GEOLOGICKÝ ZBORNÍK – GEOLOGICA CARPATHICA, 41, 4, BRATISLAVA, AUGUST 1990,
Pp. 335–376

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PETROGENESIS OF GNEISSES AND GRANITOIDS FROM THE STRÁŽOVSKÉ VRCHY MTS.

(16 Figs., 7 Tabs., 1 App.)

Abstract: Granitoid rocks (tonalites, granodiorites, granites) of the Strážovské vrchy Mts. crystalline complex are the members of a common differentiation series. They are peraluminous and according to their composition they belong to the S-type of granitoids. Biotites from granitoids and gneisses correspond to Fe^{2+}-biotites. The content of Ti in biotites of granodiorites decreases from tonalites to granites. A variation of Ti content has been determined in gneisses, depending on the presence of index mineral. Muscovite is developed in the studied rocks as a primary phase. Garnets of the granitoids belong to almandines-spessartites. In Malá Magura Mts. garnets become richer in the Sps-component from tonalites to granites, in Suchý, on the other hand, the content of Sps-component decreases with differentiation. Differences in the type of zoning in garnets from gneisses are related to the presence of staurolite (marked progressive zoning) or sillimanite. The occurrence of staurolite and sillimanite in gneisses of Suchý and Malá Magura Mts. indicates two metamorphic phases in the development of crystalline complexes the of both massifs. The first metamorphic phase had regional character, it caused the formation of the assemblage with staurolite. It took place in the conditions of greenschist facies at T=460–590 °C and P=200–400 MPa. The second metamorphic phase can be considered a contact metamorphism on regional scale, where a considerable amount of heat was derived from the granitoid intrusion. It took place in the conditions of T=650–700 °C and P=365–470 MPa in Suchý Mts. and T=600–710 °C and P=450–470 MPa in Malá Magura Mts.

Резюме: Гранитоидные породы (тоналиты, гранодиориты, граниты) кристаллиникума Стражовских гор являются членами одного ряда дифференциации. Они пералюминозные и по составу они принадлежат к С-типу гранитоидов. Биотиты гранитоидов и гнейсов соответстуют Fe-биотитам. Содержание Ti в биотитах гранитоидов понижается с тоналитов до гранитов. В гнейсах было определено колебание содержания Ti в зависимости от присутствия руководящего минерала. Мусковит развит в изучаемых породах как первичная фаза. Гранаты гранитоидов – альмандин-спессартиты. В Малой Магуре гранаты с тоналитов до гранитов становятся более богатыми Sps-компонентом, и в горах Сухи наоборот содержание Sps-компонента с дифференциацией понижается. Разницы в типе зональности гранатов из гнейсов зависят от присутствия ставролита (прогрессивная зональность) или силлиманита. Присутсвие ставролита и силлиманита в гнейсах г. Сухи и Мала Магура указывает на две метаморфические фазы развития кристаллиникума массивов. Первая метаморфическая фаза имела региональный характер и она вызвала образование ассоциации с ставролитом. Она произошла в условиях зеленосланцевой фации при Т = 460–590 °С и Р = 200–400 MPa. Вторую метаморфическую фазу можно считать контактовым метаморфиз-

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мом в региональном масштабе, где значительное количество тепла происходило из гранитоидной интрузии. Эта фаза произошла в условиях T = 650–700 °C и P = 365–470 MPa в г. Сухи, и T = 600–710 °C и P = 450–470 MPa в г. Мала Магура.

Introduction

The Western Carpathian crystalline has a unique character. The so called core mountains consisting of granitoid massifs surrounded by metamorphosed rocks crop out from beneath Mesozoic and Cenozoic sediments. Not all Western Carpathian core mountains attract equal attention of geologists. Crystalline of the Strážovské vrchy Mts. is one of the areas awaiting concrete and accurate study of their historical evolution and forming processes.

The submitted work is associated with earlier results dating from the 1960s which suggest mutual relationship between gneisses and granitoid rocks of this crystalline. The work has therefore been aimed at obtaining sufficient information on the character of these rock types and employing it by their mutual comparison which may result in a more complete picture of their relationships.

Geology of the area

The Strážovské vrchy crystalline consists of two massifs – Suchý and Malá Magura Mts. (Fig. 1). The massifs extend on the area of about 180 km^2 and have the shape of triangles elongated in a NNE-SSW direction.

Both these massifs are made up of an inhomogeneous complex of crystalline schists, migmatites (not dealt with in this work) and granitoids. They constitute complex megaanticlinoria, with their crests forming central ridges composed mainly of granitoids. Both massifs are characterized by parallel rock belts of different petrographic types of several dm to several m in thickness. From the regional point of view, the belts trend N-S in southern parts of the massifs, bend to a-NE-SW direction in their central parts and further they trend E-W (K a h a n, 1979). The principal Hercynian structures have also N-S trend (K l i n e c, 1958). H r o u d a et al. (1983) assume that the both massifs were emplaced side by side by shear movements along a fault which separates one from another. The rocks do not bear signs of intensive deformation processes. Mylonites and phyllonites occur only scarcely on the periphery of the massifs (H r o u d a et al., l.c.).

The whole crystalline forms compact units. Its southern and eastern boundaries with Mesozoic and Tertiary units are tectonic, whereas northern and northwestern ones are stratigraphic (K a h a n, 1985). The oldest crystalline rocks are gneisses of garnet-amphibolite facies, now regionally and contact-metamorphosed (Z o u b e k, 1936; I v a n o v, 1957; K l i n e c, 1985). No exact data on their age, however, are available so far, the only exception being a find of organic kerogen in graphitic gneiss in the western part of Suchý suggesting its Early Paleozoic age (Č o r n á – K a m e n i c k ý, 1976). The only concrete age data have been obtained by K r á ľ et al. (1987) who give Rb-Sr isochrone age of a granitoid intrusion at 393 ± 6 m.y.

A characteristic feature of the studied crystalline is a close mutual relationship between granitoids and gneisses. No changes have been observed at their contacts, although gneisses frequently form separate blocks or extensive layers amidst granitoids.

Fig. 1. Tectonic sketch map of the crystalline complex of the Strážovské vrchy Mts. compiled by K a h a n (1980 in H r o u d a et al., 1983). Legend: 1 – paragneisses; 2 – migmatites, Závada type; 3 – migmatites, Lieštany type; 4 – granitoids; 5 – Mesozoic; 6 – Tertiary; 7 – metamorphic schistosity (S_1) in gneisses; 8 – palimpsests of S_1 foliation in migmatites; 9 – palimpsests of S_1 foliation in granitoids; 10 – geological boundaries; 11 – main systems of joints; 12 – strike of fold axes; 13 – faults; 14 – assumed faults; 15 – thrust planes; 16 – mylonites; 17 – axes of antiforms and synforms.

Gneisses

Gneisses in the Suchý Mts. occur in marginal parts of the crystalline. The principal gneiss mass in the form of a NE-SW belt along the massif's western part makes up almost a half of its

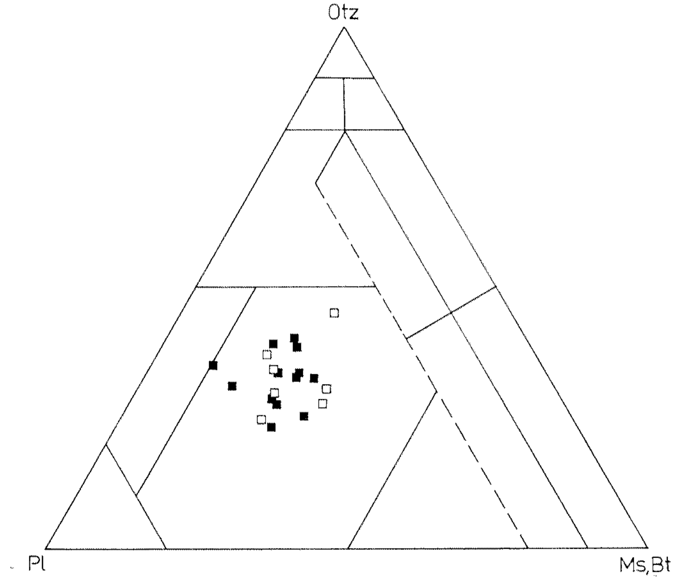


Fig. 2. Biotite-plagioclase gneisses in W i n k l e r ' s (1979) classification diagram.

Explanations: Open squares – Malá Magura, solid squares – Suchý.

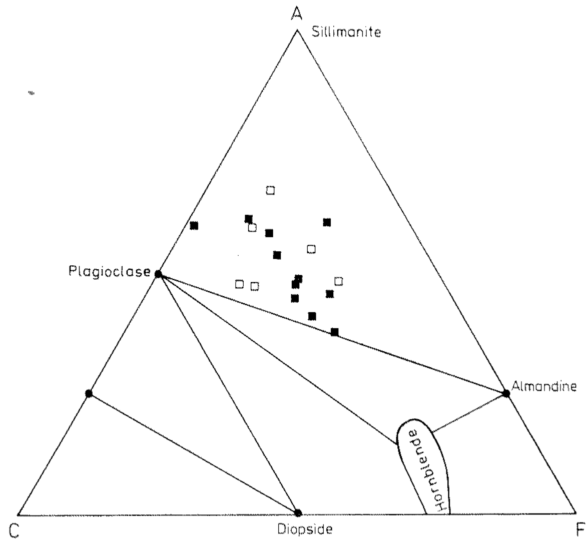


Fig. 3. Mineral assemblages observed in the studied gneisses compared to almandine-amphibolite facies assemblage in W i n k l e r ' s (1979) ACF diagram.

For explanations see Fig. 2.

Table 1
Assemblages present in Suchý and Malá Magura gneisses and characteristics of their mineral phases

	SUCHÝ	MALÁ MAGURA
Assemblages	Qtz+Pl+Bt ±Grt Qtz+Pl+Bt+Ms+Grt±Sil Qtz+Pl+Bt+Ms±Grt±St±Sil	Qtz+Pl+Bt+Ms Qtz+Pl+Bt+Ms+Grt±Sil Qtz+Pl+Bt+Ms+Grt+Kfs
Plagioclases hypidiomorphic, allotriomorphic, unzoned, exceptionally twinned	34—50 vol. % An_{18-22} in gneisses with staurolite are part of groundmass	29—46 vol. % An_{20-34}, in gneiss with K-feldspar An_{14}
Quartz allotriomorphic, sometimes undulatory	22—39 vol. %	23—45 vol. %
Biotite preferentially oriented along schistosity	9—26 vol. % with Ms+Acc inclusions, forms aggregates with sillimanite, slightly chloritized	17—31 vol. % with Ms+Acc inclusions, forms aggregates with sillimanite, less chloritized
Muscovite primary in biotite + intergrown with Bt, secondary as sericite	0.1—9 vol. % secondary also as pseudomorphs after staurolite	0.2—4 vol. %
K-feldspar	–	0.9 vol. % coarse-perthitic porphyroblasts
Accessories	0.2—2.4 vol. % (except garnet)	0.1—1.5 vol. % (except garnet)
Garnets	0—1.4 vol. %	0—0.8 vol. %
indiomorphic, hypidiomorphic	zoned and unzoned	zoned, fine
Monazite	+	+
Zircon	+	+
Apatite	+	+
Titanite	+	+
Tourmaline	+	–
Fe-Ti *oxides*	0.3—2.2 vol. %	0.2—1.8 vol. %
Graphitic matter	+	–

extent. In the southern part, gneisses are sporadically accompanied by migmatites. In the Malá Magura Mts., gneisses form discontinuous belts. A more continuous belt is in the SW part separating the both massifs along a fault.

The studied gneiss complexes are very monotonous, dominated by biotite-plagioclase types of tonalite composition (Fig. 2). Gneisses with graphitic matter, only in the western part of Suchý, and migmatitized gneisses occur less freguently. The biotite-plagioclase gneisses are of dark brown to gray-black colour. Their structure is variable. There are fine-grained types, relatively massive, of plane-parallel structure (mainly in the Malá Magura Mts.), banded (with alternating biotite and quartz-plagioclase bands 1 to 4 mm thick) and eyed types (eyes up to 1 cm, composed of plagioclase and quartz which have been found in the NW Suchý). The gneiss textures are granoblastic to granoporphyroblastic, granolepidoblastic and eyed. Mineral assemblages observed in gneisses are consistent with their position in an ACF-diagram in Fig. 3. Microscopic study has revealed signs of retrograde effects in some samples. The samples contain chloritized/muscovitized staurolite/garnet, accompanied by sericitized to muscovitized plagioclases (D y d a, 1988).

Tab. 1 briefly shows mineral assemblages in gneisses of the both massifs and characterizes their mineral phases. It clearly suggests that gneisses of the both investigated massifs differ mainly in the presence of staurolite, graphitic matter as well as tourmaline and absence of K-feldspar.

K o r i k o v s k y et al. (1987) have distinguished two metamorphic zones in the Suchý crystalline, staurolite-andalusite-biotite and sillimanite-biotite-muscovite. Andalusite, however, has so far been identified in the studied samples neither by us, nor by authors investigating the Strážovské vrchy crystalline.

Granitoid rocks

Crystalline of the both massifs is dominated by granitoid rocks. Individual granitoid types are not confined only to definite areas but often alternate with gneisses. In the Suchý Mts., most area is occupied by granodiorites and tonalites (Fig. 4). The granodiorites are biotitic, biotite-muscovitic and leucocratic, sometimes with sillimanite. The tonalites are represented by biotitic types, in places also with sillimanite. Rocks of granite composition in the Suchý Mts. are usually coarse-grained, pegmatitic, with marked presence of garnet, less frequently fine-grained and aplitic. The Malá Magura Mts. is dominated by tonalites and granites. The tonalites (and/or leucotonalites) are biotitic. Unlike granites of the Suchý Mts., those of the Malá Magura Mts. are medium-grained, containing also muscovite and garnet. The Malá Magura granodiorites are largely leucocratic, muscovitic. In contrast to the Suchý granodiorites, they are devoid of sillimanite (V i l i n o v i č o v á, 1988). As a product of postmagmatic processes, sillimanite indicates that rocks of the Suchý Mts. were more intensively altered than those of the Malá Magura Mts., the former having been subject to

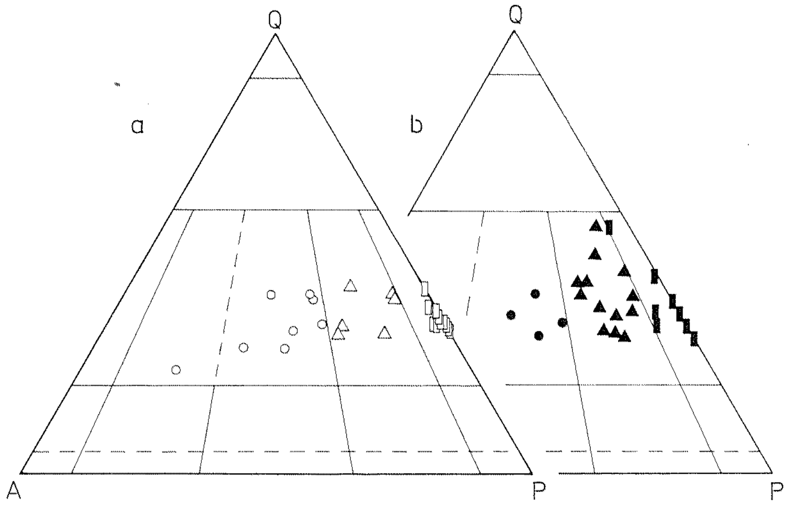


Fig. 4. Granites (circle), granodiorites (triangle) and tonalites (column) of Strážovské vrchy crystalline in S t r e c k e i s e n ' s (1976) classification diagram.
a – Malá Magura, b – Suchý.

Table 2

Principal types of granitoid rocks of the Suchý and Malá Magura Mts. with detailed characteristics of individual mineral phases

	SUCHÝ			MALÁ MAGURA		
	granites	granodiorites	tonalites	granites	granodiorites	tonalites
	coarse-grained, muscovite	medium-grained, biotite, biotite-muscovite	medium- to fine-grained, biotite also leucocratic	medium-grained, muscovite	mostly leucocratic, biotite	medium- to fine-grained, biotite
Plagioclases hypidiomorphic, allotriomorphic, sometimes zoned or twinned, replaced by K-feldspar	29—39 vol. % An_{12-15}	31—52 vol. % An_{14-26}	37—58 vol. % An_{12-18}Or An_{25-31} sericitized, saussuritized	28—39 vol. % An_{11-16}	41—51 vol. % An_{17-21}	51—59 vol. % An_{21-41} sericitized, saussuritized
K-feldspars hypidiomorphic	22—31 vol. % size up to 1 cm with Qtz, Pl, Ms, Acc inclusions perthitic transient micro-cline and maxi-mum micro-cline	6—15 vol. % perthitic, poikilitic phenocrysts with Pl, Qtz, Bt, interstitial orthoclase, transient and ma-ximum microcline	0.7—5.3 vol. % allotriomorphic, interstitial, nonperthitic orthoclase	20—54 vol. % up to 1 cm, with Qtz, Ms, Pl, Acc inclusions transient micro-cline and maxi-mum microcline	6—20 vol. % perthitic, poikilitic phenocrysts of Qtz, Pl, Bt. Also interstitial orthoclase, transient and ma-ximum microcline	0.2—2.2 vol. % allotriomorphic, interstitial, nonperthitic orthoclase
Quartz allotriomorphic, interstitial, someti-mes slightly undulatory	29—37 vol. %	27—46 vol. %	24—38 vol. %	22—40 vol. %	28—41 vol. %	25—38 vol. %
Biotite hypidiomorphic, with Ms, Acc inclu-sions	up to 2.6 vol. % fine, partly chloritized with sillimanite	1—8.6 vol. % partly chloritized, with Ms inclusions or intergrown with Ms	0.4—18.4 vol. % unaltered or chloritized	0—1.7 vol. % allotriomorphic	0.6—10 vol. % partly chloritized, intergrown with Ms	2—19 vol. % highly chloritized

Continuation of Tab. 2

	SUCHÝ			MALÁ MAGURA		
	granites	granodiorites	tonalites	granites	granodiorites	tonalites
	coarse-grained, muscovite	medium-grained, biotite, biotite-muscovite	medium- to fine-grained, biotite also leucocratic	medium-grained, muscovite	mostly leucocratic, biotite	medium- to fine-grained, biotite
Muscovite hypidiomorphic	3—5 vol. % secondary, primary only as intergrowths with Bt or inclusions in Bt	1—10 vol. % tabular, intergrown with Pt, secondary with sillimanite	0.4—4 vol. % allotriomorphic	0.6—11 vol. % secondary, primary only as intergrowths with Bt	0.6—4 vol. % tabular, intergrown with Bt	0.2—3 vol. % allotriomorphic
Garnet almandine-spessartite, idiomorphic to hypidiomorphic	up to 0.5 cm exceptionally partly replaced by Bt+Ms	sometimes partly replaced by Bt+Ms	inclusions in Pl, fine	up to 0.5 cm exceptionally partly replaced Bt+Ms	sometimes partly replaced by Bt+Ms	inclusions in Pl, fine
Apatite idiomorphic, hypidiomorphic	individual grains are idiomorphic, also interstitial allotriomorphic	individual grains or oval in Pl, or associated with Bt	prismatic, sometimes with dark core	individual grains are hypidiomorphic, allotriomorphic	associated with Bt	prismatic, sometimes with dark core
Other accessories	0.2—3.2 vol. %	0.3—7.8 vol. %	1—3.6 vol. %	0.1—0.6 vol. %	0.1—0.6 vol. %	0.3—7.2 vol. %
Zircon	+	+	+	+	+	+
Monazite	+	+	+	+	+	+
Allanite	–	–	+	–	–	+
Titanite	–	–	+	–	–	+
Fe-Ti *oxides*	+	+	+	+	+	+

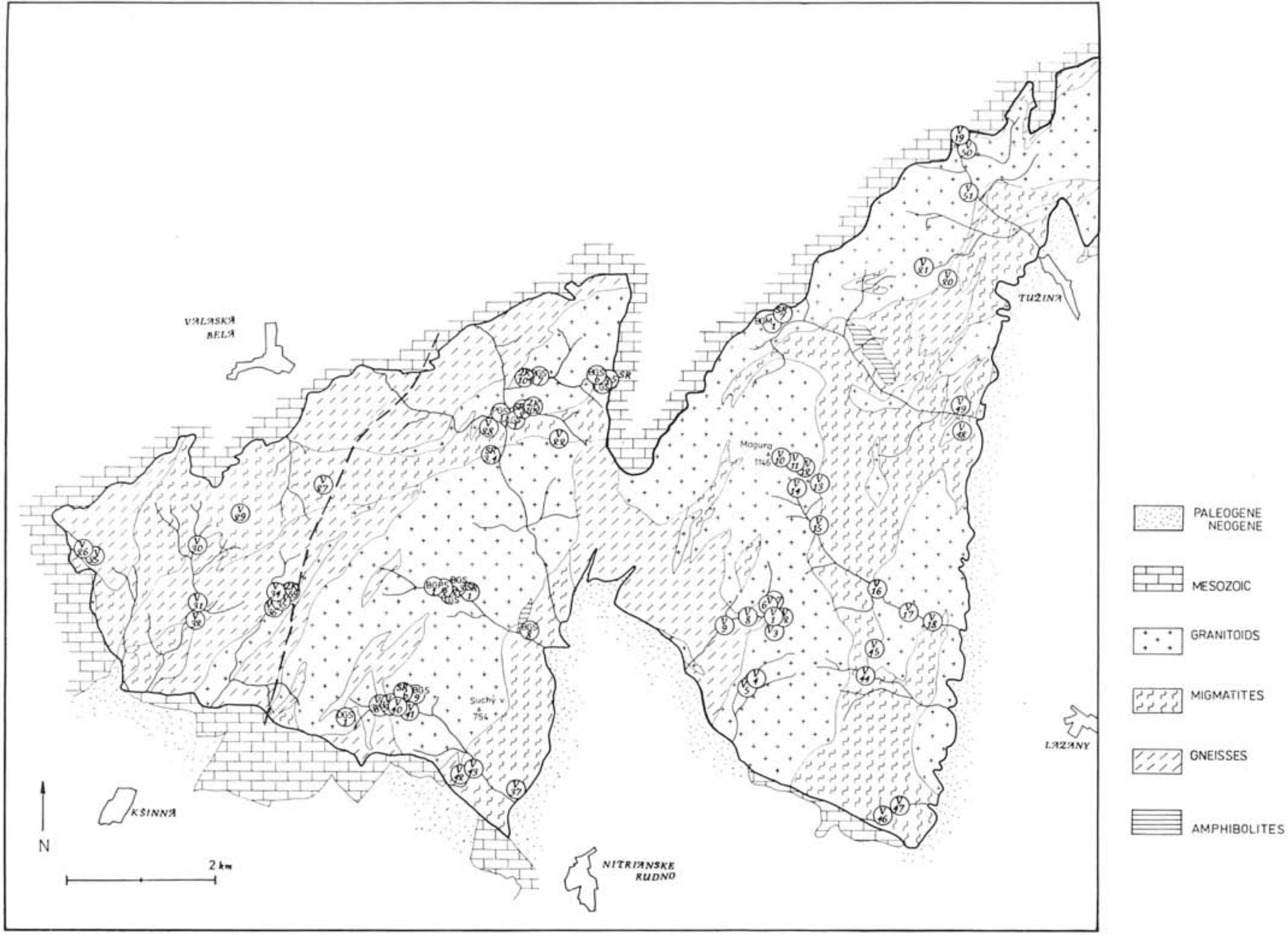


Fig. 5. Location of the studied samples.
Staurolite occurrences in gneisses of the western Suchý and areas with sillimanite eastward as far as the Malá Magura Mts. are divided by dashed line.

stronger sericitization and saussaritization of plagioclases. In addition to these basic granodiorite types, also small occurrences of biotite-amphibolite quartz diorites have to be noted (K a h a n, 1979). Both crystalline cores sporadically contain lamprophyres and quartz porphyries. The whole crystalline is interlaced with abundant pegmatite and aplite veins of various thickness, whose composition corresponds to that of syenogranites-monzogranites. Tab. 2. summarizes properties of principal granitoid types of the both massifs, modal composition of individual mineral phases as well as form ot their occurrence.

Applied techniques

The investigated set totalling 69 rock samples comprises 24 granitoid and 7 gneiss samples from the Malá Magura Mts. as well as 25 granitoid and 13 gneiss samples from the Suchý Mts. The samples, whose location is shown in Fig. 5, are represented by unweathered rocks.

All whole-rock analyses (see Appendix) have been carried out by X-ray-fluorescence at the Geological Institute of the Slovak Academy of Sciences. FeO content has been determined at the Geological Institute of Comenius University, whereas P_2O_5 contents have been determined by classical assays introduced by W a l z e l (in C a m b e l – W a l z e l, 1982). Trace element contents in the rocks (see Appendix) have been spectrochemically analysed by M e d v e ď (C a m b e l – M e d v e ď, 1981).

Composition of minerals from 17 unaltered samples has been studied by an electron microanalyser JXA – 5A JEOL at the Slovak Technical College, Bratislava. Minerals of the following samples have been analysed: V-21, 22, 50 (granites); V-1, 18, 35, 40 (granodiorites); V-5, 9, 13, 41, SR-5 (tonalites) and V-15, 19, 25, 39, 42 (gneisses).

To designate individual minerals K r e t z ' s (1983) abbreviations are used.

Minerals of the studied rocks

F e l d s p a r s

The overall comparison of the chemical composition of plagioclases from the Strážovské vrchy granitoids suggests that plagioclases in Suchý granitoids contain on average less Ab-component and more Or as well as An-components than plagioclases of the Malá Magura granitoids. Chemical composition of observed plagioclase phenocrysts is homogeneous. In plagioclases of the Suchý tonalites CaO contents are variable and basicity varies in the range An_{14-19} or An_{26-31}.

K-feldspars of the Strážovské vrchy granitoids are of perthitic character averaging $Or_{90}Ab_{9.9}An_{0.1}$ in tonalites, $Or_{84}Ab_{15}An_1$ in granodiorites and $Or_{87}Ab_{12.5}An_{0.5}$ in granites. Structural states of K-feldspars (orthoclases in tonalites to microclines in granites) observed by X-ray-diffraction studies reflect slow cooling of the both massifs. Two-feldspar thermometres suggest temperatures T= 460–593 °C at pressure P= 400–500 MPa (V i l - i n o v i č o v á, 1989).

Average composition of plagioclases in gneisses corresponds to $Or_1Ab_{75}An_{24}$. The lowest basicity An_{15} was observed in plagioclases associated with K-feldspar. Alkali feldspar has been identified only in one case, in the NW Malá Magura. Its K-phase contained $Or_{88}Ab_{11}An_1$ and its bulk composition was $Or_{78}Ab_{22}An_{0.2}$. Plagioclase basicity in some of the Malá Magura gneisses attains An_{34}. All analyses of feldspars have been published by V i l i n o v i č o v á (1989).

Micas

Biotite is developed in the studied granitoid rocks and gneisses as a primary phase. Its chemistry (Tab. 3) depends mainly on the rock composition and mineral assemblage. As shown in Fig. 6., the studied biotites are regularly enriched in iron (Fe/Fe + Mg ratio varies from 0.59 to 0.68 in granitoids and from 0.45 to 0.62 in gneisses) and Al contents vary only

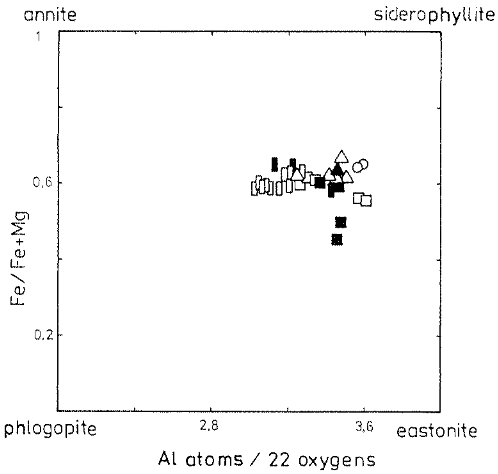


Fig. 6. Composition of biotites from the Strážovské vrchy granitoids and gneisses in Anderson's (1980) diagram.

For explanations see Figs. 2 and 4.

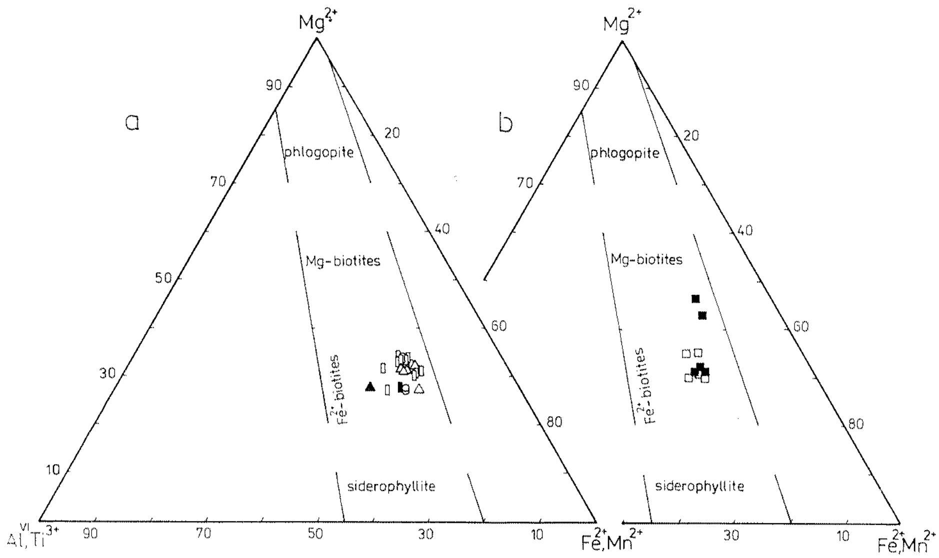


Fig. 7. Composition of analysed biotites from granitoids (a) and gneisses (b) in Foster's (1960) diagram.

For explanations see Figs. 2 and 4.

Table 3

Chemistry of biotites from granitoids and gneisses of the Malá Magura (MM) and Suchý (S) Mts.

	V-50		V-1				V-18	V-13			V-9					
SiO_2	35.23	35.52	34.40	34.97	35.67	34.69	32.84	34.07	33.96	34.80	36.40	36.60	36.51	36.36	35.73	36.54
TiO_2	1.60	1.53	2.40	2.84	2.77	2.87	2.69	2.96	3.24	2.40	3.75	3.78	3.34	3.70	3.36	3.59
Al_2O_3	20.03	19.78	19.37	19.00	18.95	17.88	18.44	17.71	17.05	17.41	17.30	17.31	17.73	17.23	17.18	16.99
FeO	22.30	22.20	21.99	22.01	22.38	22.41	23.65	22.00	22.11	21.39	20.97	21.47	20.85	21.06	20.84	21.38
MnO	0.71	0.70	0.02	0	0.02	0.15	0.19	0	0	0	0.19	0.21	0.17	0.12	0.17	0.16
MgO	6.76	6.84	7.69	7.81	7.89	7.79	6.49	7.18	7.39	7.83	8.23	8.22	8.20	8.27	8.25	8.26
CaO	0.02	0.02	0.04	0	0	0.03	0.09	0.03	0.03	0.03	0.05	0.01	0.03	0.03	0.03	0
Na_2O	0.09	0.12	0.19	0.08	0	0	0.06	0.12	0.17	0.09	0.10	0.09	0.12	0.13	0.09	0.11
K_2O	9.99	10.06	9.95	9.87	10.67	10.25	8.33	10.56	10.09	10.60	10.23	10.33	10.44	10.57	10.43	10.22
Total	96.73	96.78	96.05	96.58	98.35	96.35	92.78	94.63	94.05	94.56	97.21	98.02	97.39	97.47	96.07	97.25
	Cations on basis of 11 oxygens															
Si	2.689	2.708	2.645	2.667	2.682	2.681	2.629	2.679	2.686	2.726	2.749	2.747	2.751	2.745	2.739	2.763
Al^{IV}	1.311	1.291	1.355	1.333	1.318	1.319	1.371	1.321	1.314	1.274	1.251	1.253	1.249	1.255	1.261	1.237
Al^{VI}	0.492	0.487	0.400	0.375	0.362	0.309	0.369	0.320	0.276	0.334	0.288	0.278	0.326	0.279	0.291	0.277
Fe	1.424	1.416	1.414	1.404	1.407	1.448	1.583	1.447	1.462	1.401	1.324	1.347	1.314	1.330	1.336	1.352
Mn	0.046	0.045	0.001	0	0.001	0.010	0.013	0	0	0	0.012	0.013	0.011	0.008	0.011	0.010
Mg	0.769	0.778	0.881	0.888	0.884	0.897	0.775	0.842	0.871	0.914	0.927	0.920	0.921	0.931	0.943	0.931
Ti	0.092	0.088	0.138	0.163	0.157	0.167	0.162	0.175	0.192	0.141	0.213	0.214	0.189	0.210	0.194	0.204
Ca	0.002	0.002	0.003	0	0	0.003	0.008	0.002	0.003	0.002	0.004	0.001	0.002	0.002	0.002	0
Na	0.014	0.017	0.029	0.013	0	0	0.009	0.018	0.026	0.013	0.015	0.013	0.017	0.020	0.013	0.016
K	0.973	0.979	0.976	0.960	1.023	1.010	0.851	1.059	1.018	1.060	0.985	9,089	1.003	1.018	1.020	0.986

Continuation of Tab. 3

	V-35	V-41		V-15	V-19			V-25		V-39		
SiO_2	37.76	38.73	37.73	35.81	36.86	36.47	36.33	34.12	34.61	35.70	35.19	35.37
TiO_2	3.33	3.42	3.28	2.86	2.40	2.59	2.50	1.24	1.24	3.06	2.89	2.53
Al_2O_3	19.81	18.46	17.71	20.95	19.18	18.52	19.00	19.28	19.74	19.18	18.76	19.33
FeO	19.49	21.03	21.78	20.16	21.07	21.63	21.74	18.41	20.02	20.61	21.13	20.99
MnO	0.20	0.25	0.35	0	0.16	0.15	0.15	0.07	0.11	0.33	0.38	0.33
MgO	6.68	6.64	6.71	8.96	7.70	7.34	7.74	12.26	11.44	7.87	7.83	8.03
CaO	0.08	0	0.02	0	0	0	0	0	0	0.01	0.04	0.04
Na_2O	0	0.15	0.12	0	0	0	0	0.06	0.06	0.13	0.14	0.14
K_2O	10.49	9.65	9.98	11.25	10.38	10.65	10.32	10.03	10.11	9.97	10.27	9.80
Total	97.84	98.34	97.69	99.99	97.75	97.35	97.78	95.47	97.33	96.86	96.63	96.56
					Cations on basis of 11 oxygens							
Si	2.792	2.855	2.829	2.620	2.864	2.756	2.729	2.600	2.601	2.696	2.683	2.684
Al_{IV}	1.208	1.145	1.171	1.380	1.136	1.244	1.271	1.400	1.399	1.304	1.317	1.316
Al^{VI}	0.519	0.458	0.394	0.426	0.488	0.406	0.411	0.331	0.341	0.404	0.368	0.413
Fe	1.205	1.296	1.366	1.234	1.266	1.367	1.366	1.173	1.258	1.302	1.347	1.332
Mn	0.013	0.016	0.022	0	0.010	0.010	0.010	0.005	0.007	0.021	0.025	0.021
Mg	0.736	0.730	0.750	0.977	0.825	0.827	0.866	1.392	1.281	0.885	0.890	0.908
Ti	0.185	0.190	0.185	0.157	0.130	0.148	1.141	0.071	0.070	0.174	0.166	0.144
Ca	0.006	0	0.001	0	0	0	0	0	0	0.001	0.003	0.004
Na	0	0.022	0.018	0	0	0	0	0.009	0.009	0.019	0.021	0.021
K	0.990	0.908	0.954	1.050	0.952	1.026	0.989	0.975	0.969	0.961	0.999	0.949

Remark: V-50 granite (MM), V-1, 18 granodiorites (MM), V-9, 13 tonalites (MM), V-35, 41 tonalites (S), V-15, 19 gneisses (MM), V-25, 39 gneisses (S).

Table 4

Chemistry of muscovites from granitoids and gneisses of the Malá Magura (MM) and Suchý (S) Mts.

	V-50		V-1			V-18	V-13			V-22	
SiO_2	46.22	44.15	46.99	46.50	44.57	45.28	45.31	44.58	44.76	46.62	45.95
TiO_2	0.22	0.25	0.95	1.29	1.15	0.52	1.30	1.36	0.68	0	0.03
Al_2O_3	35.42	34.55	36.19	34.46	34.81	35.59	31.43	31.10	32.58	35.32	36.24
FeO	1.50	1.47	1.44	1.75	1.88	1.30	1.56	1.41	1.27	0.82	0.88
MnO	0.17	0.16	0	0	0	0	0	0	0	0	0
MgO	0.79	0.64	0.73	0.74	0.84	0.53	0.68	0.58	0.65	0.42	0.38
CaO	0.06	0.01	0	0	0.02	0	0.01	0	0	0.04	0.03
Na_2O	0.33	0.42	0.59	0.39	0.58	0.47	0.26	0.34	0.39	0.27	0.34
K_2O	10.98	11.35	11.09	11.22	11.17	11.18	10.85	11.10	10.58	11.26	10.50
Total	95.69	93.00	97.98	96.36	95.01	94.87	91.40	90.47	90.91	94.75	94.35
	Cations on basis of 11 oxygens										
Si	3.074	3.040	3.053	3.082	3.009	3.042	3.162	3.151	3.130	3.118	3.075
Al^{IV}	0.926	0.960	0.947	0.918	0.991	0.958	0.838	0.849	0.870	0.882	0.925
Al^{VI}	1.852	1.844	1.824	1.774	1.779	1.861	1.746	1.741	1.815	1.901	1.933
Fe	0.084	0.085	0.079	0.097	0.106	0.073	0.091	0.083	0.074	0.046	0.049
Mn	0.010	0.009	0	0	0	0	0	0	0	0	0
Mg	0.078	0.066	0.071	0.073	0.085	0.053	0.071	0.061	0.068	0.042	0.038
Ti	0.011	0.013	0.046	0.065	0.058	0.026	0.068	0.072	0.036	0	0.001
Ca	0.004	0	0	0	0.001	0	0.001	0	0	0.003	0.002
Na	0.043	0.056	0.075	0.051	0.076	0.062	0.035	0.047	0.053	0.036	0.043
K	0.932	0.997	0.919	0.949	0.962	0.958	0.966	1.001	0.944	0.960	0.897

Continuation of Tab. 4

	V-35		V-41		V-19			V-39		
SiO_2	44.30	44.16	48.13	47.44	46.77	46.69	46.41	45.51	44.25	44.90
TiO_2	0.18	0.07	1.34	0.91	0.44	0.69	0.53	0.65	0.88	0.97
Al_2O_3	35.40	35.10	33.58	33.69	34.53	34.50	34.76	35.02	34.97	33.84
FeO	1.37	1.31	1.23	1.28	1.12	1.13	1.23	1.09	1.12	2.70
MnO	0.05	0.02	0	0.01	0	0	0	0.04	0.06	0
MgO	0.53	0.46	0.46	0.48	0.54	0.48	0.47	0.54	0.61	0.63
CaO	0	0.01	0	0	0	0	0	0	0	0.02
Na_2O	0.41	0.51	0.55	0.41	0.50	0.49	0.41	0.53	0.56	0.48
K_2O	10.38	9.86	10.87	10.46	11.39	11.26	11.29	10.81	10.84	10.85
Total	92.62	91.50	96.15	94.67	95.29	95.23	95.10	94.19	93.29	94.40
	Cations on basis of 11 oxygens									
Si	3.037	3.054	3.174	3.169	3.123	3.118	3.106	3.070	3.023	3.055
Al^{IV}	0.963	0.946	0.826	0.831	0.877	0.882	0.894	0.930	0.977	0.945
Al^{VI}	1.897	1.914	1.783	1.822	1.840	1.833	1.847	1.854	1.839	1.768
Fe	0.079	0.076	0.068	0.071	0.062	0.063	0.069	0.062	0.064	0.154
Mn	0.003	0.001	0	0	0	0	0	0.002	0.003	0
Mg	0.054	0.047	0.045	0.048	0.054	0.048	0.047	0.055	0.063	0.064
Ti	0.009	0.004	0.066	0.046	0.022	0.035	0.027	0.033	0.045	0.050
Ca	0	0.001	0	0	0	0	0	0	0	0.001
Na	0.054	0.068	0.070	0.053	0.065	0.063	0.053	0.069	0.074	0.063
K	0.908	0.870	0.914	0.891	0.970	0.959	0.964	0.930	0.945	0.942

Remark: V-50 granite (MM), V-1, 18 granodiorites (MM), V-13 tonalite (MM), V-22 granite (S), V-35 granodiorite (S), V-41 tonalite (S), V-19 gneiss (MM), V-39 gneiss (S).

within a narrow range (3.0–3.6 Al atoms to 22 oxygen atoms). According to F o s t e r (1960), the chemistry corresponds to Fe^{2+}-biotites (Fig. 7). High Al content in biotites depends on high Al content in the rock (Al_2O_3 = 12.85–19.18 wt. %).

Chemistry of biotites may be significantly influenced also by coexisting plagioclases (A n d e r s o n, 1980). This is also proved by the occurrence of Al-rich biotites coexisting with plagioclases of basicity An_{11-20} in granites and granodiorites, and low-Al biotites coexisting with plagioclases of basicity An_{21-43} in tonalites of the both massifs.

Ti content in biotites drops from tonalites through granodiorites to granites, which probably results from decreasing temperature during the process of magmatic crystallization. R o b e r t (1975 in A n d e r s o n, 1980) and G u i d o t t i et al. (1977) state that solubility of Ti in biotites decreases with decreasing temperature.

Biotite of gneisses contains more Mg and less Ti in comparison with granitoid rocks. Ti content in biotites from gneisses depends on the presence of index mineral. Biotites associated with staurolite contain 1.24 wt. % TiO_2 and those associated with sillimanite contain 2.4–3.06 wt. % TiO_2. Biotites in gneisses with staurolite are enriched also in Mg. We have observed no enrichment in Fe or Mg in biotites directly contacting garnets.

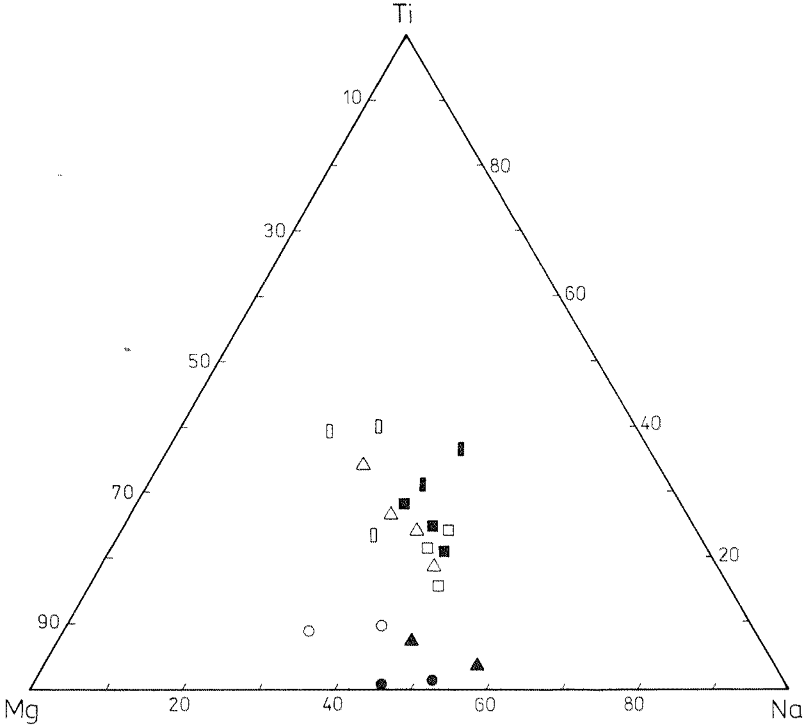


Fig. 8. Composition of analysed muscovites from granitoids and gneisses in Ti-Mg-Na diagram (M i l l e r et al., 1981).
For explanations see Figs. 2 and 4.

Primary muscovites can be distinguished not only by microscopic textural studies, but also because of their different chemistry – they contain more Ti, Na, Al and less Mg and Si (Tab. 4). Analyses show that muscovites from granites of the both massifs contain less Ti than those from granodiorites, tonalites and gneisses (Fig. 8). This is due to the fact that among muscovites of granite samples (V-22, V-50) selected for analyses, secondary muscovites prevail over primary ones. The highest Ti content in muscovites corresponds to the highest Ti content in coexisting biotites.

Garnets and thermometry

Garnets, as a minor component, have been observed in all granitoid types of the both investigated massifs. Garnets from tonalites, granodiorites and granites are represented exclusively by almandine-spessartite along with a variable content of pyrope and grossularite. The most interesting difference between garnets of the both massifs is that in the Malá Magura, garnet becomes richer in spessartite component from tonalite to granites, whereas in the Suchý Mts., spessartite content decreases with advancing differentiation. Magmatic garnets will be dealt with in more detail in a paper which is currently being prepared.

All garnets from gneisses are characterized by high Fe and Al contents. Selected studied garnets are usually zoned (Tab. 5). Distinct zoning characterizes garnets associated with staurolite from the western part of Suchý whose Ca and Mn contents decrease from the core to the rim, whereas Fe and Mg contents increase (Fig. 9a). Mg/Mg + Fe ratio (0.06–0.01) decreases towards the grain centre. This is in agreement with the trend of prograde metamorphism noted by many authors (Tilley, 1926; Atherton, 1968; Crawford, 1977; Kleinschmidt, 1984). Hollister (1969) regards such "bell-shaped" Mn profiles as characteristic of growth of zoning without internal diffusion. The form of the MnO and CaO curves suggest a simple segregation process involving garnet and the matrix (other coexisting phases). Such zoning is preserved also in some indistinctly zoned garnets, also associated with sillimanite. In the Suchý massif, slightly zoned and unzoned garnets accompanied by sillimanite have been found (Fig. 9b). Indistinct zonal pattern of Suchý garnets is accompanied by Mg/Mg + Fe ratio (0.05–0.08) increasing from the rim to the core of garnet grain.

The above-mentioned distinct zoning of garnets has not been observed in gneisses with sillimanite or only with biotite collected in the Suchý and Malá Magura Mts. alike. Garnets from these samples are characterized by variable chemical zoning (Fig. 9b, c). Another characteristic feature is that their Fe and Mg contents decrease from the core towards the rim, whereas Mn content increases. Mg/Mg + Fe ratio increases towards the core and its highest values occur in garnets from the Malá Magura Mts. (up to 0.14). Zonal pattern of garnets from the Malá Magura gneisses is characterized by Mg content first increasing from the centre towards the margin and then abruptly falling (Fig. 9c).

Analyses of garnets and biotite have been employed to calculate temperatures of metamorphic processes by means of changes in Fe-Mg distribution in garnet-biotite pairs. Calibrations of Ferry – Spear (1978), Hodges – Spear (1982), Ganguly – Saxena (1984) and Perchuk et al. (1984) have been used in this work. Pressure for Qtz+Pl+Bt+Ms+Grt+Sil assemblage has been calculated according to Perchuk et al. (l.c.).

Within each sample, average temperatures have been calculated from several garnet-biotite pairs. Tab. 6 summarizes the calculated temperatures suggesting that individaul thermometres have yielded similar data. The highest differences in a single sample do not exceed 30 °C with the exception of the sample V-25. Apart from the observed various types of garnet

Table 5

Chemistry of garnets from gneisses of the Malá Magura (V-15, 19, 47) and Suchý (V-25, 39, 42) Mts.

	V-15						V-19		V-47	
	R	I	C	R	I	C	R	C	R	C
SiO_2	35.89	34.15	36.29	35.92	35.86	36.35	36.47	36.27	37.44	37.61
TiO_2	0	0.11	0	0	0	0	0.01	0	0.05	0.06
Al_2O_3	21.40	21.44	21.17	21.17	21.23	21.17	21.13	21.48	21.77	22.06
FeO	32.94	31.75	33.81	32.34	32.62	33.41	30.49	29.68	30.47	29.95
MnO	6.09	5.22	4.55	6.65	5.05	5.10	7.86	8.07	6.99	5.59
MgO	2.77	6.20	3.31	2.83	4.10	3.12	2.61	2.52	3.17	3.27
CaO	0.90	1.15	0.87	1.09	1.14	0.85	0.82	0.78	1.09	1.14
Total	99.99	100.02	100.00	100.00	100.00	100.00	99.39	98.80	100.92	99.68
	Cations on basic of 12 oxygens									
Si	3.000	2.997	3.003	2.994	2.997	3.003	2.972	2.965	2.982	3.005
Al^{IV}	0	0.003	0	0.006	0.003	0	0.028	0.035	0.018	0
Al^{VI}	1.998	1.995	1.996	1.998	2.000	1.998	2.002	2.034	2.025	2.077
Fe	2.227	2.093	2.276	2.186	2.180	2.252	2.078	2.029	2.029	2.001
Mn	0.411	0.326	0.304	0.450	0.330	0.342	0.543	0.559	0.472	0.378
Mg	0.295	0.559	0.362	0.294	0.420	0.340	0.317	0.307	0.376	0.389
Ti	0	0	0	0	0	0	0.001	0	0.003	0.004
Ca	0.070	0.030	0.058	0.077	0.072	0.065	0.072	0.068	0.088	0.098
Prp	9.8	18.6	12.1	9.8	14.0	11.3	10.5	10.4	12.7	13.6
Alm	74.2	69.6	75.9	72.7	72.6	75.1	69.0	69.8	68.4	69.8
Sps	13.7	10.8	10.1	15.0	11.0	11.4	18.0	18.9	15.9	13.2
Grs	2.3	1.0	1.9	2.6	2.4	2.2	2.4	2.3	3.0	3.4

1st continuation of Tab. 5

	V-25						V-39				
	R	I	C	R	I	C	R	I	C	R	C
SiO_2	36.95	37.17	37.20	36.98	37.07	37.10	36.54	36.44	36.55	36.52	36.33
TiO_2	0.11	0.02	0.09	0	0.11	0.13	0	0	0	0	0
Al_2O_3	20.80	20.75	20.71	21.06	21.02	20.88	21.30	21.52	21.26	21.43	21.17
FeO	32.35	32.09	25.97	34.03	31.09	21.28	30.88	30.86	31.16	30.55	31.13
MnO	3.43	3.40	5.99	3.70	5.35	11.83	8.14	7.92	7.88	8.01	7.99
MgO	2.18	2.32	0.40	2.20	2.25	0	2.53	2.68	2.54	2.73	2.80
CaO	2.51	2.72	8.57	1.57	3.42	7.90	0.61	0.58	0.61	0.75	0.58
Total	98.33	98.47	98.93	99.54	100.31	99.12	100.00	100.00	100.00	100.00	100.00
	Cations of basis of 12 oxygens										
Si	3.022	3.031	3.022	3.004	2.985	3.016	2.965	2.953	2.966	2.958	2.952
Al^{IV}	0	0	0	0	0	0	0.035	0.047	0.034	0.042	0.048
Al^{VI}	2.005	1.994	1.983	2.016	1.995	2.001	2.002	2.009	2.000	2.004	1.979
Fe	2.212	2.189	1.764	2.311	2.094	1.447	2.096	2.092	2.115	2.070	2.115
Mn	0.238	0.235	0.412	0.255	0.365	0.815	0.559	0.544	0.542	0.550	0.550
Mg	0.266	0.282	0.048	0.266	0.270	0	0.306	0.324	0.307	0.330	0.339
Ti	0.007	0.001	0.005	0	0.007	0.008	0	0	0	0	0
Ca	0.220	0.238	0.746	0.137	0.295	0.688	0.053	0.050	0.053	0.065	0.050
Prp	9.1	9.6	1.6	9.0	8.9	0	10.2	10.8	10.2	10.9	11.1
Alm	75.3	74.4	59.4	77.8	69.2	49.1	69.5	69.5	70.1	68.7	69.3
Sps	8.1	8.0	13.9	8.6	12.1	27.6	18.5	18.1	18.0	18.2	18.0
Grs	7.5	8.1	25.1	4.6	9.8	23.3	1.8	1.7	1.8	2.2	1.6

2nd continuation of Tab. 5

	V-42								
	R	I	C	R	I	C	R	I	C
SiO_2	36.07	35.83	35.45	36.10	35.63	35.57	35.06	36.09	36.10
TiO_2	0	0	0	0	0	0	0	0	0
Al_2O_3	20.91	21.16	20.95	21.14	21.04	21.04	20.56	20.98	20.98
FeO	33.41	34.05	33.84	33.38	32.94	32.92	33.84	32.65	32.45
MnO	6.22	5.27	5.34	7.07	7.02	6.99	7.43	7.19	6.90
MgO	2.78	3.04	3.55	1.80	2.64	2.66	2.31	2.42	2.79
CaO	0.62	0.65	0.88	0.52	0.73	0.83	0.80	0.67	0.73
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Cations on basis of 12 oxygens								
Si	2.942	2.894	2.894	2.953	2.915	2.911	2.894	2.946	2.946
Al^{IV}	0.068	0.080	0.106	0.047	0.085	0.089	0.106	0.054	0.055
Al^{VI}	1.942	1.953	1.910	1.991	1.944	1.940	1.894	1.955	1.959
Fe	2.279	2.321	2.310	2.283	2.254	2.253	2.336	2.229	2.211
Mn	0.430	0.364	0.369	0.490	0.486	0.484	0.520	0.497	0.476
Mg	0.338	0.369	0.432	0.219	0.322	0.324	0.284	0.294	0.339
Ti	0	0	0	0	0	0	0	0	0
Ca	0.054	0.057	0.077	0.046	0.064	0.073	0.071	0.059	0.064
Prp	10.9	11.9	13.6	7.2	10.3	10.3	8.8	9.5	11.0
Alm	73.4	74.6	72.5	75.1	72.1	71.9	72.7	72.4	71.6
Sps	13.9	11.7	11.6	16.1	15.5	15.4	16.2	16.1	15.4
Grs	1.7	1.8	2.4	1.5	2.0	2.3	2.2	1.9	2.1

Remark: R – rim, I – intermediate zone (between rim and core), C – core.

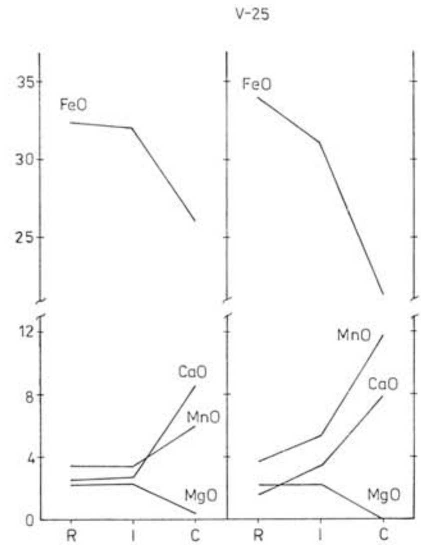


Fig. 9a. Progressive zoning of garnets associated with staurolite in Suchý gneiss.
R – rim, I – intermediate zone, C – core.

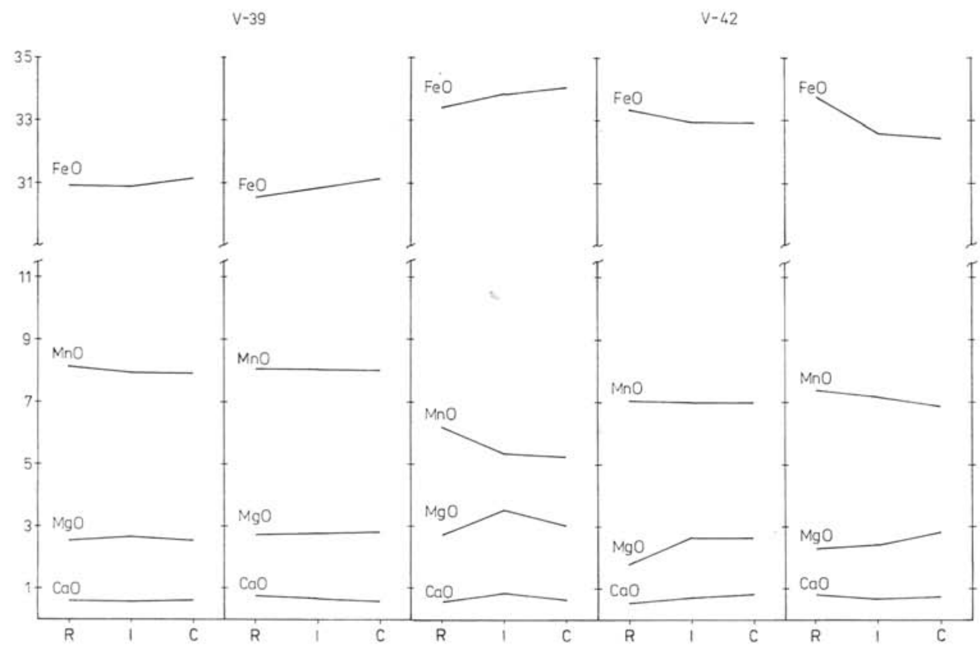


Fig. 9b. Unzoned and slightly zoned garnets of Suchý gneisses.
R – rim, I – intermediate zone, C – core.

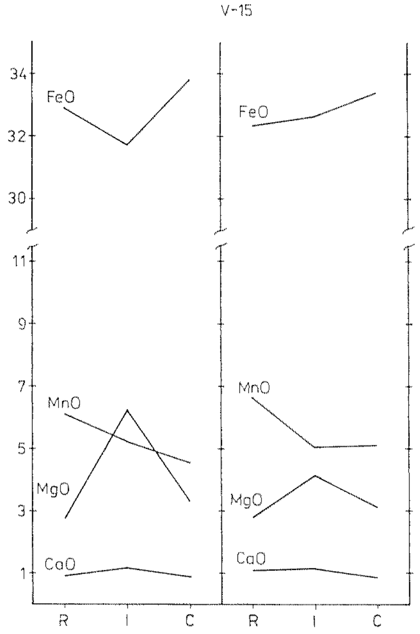


Fig. 9c. Zoning of garnets from Malá Magura gneisses.
R – rim, I – intermediate zone, C – core.

Table 6
Temperatures and pressures calculated for the studied gneisses of the Strážovské vrchy Mts.

	Spec.	Mineral		F & S (°C)	G & S (°C)	H & S (°C)	P (°C)	Pressure (MPa)
SUCHÝ	V-25	Grt	core	488	504	518	569	400*
		Grt	rim	434	459	462	525	260*
	V-39	Grt	core	685	694	692	683	470
		Grt	rim	682	694	691	683	460
	V-42	Grt	core	699	690	709	678	470
		Grt	rim	650	656	657	657	420
M. MAGURA	V-15	Grt	core	661	636	671	653	445
		Grt	rim	600	606	610	633	365
	V-19	Grt	core	693	711	703	690	470
		Grt	rim	678	696	688	681	455
	V-47	Grt	core	628	616	640	651	440
		Grt	core	641	614	655	650	450

Remark: F & S Ferry – Spear (1978); H & S Hodges – Spear (1982); G & S Ganguly – Saxena (1984); P Perchuk et al. (1984).
*Pressure calculated according to Ghent et al. (1979) and taken from Dyda (1990).

zoning, the calculated temperature values in each sample indicate decreasing temperature from the core to the rims. Changes in temperature have also been tested by pressures ranging from 300 to 500 MPa, but the temperature never changed by more than 10 °C, thus suggesting that pressure did not substantially control Fe and Mg distribution.

Variations in garnet zoning (Méres et al., 1986; Méres – Hovorka, 1989), mainly in garnets from gneisses without staurolite, are likely to have been caused by retrograde exchanges in response to cooling in the regressive stage following metamorphic peak, by which an important role was played by local temperature conditions. This is suggested also by small differences in temperature between the core and rims. Homogeneous garnets indicate a more complex mechanism (V-39 near the contact with granitoids) by which during prograde growth, diffusion rates within single garnet grains were able to eliminate their earlier growth zoning.

Results obtained by thermometres indicate that the temperature increased from the western part of the Suchý Mts. (T = 470–560 °C in sample V-25) towards the east (T = 660–700 °C in samples V-39, 42). Metamorphic temperature in the Malá Magura area corresponds to 620–680 °C.

Geochemical characteristics of granitoids and gneisses

Petrographic and geochemical features suggest that tonalites, granodiorites and granites of the Strážovské vrchy Mts. are members of a differentiation sequence. The sequence, however, has only a narrow composition range because it is devoid of intermediate and basic rocks (Fig. 10). The Strážovské vrchy granitoids have therefore an apparent character of the calc-alkaline series.

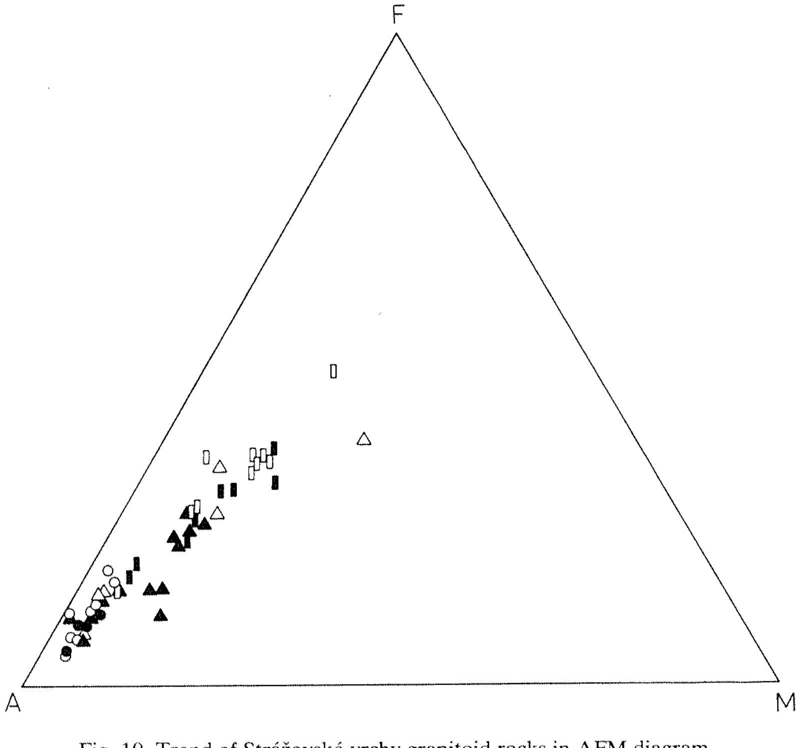


Fig. 10. Trend of Strážovské vrchy granitoid rocks in AFM diagram. For explanations see Fig. 4.

Silica content within the whole set of granitoids ranges from 61 to 77 wt. %. Interesting, high silica contents (73–77 wt. %) occur in some of the Suchý granitoids which, at the same time, have also high K_2O contents (over 3 %). H a r k e r ' s variation diagrams indicate that in the both investigated massifs there are equal negative correlations between major elements and TiO_2, Al_2O_3, Fe_2O_3, FeO, MgO and CaO, whereas the correlation between K_2O and SiO_2

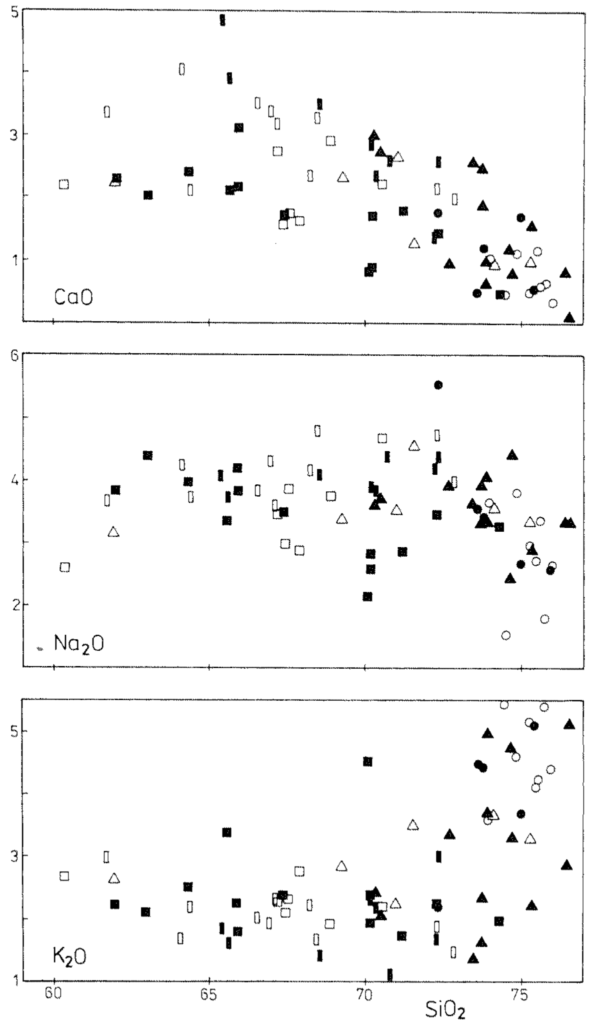


Fig. 11.

is positive (Fig. 11). Correlation between high Na_2O content and those of K_2O (Fig. 12) as well as MgO is negative. Distinct wide range of K_2O contents in Suchý granodiorites resulted from intensive alteration processes.

As $Al_2O_3/CaO + Na_2O + K_2O$ molar ratio exceeds 1 (Fig. 13), the studied granitoids are peraluminous. We cannot unambiguously state that they are S-type granitoids because their

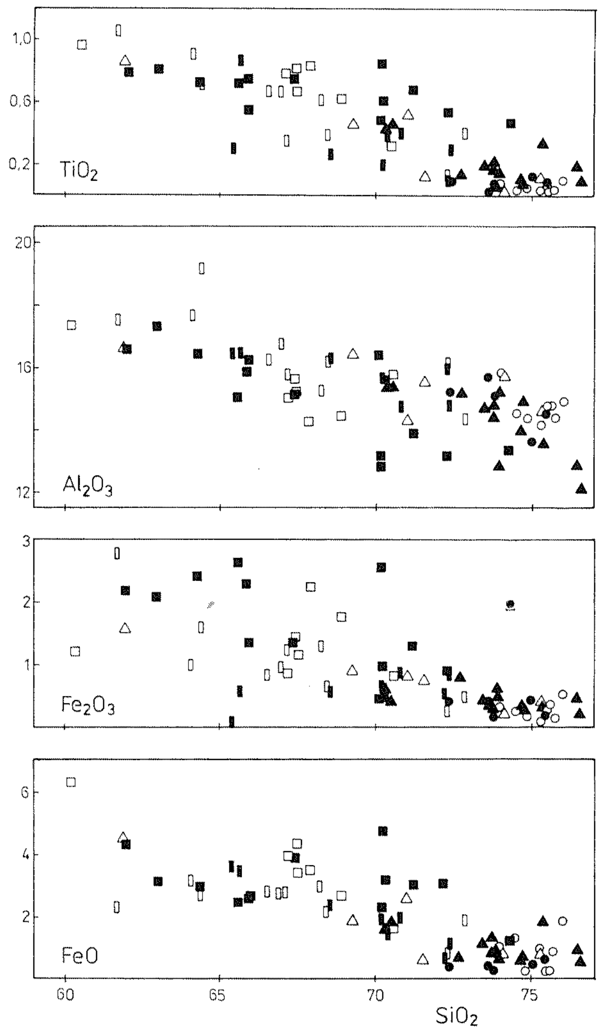


Fig. 11.

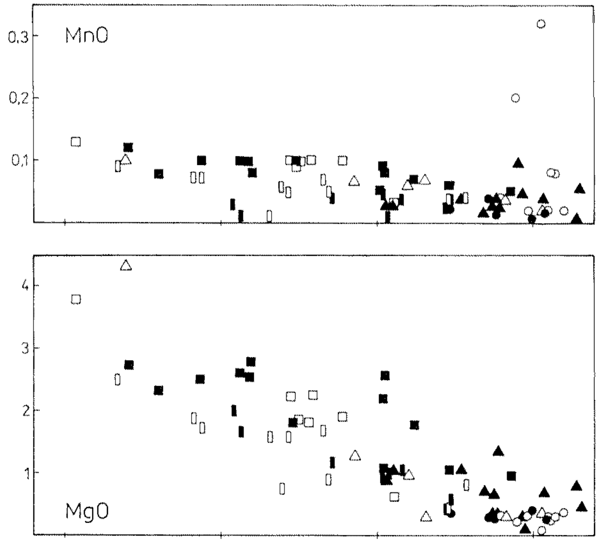


Fig. 11. H a r k e r ' s variation diagrams for granitoid rocks and gneisses of the Strážovské vrchy Mts. For explanations see Figs. 2 and 4.

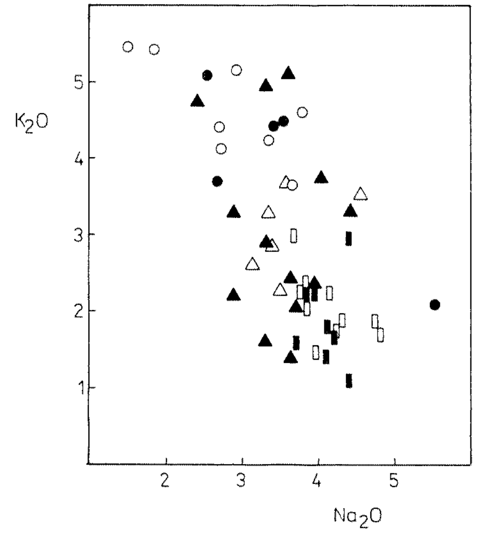


Fig. 12. K_2O-Na_2O correlation (in wt. %) in the studied granitoids. For explanations see Fig. 4.

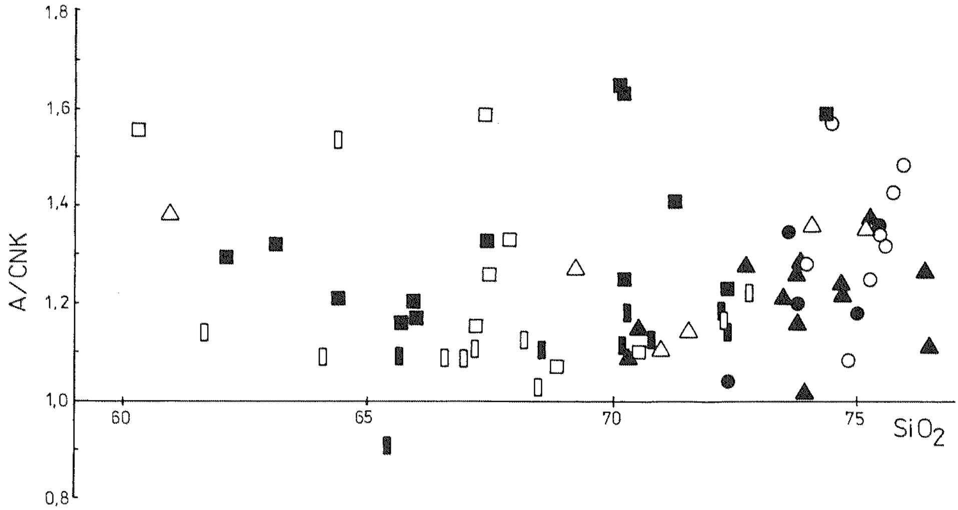
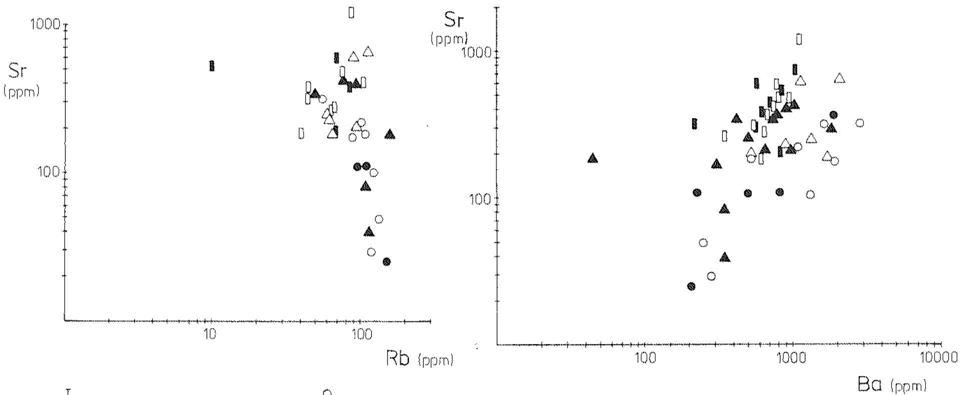


Fig. 13. SiO_2 – A/CNK relationships in granitoids and gneisses of the Strážovské vrchy Mts. For explanations see Figs. 2 and 4.



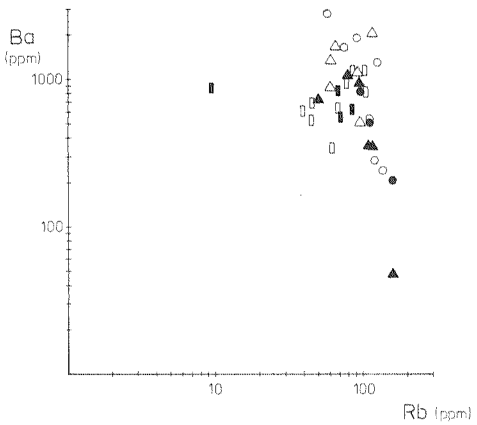


Fig. 14. Graphs to show Sr-Rb, Ba-Rb and Sr-Ba ratios in granitoid rocks. For explanations see Fig. 4.

Table 7
Rare earth contents (ppm) in selected samples of granitoids and gneiss V-19

	Sample	La	Ce	Sm	Eu	Tb	Yb	Lu
Tonalites	V-7	39.2	75.1	3.86	1.13	<1	<1	0.53
	V-9	23.8	51.7	2.94	1.03	<1	<1	<0.2
	BGPS-2	70.6	147	7.78	2.15	<1	<1	<0.2
	SR-4	37.5	65.8	3.89	1.17	<1	<1	<0.2
	SR-5	42.1	67.7	4.40	1.13	<1	1.38	<0.2
	SR-7	22.6	71.7	3.97	1.28	<1	<1	0.25
Grano-diorites	V-1	19.1	54.1	4.77	1.43	<1	3.83	0.59
	V-4	9.77	70.4	1.43	1.38	<1	2.65	0.36
	V-51	34.3	66.9	2.53	1.18	<1	1.84	0.2
	BGS-7	30.3	52.7	3.31	0.93	<1	<1	0.23
Granites	V-2	<1	6.85	<1	0.63	<1	4.35	0.64
	V-11	3.02	7.87	<1	<0.1	<1	1.12	0.2
	V-50	9.41	21.9	1.57	0.72	<1	<1	0.24
	SR-6	2.18	3.46	<1	0.43	<1	<1	0.2
	V-19	25.7	50.7	4.09	1.0	<1	3.61	0.74

Remark: determined by instrumental neutron activation analysis in state company Geoindustria, Černošice.

Na_2O content is high and $^{87}Sr/^{86}Sr$ initial ratio is low (0.706, Kráľ et al., 1987). The source of ideal S-type granitoids allegedly probably consists of a mixture of graywackes and shales.

Similar distributions of trace elements in granitoid rocks of the both massifs do not allow to speak of their mutual differences. Most trace elements show no distinct systematic variations associated with silica content and therefore distribution of Ba, Be, B, Sn, Cu, Ni, Co, Y, (Cr) was not substantially affected by the differentiation process. There exists a moderate positive correlation between Rb, Pb and SiO_2. These elements are incompatible. Correlation between silica and Sr, Zr is highly negative, whereas that between silica and V, Sc is moderately negative. In the process of differentiation from tonalites to granites, these elements behaved compatibly.

As shown in Fig. 14, stronger mutual geochemical relationships in granitoids occur between Sr, Rb and Ba. Fig. 14 shows that tonalites constitute a fairly compact field of these elements, whereas granites and granodiorites have considerable range of Sr and Ba contents. Ba/Sr ratio in tonalites is close to 2, but it increases substantially towards granites (Ba/Sr equals approx. to 7). Limited number of Rb assays shows that contents of this element are very low and vary within a narrow range.

Contents of rare earths (Tab. 7) La, Ce, Sm, Eu, Tb, Yb and Lu analysed in 15 selected samples of all investigated types provide a piece of preliminary information. REE analyses (Fig. 15) clearly suggest a common evolution of granitoid rocks in the both massifs. Tonalites are markedly enriched in light REE, whereas heavy REE contents in tonalites, granodiorites and granites are essentially equal. The increased contents of light REE in tonalites are related to the presence of accessory minerals such as allanite, monazite and titanite which substantially control REE distribution in rocks (Miller – Mittlefehldt, 1982).

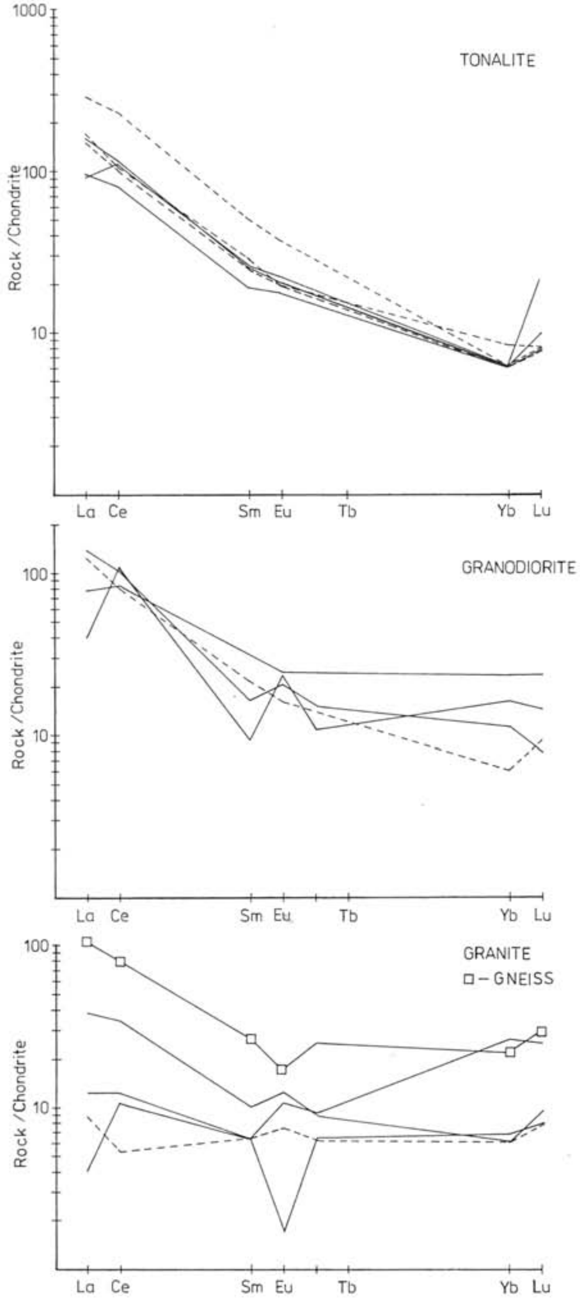


Fig. 15. Distribution of rare earths in Strážovské vrchy granitoid rocks.
Solid lines – Malá Magura, dashed lines – Suchý. Normalized according to E v e n s e n et al. (1978).

Predominance of light REE over heavy ones in tonalites is indicated also by high Ce_N/Yb_N ratio ranging from 12.6 to 37. 8. Decreasing value of this ratio from tonalites towards granites allows to characterize differentiation trend of the both massifs in which light REE were more compatible than heavy ones. In granodiorites and granites (except 1 sample) there is a positive Eu anomaly, in tonalites such anomaly does not exist.

Relative to the granitoid rocks, geochemical properties of gneisses of the both massifs have also been studied in order to obtain data on the character of the original source material.

Overall chemistry of gneisses resembles average chemistry of tonalites (granodiorites). Results show that silica content varies from 60 to 72 wt. %. In comparison with granitoids, gneisses are more oversaturated with aluminium (Fig. 13) and mesonormative calculation suggests that they contain also normative corundum (1.16 to 6.55). This fact corresponds to the presence of biotite, muscovite ± garnet, ± sillimanite and absence of amphibole. Relative to granitoids, gneisses contain more TiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, MnO, what is caused by higher biotite contents (in volume %) in gneisses. Contents of alkalies are fairly high, ranging from 4.2 to 6.9 wt. %.

Trace elements (mainly REE) are relatively immobile in the metamorphic process (Muecke et al., 1977 in Dusel-Bacon – Aleinikoff, 1985), which concerns all variation diagrams of Rb, Ba, Pb, Sr, Zr, Y relative to SiO_2. No mutual correlations have been found between Ba-Rb, Sr-Rb, Sr-Ba and Y-Zr. Position points for gneisses of the both investigated massifs form common fields.

Discussion and conclusion

The obtained results suggest numerous interesting features of the Strážovské vrchy crystalline. First of all we can state that the granitoid massifs exposed on the surface do not exhibit a zonal pattern. Surface distribution of tonalites, granodiorites and granites is irregular. Biotite tonalites are abundant in the both massifs, but trondhjemites are also present. It is noteworthy that rocks of a typical granite composition are more abundant in the Malá Magura Mts. than in the Suchý Mts.

All types of Strážovské vrchy granitoids (including tonalites and granodiorites) are peraluminous, what is reflected also in their modal composition: in addition to biotite they contain also muscovite, garnet and finally sillimanite. This fact contradicts the assumption of Hovorka – Fejdi (1983) that biotite granodiorites of the Suchý and Malá Magura Mts. are of a metaluminous character. According to these authors, an intrusion of metaluminous granodiorites caused partial melting of Al-rich (clayey) metasediments thus giving rise to peraluminous, garnet-bearing granite melt. In contrast, on the basis of observed petrographic and geochemical features I assume that tonalites, granodiorites and granites of the Strážovské vrchy Mts. are members of a differentiation sequence of a fairly narrow composition range (without intermediate and basic members).

Comparing Strážovské vrchy Mts. granitoids with genetic types of granitoids, whose characteristics have been outlined by Cambel – Vilinovič (1987), we can see that they mostly resemble S-types. The composition and properties of the studied granitoids, however, do not correspond to the ideal S-type, because Suchý and Malá Magura granitoids, e. g., have a high Na_2O content, negative K_2O/Na_2O correlation and low initial ratio $^{87}Sr/^{86}Sr = 0.706$ (Kráľ et al., 1987). This suggests that their magma did not originate by partial melting of metasedimentary rocks, graywackes and shales, as in the case of S-type granitoids (Chappell – White, 1974; White – Chappell, 1977, 1983) but from less mature crustal material (Cambel – Petrík, 1982; Flood – Shaw, 1977) as is indicated by the position of samples in a R_1R_2 diagram (Fig. 16).

From geochemical point of view, some major and trace elements in granitoids of the both massifs are compatible (e.g. Ti, Al, Fe, Mg, Ca, Sr, Zr, V), while others i.e. K, Rb, Pb behave in an incompatible way. Intensive secondary alterations which affected mainly Suchý granitoids are responsible for a great variability in K_2O contents as well as for a high silica content in granodiorites. These secondary signs (sillimanite-muscovite aggregates) observed largely in Suchý granitoids did not result from high-temperature acid leaching in the sense of Korikovsky et al. (1987), because no removal of Mg, Fe, Ca, Na and K from the rocks has been noted. This process would have to cause e.g. albitization of plagioclases, resorbtion of K-feldspars and baueritization of biotites. The secondary signs therefore resulted from circulation of hydrothermal solutions associated with granitoid emplacement.

Rb contents are very low and, as has been stated by Kráľ et al. (1987), the magma source must have also been poor in Rb, with a low Rb/Sr ratio. Most trace elements (Ba, Be, B, Sn, Cu, Ni, Y, Cr) do not show marked systematic variations related to silica contents. Their

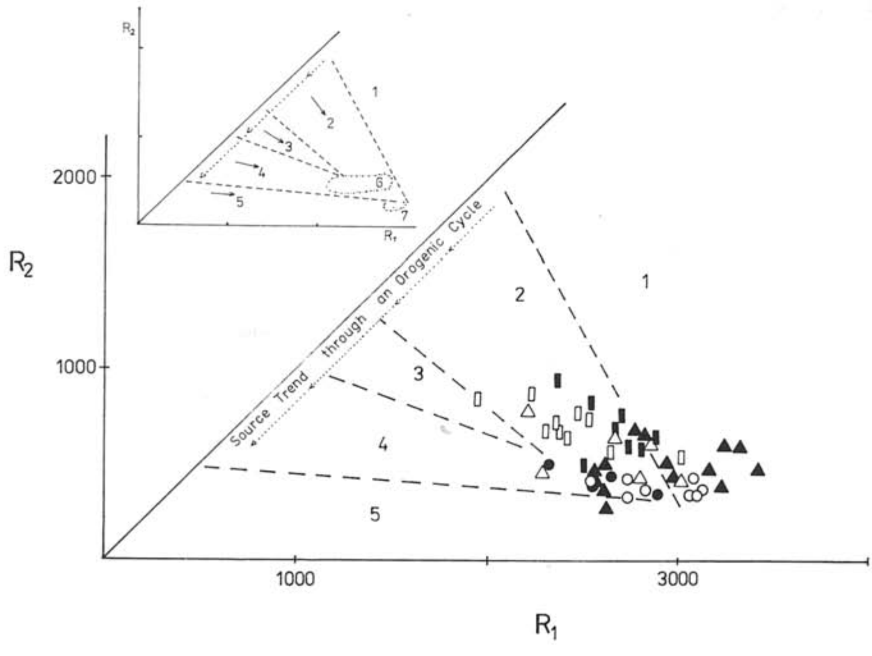


Fig. 16. Position of investigated granitoid rocks in a multication R_1R_2 diagram (De la Roche et al., 1980).

Fields 1–7 represent tectonomagmatic settings defined by Pitcher (1979, 1982 in Batchelor – Bowden, 1985): 1 – products of mantle fractionation; 2 – precollision assemblages; 3 – postcollision assemblages; 4 – lateorogenic assemblages; 5 – anorogenic assemblages; 6 – syncollision assemblages; 7 – postorogenic assemblages. For further explanations see Fig. 4.

distribution was not significantly affected by the differentiation process, which was already stated by Ivanov (1957). We may therefore assume that the differentiation took place through an equilibrium crystallization which, in contrast to fractional crystallization, does not substantially affect contents of trace elements. This is suggested also by frequent occurrences of plagioclases without zonal pattern, indistinct zoning of garnets and absence of cumulate textures in Strážovské vrchy granitoids.

In graphs showing Sr-Rb, Ba-Rb and Sr-Ba relationships (Fig. 14), however, samples follow some trends which are comparable, e.g., with trends of fractional crystallization of the Bratislava Massif (Cambel – Vilinovič, 1987). Light rare earth elements also bear signs of fractional crystallization (Fig. 15).

All petrographic types of Suchý and Malá Magura granitoids contain garnets of almandine-spessartite composition with varied contents of pyrope and grossularite. If slightly zoned, then MnO content increases from the core towards the rims of individual garnet grains and vice versa FeO and MgO contents usually drop. The most remarkable difference between garnets of the both investigated massifs is that in the Malá Magura Mts. spessartite content in garnets increases from tonalites to granites, whereas in the Suchý Mts. it decreases with advancing differentiation. According to Green's (1976, 1977) experiments, composition of Malá Magura garnets can be explained by their crystallization during magma ascent. The magma may have started to ascend from a depth of 18 km > (garnet from tonalite contains some 8.5 mol. % Sps) and ended less than 12 km below the surface (Sps content in garnet from granite is approximately 22 mol. %). Decreasing pressure due to the magma ascent is also reflected in reduced CaO contents within individual garnet grains as well as within the succession from tonalite to granite. Increasing MnO content stabilized garnet in the granitic melt at lower pressures. A reverse trend in chemistry of Suchý garnets may be probably explained by their later crystallization at shallower depths, when MnO content in the melt was already low. Garnets from investigated granitoids, however, differ from those of surrounding gneisses in their magmatic character and textural features.

Observed structural states of K-feldspars (orthoclases in tonalites to maximum microclines in granites) reflect conditions of slow cooling and magma enrichment in water, because the process of crystallization began from disordered orthoclase and later progressed through various ordering states to maximum microcline (Vilinovičová, 1989). Temperatures determined by means of two-feldspar thermometer (Ghiorso, 1984 in Vilinovičová, l. c.) T = 460–593 °C at assumed pressure P = 400–500 MPa are clearly subsolidus reflect temperatures at which last interchange of constituents between feldspars took place.

Investigated biotite-plagioclase gneisses of the Suchý and Malá Magura Mts. reflect conditions of almandine-amphibolite facies. According to Winkler's (1979) classification, there continued metamorphic conditions up to the limits of the cyanite-almandine-muscovite or sillimanite-almandine-orthoclase subfacies, which is suggested by the presence of muscovite that was only exceptionally converted to sillimanite. The presence of orthoclase so far observed in a single sample from the NW Malá Magura Mts. proves a relatively high metamorphic grade (Bernotat – Bambauer, 1982) in this part of the Strážovské vrchy Mts.

In comparison with granitoid rocks, gneisses are more peraluminous, show increased Ti, Fe, Mg, Mn contents and mainly higher contents of trace elements Y, Ni, Cu, Cr, V, Sc, (Zr) and (Co). Despite existence of some structural types (massive-homogeneous, banded, eyed), geochemical properties of gneisses reflect immobility of trace elements in the metamorphic process.

Mineral assemblages observed in Suchý and Malá Magura gneisses allow to divide the studied territory into two metamorphic zones: staurolite-biotite and sillimanite-biotite. As the territory is tectonically undisturbed, these two zones are well preserved. They are separated from one another by a zone in which staurolite gradually gives way to sillimanite. This transient staurolite-sillimanite zone is marked by a dashed line in Fig. 5 and has already been noted by Dyda (1987).

These metamorphic zones indicate two metamorphic events in the development of the Suchý and Malá Magura crystalline. The first metamorphic event (M1) of regional character gave rise to the assemblage with staurolite and took place under the conditions of the greenschist facies at temperature T = 460−590 °C and pressure P = 200−400 MPa. It is likely to have affected also the Malá Magura area, although staurolite has not yet been identified there (nor in relics). The absence of M1 manifestations in the Malá Magura Mts. may be related to the fact that this area underwent deeper erosion and contains less mantle rocks (Kahan, 1979; Dyda, 1990). Manifestations of M1 metamorphism are preserved in the westernmost Suchý Mts., i.e. in the area most distant from plutonic rocks.

The second metamorphic event (M2) may be considered as contact metamorphism on a regional scale or as regional metamorphism in which a considerable amount of heat was derived from the granitoid intrusion. The second event M2 is related to the granitoid intrusion and took place under the following conditions: T = 650−700 °C, P = 365−470 MPa in the Suchý Mts. and T = 600−710 °C, P = 450−470 MPa in the Malá Magura Mts. The event caused breaks down of staurolite in the rocks containing garnet by the continual reaction into sillimanite in the presence of Mn and Ca in garnet: $St+Ms+Qtz \rightarrow Grt+Sil+Bt+H_2O$ (Dickerson − Holdaway, 1989).

The reflections of M2 metamorphism event in this crystalline area have a more specific character in comparison with, e.g., contact metamorphism in the Malé Karpaty Mts. (southern part of the Western Carpathians) where contact effects related to crystallization of the Modra granitoids gave rise to the contact hornfel aureole with andalusite and cordierite (Korikovsky et al., 1985). In the Strážovské vrchy Mts., the granitoids most probably intruded regionally metamorphosed rocks (event M1) at great depths (some 18 km) where gneisses were fairly well heated. That is the reason why such close mutual relationships between granitoid rocks were established. The granitoid intrusion also caused uplift and thus affected common process of cooling. The second metamorphic event (M2 of periplutonic character) is therefore related to the granitoid intrusion. This sequence of metamorphic processes has been already proved by geochronologic data in the Malé Karpaty Mts. (Cambel − Kráľ, 1989) and probably took place also in other Western Carpathian core mountains.

Acknowledgement: I am thankful to RNDr. D. Jančula from the Slovak Technical College for his help in measuring on electron microanalyzer, to RNDr. B. Toman (Geological Institute of the Slovak Academy of Sciences) for making chemical analyses of rocks by X-ray fluorescence and to RNDr. J. Medveď, CSc. (GI SAS) for trace-element analyses of rocks by spectral analysis. I am obliged to RNDr. I. Petrík, CSc. (GI SAS) for allowing me to study his samples marked BGM, BGPS, DGS, LGS nad PGS.

Translated by Ľ. Böhmer

APPENDIX

Chemical composition of granitoids and gneisses from the Strážovské vrchy Mts.

	Granites (Malá Magura)								*Granodiorites* (Malá Magura)			
	V-2	V-6	V-11	V-12	V-17	V-20	V-21	V-50	V-1	V-4	V-8	V-18
SiO_2	74.51	74.85	75.62	75.50	75.78	75.99	75.27	73.99	61.94	71.00	71.57	75.29
TiO_2	0.03	0.05	0.03	0.05	0.03	0.15	0.02	0.08	0.86	0.53	0.13	0.11
Al_2O_3	14.50	14.36	14.78	14.75	14.35	14.39	14.12	15.25	16.65	14.32	15.53	14.52
Fe_2O_3	0.24	0.16	0.37	0.28	0.12	0.53	0.08	0.37	1.58	0.82	0.76	0.41
FeO	1.32	0.25	0.26	0.25	0.90	0.93	0.94	0.63	4.57	2.62	0.63	0.76
MnO	0.20	0.02	0.08	0.02	0.08	0.02	0.32	0.04	0.10	0.06	0.07	0.02
MgO	0.23	0.30	0.25	0.29	0.29	0.38	0.04	0.30	4.31	0.99	0.30	0.34
CaO	0.47	1.13	0.61	1.17	0.65	0.35	0.51	1.04	2.25	2.65	1.28	1.00
Na_2O	1.51	3.80	3.36	2.72	1.81	2.64	2.95	3.67	3.14	3.50	4.56	3.34
K_2O	5.47	4.61	4.24	4.10	5.41	4.40	5.15	3.63	2.63	2.25	3.52	3.29
P_2O_5	n. d.	n. d.	n. d.	n. d.	n. d.	n. d.	n. d.	0.05	n. d.	n. d.	n. d.	n. d.
H_2O^+	0.86	0.53	0.64	0.70	0.43	1.08	0.45	1.03	1.25	0.71	1.11	0.92
H_2O^-	0.09	0.16	0.09	0.14	0.06	0.08	0.05	0.11	0.32	0.23	0.08	0.18
Total	99.43	100.22	100.33	99.97	99.91	100.40	99.90	100.19	99.60	99.68	99.54	100.18
Rb	89	76	120	58	102	126	138	111	95	62	116	65
Ba	1930	1640	280	~2820	1150	1290	245	530	525	890	2140	1740
Be	~1.9	~2.2	4.3	~1.9	~2.3	3.2	~2.7	3.2	~2.3	~2.1	4	~2.9
B	10.2	11.7	10.4	13.2	12.9	26.9	5	12.3	~2.8	3.9	9	22.4
Pb	59	46	23.4	38	62	25	26	27.5	20.4	26	48	50
Sn	3.2	~2.9	~1.6	<1	<1	<1	<1	~1	4.8	<1	~1.4	<1
V	11	5	<3	4	<3	10	<3	<3	110	64	4	6
Cu	7.1	5.5	9.8	8.3	7.2	6.6	5.5	~2	21.4	16.4	3	10.1
Ni	6.1	<1	4.1	3.3	~1.9	4	3.2	4.7	44	21.4	7.1	3
Zr	16	28	20	~5	~5	49	22	25	189	155	34	28
Co	10.7	12	6.7	8.1	7.2	17	17	7.5	26.3	11.5	<2	23.6
Y	53	<2	7.2	16	15.9	16.2	22.4	13.2	30.5	26.3	15.5	13.8
Sc	8.9	~1.6	~2.2	~1.9	4.3	3.7	~2.4	~2.7	15.3	11.7	4.5	3.4
Cr	<1	<1	<1	<1	<1	<1	<1	10	15.3	30	<3	~2.1
Sr	178	320	29	325	221	102	49	184	200	236	650	186

1st continuation of App.

	Granodiorites (Malá Magura)		*Tonalites* (Malá Magura)									*Granites* (Suchý)
	V-49	V-51	BGM-1	SR-7	V-3	V-5	V-7	V-9	V-13	V-14	V-45	LGS-2
SiO_2	74.09	69.24	66.58	67.18	61.70	72.84	64.09	66.97	68.24	64.42	72.31	74.98
TiO_2	0.01	0.46	0.67	0.35	1.06	0.40	0.91	0.66	0.61	0.72	0.15	0.19
Al_2O_3	15.70	16.45	16.32	15.80	17.58	14.38	17.71	16.78	15.28	19.18	16.23	13.64
Fe_2O_3	0.21	0.92	0.83	1.27	2.76	0.46	0.99	0.96	1.32	1.59	0.28	0.43
FeO	0.39	1.84	2.83	2.81	2.29	1.95	3.20	2.77	2.94	2.72	0.93	0.42
MnO	0.04	0.07	0.01	0.05	0.09	0.04	0.07	0.06	0.07	0.07	0.04	0.01
MgO	0.32	1.30	1.54	1.57	2.50	0.82	1.88	0.76	1.70	1.70	0.42	0.40
CaO	0.96	2.34	3.51	3.22	3.37	2.00	4.10	3.40	2.38	2.12	2.18	1.72
Na_2O	3.56	3.39	3.85	3.58	3.68	3.97	4.25	4.32	4.14	3.76	4.76	2.68
K_2O	3.65	2.84	2.04	2.37	2.99	1.48	1.67	1.92	2.25	2.23	1.88	3.70
P_2O_5	0.09	0.07	0.42	0.22	n. d.	n. d.	n. d.	n. d.	n. d.	n. d.	0.02	0.56
H_2O^+	0.83	0.68	0.90	1.16	1.75	1.17	0.61	0.83	0.65	1.11	0.60	0.70
H_2O^-	0.05	0.09	0.44	0.22	0.11	0.24	0.13	0.16	0.09	0.08	0.09	0.38
Total	99.90	99.69	99.94	99.80	99.88	99.75	99.61	99.59	99.67	99.70	99.89	99.81
Rb	60	90	n. d.	113.7	105	40	88	78	67	63	45	n. d.
Ba	1350	1115	820	790	760	610	1120	955	650	350	540	1930
Be	~1.5	3.3	3.2	3.6	~2.6	~2	~2.3	8.5	~1.7	~2	3	~1.5
B	5.3	15	4.7	14.1	4.9	17	4.7	10.7	~2.2	6.2	10.2	4.7
Pb	22	24.5	20	14.8	10.5	35	16	27.2	16.5	19.1	33	35
Sn	<1	3.5	~1.6	~2.1	3.5	3.4	6.2	4	<1	<1	~1.6	<1
V	<3	51	14	73	75	39	78	63	63	38	21	4.4
Cu	3.6	3.8	55	15.9	10	37	12	20.4	7.8	3.2	4	<2.3
Ni	5.6	6.8	13.5	6.8	11.8	13.2	12.8	5.2	24	14	6.8	5.6
Zr	25	174	207	239	82	79	188	209	115	68	89	25.1
Co	8.2	7.5	6.8	12	6.9	32	8.2	14.5	7.8	6.8	4.9	<2
Y	12.6	20.5	12.6	12.9	17.8	31	16.2	17	19.6	24.1	23.9	13.8
Sc	3.1	5.8	8.3	6.9	6.9	5.4	7.1	7	11	10.8	3.7	3.65
Cr	16	18	14	10.2	12	8.3	3.8	~2.6	37	9.6	28	~1.9
Sr	248	600	496	590	415	186	~1200	480	280	263	311	365

2nd continuation of App.

	Granites (Suchý)				*Granodiorites* (Suchý)							
	SR-2	SR-6	V-22	V-34	BGS-3	BGS-6	BGS-7	BGS-8	BGS-9	DGS-1	LGS-1	PGS-1
SiO_2	72.36	73.80	75.45	73.61	73.48	70.50	70.32	73.76	73.74	72.70	74.66	73.92
TiO_2	0.10	0.07	0.08	0.02	0.19	0.46	0.42	0.22	0.17	0.14	0.10	0.15
Al_2O_3	15.22	15.15	14.49	15.68	14.67	15.38	15.38	14.75	14.48	15.22	13.96	12.85
Fe_2O_3	0.41	0.18	0.21	0.40	0.40	0.44	0.65	0.30	0.37	0.82	0.32	0.63
FeO	0.41	0.26	0.59	0.43	1.19	0.84	1.58	1.32	0.80	0.71	0.59	0.57
MnO	0.03	0.02	0.02	0.04	0.02	0.03	0.03	0.02	0.03	0.04	0.10	0.03
MgO	0.35	0.29	0.29	0.33	0.73	1.05	0.94	0.68	0.44	1.08	0.36	1.36
CaO	1.78	1.22	0.53	0.52	2.60	2.78	3.02	2.49	1.94	0.97	1.21	1.02
Na_2O	5.53	3.42	2.56	3.54	3.62	3.73	3.62	3.31	3.93	3.93	2.43	3.31
K_2O	2.16	4.42	5.09	4.48	1.37	2.04	2.43	1.62	2.34	3.36	4.74	4.95
P_2O_5	0.27	0.15	n. d	0.04	0.44	0.42	0.31	0.48	0.25	0.27	0.31	0.17
H_2O^+	1.04	0.72	0.76	0.39	0.76	0.82	0.74	0.74	0.96	0.78	0.46	0.72
H_2O^-	0.24	0.18	0.18	0.25	0.36	0.30	0.40	0.36	0.34	0.28	0.42	0.16
Total	99.90	99.88	100.25	99.74	99.83	99.79	99.84	99.75	99.79	100.30	99.86	99.84
Rb	73.3	110	97	155	n. d.	n. d.	95	n. d.	n. d.	n. d.	n. d.	n. d.
Ba	234	500	830	204	425	785	940	495	309	940	665	1860
Be	6.2	3.1	~2.7	5.5	<1	~2.5	~2.4	~1.4	~2.3	4.9	<1	2.6
B	7.6	7.6	14.5	11.7	~1.7	~2	3.6	~2.6	~1.7	7.5	~2.8	5.8
Pb	17.8	46	37.5	42	18.6	20.2	23.6	19.8	23.6	36	41.5	25.7
Sn	~1.5	~2	<1	5.6	<1	<1	~1.6	<1	<1	~2.3	<1	~1.7
V	<3	<3	4	<3	~1.8	~2.1	~2.9	~2.9	~2.2	~2.6	<3	~2.8
Cu	4.4	3.3	7.2	6.9	5.8	41.5	38.5	7	3.5	15	~2.4	13
Ni	4.4	<1	~2.6	20	~3	5	5.4	5.5	~4.6	44	<3	~4.8
Zr	14	<5	22	13	71	182	155	117	51	82	16	108
Co	7.9	11.2	8.1	<2	~2.6	3.7	4.2	3.1	<2	14.3	<2	46
Y	11.6	<2	10.5	12.3	11.7	10.9	12.6	16.8	10.8	15.3	9.3	11.6
Sc	~2.7	<1.9	~2.3	~2.8	6.55	6.2	6.5	7.9	3.6	4.6	~2.95	3
Cr	<1	<1	<1	18	4	5.8	5.1	4.9	3.1	6	~2.4	~1.7
Sr	115	113	110	25	345	375	400	257	164	211	214	290

3rd continuation of App.

	Granodiorites (Suchý)					*Tonalites* (Suchý)						
	V-35	V-40	ZK-59 (K)	ZK-102 (P)	ZK-104 (P)	BGPS-1	BGPS-2	LGS-3	SR-1	SR-3	SR-4	SR-5
SiO_2	73.93	75.37	74.69	76.58	76.44	70.82	65.66	70.34	72.25	65.41	68.54	70.21
TiO_2	0.06	0.33	0.08	0.10	0.19	0.40	0.87	0.38	0.11	0.30	0.27	0.20
Al_2O_3	15.22	13.57	14.95	12.23	12.88	14.80	16.49	15.42	15.95	16.48	16.31	15.74
Fe_2O_3	0.48	0.37	0.28	0.19	0.44	0.89	0.60	0.55	0.53	0.00	0.60	0.65
FeO	0.78	1.77	0.67	0.51	0.78	1.99	3.42	1.55	0.77	3.63	2.38	1.91
MnO	0.04	0.04	0.05	0.06	0.01	0.04	0.01	0.01	0.03	0.03	0.04	0.05
MgO	0.36	0.72	0.09	0.44	0.80	1.05	1.65	0.98	0.45	2.00	1.22	0.93
CaO	0.66	1.62	0.79	0.09	0.84	2.60	3.97	2.38	2.63	4.89	3.52	2.93
Na_2O	4.04	2.88	4.40	3.59	3.32	4.40	3.73	3.85	4.21	4.10	4.10	3.89
K_2O	3.72	2.21	3.30	5.09	2.85	1.10	1.60	2.20	1.68	1.84	1.39	2.29
P_2O_5	0.01	0.05	0.04	0.06	0.21	0.25	0.65	0.36	0.18	0.28	0.22	0.20
H_2O^+	0.50	0.69	0.74	0.88	1.12	1.00	0.92	1.48	0.72	0.74	1.00	0.76
H_2O^-	0.31	0.13	0.01	0.12	0.16	0.44	0.30	0.38	0.36	0.24	0.32	0.28
Total	100.19	99.90	100.09	99.94	100.04	99.78	99.87	99.88	99.87	99.94	99.91	100.04
Rb	118	78	161	109	51.5	n. d.	210	n. d.	40.22	64.53	71.5	84.5
Ba	355	1050	47	350	740	220	850	730	555	1100	575	630
Be	3.6	~2.7	9.1	~2.1	~2	<1	<1	~2.8	~2	~2.3	~2.5	~2.5
B	11.1	5.9	16.6	3	3	3.5	~1.3	6.2	4.9	<2	~2.3	<2
Pb	39	19.8	n. d.	38	22.9	26.6	12.9	20	316	21.4	27	19.1
Sn	3.3	~1.3	16.6	~1	1	~1.2	~2.1	<1	~1	4.6	~2.2	~1
V	<3	43	3	~2.88	6.2	39	74	41	<3	115	51	40
Cu	~2.3	3.9	87	~1.74	2.57	9.1	5.8	~2.9	7.4	19	10.5	3.5
Ni	4.1	11.2	n. d.	3.8	4	5.4	8.1	7.2	6.8	8.6	5.1	3.6
Zr	35	215	27.5	14.8	43	253	380	162	25	251	193	178
Co	<2	5.6	n. d.	~1.72	~2.63	3.8	7.2	3.9	8.9	13.3	10.2	13.8
Y	17	12.5	4.1	12.6	16.8	13.3	10.7	12.6	5.4	12.3	10.2	10.4
Sc	3.8	4.7	3	~2.69	6.6	9.2	6	6.25	5	9.1	5.5	4.7
Cr	10.3	11.5	n. d.	~1.86	~4.2	4.7	4.5	4.5	<1	14.4	5.5	3.2
Sr	39	412	182	83	350	316	530	430	300	710	600	380

4th continuation of App.

	Tonalites (Suchý)	*Gneisses* (Malá Magura)							*Gneisses* (Suchý)			
	V-41	V-10	V-15	V-19	V-44	V-46	V-47	V-52	V-25	V-26	V-27	V-28
SiO_2	72.37	70.58	60.33	67.44	67.90	67.20	68.91	67.52	70.23	62.05	63.05	65.90
TiO_2	0.29	0.33	0.96	0.79	0.83	0.75	0.62	0.66	0.60	0.78	0.80	0.74
Al_2O_3	14.83	15.76	17.32	15.65	14.28	15.06	14.48	15.22	13.13	16.60	17.33	15.85
Fe_2O_3	0.83	0.80	1.21	1.43	2.26	0.85	1.77	1.15	2.57	2.20	2.08	2.31
FeO	1.08	1.68	6.21	4.29	3.50	3.92	2.65	3.41	3.12	4.31	3.03	2.58
MnO	0.04	0.03	0.13	0.09	0.10	0.10	0.10	0.10	0.08	0.12	0.08	0.10
MgO	0.58	0.60	3.76	1.81	2.24	2.21	1.97	1.87	2.54	2.71	2.31	2.52
CaO	1.42	2.24	2.21	1.59	1.69	2.73	2.93	1.75	0.97	2.31	2.02	2.18
Na_2O	4.37	4.69	2.54	2.92	2.83	3.43	2.69	3.84	2.53	3.83	4.36	4.16
K_2O	2.99	2.22	2.69	2.01	2.77	2.30	1.94	2.36	1.98	2.21	2.10	2.25
P_2O_5	0.08	n. d.	n. d.	n. d.	0.07	0.02	0.08	0.02	0.05	0.06	0.05	0.03
H_2O^+	0.94	0.81	1.11	1.39	0.86	0.87	0.73	1.27	1.23	1.99	1.07	0.87
H_2O^-	0.20	0.23	0.28	0.13	0.13	0.15	0.11	0.26	0.45	0.48	0.46	0.52
Total	100.06	99.97	99.02	99.54	99.46	99.59	99.98	99.43	99.78	100.07	99.92	100.27
Rb	67	59	121	96	n.d.	n. d.	72	72	65	73	76	76
Ba	850	490	450	455	498	730	358	615	640	430	715	595
Be	~2.6	~1.7	~1.8	3.3	~1.8	~2.3	~2.5	~2.3	~2.2	~2.5	~2.9	~2.4
B	5.4	3.2	<2	6.6	4.8	7.1	4.5	7.8	7.4	8.4	6.5	4.9
Pb	18	23.4	13.8	13.5	16.6	14.8	12.6	14	11.3	12	21	11.3
Sn	~1.7	<1	4.3	5	3.7	4.2	~2.4	3.5	3.5	4.9	5.6	3.7
V	21	19	138	120	91	84	77	78	92	117	120	78
Cu	5.4	4.7	36	42.5	7.5	17	12.1	10.7	7.9	31	6.8	37
Ni	9	3.4	52	32	36	18	29	31.6	35.5	58	20	28.2
Zr	134	198	186	242	110	234	155	168	160	229	252	214
Co	4.3	27	26.3	15	23	10.3	11	12.4	17.4	22.9	9.2	10.4
Y	23.9	20.1	31.6	35	23.5	24.8	26.9	23.5	35	41.5	36	33.5
Sc	4	5.2	20.6	16.4	21.9	14.6	15.9	13.7	15.7	15.1	14.5	12.9
Cr	13.6	<1	73	41	66	88	86	76	88	96	76	82
Sr	200	220	219	222	214	318	325	251	99	178	214	168

5th continuation of App.

	Gneisses (Suchý)								
	V-29	V-30	V-31	V-33	V-37	V-38	V-39	V-42	V-43
SiO_2	65.63	74.32	64.35	65.95	70.20	67.43	72.31	71.21	70.15
TiO_2	0.71	0.46	0.72	0.54	0.84	0.74	0.57	0.67	0.47
Al_2O_3	15.01	13.36	16.41	16.25	12.85	15.17	13.14	13.91	16.37
Fe_2O_3	2.65	1.97	2.44	1.36	0.95	1.36	0.89	1.32	0.48
FeO	2.49	1.23	2.93	2.69	4.74	3.90	3.10	3.07	2.25
MnO	0.10	0.05	0.10	0.08	0.09	0.10	0.06	0.07	0.05
MgO	2.59	0.93	2.50	2.77	2.17	1.85	1.06	1.78	1.03
CaO	2.13	0.47	2.41	3.13	1.69	1.74	1.45	1.82	0.83
Na_2O	3.32	3.25	3.93	3.77	2.80	3.46	3.41	2.85	2.10
K_2O	3.37	2.02	2.52	1.80	2.43	2.39	2.25	1.75	4.55
P_2O_5	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.05	0.03
H_2O^+	0.98	1.15	0.98	1.18	0.60	0.95	0.99	0.90	1.25
H_2O^-	0.53	0.48	0.35	0.37	0.32	0.47	0.41	0.12	0.08
Total	99.79	99.83	99.97	100.19	100.21	99.99	99.99	99.81	99.86
Rb	98	63	78	49	87	89	66	64	122
Ba	870	810	890	525	655	840	890	500	1780
Be	~2.2	~2.5	~2.3	~2.3	~1.8	~2.3	~2.4	~2.2	~2
B	12.5	9.8	5.8	4.9	5.6	5.4	6.5	4.1	7.9
Pb	99	11.7	18.2	7	17.6	11.5	11.6	15.3	35.5
Sn	3.5	3.3	4.4	~1.7	3.2	3.2	3.2	~2.9	~2.6
V	79	63	81	71	98	93	90	79	36
Cu	35.5	5.6	16.5	11.6	28	25	45	47.5	58
Ni	28	23.7	42	43	30	30.5	24	30.2	14
Zr	190	138	182	160	288	220	190	229	229
Co	11.1	7.5	13.4	12.7	12	13.6	10.2	11.7	8.8
Y	35	25.7	26.3	22.4	30.8	36.5	27.2	35	20.6
Sc	12.9	9.1	11.7	10.1	15.7	13.3	10.9	11	10.5
Cr	69	46	63	68	83	57	51	73	20
Sr	204	107	263	280	227	220	219	206	280

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Manuscript received February 13, 1990.