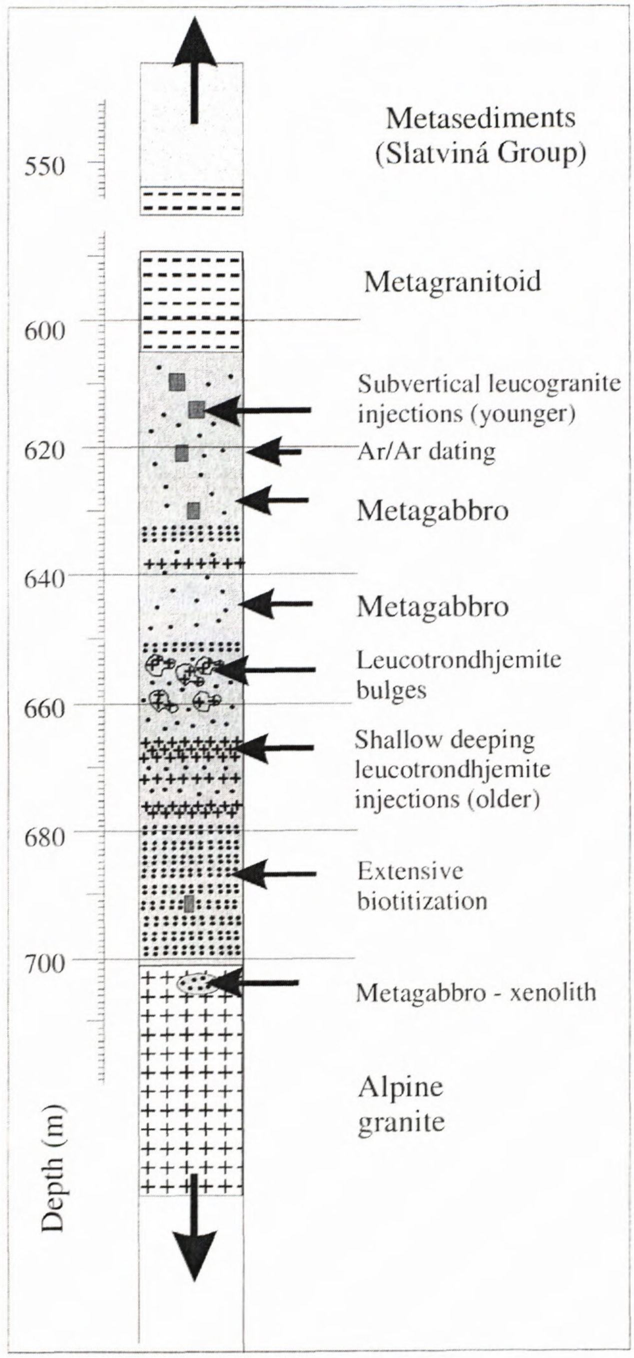


Fig. 1 Position of metagabbro and Late Cretaceous granite (borehole KV-3) near Rochovce village. The metagabbro was found only in borehole KV-3.

granitoids and hornblendites in the Stolica massif. The position of metagabbro beneath Veporic metagranitoids of the Kohút massif can be explained also in the case that gabbroidic rock is Alpine and intruded before the granite intrusion – so the metamorphic imprint in the mineral association of metagabbro are related only to the influence of granitic intrusion.

3. Petrographic description of analysed sample

Analysed sample was taken from the uppermost part of metagabbro in the approximate distance 80 m from the

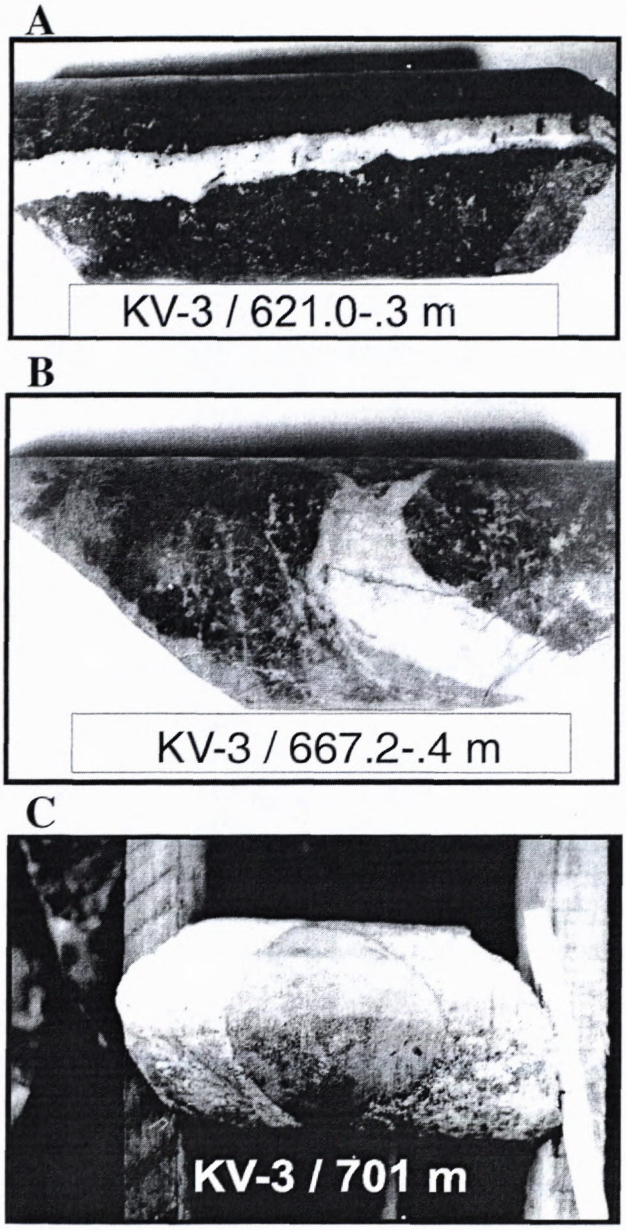


Fig. 2 Mutual relation of Rochovce granite and gabbro. A) Penetration of the Rochovce granite vein into the metagabbro. B) Aplitic, leucotrondhjemitic veins and bulges in metagabbro (products of melting of gabbroidic protolith?) C) Xenolith of metagabbro in the upper part of Rochovce intrusion.

contact with underlying granite. The approximately 1 cm thick subvertical aplite veinlet is coursing around (Fig. 2A) and its contact with metagabbro is sharp. The more fine-grained aplite development is visible at the margin, indicating, that during granite intrusion the metagabbro was already solidified and had distinctly lower temperature than the temperature of aplitic leucocratic magma.

Studied rock is of dark-brown colour (predominance of biotite) with green nests of prevailing amphibole. Amphiboles usually reach millimetre size and structurally belong to primary magmatic association. There is often the formation of randomly oriented fine-grained amphiboles closed in idiomorphic remnants of former porphyrocrysts of amphibole, with their composition reflecting rather a metamorphic genesis. The sample contains two basic types of amphibole – the prevailing dark-green amphibole (Tab. 1, analyse 2) can be classified as edenite (sensu Leake et al., 1997) and pale-greenish amphibole represents the actinolite close to projection field of tremolite (an. 3). The rare phases of amphibole with brown pleochroism are characterized with increased content of Ti – the mineral correspons to pargasite (Tab. 1, an. 1), which can represent the relict magmatic amphibole. The relative age and genetic relations between individual amphibolic phases are not unambiguous and their analysis is above the frame of this chapter – in the majority of cases there is valid the overgrowth of strongly pleochroic amphiboles by pale-green tremolite (Fig. 3 right upper side). The nests of actinolite appear locally also in older position, so there cannot be excluded that they represent the pseudomorphs after magmatic olivine. Regarding the superimposed metamorphic recrystallization we can speculate that both amphibole types are more-or-less syngenetic. Hb2 is only very rarely replaced by neoblasts of minute biotite.

The dominating final rock overprint was biotitization. It affects preferably the strongly pleochroic amphiboles because of their suitable chemical composition. Tiny randomly oriented flakes, denoted Bt2, occasionally represent more than 90 % of the amphibole volume. They penetrate also the large-flakes of biotite Bt1. It proves their relative younger age. This secondary biotitization (Bt2) is accompanied with origin of accessoric minerals like titanite, apatite, epidote and allanite (Fig. 3). The chemical composition of newly-formed allanite (Tab. 3, analyses 2 a 3) contributed significantly to the increase of the total REE content in the rock. The biotite formation is rather younger than the origin of amphiboles and blasteses prograde from the development of bigger porphyroblasts (Bt1) till the ubiquitous fine-grained biotite aggregates (Bt2) of identical chemical composition than Bt1. Biotite locally associates with rare syngenetic chlorite.

Plagioclases (An_{33}) large to 5 mm are not intensively recrystallized. They originated most probable from magmatic phase. Their relatively homogenous composition

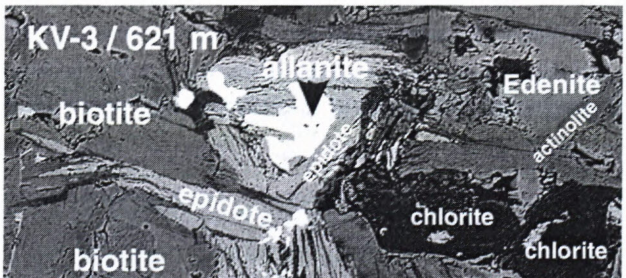


Fig. 3 Scanning picture depicting the younger metamorphic mineral association expressed mainly by biotitization („bt 2"), being accompanied by the development of epidote and syngenetic allanite – the main bearer of increased REE contents in the rock (cf. Tabs. 2 and 3).

Tab.1 Representative chemical composition of amphiboles in sample KV-3/621 (all iron as Fe^{2+})

Mineral	Hornblende		
sample	KV-3 / 621 m		
	an. 1	an. 2	an. 3
SiO_2	41,86	45,57	56,11
TiO_2	2,09	0,68	0,02
Al_2O_3	13,69	11,86	3,31
FeO tot	10,19	9,91	5,85
MgO	13,28	14,94	20,22
MnO	0,26	0,18	0,17
CaO	10,04	10,85	11,51
Na_2O	2,03	1,73	0,45
K_2O	1,11	0,94	0,12
Total	94,55	96,66	97,76
	calculated on basis of 23 oxygens p. f. u.		
Si IV.	6,291	6,645	7,769
Al IV.	1,709	1,355	0,231
sum	8,000	8,000	8,000
Al VI.	0,716	0,683	0,309
Ti VI.	0,236	0,075	0,002
Mg	2,975	3,248	4,173
Fe2+	1,073	0,994	0,516
sum	5,000	5,000	5,000
Fe2+B	0,208	0,214	0,161
Mn	0,033	0,022	0,020
Ca	1,616	1,694	1,707
Na	0,143	0,070	0,112
sum	2,000	2,000	2,000
NaA	0,449	0,419	0,009
K	0,213	0,175	0,021
sum	0,662	0,594	0,030
M/MF	0,748	0,777	0,894

Tab. 2 Chemical analyses of newly formed epidote (an. 1) and allanite (an. 2, 3) as the main bearers of REE in the rock.

	anal. 1	**anal. 2**	**anal. 3**
SiO_2	36,481	33,628	31,627
Al_2O_3	19,032	19,910	16,622
CaO	21,973	16,224	12,232
FeO	16,340	11,067	10,269
TiO_2	0,168	0,333	0,592
MgO	0,000	0,545	2,338
MnO	0,086	0,411	0,185
P_2O_5	0,008	0,065	0,021
F	0,071	0,000	0,280
Cl	0,019	0,012	0,003
La_2O_3	0,000	2,940	6,955
Ce_2O_3	0,088	5,492	10,680
Pr_2O_3	0,005	0,617	1,272
Nd_2O_3	0,000	2,551	2,841
SmO	0,099	0,232	0,204
EuO	0,135	0,171	0,162
Gd_2O_3	0,006	0,637	0,898
Tb_2O_3	0,096	0,025	0,121
Dy_2O_3	0,044	0,000	0,000
Ho_2O_3	0,135	0,000	0,055
Er_2O_3	0,074	0,036	0,000
Tm_2O_3	0,157	0,000	0,073
Yb_2O_3	0,039	0,014	0,044
Lu_2O_3	0,211	0,385	0,000
Y_2O_3	0,035	0,150	0,046
U_2O_3	0,000	0,000	0,000
SrO	1,472	0,430	0,087
ZrO_2	0,008	0,000	0,000
HfO_2	0,000	0,117	0,576
ThO_2	0,000	1,622	0,856
total	96,781	97,612	99,041

can indicate, that the metamorphic conditions persisted in the field of stability of plagioclase of this composition. The coexistence of both amphiboles in association with plagioclase of similar composition reflects metamorphic conditions of upper part of greenschist facies, where in low-pressure conditions at 420-450 °C the actinolite is transformed to amphibole of hornblenditic composition (Maruyama et al., 1983). Though, in the drill core also domains with lower degree of superimposed metamorphism occur – the results of these changes are also amphiboles of bimodal composition. In fine-grained development, there is also present chlorite, albite and carbonate with inclusions of actinolite of needle shape. The character of this metamorphic overprint resembles more the Alpine regional metamorphism as we know from overprinting reactions in Hercynian amphiboles (Kováčik et al., 1996). In the regional scale the intermediary plagioclase in Pre-Alpine mafic rocks is usually changed to albite and fine-grained mixture with prevailing clinozoisite and older amphiboles to amphibole of actinolitic type, chlorite and biotite. These less metamorphosed zones can also express the lower thermal conditions of Rochovce aureole. Generally the newly formed mineral assemblages of Rochovce gabbro are in the large extent tied with allochemical metamorphic processes and correspondingly demonstrate the marked spatial variability. The Alpine regional deformation (preferably the penetrative lineations), being observed in the rocks of broad surrounding, is not so typical for gabbroidic rocks. It can be explained by several ways – for example by the more resistant gabbro rheology, the younger intrusive age than the bulk Alpine deformation, or by postdeformation recrystallization of amphibolite and biotites.

4. Chemical and isotopic composition of metagabbro

From until now published metagabbro geochemical data only those of Ivanov (1984) about the metagabbro REE content are known. Further analyses are from unpublished archive data (analyses of major elements) and three new analyses of main and trace elements.

Tab. 3 a,b: Chemical analyses of metagabbro from the borehole KV-3 (including data from archives – Klinec, Ivanov, ŠGÚDŠ laboratory)

Depth (m)	611,0	617,5	621,0	622,5	624,2	624,5	625,0	625,0	625,0	629,3	630,0	634,0	650,0	653,4	684,5	689,5	692,5	693,0	695,2	695,6	696,0
Author	Ivanov	SGUDS	Hrasko	SGUDS	Klinec	Hrasko	Hrasko	SGUDS	SGUDS	Ivanov	Klinec	Klinec	Ivanov	Klinec	Ivanov	SGUDS	SGUDS	SGUDS	SGUDS	SGUDS	Klinec
SiO_2		45,31	48,76	45,97	48,26	47,89	50,72	45,70	46,34		46,76	47,71		49,93		43,65	46,29	44,50	44,58	45,20	46,94
TiO_2	0,86	0,95	0,78	1,10	1,74	0,78	0,62	0,95	0,90	0,83	1,83	1,49	0,97	1,24	0,92	0,88	0,95	0,65	0,78	0,79	1,13
Al_2O_3		11,39	11,22	10,68	9,29	10,53	9,79	9,45	9,30		8,39	8,53		6,97		7,25	11,02	8,06	7,85	7,12	10,43
Fe_2O_3		7,78	2,34	7,22	1,29	2,32	2,25	1,68	2,34		3,43	3,59		3,48		5,76	3,31	5,23	2,95	1,89	2,57
FeO		0,20	5,16	0,71	6,29	4,93	4,84	5,69	5,62		5,65	4,85		4,63		4,54	5,30	10,95	5,36	6,04	5,31
MgO		14,77	16,21	15,77	14,80	16,69	16,08	16,21	17,05		16,60	16,06		14,67		19,04	12,99	13,00	13,35	16,46	16,16
MnO		0,210	0,165	0,130	0,180	0,133	0,134	0,150	0,140		0,300	0,280		0,270		0,160	0,220	0,210	0,210	0,150	0,220
CaO		11,02	7,44	11,01	9,89	8,82	7,16	10,47	11,00		9,25	9,78		12,56		11,52	9,99	10,00	16,36	15,95	11,17
Na_2O		1,55	1,74	1,60	2,50	1,69	1,55	1,30	1,50		1,87	1,88		2,30		0,98	2,45	1,10	1,05	1,00	2,00
K_2O		2,95	2,76	3,30	2,61	2,78	2,41	3,64	2,72		3,17	2,48		0,82		1,60	2,85	1,50	2,72	2,29	1,38
P_2O_5		0,41	0,34	0,39	0,22	0,33	0,35	0,39	0,20		0,36	0,29		0,18		0,68	0,68	0,26	0,59	0,28	0,19
H_2O+		2,50	2,50	1,00	2,46	2,00	1,14	2,20	1,20		1,75	2,60		2,35		2,50	2,50	2,50	2,50	2,50	2,00
H_2O-		0,33	0,25	0,09	0,10	0,16	0,43	0,12	0,05		0,31	0,04		0,10		0,15	0,24	0,12	0,19	0,19	0,30
CO_2			0,70	n.a.	n.a.	1,20	3,04	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Total		99,37	100,37	98,97	99,63	100,25	100,51	97,95	98,36	0,83	99,67	99,58		99,50		98,71	98,79	98,08	98,49	99,86	99,80

Tab. 3 a, b displays the contents of major and trace elements from metagabbro. In comparison with the mean values of the element contents in the average basic rocks of this type (Rösler & Lange, 1972) the metagabbro is significantly enriched by alkalies (Cs, Rb, Li – Fig. 4, Tab. 3), U, Th and light REE (La, Ce, Eu, Nd, Sm). The contents of Cr, Ba and Sr can probable represent the primary geochemistry of the body. The significant changes of the primary chemical composition can be assigned to the interaction of fluids derived from underlying Cretaceous intrusion with former gabbro (in the same way like it was interpreted by Hovorka, 1983). The mechanism of changes could be similar like that during the changes of chemical composition of mafic enclaves in granitic magma being influenced by diffusion of ions from granitic magma into the environment rich in amphiboles – one of its conspicuous effects is the biotitization and forming of allanite as a main carrier of LREE (Tab. 2). These processes were described for example by Orsini et al. (1991) and in Western Carpathian granitoids by Petrík & Broska (1989), Broska & Petrík (1993) and Hraško et al. (1998).

Tab. 3b

Depth (m)	611,0	621,0	624.5	625.0	629,3	650,0	684,5	699,0
Author	Ivanov	Hraško	Hraško	Hraško	Ivanov	Ivanov	Ivanov	Ivanov
Ba		635,5	677,9	670,6				
Be				0,1				
Ce	143,0	109,7	104,4	128,0	157,0	161,0	161,0	148,0
Co		43,0	46,0	48,3				
Cr		634,0	608,0	600,0				
Cs				8,7				
Cu		6,0	27,0	32,0				
Eu	3,5	2,5	2,6	2,8	3,4	4,1	4,0	3,7
Ga				6,80				
Hf	3,2	5,1	4,2	3,1	3,3	3,4	3,3	2,9
La	53,0	60,0	59,5	60,0	62,0	61,0	57,0	64,0
Li		47,0	37,0	25,0				
Lu	0,19	0,19	0,38	0,27	0,26	0,26	0,21	0,28
Nb	6,8	4,8	4,2		7,6	9,0	9,4	10,0
Nd	97,0	76,2	79,0	55,0	97,0	104,0	97,0	74,0
Ni		283,0	293,0	171,0				
Rb		139,0	83,0	62,0				
Sc	31,0			29,9	30,0	45,0	36,0	53,0
Sm	12,6	9,9	10,2	12,7	13,0	14,3	16,4	13,0
Sn				< 5				
Sr		637,9	1 809,6	720,0				
Ta	0,3	0,5	0,5	0,4	0,3	0,3	0,3	0,2
Tb	1,0	0,5	0,5	1,0	1,0	1,5	1,0	1,0
Tm	0,24				0,35	0,32	0,32	0,28
Th	8,2	8,8	8,1	11,7	8,9	8,6	10,1	10,9
V		118,0	121,0	110,0				
U		4,0	3,0	2,1				
Y	19,0	18,0	17,0	16,0	18,0	22,0	20,0	18,0
Yb	1,5	1,4	1,3	1,9	0,0	2,2	1,8	1,8
Zn				90,0				
Zr	100,0	122,9	89,5	115,0	114,0	112,0	108,0	132,0

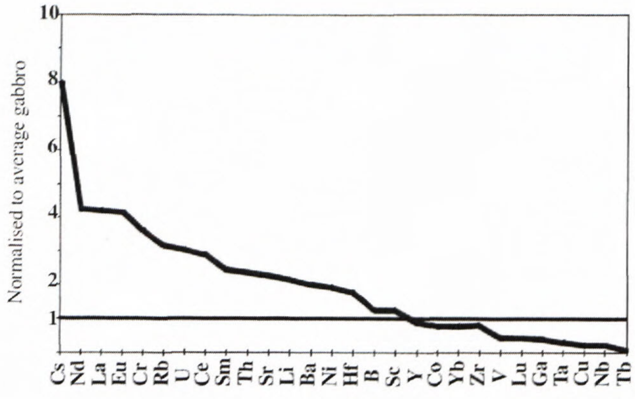


Fig. 4 Comparison of concentration of chosen elements in metagabbro and in rocks of similar type. Normalization is done to average gabbro (data in Rösler & Lange, 1972).

The judgement of influence of younger changes for chemical and isotopic characteristics of gabbroidic body is important also from the viewpoint of interpretation of basic end-member characteristic during the genesis of Hercynian granites (Kohút et al., 1999) as well as evaluation of validity of use of this data in genetic models of Hercynian granitoids.

During study of biotitization effects for the major element content we have used the classification diagrams by Debon & LeFort (1983), Irvine & Baragar (1971), Winchester & Floyd (1977) and Le Maitre (1989) – Fig. 5 A, B, C, D. It is obvious that biotitization caused the overal decrease of the SiO_2 content in gabbroidic rock and increase of K_2O. In the classification diagram it is manifested by the shift of projection points from the association of subalkaline to alkaline basaltoid magmas (Fig. 5 – B, C), eventually into the area away of common magmatic associations (Fig. 5D) and with moderate increase of aluminium content – Fig. 5A (shift from the field V – associations with clinopyroxene towards the field IV – associations with hornblende and biotite). It is obvious, that the composition of rocks before biotitization was close to composition of hornblendites from the closely located Hercynian granitoid of Stolica massif (original data by authors).

From the spiderogram of normalized values of composition towards MORB (Fig. 6A) there follows, that the Ti, Y , Zr, Hf, Nb and HREE contents have the typical MORB characteristics, while the further elements are relatively enriched in decreasing enrichment trend from Cs, Rb, Ba, Th, U, K, and LREE, with decreasing degree of enrichment from La towards Eu and correspondingly with the enlargement of Nd/Sm ratio in comparison with the primary composition.

The relative stability of Ti, Zr, Y (Mn, P) allows use of diagrams by Mullen (1983) and Pearce & Cann (1973) for classification characteristic of the former gabbroid. The calc-alkaline character of original magma is shown in Fig. 7 A, B.

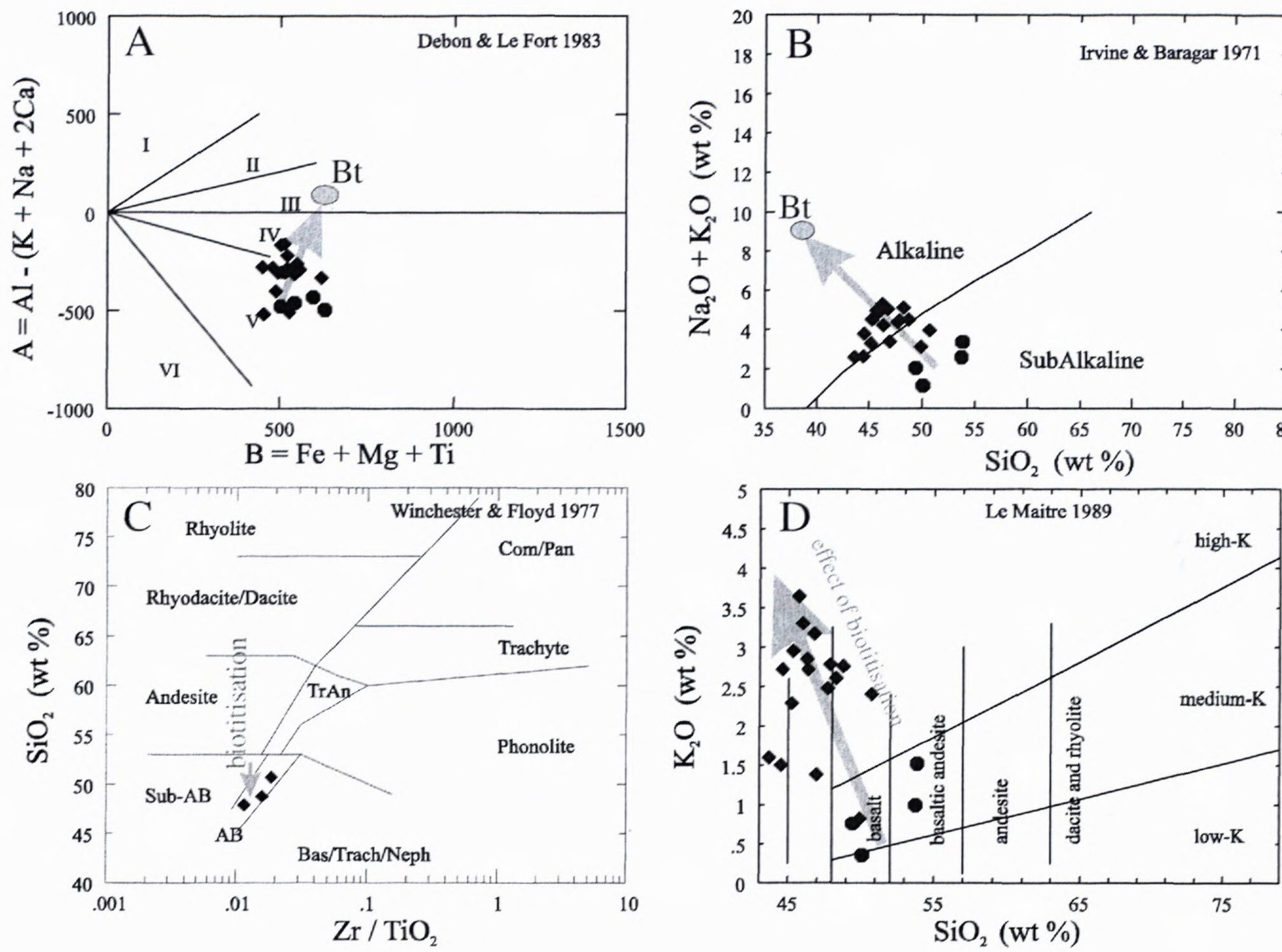
Naturally, the distinct changes of former chemical composition had to be manifested also in the change of former isotopic composition of Sr and Nd. In Tab. 4 we overviewed already published basic analytical data about isotopic composition of Nd from metagabbro, being taken from the work by Hraško et al. (1993) and later re-cited by Kohút et al. (1999). The value of Sr isotopic composition from metagabbro is taken from the work of Kohút et al. (1999) and the value of Sr and Nd from Rochovce granite is taken from the works by Kovách et al. (1986), Cambel et al. (1989), resp. Hraško et al. (1998). Values ε(Nd,Sr) partially differ from data published until now, because for the isotopic development DM we took parameter from the work by Michard et al. (1995).

In comparison of analytical data from gabbro and granite there is remarkable the high content of Rb in gabbro (Tab. 4). For average gabbro the Rb concentrations in the range 18–30 ppm are stated by Heier (1972) and the average 32 ppm by Faure (2001). The Sr concentration are in the range 97–534 ppm (Faure, 1978), the average 293 ppm; the published range for alkaline gabbro is 445–2115 ppm (Faure, 2001). Thompson et al. (1982) found from Paleocene basalts the Rb concentrations 2-22 ppm and Sr contents in the range 279–658 ppm ($^{87}Rb/^{86}Sr$ = 0.01–0.08), with recent $^{87}Sr/^{86}Sr$ ratios between 0.70342–0.70495. The Rb/Sr isotopic signatures of Neocomian basalts indicate, that depleted mantle has $^{87}Sr/^{86}Sr<0.703$ with Rb/Sr ratio <0.01(Samoilov et al., 1998).

*Tab. 4: Principal geochemical and isotopic data from the Rochovce gabbro and granite. Rb/Sr data from gabbro (1 sample) are taken from Kohút et al. (1999). Rb/Sr data from granite are taken from the works by Kovách et al. (1986) and Cambel et al. (1989) – 4 samples. Sm/Nd ratio from gabbro and granite (1 sample) is taken from Hraško et al. (1993, 1998) and Kohút et al. (1999). *- data calculated using the values for crust (McCulloh & Bennet, 1994), **- data calculated using the values for DM (according to Michard et al. 1985).*

	metagabbro	granite
Rb(ppm)	139	98-244
Sr (ppm)	638	440-993
$^{87}Rb/^{86}Sr$	0.630	0.711-1.003
$^{87}Sr/^{86}Sr$	0.70330	0.7093-0.7137
$(^{87}Sr/^{86}Sr)_{76}$	0,702620	0.7083 – 0.7126
$\varepsilon_{Sr}(0)$*	10.7	+6.4 » -55.2
$\varepsilon_{Sr}(76)$*	1.3	-3.4 » -63.4
Sm (ppm)	11.39	6.73
Nd (ppm)	65.68	39.28
$^{147}Sm/^{144}Nd$	0.10515	0.10385
$^{143}Nd/^{144}Nd$	0.512715	0.512435
$(^{143}Nd/^{144}Nd)_{76}$	0.512663	0.512383
$\varepsilon_{Nd}(0)$**	-7.8	-13.2
$\varepsilon_{Nd}(76)$**	-6.7	-12.1
T(DM) in Ma**	521	876

The Rb concentration in Rochovce gabbro reaches the Rb concentration of the samples from granite. From it follows also the high $^{87}Rb/^{86}Sr$ ratio in gabbro, but at distincly low ratio of $^{87}Sr/^{86}Sr$. When using these parameters for the evolution of Sr isotopes in gabbro in 521 Ma there would the $^{87}Sr/^{86}Sr$ ratio lower than BABI = 0.69899 (Papanastassiou & Wasserburg, 1969), which is unrealistic. The line of DM evolution the gabbro crosses at the model age 91 Ma. In comparison with granite, the Sm/Nd ratio is also near, similarly as the Nd isotopic composition. The average concentrations of Sm and Nd in gabbros (Herrman, 1970) vary between 0.9–5.9 ppm, resp. 4.3–20 ppm, and in granites the average for Sm concentration is 8.3 ppm with higher Nd content (46 ppm). Similarly like in granites, also in gabbro the Nd concentration is higher than Sm concentration. The position of gabbro and granite from Rochovce is shown in the graph $^{143}Nd/^{144}Nd$ vs $^{87}Sr/^{86}Sr$ (Fig. 8). The recent $^{87}Sr/^{86}Sr$ value of gabbro still falls into the field of MORB, but $^{143}Nd/^{144}Nd$ is markedly lower. The Late Cretaceous Rochovce granite is lying in the field of Western Carpathian Hercynian granitoid rocks



Obr. 5 Effect of biotitization on geochemical composition of gabbroidic rock in classification diagrams: A. Debon & LeFort (1983); B. Irvine & Baragar (1971); C. Winchester & Floyd (1977); D. Le Maitre (1989). Explanations of symbols: full circles – Paleozoic hornblendites in the Stolica granitic massif; full squares – Rochovce metagabbro; grey arrow depicts the trend of chemical composition changes of the main elements at biotitization.

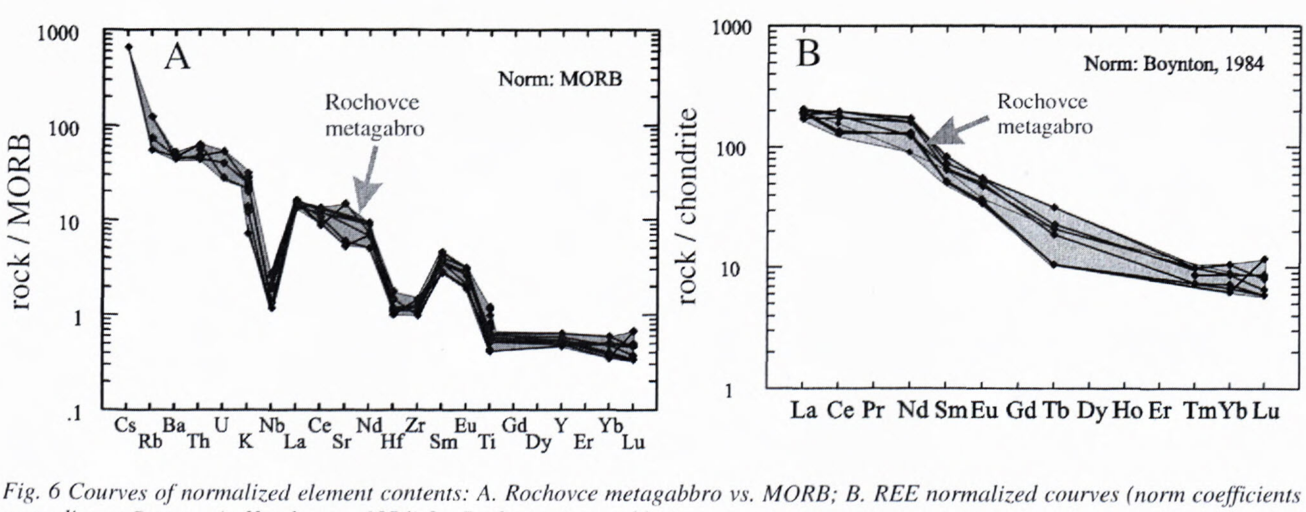


Fig. 6 Courves of normalized element contents: A. Rochovce metagabbro vs. MORB; B. REE normalized courves (norm coefficients according to Boynton in Henderson, 1984) for Rochovce metagabbro.

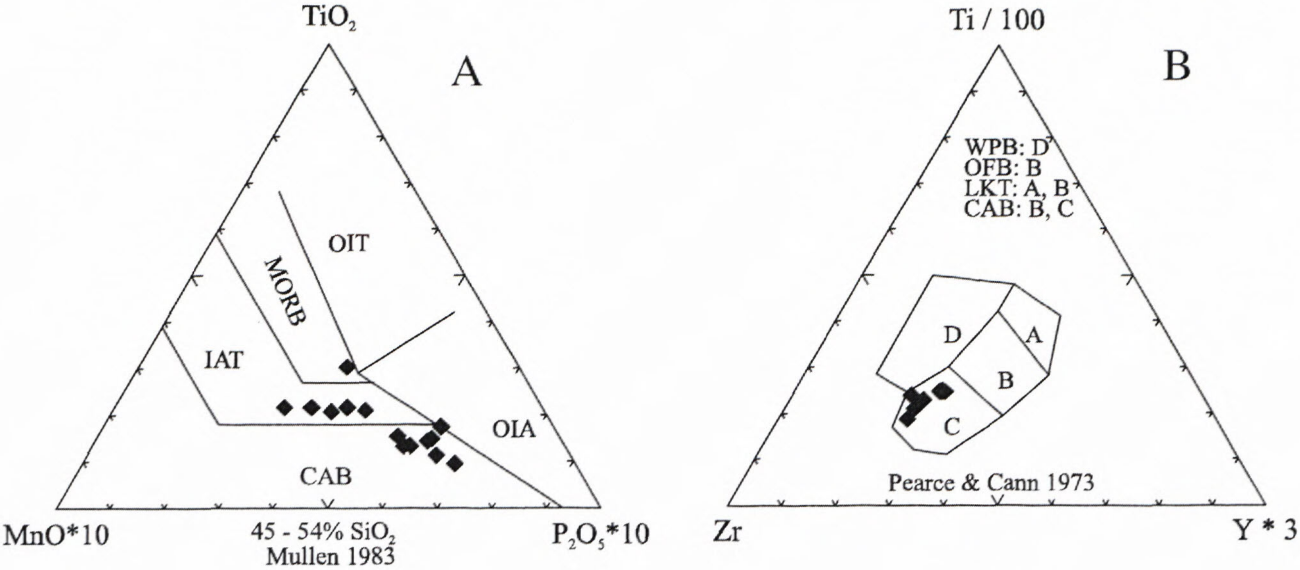


*Fig. 7 Classification diagrams reflecting the primary character of Rochovce metagabbro. A. Diagram $MnO*10-TiO_2-P_2O_5$ (Mullen, 1983): CAB – calc-alkaline basalts, IAT - island arc tholeiites, OIA - ocean island andesites, OIT - ocean island tholeiites, MORB - middle oceanic ridge basats. B. Diagram Zr–Ti/100–Y*3 (Pearce & Cann, 1973): WPT - within plate basalts, OFB – ocean floor basalt, LKT – low K tholeiites, CAB - calc-alkali basalts*

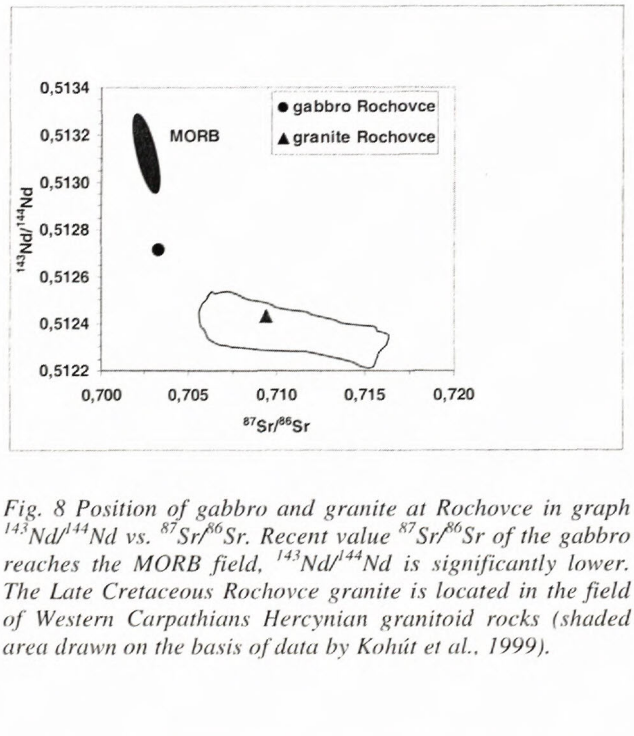
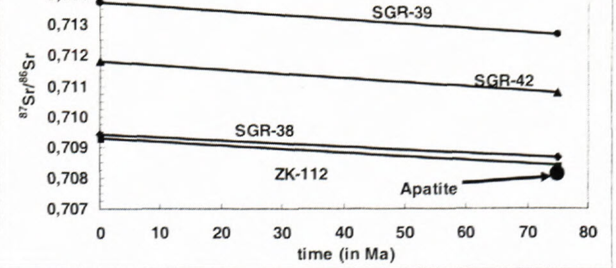


Fig. 8 Position of gabbro and granite at Rochovce in graph $^{143}Nd/^{144}Nd$ vs. $^{87}Sr/^{86}Sr$. Recent value $^{87}Sr/^{86}Sr$ of the gabbro reaches the MORB field, $^{143}Nd/^{144}Nd$ is significantly lower. The Late Cretaceous Rochovce granite is located in the field of Western Carpathians Hercynian granitoid rocks (shaded area drawn on the basis of data by Kohút et al., 1999).



(weakly shadowed area being drawn using data by Kohút et al., 1999). The summarized data therefore indicate the distinct changes of former chemical and isotopic composition of gabbro.

Information about the estimated initial ratio $(^{87}Sr/^{86}Sr)_{76}$ of Rochovce granite is discrepant. The $^{87}Sr/^{86}Sr$ evolution lines from the four until now published whole-rock analyses of the Rochovce granite are more-or-less parallel and has no common starting point. The values of calculated initial ratio $(^{87}Sr/^{86}Sr)_{76}$ for individual samples vary between 0.7083–0.7126 (Tab. 4, Fig. 9). The reason of this phenomenon is until now unknown. The data indicate the isotopic inhomogeneity of Rb-Sr system, which in no case fulfil the criteria of isochron concept (Nicolaysen, 1961). Though the isotopic inhomogeneities were described in the case of young as well as old plutonic rocks (USGS, 1986; Kostitsyn & Volkov, 1990), they have significantly lower variability than the samples of Rochovce granite. We hardly can exclude also the contamination of granite by strontium from gabbro having lower isotopic ratio (< 0.70262). In this case the scattering of $^{87}Sr/^{86}Sr$ in granite indicates the differing volume of contaminating strontium and also the high initial ratio of $^{87}Sr/^{86}Sr$ in granite (ca 0.713).

Fig. 9 Evolution of $^{87}Sr/^{86}Sr$ ratio in the samples of the Rochovce granite. Samples do not fulfil the condition of isochron concept (Nicolaysen, 1961). As an initial value $(^{87}Sr/^{86}Sr)_{initial}$ the mean value 0.70809 ± 0.00026 (± 2xSD) can be accepted, being found from three samples of accessoric apatite (Tab. 4).

Contrasting to stated inditions of isotopic inhomogeneity in Rochovce granite, the $^{87}Sr/^{86}Sr$ ratio, being found in accessoric apatite from granite of different depths (Tab. 5), documents only small variability around the mean value 0.70809 ± 0.00026 (±2SD). This value, regarding to very small Rb/Sr ratio in apatite (Faure, 2001), can be supposed as a initial value $(^{87}Sr/^{86}Sr)_{initial}$ in Rochovce granitic body. Only two whole-rock samples taken from Kovách et al. (1986) and Cambel et al. (1989) converge to this value and their calculated ratios $(^{87}Sr/^{86}Sr)_{76}$ are ca 0.7083. The $^{87}Sr/^{86}Sr$ ratio in apatites is slightly higher than estimated $(^{87}Sr/^{86}Sr)_{initial}$ ratios from the whole rock isochrons of Hercynian Western Carpathians granitoid rocks with S-type tendency (Kráľ, 1994).

Tab. 5 $^{87}Sr/^{86}Sr$ in accessoric apatite from drill cores localized in the Rochovce granite. Analytical error of isotopic measurements (± 2xS.E. – standard error of the mean) relates to the last two digits of isotopic ratio. The measured isotopic ratio $^{87}Sr/^{86}Sr$ was adjusted on the value NIST 987 = 0.710248. Apatite KV-3 was separated from granite in the proximity of gabbro. In the boreholes RO-2, RO-6 the gabbro is not present.

Borehole/depth (meters)	$^{87}Sr/^{86}Sr$ ± 2x S.E.
KV-3/ 723,5 – 723,8 m	0.707945 ± 21
RO-2/ 630 – 633 m	0.708200 ± 28
RO-6/ 370 – 372 m	0.708118 ± 21

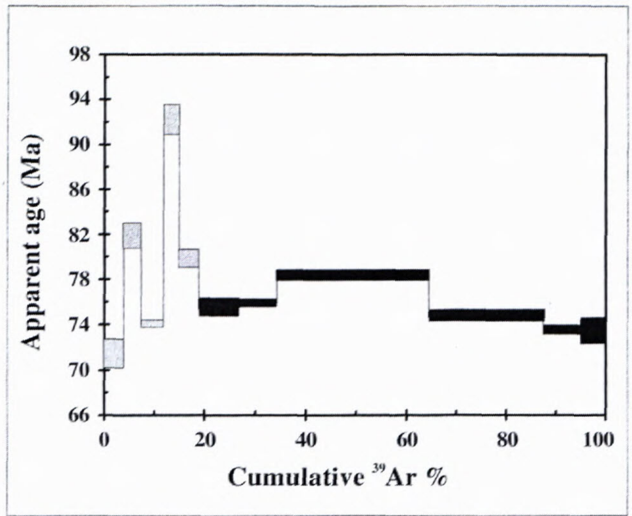
5. $^{40}Ar/^{39}Ar$ dating

The $^{40}Ar/^{39}Ar$ dating of separated amphibole from the borehole KV-3 was made in Geozentrum, University Wien, using methodology described in more details in the work by Kráľ et al. (1996). The hand-picked amphibole using the binocular microscope has a minimal amount of tiny biotites ingrowths without possibility to be removed from the amphibole. The separated amphibole grains were optically controlled by polarizing microscope. The purity of analysed sample was ca 95 %. The obtained apparent ages spectrum is shown in Fig. 10A together with the graph of K/Ca ratio variability during analysis (Fig. 10B). The analytical data are given in Tab. 6.

Tab. 6 $^{40}Ar/^{39}Ar$ analytical data from hornblende, KV-3/621-622 m metagabbro, borehole, Rochovce.

Step	T (°C)	%^{39}Ar	% ^{40}Ar*	^{40}Ar* /^{39}Ar	Age (Ma) ± 2 SD
1	730	3,8	40,0	13,43 ± 2,5	71,2 ± 1,8
2	780	3,6	55,6	15,46 ± 1,7	81,8 ± 1,4
3	820	4,4	66,6	13,94 ± 0,5	73,9 ± 0,4
4	840	3,1	56,2	17,47 ± 1,7	92,2 ± 1,5
5	870	4,0	63,4	15,07 ± 1,3	79,7 ± 1,0
6	900	7,8	80,3	14,20 ± 1,5	75,3 ± 1,1
7	930	7,6	84,5	14,29 ± 0,7	75,7 ± 0,5
8	980	30,2	92,0	14,77 ± 0,4	78,2 ± 0,3
9	1020	23,0	76,2	14,08 ± 1,0	74,6 ± 0,7
10	1060	7,5	89,4	13,82 ± 0,9	73,3 ± 0,6
11	1100	5,0	72,5	13,80 ± 2,2	73,2 ± 1,6

J = 0.002868 ± 0.4 % total gas age: 76,5 ± 2,4 Ma
81 % gas age: 75,9 ± 1,8 Ma



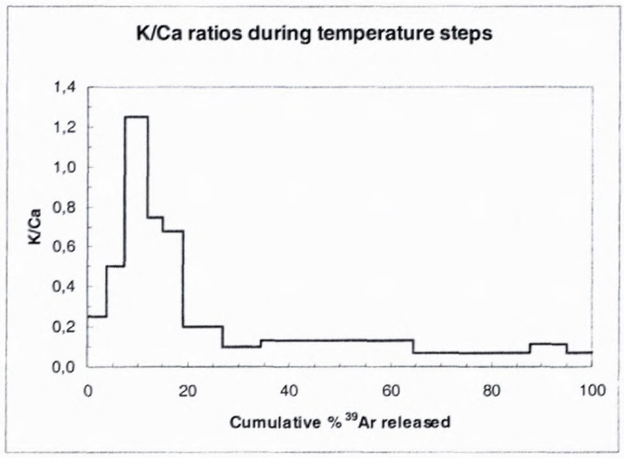


Fig. 10 Plot of $^{40}Ar/^{39}Ar$ apparent ages spectra from amphibole of Rochovce gabbro (A) and graph of variability of K/Ca ratio during the course of $^{40}Ar/^{39}Ar$ analysis (B). The higher variability of apparent ages and increase of K/Ca ratio in the lower temperature part of the spectrum is probable caused by degassing of tiny biotite inclusions.

The spectrum of apparent $^{40}Ar/^{39}Ar$ ages of step-by-step degassing of the sample varies in the range from 71.2 Ma to 92.2 Ma. The biggest variability of apparent ages is registered in the first four steps of low-temperature part of the spectrum. Correspondingly there was registered the increasing K/Ca ratio. We suppose, that in the first steps the outgassed ^{40}Ar is partially derived from inclusions of fine biotite in the amphibole grains. The spectrum of apparent ages in the low-temperature steps in analysed sample is clearly different from the amphibole spectra of Veporic amphiboles of Paleozoic age, being characteristic in the low-temperature part of the spectra with high apparent ages – up to 1500 Ma (Kráľ et al., 1996). The apparent ages in the higher temperature part of the analysed sample spectra vary in the more narrow range (78.2–73.2 Ma). The resulting age from this part of the spectra (five last temperature steps) is 75.9 ± 1.8 Ma, being in the range of analytical error identical with the U/Pb dating of zircons from the Rochovce granite (Poller et al., 2001). From the published $^{40}Ar/^{39}Ar$ ages of amphiboles from Veporicum it is until now the youngest age.

Slovak Geol. Mag., 10, 4 (2004), 263 – 276

It is possible, that $^{40}Ar/^{39}Ar$ spectrum (Fig. 10A) is derived from the mixture of at least two amphibolite types (Tab. 2) without possibility to be mutually separated. It can express the contact-metamorphic change by the temperature overreaching the closing temperature of K-Ar system in amphibole (ca 500 °C; Harrison, 1981). The final age therefore represents the rapid cooling/uplift of studied area. Different intepretation can be found in the process of blastesis or recrystallization of amphiboles, occurring synchronously with the contact effects of Rochovce granite and so the temperature conditions of their origin can be slightly lower than the blocking temperature of amphibole.

6. Discussion

The arguments presented above do not allow to interpret the metagabbro position in the overlier of Rochovce granite like the post-granitic displaced allochthonous body in tectonic position above granitoid. Also xenoliths of metagabbro found in the upper part of Rochovce granite (Fig. 2C) as well as the penetration of metagabbro by subvertical veins of later phases of Rochovce intrusion (Fig. 2A) exclude the tectonic position of metagabbro. The veinlets of granite composition has fine-grained development at their margin, which indicates the quick cooling and the relative lower temperature of metagabbro in comparison with intruded granitic body (above 800 °C, Hraško et al., 1998) No alteration of gabbroidic rock is related with the origin of these last veinlets (Obr. 2A). Older shallow dipping veins of leucotrondhjemitic aplites (Fig. 2B) and bulges of leucotrondhjemitic melts (Fig. 1) probably represent the utmost stage of thermal effect in relation with intrusion of the Rochovce granite. The discussed area (contact zone of Gemericum with Veporicum) was during the intrusion of Rochovce granite coolled to ca 300 °C, as is documented by K/Ar data on biotites from the Kohút zone (Kantor, 1959, 1960), and moreover these from the Rochovce area belong among the youngest from the Veporicum (Kantor & Rybár, 1979a; Cambel et al., 1980). The zones with intensively superimposed metamorphic recrystallization we connect with the thermal influence of the Rochovce granite. The changes of primary olivine, pyroxene and magmatic amphibole have postkinematic character and indicate slightly higher temperature conditions like the Alpine regional dynamometamorphism. The higher metamorphic degree of studied sample is indicated not only by the amphibole of hornblenditic composition (Leake et al., 1997), but mainly by the newly formed plagioclase of andesine composition. Contrary to this, in the regional scale in Pre-Alpine mafic rocks the intermediate plagioclase is usually changed to albite and fine-grained mixture with the prevailing clinozoisite.

The main mineral and chemical changes of the former composition of metagabbro relate with the temperature and material effect of the Rochovce granite intrusion. When we admittedly accept the older age of gabbro, then the $^{40}Ar/^{39}Ar$ amphibole dating proves the K-Ar system resetting and total lost of *in situ* accummulated radiogenic $^{40}Ar^*$ in gabbro by the temperature above 500 °C during the granite intrusion, which is the blocking temperature of K/Ar system for amphibole (Harrison, 1981). The amphibole $^{40}Ar/^{39}Ar$ plateau ages therefore can be interpreted as an independent confirmation of the intrusion age of the Rochovce granite.

The K-Ar and Ar^{40}/Ar^{39} data allow a real assumption, that during that time the studied area could be cooled to 300 °C temperature level (review of K/Ar data is available in Cambel et al., 1990; Kováčik et al., 1996; Janák et al., 2001). On the other hand some of the age spectra suggest, that also in Upper Cretaceous the temperature about 300 °C persisted in some parts of Kohút crystalline basement, which allows possible interconnection of Alpine regional metamorphism and Rochovce contact aureole.

The increase of Alpine overheating towards NE appears in the Kohút zone. It is simultaneously manifested by partial decrease of K/Ar and Ar/Ar ages (Kováčik, 1998). From three episodes of the schematic division of Alpine metamorphic processes, the first two have a character of Barrovian regional metamorphism. The last metamorphic episode was caused by the Rochovce thermal aureole being situated exactly in the studied north-eastern part of the Kohút zone. The relation of this contact metamorphic episode to preceding regional Cretaceous metamorphism is not fully clear. Shortly before the time of intrusion of Rochovce granite the collisional-compressional conditions, accompanying the Alpine regional metamorphism, were probable changed to crustal extension with the increased geothermic gradient.

From the above stated arguments we can deduce, that specially the intrusion of the Rochovce granite had the decisive influence on geochemical characteristics and isotopic composition of gabbro, as is recently known. Using above listed data we suppose the recent isotopic composition of Sr, Nd and concentration of Rb, Sr, Sm and Nd resp. further elements in the gabbro as a result of contamination by intruded granite. With a high probability we can suppose, that after the intrusion of Rochovce granite and following cooling of the region accompanied with uplift, the isotopic (geochemical) systems were quickly closed. The only thing we can reconstruct with certainty, using the evolution diagrams of Sr and Nd isotopes, is the time interval in the range Late Cretaceous (76 Ma) $\Rightarrow$ Present (0 Ma). The isotopic resp. geochemical characteristics of gabbro before intrusion of the Rochovce granite are not fully clear, but using analysis of geochemical data we can subtract the biotitization effect (Fig. 4). The reconstruction of these data can be based only on more-or-less speculative assumptions, however being limited by published data. Firstly, the depleted mantle according to Dosso et al. (1999) has no character of homogenous source: it is typical with variability of $^{87}Sr/^{86}Sr$ between 0.70215-0.70290 and low ratios $^{87}Rb/^{86}Sr$ (0.005-0.04). The data about isotopic composition of Mesozoic and Paleozoic basic melts in the Western Carpathian area are not available until now. The isotopic characteristics of the mantle in Carpathian-Pannonian region (CPR), obtained from basic volcanic rocks (Upper Cretaceous–Pliocene) indicate three different components (Embey-Isztin & Dobosi, 1995; Downes & Vaselli, 1995; Rosenbaum et al., 1997). It is reflected in the isotopic signature of volcanites and xenoliths. The oldest basic alkaline volcanites in this area (basanites from Poiana Rusca, Rumania (48-58 Ma) have ratios $(^{87}Sr/^{86}Sr)_{initial}$ and $(^{143}Nd/^{144}Nd)_{initial}$ 0.7029–0.7032, resp. 0.51293–0.51286 (Downes et al., 1995). The use of the isotopic ratios of Sr and Nd allows us to suppose, that the mantle in CPR was depleted earlier, already before Upper Cretaceous (Rosenbaum et al., 1997).

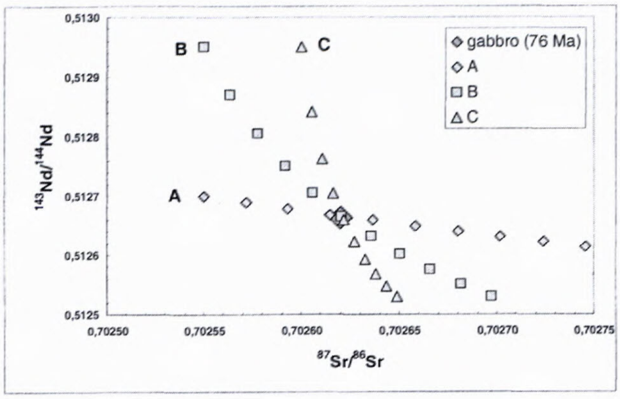


Fig. 11 The results of binary mixing of Sr and Nd between granite and gabbro . A – 0.005, B – 0.01, C – 0.002.

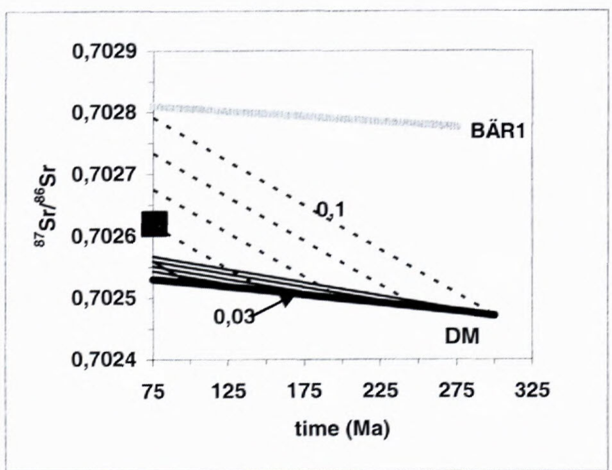


Fig. 12 Evolution lines $^{87}Sr/^{86}Sr$ in hypthetic gabbro unmixed from DM (thick line)m, of different age with various $^{87}Rb/^{86}Sr$ ratios (0.1 – dashed line, 0.03 – full line). Full square shows the value $(^{87}Sr/^{86}Sr)_{76}$ after gabbro contamination by Rochovce granite and represents the uppermost limit for former isotopic composition of strontium in the gabbro. BÄR1-evolution line for unchanged gabbro (Koralpe, Thöni & Jagoutz, 1992).

When accepting an idea, that $(^{87}Sr/^{86}Sr)_{76}$ and $(^{143}Nd/^{144}Nd)_{76}$ are the results of binary mixing of isotopic systems, then two end-members of the mixing with the particular concentrations of Sr, Nd and their isotopic ratios would have their restrictions. Though also this allows a large variability of input data. The results of three variations of binary mixing and input parameters in different combinations we introduce in Fig. 11 and Tab. 7. Instead of the element concentrations we state rather the ratios of concentrations, because in used calculation there are not determining the absolute concentrations, but their mutual ratios between the end-members. The calculation was made by procedure according to Faure (1986). For the primeval isotopic composition of gabbro in the time t = 76 Ma there are not many possibilities. The ratio $(^{87}Sr/^{86}Sr)_{76}$ is 0.702620 (already as a result of contamination) and equivalent value of depleted mantle (DM) at this time according to McCulloh & Bennet (1994) is 0.70253. Hence the gabbro before interaction with granite should have the primeval isotopic ratio $^{87}Sr/^{86}Sr$ between these two values. On the other hand, we suppose that the recent distinctly lowered ratio $^{143}Nd/^{144}Nd$ is the result of contamination with the crustal (granitic) Nd. Contrary to this, the gabbro contamination by granitic strontium was minimal, because the low values of $^{87}Sr/^{86}Sr$ were preserved. This finding is a paradox, because during epigenetic, resp. metamorphic changes of basic rocks we can expect the more distinctive changes just in the isotopic composition of strontium (Thöni & Jagoutz, 1992). From Fig. 11 there follows, that if the contamination process would be described by the function of binary mixing, then the most probable alternatives of the initial isotopic composition and Sr, Nd concentrations in granite and gabbro would vary between models A and B, because the models B and C led to the strong increasing of ratios of Nd concentrations in end-members.

During contamination there occurred the change in Rb/Sr and Sm/Nd ratios in Rochovce gabbro. Concentration of Rb in gabbro is apparently extreme, while the Sr concentration can be supposed to be common. The change of Rb/Sr ratio caused the distinct steeper slope of the of Sr evolution line (not showed in Fig. 13), when comparing for example with unchanged and noneclogitized Permian gabbro (BÄR1) from Koralpe (Thöni & Jagoutz, 1992). The change of Sm/Nd ratio caused not only the noticeable lowering of value $^{143}Nd/^{144}Nd$, but also the adjustment of $^{147}Sm/^{144}Nd$ ratio in gabbro with granite (Fig. 12). The slopes of Nd evolution lines of granite and gabbro are nearly parallel (that means the Sm/Nd ratio in both rocks is very close). The Nd isotopic signature in Rochovce gabbro, contrary to the comparing sample BÄR1, copy the granitic Nd signature. This is the reason why the evolution line of Nd isotopes in gabbro is only the reflection of contamination with granitic Sm and Nd and therefore the model age T(DM) is unreally high.

The precise age of Rochovce gabbro is until now not known. Geological, structural and partially also petrographic data demonstrate, that the model ages of gabbro, being published by Kohút (1999), resp. from Tab. 3 are unrealistic. Based on these data, the real age of gabbro can be estimated only in the wide diapason between the formation of Hercynian (Carboniferous) granitoids of Veporicum and the lower age limit is given by the intrusion of the Rochovce granite. The diagram of Sr evolution for differing age and differing $^{87}Rb/^{86}Sr$ ratio (0.1, 0.03) is shown in Fig. 13. The full square shows the isotopic ratio $^{87}Sr/^{86}Sr$ for time t = 76 Ma (after the contamination by granite). For comparison we again use the gabbro BÄR1, whose Sr evolution line under low $^{87}Rb/^{86}Sr$ ratio and the age 275 Ma does not begin from DM - $(\varepsilon Sr)_{275}$ has the value +4.2. If it is the case of

Tab. 7 Input parameters of alternative models for binary mixing of Sr and Nd between Rochovce gabbro and granite. Calculation made according to Faure (1986). Indexes: gb – gabbro, gr – granite. Sr_{gr}/Sr_{gb} , Nd_{gr}/Nd_{gb} – ratio of concentrations Sr and Nd between granite and gabbro. Individual points on mixing lines represent a fraction of granite component against gabbro with the step:

	$(^{87}Sr/^{86}Sr)_{gb}$	$(^{143}Nd/^{144}Nd)_{gb}$	$(^{87}Sr/^{86}Sr)_{gr}$	$(^{143}Nd/^{144}Nd)_{gr}$	Sr_{gr}/Sr_{gb}	Nd_{gr}/Nd_{gb}
A	0,70255	0,512700	0,70800	0,512155	0,79	4
B	0,70255	0,512950	0,70800	0,512220	0,25	12,2
C	0,70260	0,512950	0,70800	0,512300	0,5	100

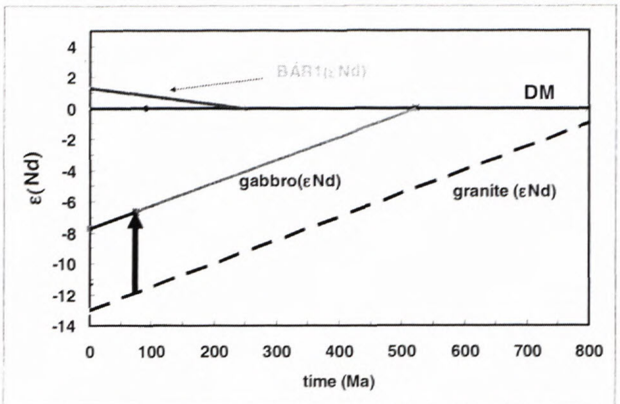


Fig. 13 Evolution of Nd isotopes in Rochovce gabbro and granite. DM – depleted mantle. The development of Nd isotopes in unchanged gabbro (sample BÄR1, Koralpe, Thöni & Jagoutz, 1992) is presented for comparison.

the Rochovce gabbro, then in the case of Late Paleozoic age this value should be much lower. As the Fig. 12 shows, only those $^{87}Rb/^{86}Sr$ ratios can be accepted which, regarding the age, have the $(^{87}Sr/^{86}Sr)_{76}$ ratio lower than the gabbro after contamination. Hence, if the Rochovce gabbro would originate directly from DM, then $(^{87}Sr/^{86}Sr)_{76}$ would be reached after 275 Ma at the range $^{87}Rb/^{86}Sr = 0.05$. These thoughts allow several age alternatives and also the Alpine age cannot be excluded. The Rochovce gabbro is lying in Paleozoic rocks characteristic with the strong mineral lineation, being commonly supposed to be Alpine, as it was well documented from the borehole cores. Though the mylonitic zones exist in the gabbro, the mineral lineation is not present there. It can be explained by stronger rheology of the gabbro, or by its younger, postdeformational age. When accepting the second argument, then the intrusive age of the gabbro would be younger as the origin of lineation, which indicates the Alpine age. Absence of stronger mineral lineations could be obscured also by the postkinematic recrystallization of amphiboles and biotite during the contact metamorphism.

Conclusion

The given petrographic, geochemical and isotopic data manifest, that the position of Rochovce gabbro above the Rochovce Late Cretaceous granite is autochthonous and pre-granitic. The granite intrusion caused not only the origin of aplitic veinlets penetrating gabbro, but also strongly influenced its former chemical and isotopic composition. These contamination processes affected selectively. The process of biotitization and formation of new allanite caused the extreme enrichment of gabbro by alkalies (Cs, Rb, K), U, Th and LREE. Concerning the isotopic composition of strontium $(^{87}Sr/^{86}Sr)_{76}$, after the contamination by granite it remained near the former composition. The Nd isotopic composition is distinctly lowered. The result of the contamination process is, that the isotopic ratio $^{143}Nd/^{144}Nd$ and the Sm/Nd ratio in gabbro practically copy these of granite. This is the reason, why the chemical and isotopic characteristics of the gabbro cannot be used as characteristic end-member in geochemical considerations relating the interaction (mixing) of mafic and acid melts during the genesis of Hercynian granitoid rocks of the crystalline basement of the Western Carpathians.

The dating of amphibole from contact metamorphic gabbro shows the complet loss of till then *in situ* accummulated $^{40}Ar^{*}$. $^{40}Ar/^{39}Ar$ age 75.9 ± 1.8 Ma of amphibole from gabbro corresponds with the U-Pb age of Rochovce granite 76 ± 1.1 Ma (Poller et al., 2001), resp. 82 ± 1 Ma (Hraško et al., 1999), $^{40}Ar/^{39}Ar$ plateau age obtained on amphibole can be interpreted as independent confirmation of the age of intrusion of Rochovce granite. Because that time the studied area was cooled down to the temperature level 300 °C, the determined age represents also the age of the origin of newly formed amphiboles in gabbro during the contact metamorphic recrystallization caused by intrusion of the Rochovce granite.

Until now the intrusion age of the Rochovce gabbro was not exactly determined. Accounting the geological, structural and partially also petrographic data it is possible to limit the upper age by intrusion of Hercynian granites in Veporicum (350 – 300 Ma) and the lower age limit by the Cretaceous intrusion of Rochovce granite. It is not possible to exclude also Alpine age of the gabbro. The ages of the crustal residence T(DM) published by Kohút et al. (1999), resp. stated in this article are unrealistically high and reflect only the result of geochemical (isotopic) interaction of gabbro with granite and in no case they contain the age information.

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