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The Karavanke Granitic Belt (Slovenia) – a bimodal Triassic alkaline plutonic complex

by Meta Bole[1], Tadej Dolenec[1], Nina Zupančič[1] and Breda Činč-Juhant[2]

Abstract

The rocks of the Karavanke Granitic Belt belong to a bimodal magmatic association consisting of predominant syenogranite and syenite and contemporaneous mafic and intermediate rocks of alkaline character. Mafic rocks (gabbro, monzogabbro) represent about 20% of the whole massif, and range in size from decimetric microgranular enclaves to large decametric bodies. The intermediate rock types (monzodiorite, monzonite) show field, textural and chemical features suggesting that they have formed as a result of the interaction between felsic and mafic magmas. The porphyry syenite with rapakivi texture, which occurs in close spatial association with mafic enclaves, is interpreted as a piece of evidence for such interaction.

Although the rocks represent a continuous series, only minor part of the mafic rocks on one hand and acid rocks on the other hand could be reasonably presented as the product of crystal fractionation. Geochemical features suggest that the majority of the rock types were affected by the interaction of felsic and mafic magmas.

Geochemical character and age of the Karavanke Granitic Belt suggest its pertinence to the alkaline Western Mediterranean Magmatic Province (BONIN et al., 1987) of late Permian to Triassic age.

Keywords: alkali granite, mafic enclaves, magma mixing, rapakivi, Karavanke igneous zone.

1. Introduction

The intrusive magmatic rocks of the Karavanke Granitic Belt (Slovenia) represent a heterogeneous massif, consisting of predominant syenogranite and syenite with contemporaneous mafic and intermediate rocks of alkaline character. Dikes of porphyry syenite with K-feldspar rimmed by plagioclase (e.g. rapakivi texture) cut large mafic bodies. The area has been investigated by several authors (EXNER, 1971, 1976; FANINGER, 1976; MIOČ, 1983), who mostly described different types of rocks as differentiates of the same parental magma, which is unlikely due to the volume ratio of mafic to felsic rocks.

The association of mafic enclaves in granitic rocks are not uncommon. Different types of enclaves in intrusive bodies have been the object of many studies and were recently reviewed by DIDIER and BARBARIN (1991; and references therein). Enclaves have been interpreted as reworked xenoliths, restites, autoliths, disrupted fine-grained borders of the wall of the magma chamber, or blobs of mantle derived magma that intrude felsic, evolved magma. Among these types of enclaves, the "mafic microgranular enclaves" (MME) are generally considered as evidence for magma mixing, as the magma mixing model fits best with most of the main features of mafic microgranular enclaves (BONIN, 1991).

According to many authors, the formation of intermediate rocks as well as the rapakivi texture may be assigned to the interaction of mafic and felsic magmas (FOURCADE and ALLEGRE, 1981; HIBBARD, 1981; REID et al., 1983; BUSSY, 1990; CASTRO et al., 1990; DIDIER and BARBARIN, 1991 and references therein; EKLUND et al., 1994; SALONSAARI and HAAPALA, 1994; RÄMÖ and HAAPALA, 1995 and references therein; BELLIENI et al., 1996; CHAPPELL, 1996).

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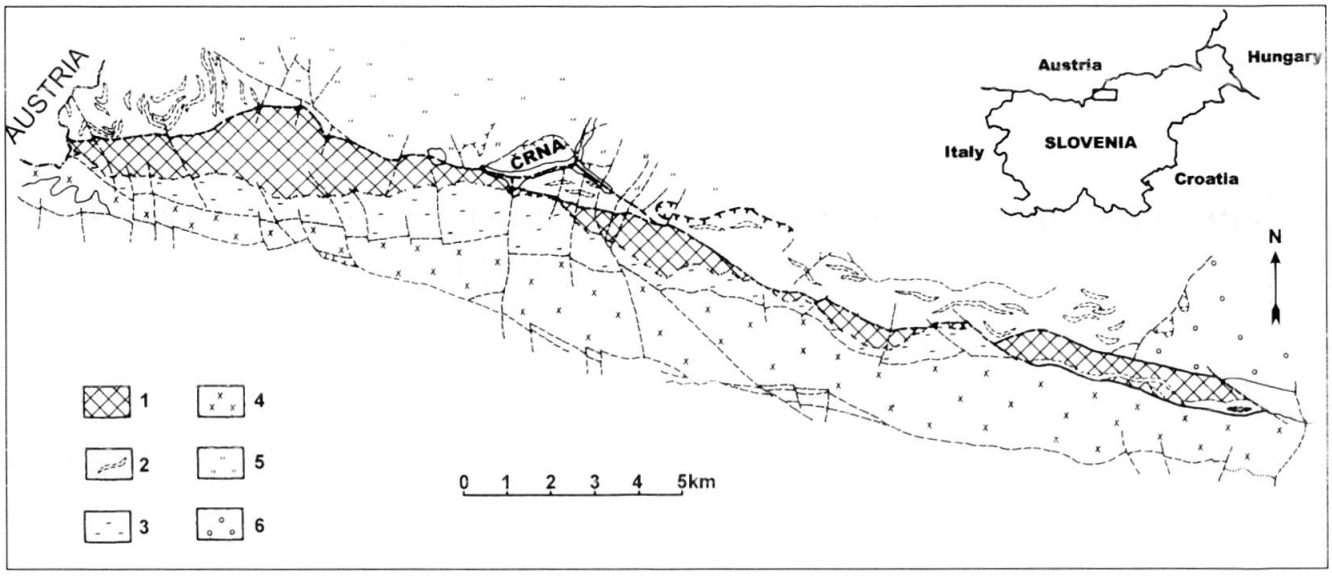


Fig. 1 Geological sketch map of the Karavanke Igneous zone and the investigated area (simplified after MIOČ and ŽNIDARČIČ, 1978). 1 = granitic belt, 2 = Paleozoic green schist with diabase lenses, 3 = fine grained gneiss, 4 = tonalite, 5 = Triassic dolomite, 6 = Miocene conglomerate.

In this work, new field, petrographic and geochemical data on rocks of the Karavanke Granitic Belt (KGB) are presented and a possible model for the genesis and evolution of this magmatic suite is proposed.

2. Geological setting and previous work

The central Karavanke magmatic zone consists of two parallel elongated massifs, the Northern Karavanke Granitic Belt (hereafter Granitic Belt), which is the object of the present paper, and the Southern Tonalitic Belt, related to a distinct magmatic event (FANINGER, 1976). The massifs are separated by a thin belt of metamorphic rocks (Fig. 1). The Karavanke magmatic zone lies along the Periadriatic lineament, and outcrops mainly in the northeastern part of Slovenia and partly in the Austrian area, where it is represented by the "Eisenkappel (Karawanken) Granite" and "Karawanken Tonalite Gneiss". It extends for about 35 km from the Slovene–Austrian border on the west to the Tertiary sediments of the Pannonic basin near Plešivica to the east.

The Granitic Belt is bordered by Paleozoic phyllitoid shales with diabase dikes and Triassic dolomite to the north and by a metamorphic complex to the south (MIOČ and ŽNIDARČIČ, 1978; MIOČ, 1983). Metamorphic xenoliths are common near the contacts with the country rocks. Granite intrusion caused contact metamorphism in the surrounding pelitic and quartzo-feldspathic rocks on the northern and the southern side of the massif (EXNER, 1971; HINTERLECHNER-RAVNIK, 1978). Both contacts have later been tectonized. The contact to Triassic dolomite is tectonic.

The succession from mafic to felsic rocks of the Granitic Belt has been interpreted as the result of the evolution of the same parental magma during crystallization (EXNER, 1971, 1976; FANINGER, 1974). The porphyry syenite with rapakivi texture which appears as dikes separating diorite and granite, is considered to be a rock of mixed origin produced in the reaction zones (EXNER, 1971). Magmatic breccias with sharp-cornered fragments of ultramafic rocks inside porphyry syenite suggest that mafic rocks are older than granite, wich is consistent with the differentiation series. Ultramafic fragments from magmatic breccias consist of predominant olivine (60%), partly amphibolized clinopyroxene, brown amphibole and phlogopite (all three minerals 30%), with smaller amounts of calcium feldspar (5%), magnetite, ilmenite and pyrite (5%), representing mantle rocks, crystallizing in lower crust or upper mantle (HINTERLECHNER-RAVNIK, 1988/89).

The stratigraphic age of the Granitic Belt was long a matter of debate. ISAILOVIĆ and MILIĆEVIĆ (1964) found blocks of metamorphic rocks, impregnated by granite inside the tonalite massif, which suggests that the Granitic Belt is older than the Tonalitic Belt.

ŠTRUCL (1970) and FANINGER (1974) date the Granite Belt as Variscan on the stratigraphic basis that the granite intrusion caused contact metamorphism on Paleozoic phyllitoid shales. The Tonalite Belt is of Alpine age. Radiometric data

show that the Granite Belt is of Triassic age. According to LIPPOLT and PIDGEON (1974), the rocks of the Granitic Belt yielded ages of 227 ± 7 Ma measured on biotite (K/Ar), 244 ± 8 Ma on hornblende (K/Ar) and 230 ± 5 Ma on titanite (U/Pb). SCHARBERT (1975) obtained approximately the same ages of 224 ± 9 Ma and 216 ± 9 Ma, dating the biotites of "granodiorite porphyry" with the Rb/Sr method. It is worth noting that according to her description, the analyzed "granodiorite porphyry" fits the petrographic character of the rocks that we would here classify as "porphyry syenite". An initial $^{87}Sr/^{86}Sr$ isotopic value of 0.71437 was obtained on a porphyry syenite (corrected for 220 Ma) (DOLENEC, 1994). The value suggests a crustal origin for the felsic magma.

The alkaline Permo-Triassic igneous activity with ages around 270–200 Ma of the Briançonnais and Acceglio zone in the French and Italian Western Alps, and the Monzoni-Predazzo plutonic-volcanic complex, Italy (FERRARA and INNOCENTI, 1974; BONIN et al., 1987 and references therein), corresponds to the period immediately preceeding the breakup and fragmentation of the Pangean continental block. BONIN et al. (1987) propose to name this collection of alkaline massifs of Permo-Triassic age, the Western Mediterranean Province.

3. Field relationships, petrography and mineral chemistry

The Granitic Belt is mainly composed of syenogranite and syenite with contemporaneous mafic and intermediate rocks which constitute about 30% of the whole massif. They range from decimetric, rounded enclaves, to large, decametric bodies. The shape of the large mafic bodies is not clearly recognizable due to the presence of soil and vegetation. Small mafic enclaves are medium to fine grained, with sharp contact to the syenogranite. In the vicinity of the enclaves, K-feldspar megacrysts of the host syenogranite are mantled by plagioclase. Large bodies of mafic rocks are occasionaly cut by veins of porphyry syenite with rapakivi texture. In some of the intermediate rocks quartz ocelli are observed. Intrusive breccias with obvious penetration of K-feldspar megacrysts from felsic into mafic magma are present as well. Features like quartz ocelli, plagioclase mantled K-feldspar and intrusive breccia indicate that some interaction between mafic and felsic magmas has occurred.

Sampling has been carried out with the aim of collecting the various lithologies which make up the Karavanke Granitic Belt. Rocks have been classified on chemical basis, following the BELLIENI et al. (1995) proposal. Further distinctions were based on field relationships and petrographic texture.

According to BELLIENI et al. (1995) proposal (Fig. 2) mafic rocks range from gabbro (or diorite) to monzogabbro (or monzodiorite). Intermediate rocks are represented by monzonite, whilst felsic rocks range from syenite ($61\% < SiO_2 < 69\%$) to syenogranite ($SiO_2 > 69\%$). In the DE LA ROCHE et al. (1980) classification diagram (Fig. 3), mafic and intermediate rocks range from: olivine gabbro, syeno gabbro, syeno diorite to monzonite, whereas the composition of felsic rocks falls along the line which separates quartz monzonites from syenite and quartz syenite as well as granite from alkali granite. The analyzed rocks belong to an alkaline series (Fig. 2). The higher abundance of K_2O than that of Na_2O (Tab. 1) indicates that, according to ZANNETIN (1986), these rocks belong to a potassic series.

It is worth noting that some authors (EXNER, 1971, 1976; FANINGER 1974, 1976; LIPPOLT and PIDGEON, 1974; SCHARBERT, 1975; MIOČ, 1983) assigned rocks of the Karavanke Granitic Belt as "gabbro, diorite, granodiorite, granite" and thus obscurred the true alkaline nature of those rocks.

3.1. MAFIC AND INTERMEDIATE BODIES

Gabbro is a fine to medium grained rock containing normal to alkaline amphiboles (Mg-hornblende and edenite after LEAKE et al. (1997)), plagioclase (An_{45-70}) (Tab. 2) orthopyroxene (Fs_{22-31}), and olivine (Fo_{73-79}). Sometimes hornblende replaces pyroxene, or forms wormlike overgrowths with pale green pyroxene. In some samples, there are two generations of hornblende. The first generation is brown (edenitic composition), euhedral, while the second generation forms green (Mg-hornblende), fine grained, polycrystalline agregates. Anhedral plagioclase grains show deformed twin lamellae. The accessory minerals are apatite in long needles, titanite, zircon, opaque minerals, and secondary epidote.

Monzogabbro and Monzodiorite are fine to coarse grained rocks, containing normal to alkaline amphiboles (Mg-hornblende and edenite), plagioclase, biotite and clinopyroxene of diopsidic composition ($Wo_{48}En_{35}Fs_{17}$). Two generations of hornblende were recognized. The older one is brown (edenite), whilst the younger is green (Mg-hornblende). In monzodiorite, green hornblende sometimes contains a brown core. Hornblende is partly transformed to actinolite and altered to chlorite. Plagioclases are euhedral, elongated,

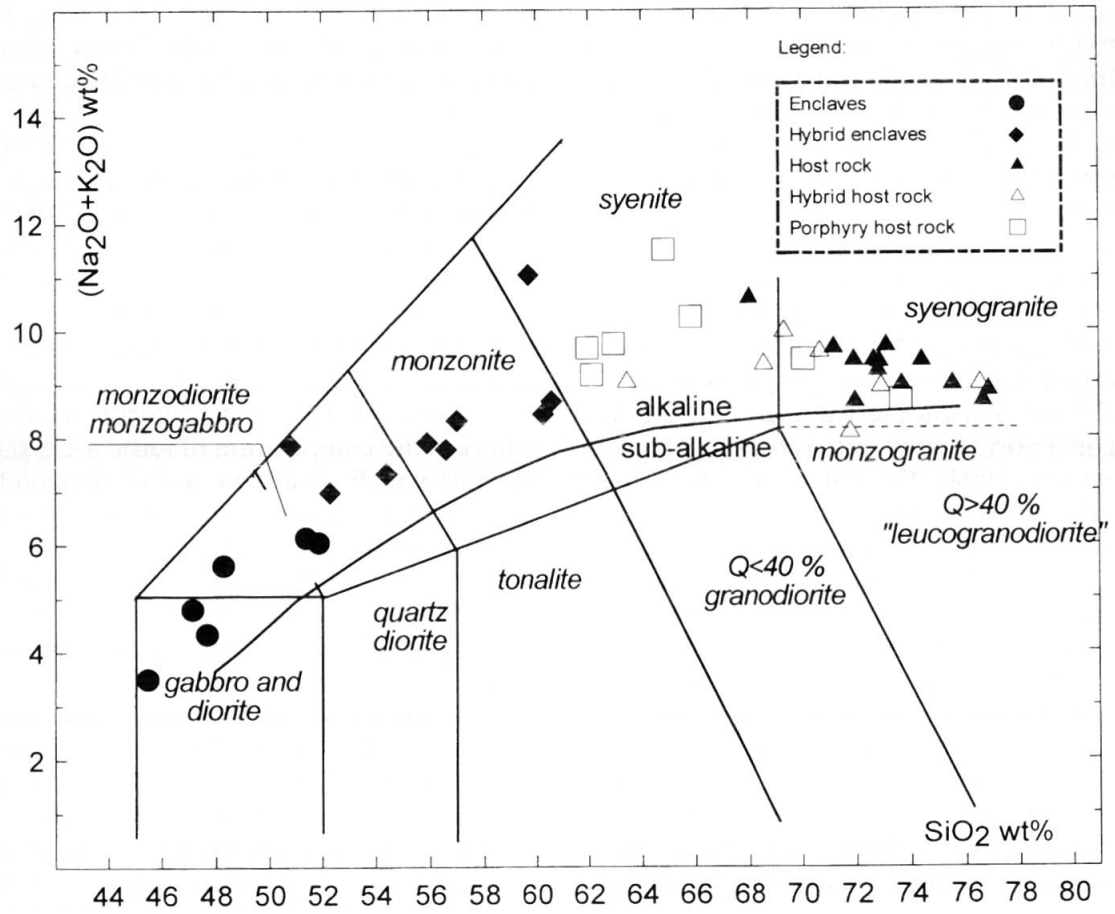


Fig. 2 Classification of KGB rock types (BELLIENI et al., 1995). Alkaline-subalkaline border from MIYASHIRO (1978). Values recalculated to $Sum_{Ox} = 100\%$.

normally zoned (An_{47-28}), with core altered to sericite. K-feldspar is present only in one sample of monzodiorite, in wormlike overgrowths with plagioclase. Anhedral titanite prevails among accessory minerals, and apatite, opaque minerals, secondary epidote and carbonate occur as well.

Monzonite is a fine grained rock, consisting of plagioclase (An_{30}), K-feldspar, quartz of two generations, Mg-hornblende and biotite. In some samples, biotite replaces hornblende. Quartz of the first generation forms rounded grains, surrounded by hornblende and biotite, sometimes together with clinopyroxene or plagioclase. Such structure has been described in literature as quartz ocelli (BLUNDY and SPARKS, 1992). The second generation of quartz is fine grained and corrodes phenocrysts of the first generation and fills the veins and fissures in plagioclase. Monzonite contains about 1–2% of accessory apatite and zircon, secondary epidote, carbonate and opaque minerals also occur. Hornblende and biotite are often altered to chlorite.

3.2. HOST ROCKS

Syenogranite is a fine to coarse grained rock. It contains plagioclase (An < 3%), K-feldspar and quartz of two generations, biotite, and hornblende. Plagioclase of the first generation forms euhedral crystals, with inclusions of very small, optically undetermined minerals, indicating disturbances in their growth. They also appear as inclusions in K-feldspars and are mostly altered to sericite. The second generation is less altered, and often grows on crystals of the first generation with the same optical orientation and composition. The first generation of K-feldspar is represented by euhedral (up to 30 mm in coarse grained syenogranite) crystals of perthite or microcline-perthite, containing inclusions of plagioclase, quartz and biotite. The second generation is represented by fine grained microcline. At the contact between K-feldspar and plagioclase, micromyrmekite structure is observed. Quartz of the first generation forms rounded grains and small inclusions in K-feldspars. The second generation is fine grained, and fills intergranular space and

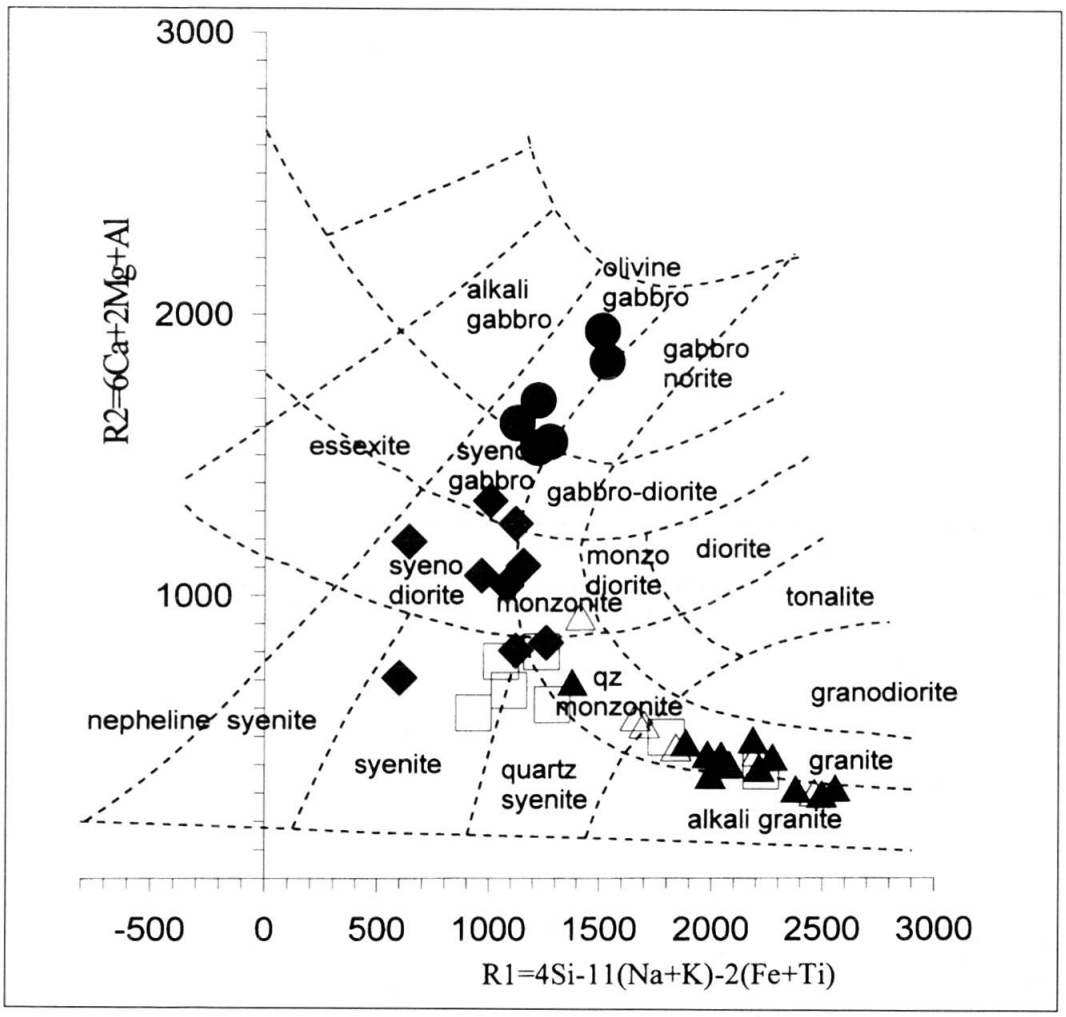


Fig. 3 Classification of KGB rock types (DE LA ROCHE et al., 1980). Symbols as in figure 2.

fissures. Biotite (annite 80–60%) and hornblende are euhedral. Hornblende rims are usually corroded by later phases (mostly quartz). In most samples, hornblende is altered to chlorite. In all felsic rocks, accessory minerals are very rare (< 0.5%) and consist of apatite, zircon and secondary epidote, allanite and clinozoisite.

Syenogranite and syenite containing muscovite differ from syenogranite because of muscovite growing in plagioclase cleavage cracks. Also plagioclase is more calcic (An_{16}). The space between grains of the first generation minerals is filled by wormlike overgrowth of plagioclase, K-feldspar and quartz of the second generation.

Porphyry syenite has fine grained matrix of anhedral plagioclase, hornblende, biotite, K-feldspar and quartz. Phenocrysts consist of biotite (annite 60–50%), plagioclase (An_{15-20}), quartz and euhedral perthitic K-feldspar (Or_{90}), usually rimmed by wormlike overgrown plagioclase (An_{20}) and quartz (Tab. 3). Euhedral K-feldspar mantled by plagioclase (oligoclase) represents rapakivi texture *sensu stricto* (RÄMÖ and HAAPALA, 1995). The cellular growth of plagioclase and infilling of voids with quartz may be a consequence of magma mixing (HIBBARD, 1981). Phenocrysts of ferrous hornblende occur as well. Accessory minerals like needles of apatite, zircon, secondary epidote, allanite and clinozoisite, and opaque minerals are very abundant (approx. 3–4%). In porphyry syenites with less then 64% of SiO_2 content, clinopyroxene is present in the matrix.

4. Geochemistry

For almost all major and some trace elements, rocks of the Karavanke Granitic Belt (Tab. 1) define a continuous trend with increasing differentiation index (D.I.) (THORNTON and TUTTLE, 1960).

Variation diagrams (Fig. 5) of major elements vs. D.I. show that the rocks of the Karavanke Granitic Belt define smooth negative trends for MgO, CaO, MnO, TiO_2 and FeOt and positive for SiO_2. Na_2O and P_2O_5 tend to increase up to the intermediate D.I. values and decrease for higher D.I. Al_2O_3 remains constant, for D.I. < 80 and decreases at higher D.I. values. Note that, mainly for felsic

and intermediate rocks with D.I. > 60, Na_2O, K_2O and P_2O_5 show a wide range of values for rocks with similar degrees of differentiation.

Such dispersion of values is particularly evident in the trace elements vs. D.I. diagrams, where the contents of many trace elements (Y, Zr, Nb, Nd, Ce, La) of felsic and mafic rocks are similar (Fig. 6). Nevertheless, Zr, Nd, Ce, La, Ba show an overall positive correlation for mafic rocks, and a negative correlation for felsic rocks, whereas the rocks of intermediate composition show a wide range of values for these elements.

All rocks show a strong fractionation of LREE ($(La/Sm)_N$=2.38–8.48), which increases from mafic to felsic rock types (Fig. 7). HREE are slightly fractionated ($(Gd/Yb)_N$= 0.75–2.81) in the mafic rocks and almost not fractionated ($(Gd/Yb)_N$= 0.69–1.34) in the felsic rocks. All rocks except gabbro show a moderate to strong negative Eu anomaly (Eu/Eu*=0.24–0.99), which tends to increase from mafic to felsic samples. Only a few samples of porphyry syenite and syenogranite show a positive Eu anomaly (Eu/Eu*=1.10–2.03).

5. Discussion

Several features, observed in the Karavanke Granite Belt indicate that some rock types were formed by the interaction of felsic and mafic mag-

Tab. 1 Major (wt%), trace element (ppm) and REE (ppm) data for KGB rock types. Major, trace and RE elements were determined at Actalab, Canada. ICP was used for major elements wilst INAA and ICP-MS for trace and RE elements.

	Host rock (syenogranite and syenite)												
SAMPLE	G5d	G8c	G8a	G8b	G5e	G16	G18a	G18gr	G18b	G15a	G1i	G1f	G24b
SiO_2	75.16	75.16	73.84	73.63	72.85	72.65	72.33	71.28	71.24	70.71	70.64	69.19	65.77
TiO_2	0.13	0.09	0.13	0.18	0.21	0.26	0.25	0.35	0.34	0.27	0.31	0.31	0.36
Al_2O_3	12.51	12.60	13.75	13.30	13.83	14.30	14.10	14.13	14.36	13.43	13.97	14.38	14.17
FeOt	1.15	0.91	1.16	1.31	1.61	1.87	1.76	2.50	2.10	2.06	1.86	2.05	2.17
MnO	0.03	0.02	0.03	0.02	0.05	0.06	0.05	0.06	0.06	0.06	0.05	0.06	0.05
MgO	0.22	0.18	0.12	0.02	0.29	0.36	0.35	0.54	0.48	0.48	0.49	0.42	0.67
CaO	0.35	0.15	0.85	0.25	1.11	0.76	0.44	1.51	1.02	1.10	0.69	1.35	3.19
Na_2O	3.93	4.21	4.11	4.12	3.96	4.41	4.52	4.11	4.39	4.23	4.39	4.25	4.83
K_2O	4.57	4.46	5.24	4.63	4.91	4.97	5.07	4.47	4.95	4.95	4.58	5.15	5.42
P_2O_5	0.04	0.03	0.03	0.07	0.08	0.10	0.10	0.14	0.14	0.11	0.13	0.12	0.17
LOI	0.51	0.50	0.42	0.81	0.47	0.78	0.77	0.52	0.69	1.14	0.86	0.57	2.78
sum	98.72	98.33	99.72	98.21	99.52	100.74	99.93	99.86	98.55	98.73	97.09	96.41	99.73
Ba	130.60	179.90	251.70	138.10	264.10	263.60	235.40	356.10	260.20	248.20	271.90	257.90	295.20
Cs	4.30	4.80	16.20	6.60	12.30	10.20	5.30	14.30	6.10	5.20	4.00	5.90	4.10
Ga	17.00	17.00	20.00	20.00	17.00	17.00	17.00	20.00	19.00	18.00	17.00	20.00	17.00
Hf	4.20	3.40	4.60	5.50	3.90	4.90	5.20	5.90	5.50	5.90	4.90	5.50	5.80
Nb	46.00	31.10	32.40	37.30	27.80	26.60	30.40	35.00	39.50	31.20	30.50	32.20	32.10
Ni	54.00	43.00	38.00	44.00	32.00	19.00	23.00	58.00	75.00	33.00	15.00	43.00	46.00
Pb	5.00	5.00	18.00	11.00	12.00	6.00	7.00	17.00	9.00	7.00	5.00	15.00	41.00
Rb	244.20	245.90	286.20	257.20	236.60	227.10	215.90	223.70	208.80	214.50	193.30	194.30	165.30
Sr	76.20	57.50	117.00	85.50	167.90	198.80	197.40	191.10	218.50	157.60	181.10	208.20	236.10
Ta	4.37	3.79	3.84	4.98	3.57	2.24	3.64	3.78	4.03	3.13	3.30	3.44	2.92
Th	37.84	27.89	30.44	46.13	24.99	31.23	27.10	26.65	33.30	30.00	29.43	27.60	24.03
Tl	0.80	1.30	1.90	2.10	1.60	1.30	1.10	2.70	0.70	0.70	0.40	0.80	2.10
V	18.00	17.00	18.00	33.00	20.00	19.00	28.00	20.00	28.00	28.00	32.00	27.00	25.00
W	5.70	6.50	6.60	6.50	10.20	2.10	3.80	5.00	3.00	4.90	3.60	4.50	2.80
Y	27.00	15.00	13.00	20.00	17.00	19.00	13.00	18.00	22.00	21.00	16.00	20.00	14.00
Zr	110.30	82.50	112.00	146.80	114.30	145.80	158.40	192.90	173.70	173.70	161.00	169.40	211.70
La	21.20	23.00	12.10	20.40	20.20	33.10	31.50	24.30	45.90	32.50	33.20	25.40	35.30
Ce	44.70	81.20	35.70	63.80	40.60	63.80	64.80	51.00	86.70	65.20	67.70	50.00	64.70
Pr	3.98	4.04	2.24	3.73	3.78	5.76	4.46	4.19	6.71	5.67	5.65	4.76	4.94
Nd	16.60	14.60	8.40	13.40	14.90	23.40	17.00	18.30	27.70	23.30	21.10	19.70	19.80
Sm	3.60	2.50	1.90	2.60	3.00	4.20	3.00	3.30	4.20	4.00	3.60	3.90	3.40
Eu	0.29	0.27	0.39	0.26	0.60	0.69	0.63	0.78	0.84	0.62	0.68	0.67	0.82
Gd	3.70	2.80	1.70	3.00	3.00	3.60	2.80	3.20	4.50	3.90	2.90	3.50	3.40
Tb	0.70	0.40	0.30	0.50	0.50	0.60	0.40	0.50	0.70	0.60	0.50	0.60	0.50
Dy	4.80	2.50	2.20	3.40	3.00	3.60	2.60	3.20	3.80	3.80	3.00	3.80	2.80
Ho	1.00	0.60	0.50	0.70	0.60	0.60	0.50	0.60	0.80	0.70	0.60	0.70	0.50
Er	3.50	1.90	1.60	2.40	1.80	2.00	1.60	2.00	2.50	2.30	1.90	2.20	1.50
Tm	0.55	0.30	0.30	0.40	0.32	0.31	0.24	0.31	0.33	0.34	0.28	0.36	0.23
Yb	3.80	2.30	2.00	3.20	2.10	2.30	1.80	2.60	2.70	2.70	2.20	2.50	1.70
Lu	0.64	0.38	0.31	0.53	0.35	0.35	0.30	0.38	0.44	0.41	0.34	0.39	0.25

ma: like K-feldspar megacrysts, with or without rapakivi rim (porphyry syenite); quartz ocelli (monzonite); the disturbances in plagioclase zoning (syenite containing muscovite); the high content of hornblende and biotite (high P_{H_2O}) (monzodiorite, monzogabbro); and the wide range of values for some major and most of the trace elements (rocks of intermediate composition) (HIBBARD, 1981; ZORPI, 1988; BUSSY, 1990; DIDIER and BARBARIN, 1991 and references therein; RÄMÖ and HAAPALA, 1995). Petrographic analyses show that in all porphyry rocks the matrix is more mafic and phenocrysts are more felsic, suggesting that felsic phenocrysts were introduced into mafic magma. The rapakivi texture, K-feldspar with oligoclase rim forming a wormlike overgrowth with quartz observed in porphyry rocks indicates the intrusion of partly crystallized granitic magma containing K-felspar megacrysts into a more mafic magma (HIBBARD, 1981; BUSSY, 1990).

In monzonite, quartz ocelli are surrounded by fine grained hornblende, pyroxene and biotite. According to VERNON (1991), this indicates the hybrid nature of the magmas. The instability of quartz grains introduced into mafic magma causes melting of the xenocryst rims. The melting uses latent heat of crystallization from adjacent melt. This localy increases the undercooling and nucleation rate, which causes the formation of fine grained aggregate of minerals that are saturated in the crystallizing magma. Such structures form during rapid cooling. When the cooling rate is lower, quartz precipitates from the evolved and modified melt, and forms the overgrowths with

Tab. 1 (cont.)

	Hybrid host rock							Porphyry syenite						
SAMPLE	G6a	G17	G13b	G19	G25a	G23a	G13c	P24a	P3bd	P1g	P18e	P6b	P28a	P13gp
SiO_2	76.37	71.19	70.60	68.47	68.12	68.03	64.58	72.43	68.80	65.25	64.90	60.83	60.65	60.28
TiO_2	0.09	0.21	0.32	0.41	0.43	0.41	0.45	0.42	0.42	0.74	0.59	0.83	0.81	1.09
Al_2O_3	12.95	14.40	14.75	14.53	16.17	15.26	18.27	13.42	14.72	15.41	16.30	16.80	17.57	16.81
FeOt	1.00	2.12	3.12	2.50	2.97	1.97	3.4	4.53	2.65	3.84	2.14	4.82	4.71	3.46
MnO	0.02	0.05	0.04	0.05	0.05	0.03	0.05	0.02	0.07	0.07	0.13	0.10	0.07	0.10
MgO	0.17	0.30	0.62	0.60	0.64	0.50	0.64	0.53	0.60	1.00	0.91	1.34	1.34	1.40
CaO	0.19	0.60	0.92	1.07	1.61	2.02	4.99	0.75	1.57	2.38	2.04	2.28	3.45	3.23
Na_2O	4.14	3.96	4.81	4.34	4.81	4.55	4.99	4.71	4.63	4.73	4.86	5.33	4.90	5.24
K_2O	4.83	4.76	3.14	4.95	4.48	5.23	4.21	3.84	4.66	5.43	6.66	4.09	4.06	4.17
P_2O_5	0.03	0.12	0.09	0.07	0.07	0.16	0.15	0.13	0.16	0.28	0.25	0.38	0.36	0.40
LOI	0.45	0.74	0.96	1.00	0.95	0.79	0.98	0.67	0.72	0.60	0.36	1.42	0.72	0.51
sum	99.15	95.72	99.65	98.27	100.72	99.10	100.15	99.31	99.33	100.22	98.31	98.56	95.71	94.51
Ba	164.50	174.60	196.60	328.40	362.80	415.50	329.70	365.20	335.70	349.50	264.10	390.30	529.80	431.10
Cs	5.20	4.00	2.00	3.70	4.30	2.20	4.10	2.30	4.30	6.60	22.80	5.30	3.50	3.30
Ga	19.00	18.00	20.00	20.00	19.00	18.00	22.00	16.00	20.00	24.00	25.00	24.00	23.00	23.00
Hf	3.60	6.90	6.90	6.40	3.20	4.90	8.60	5.10	5.40	6.60	11.00	10.40	10.50	6.30
Nb	31.30	18.30	21.50	34.80	15.30	18.50	19.70	20.50	32.50	38.60	65.20	55.90	32.90	48.30
Ni	56.00	32.00	51.00	31.00	27.00	34.00	37.00	37.00	50.00	41.00	34.00	46.00	34.00	35.00
Pb	5.00	26.00	19.00	17.00	12.00	6.00	16.00	12.00	18.00	14.00	16.00	17.00	9.00	15.00
Rb	260.30	127.70	92.70	171.40	136.70	117.40	104.60	90.50	163.90	163.40	381.00	150.40	106.30	103.80
Sr	60.40	104.00	203.50	247.70	371.70	529.70	279.10	276.20	287.70	321.80	237.30	462.00	507.00	446.10
Ta	4.43	1.20	1.46	3.07	1.13	1.10	1.26	1.65	2.46	3.10	5.51	4.03	2.27	2.59
Th	29.24	21.22	27.90	23.98	13.25	16.83	23.91	29.69	23.69	20.57	24.58	21.17	14.59	10.40
Tl	2.90	1.40	1.40	1.50	0.90	0.60	1.60	1.00	1.40	1.60	3.20	1.80	0.50	0.80
V	15.00	21.00	17.00	24.00	12.00	24.00	31.00	37.00	24.00	47.00	29.00	52.00	55.00	73.00
W	5.90	2.50	5.10	2.60	1.80	1.90	2.50	2.80	2.60	3.10	1.90	2.30	1.50	1.20
Y	14.00	8.00	12.00	17.00	10.00	13.00	16.00	8.00	20.00	21.00	28.00	38.00	21.00	21.00
Zr	78.70	251.50	218.70	213.10	93.00	168.70	342.50	166.40	182.30	218.00	408.40	359.80	385.90	250.10
La	15.50	54.80	40.50	26.00	18.30	26.30	64.70	29.10	43.20	34.00	43.50	32.10	47.00	35.80
Ce	51.30	100.60	86.80	52.70	36.50	50.70	116.80	51.70	84.70	68.40	93.80	75.90	88.90	75.60
Pr	3.13	7.84	6.71	4.50	3.21	4.24	9.06	4.04	7.23	6.30	7.99	7.66	7.72	6.88
Nd	11.20	29.90	26.00	20.40	14.00	19.00	34.00	15.20	28.60	27.80	34.00	37.00	32.10	31.00
Sm	2.10	4.00	4.10	3.90	2.40	3.30	4.80	2.30	4.50	5.10	5.80	7.60	5.60	5.80
Eu	0.26	0.52	0.53	0.91	1.56	1.18	1.06	0.93	1.07	1.36	0.97	1.50	1.58	1.46
Gd	2.10	3.50	3.70	3.60	2.20	3.10	4.70	2.30	4.50	4.80	5.80	6.90	5.20	5.40
Tb	0.30	0.40	0.50	0.60	0.40	0.50	0.60	0.30	0.60	0.70	0.90	1.30	0.70	0.80
Dy	2.20	1.70	2.50	3.20	2.00	2.50	2.80	1.80	3.80	4.20	5.30	7.10	3.90	4.40
Ho	0.50	0.30	0.50	0.70	0.40	0.50	0.60	0.30	0.70	0.80	1.10	1.40	0.70	0.80
Er	1.60	1.00	1.50	2.00	1.20	1.50	1.70	0.90	2.20	2.40	3.40	4.10	2.30	2.40
Tm	0.30	0.14	0.22	0.28	0.15	0.19	0.26	0.11	0.28	0.33	0.46	0.58	0.29	0.29
Yb	2.20	1.10	1.50	2.00	1.10	1.40	2.10	0.90	2.40	2.60	3.90	4.20	2.30	1.90
Lu	0.35	0.15	0.26	0.33	0.18	0.17	0.38	0.16	0.37	0.38	0.61	0.66	0.35	0.29

mafic minerals in xenocryst rims (VERNON, 1991; PLATEVOET and BONIN, 1991).

In most of the major elements vs. D.I. diagrams (Fig. 5), the rocks of the Karavanke Granitic Belt form a continuous series. The most mafic rock sample (D.I. < 25 – olivine gabbro) is enriched in MgO and depleted in CaO and Al_2O_3 with respect to the mafic series. The deviation can be explained by small amount of olivine cumulation in the sample.

In the trace elements vs. D.I. as well as in the P_2O_5 and TiO_2 vs. D.I. (Figs 5, 6) we observe strong dispersion of values for rocks of intermediate composition. On the other hand the content of most trace elements is similar for mafic and felsic rocks (Y, Zr, Nb, Nd, Ce, La, Ba), increasing in mafic series towards intermediate rocks values and decreasing in felsic series. The behaviour of trace elements indicates the bimodal composition of the complex, with different magma source for felsic and mafic magmas. The dispersed values of trace elements in rocks of intermediate composition are due to different stages of interaction of felsic and mafic magma. The enrichment of trace elements (Y, Zr, Nb, Nd, Ce La, Ba) in the intermediate rocks, to values higher then in mafic or felsic rocks, may be explained by the fact that high-charge-density (HCD) cations are preferably partitioned into the mafic part of the coexisting mafic and felsic magmas (EBY, 1983). The sample with D.I. of 54 is particularly enriched in Cs, Zr, Nb, Nd, Ce, La, Sr and P_2O_5, due to high content of accessory minerals – titanite and apatite.

Tab. 1 (cont.)

	Hybrid enclaves									Enclaves					
SAMPLE	M27a	M4a	M27c	M13Cb	M1c	M13Ba	M28f	M13Ca	M19a	M21a	M13d	M1a	M2a	M28e	M101k
SiO_2	58.60	58.50	58.19	56.60	55.35	55.22	53.22	51.11	49.67	50.19	49.32	46.58	46.25	46.17	43.70
TiO_2	1.07	1.07	1.06	2.40	1.64	2.11	1.63	2.51	2.64	2.06	2.21	2.30	4.12	2.62	1.79
Al_2O_3	16.99	17.71	16.26	14.64	16.49	17.59	17.22	16.38	16.37	17.56	16.22	16.93	16.09	15.96	10.30
FeOt	7.03	5.53	6.51	8.22	7.59	7.39	8.11	9.12	10.30	7.83	8.50	9.22	10.99	10.53	
MnO	0.11	0.13	0.13	0.16	0.17	0.13	0.16	0.15	0.23	0.15	0.15	0.14	0.15	0.17	0.18
MgO	1.35	1.30	1.70	3.36	2.55	2.37	3.20	4.07	4.41	4.17	5.58	6.77	5.72	6.06	17.80
CaO	3.56	2.63	3.69	5.36	5.90	5.56	6.83	7.31	5.84	8.83	8.12	11.47	9.92	8.67	6.28
Na_2O	5.59	5.00	4.27	3.97	4.38	5.28	4.22	4.27	4.44	3.96	3.76	2.69	3.13	3.28	2.17
K_2O	2.62	5.82	4.07	4.29	3.23	2.54	2.95	2.55	3.25	1.89	2.13	1.55	1.58	2.09	1.19
P_2O_5	0.52	0.42	0.44	0.36	0.67	0.72	0.47	0.49	0.87	0.40	0.36	0.26	0.35	0.51	0.30
LOI	1.58	1.04	0.96	0.76	0.76	1.01	1.24	0.51	0.94	1.76	1.40	1.93	1.18	2.21	0.85
sum	99.59	99.63	97.91	100.98	99.38	100.67	99.96	99.25	91.20	99.90	90.65	100.63	100.47	99.54	98.30
Ba	263.80	484.80	409.90	263.70	375.00	575.10	301.30	274.80	350.30	264.50	236.30	191.90	219.90	290.00	94.00
Cs	3.00	5.00	3.90	2.80	6.90	6.30	4.40	3.50	38.90	3.10	5.10	4.40	4.30	3.80	3.50
Ga	26.00	24.00	23.00	22.00	25.00	24.00	22.00	23.00	24.00	21.00	20.00	21.00	18.00	22.00	16.00
Hf	5.80	12.70	7.00	6.20	6.60	6.20	4.70	6.90	9.90	5.00	4.60	3.50	4.30	5.80	3.20
Nb	37.80	64.10	40.00	34.70	45.00	71.00	31.60	40.40	95.70	38.70	32.60	19.50	30.00	43.40	23.00
Ni	20.00	27.00	31.00	32.00	42.00	23.00	27.00	37.00	41.00	47.00	51.00	85.00	33.00	66.00	447.00
Pb	13.00	16.00	6.00	10.00	13.00	10.00	5.00	6.00	5.00	9.00	5.00	5.00	5.00	9.00	1.90
Rb	103.20	218.60	116.10	143.10	132.00	97.90	108.40	60.00	171.90	95.60	59.50	49.90	41.00	101.90	30.00
Sr	510.30	478.50	477.50	413.30	623.40	748.30	595.50	612.60	988.40	887.20	652.00	698.00	630.60	641.00	335.00
Ta	2.63	3.80	2.68	2.42	2.95	4.93	2.35	2.56	5.88	2.46	2.07	1.21	2.01	2.68	1.50
Th	13.41	15.56	13.40	15.24	15.58	11.85	10.75	7.44	6.73	5.06	4.80	2.66	3.80	4.77	3.70
Tl	0.90	1.90	0.70	1.60	2.00	0.70	0.60	0.50	2.10	1.20	0.40	0.30	0.10	1.20	0.09
V	46.00	41.00	57.00	222.00	109.00	141.00	210.00	228.00	165.00	203.00	228.00	276.00	343.00	271.00	205.00
W	2.90	2.00	2.90	2.40	1.90	2.40	4.50	1.70	2.10	2.00	0.60	1.00	0.60	2.70	0.90
Y	27.00	31.00	27.00	23.00	25.00	28.00	29.00	23.00	27.00	21.00	22.00	19.00	19.00	26.00	17.00
Zr	188.80	483.10	250.50	200.70	240.10	211.80	153.50	252.10	383.00	176.50	164.20	117.10	133.20	211.30	120.00
La	40.60	54.30	46.20	27.80	43.10	53.30	39.50	33.40	61.80	28.60	26.80	20.00	20.80	32.70	16.30
Ce	89.00	110.70	97.60	63.70	92.40	113.50	88.00	72.90	128.20	61.30	59.80	36.30	48.40	70.80	35.60
Pr	8.20	9.88	8.53	6.35	8.66	10.30	8.48	6.92	11.64	6.07	5.90	4.12	5.01	7.05	4.20
Nd	38.60	43.00	37.20	28.90	40.50	44.10	37.20	32.80	53.60	28.30	29.00	22.10	25.60	33.70	18.80
Sm	6.90	7.30	7.00	6.10	7.00	7.50	7.00	6.10	8.80	5.70	5.50	4.90	5.50	6.70	4.70
Eu	1.77	1.60	2.08	1.71	2.02	2.03	2.13	1.95	2.93	1.85	2.07	1.60	1.79	2.23	1.32
Gd	6.80	6.70	6.60	5.90	6.30	7.40	7.20	5.90	8.00	5.30	5.60	4.50	5.30	6.30	4.30
Tb	1.10	1.10	1.00	0.90	1.00	1.10	1.00	1.00	1.10	0.80	0.90	0.70	0.80	1.00	0.50
Dy	5.50	6.00	5.30	4.80	5.30	5.80	5.80	5.10	6.10	4.50	4.90	4.20	4.50	5.40	3.40
Ho	1.10	1.10	1.00	0.90	1.10	1.10	1.10	1.00	1.00	0.80	0.90	0.80	0.80	1.00	0.50
Er	3.00	3.40	3.10	2.60	2.80	3.10	3.20	2.60	3.10	2.30	2.60	2.00	2.20	2.80	1.70
Tm	0.37	0.50	0.38	0.31	0.36	0.42	0.41	0.30	0.35	0.26	0.27	0.22	0.24	0.33	0.10
Yb	2.70	3.70	2.60	2.40	2.40	2.90	2.80	2.40	2.30	2.20	2.00	1.50	1.80	2.30	1.20
Lu	0.34	0.54	0.45	0.32	0.40	0.40	0.41	0.33	0.40	0.34	0.29	0.26	0.23	0.32	0.06

Tab. 2 Representative microprobe analysis of feldspars from KGB rocks. c-core, r-rim. Mineral composition data were obtained using CAMECA Camebax 799 microprobe at CNR-Centro Studi per la Geodinamica Alpina -Padova. A PAP program (POUCHOU, 1984) was used to convert X-ray counts into weight percentages of the corresponding oxides. Structural formulae were calculated on 8 oxygen basis.

	syenogranite		porphyry syenite		mafic enclaves									
SAMPLE	G8c1	G8c2	P1g r	P1g c	M4b c	M4b r	M4b r	M19a c	M19a c	M19a c	M19a r	M19a r	M101k	M101k
SiO_2	69.42	68.02	65.01	64.66	59.49	65.31	59.23	61.4	58.13	57.38	62.28	60.93	51.14	51.06
TiO_2	0.01	0.01	0.04	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al_2O_3	20.02	20.18	22.53	22.38	25.02	23.46	26.14	24.96	26.53	26.46	24.12	25.37	31.7	30.95
Fe_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	0.07	0.07	0.17	0.10	0.15	0.11	0.06	0.12	0.35	0.31	0.27	0.08	0.00	0.00
CaO	0.08	0.16	3.69	3.69	6.92	0.77	8.18	6.34	8.87	8.68	5.91	5.27	14.62	14.01
Na_2O	11.14	10.73	9.11	9.03	7.21	8.46	6.82	6.02	6.31	6.03	7.86	7.37	3.18	3.67
K_2O	0.07	0.13	0.30	0.30	0.27	2.75	0.15	0.12	0.31	0.23	0.42	0.66	0.01	0.00
Ox_{Tot}	100.9	99.33	100.9	100.2	99.19	101	100.6	99.01	100.6	99.09	100.9	99.69	100.83	100.02
Si	2.997	2.982	2.841	2.844	2.673	2.852	2.63	2.732	2.593	2.592	2.742	2.708	2.308	2.324
Ti	0.000	0.000	0.001	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.019	1.043	1.160	1.160	1.325	1.208	1.368	1.309	1.395	1.409	1.251	1.329	1.686	1.660
Fe^{3+}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe^{2+}	0.003	0.003	0.006	0.004	0.006	0.004	0.002	0.004	0.013	0.012	0.010	0.003	0.000	0.000
Ca	0.004	0.008	0.173	0.174	0.333	0.036	0.389	0.302	0.424	0.42	0.279	0.251	0.707	0.683
Na	0.932	0.912	0.772	0.77	0.628	0.716	0.587	0.519	0.545	0.528	0.671	0.635	0.278	0.324
K	0.004	0.007	0.017	0.017	0.016	0.153	0.009	0.007	0.018	0.013	0.024	0.037	0.001	0.000
Cat_{tot}	4.961	4.956	4.972	4.969	4.985	4.977	4.984	4.877	4.991	4.974	4.979	4.964	4.985	5.003
An	0.40	0.83	17.82	17.99	33.82	3.91	39.43	36.21	42.27	43.17	28.31	27.07	71.54	67.73
Ab	98.81	98.03	79.65	79.74	63.72	78.24	59.45	62.19	54.41	54.28	68.14	68.57	28.12	31.97
Or	0.43	0.80	1.72	1.77	1.60	16.71	0.89	0.84	1.75	1.33	2.40	4.01	0.06	0.01

Tab. 3 Microprobe analysis of plagioclase mantled K-feldspar in porphyry syenite P1g. Measuring points 1–6 are located as shown in figure 4.

Measuring point No.	1	2	3	4	5	6
SiO_2	64.42	64.16	64.46	64.39	65.44	66.00
TiO_2	0.00	0.00	0.03	0.03	0.00	0.00
Al_2O_3	22.77	22.40	18.20	18.24	21.82	21.17
FeO	0.20	0.14	0.10	0.05	0.06	0.00
Fe_2O_3	0.00	0.00	0.00	0.00	0.00	0.00
CaO	4.21	3.92	0.04	0.06	2.89	2.25
Na_2O	9.02	9.15	0.44	0.45	9.70	10.41
K2O	0.35	0.30	15.59	15.59	0.19	0.06
Ox_{Tot}	101.1	100.2	98.93	98.83	100.1	99.93
Si	2.819	2.829	3.003	3.002	2.874	2.901
Ti	0.000	0.000	0.001	0.001	0.000	0.000
Al	1.174	1.164	0.999	1.002	1.129	1.097
Fe^{2+}	0.007	0.005	0.004	0.002	0.002	0.000
Fe^{3+}	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.197	0.185	0.002	0.003	0.000	0.002
Na	0.765	0.782	0.04	0.041	0.826	0.887
K	0.019	0.017	0.927	0.927	0.011	0.003
Cat_{tot}	4.986	4.987	4.979	4.98	4.979	4.995
An	19.86	18.70	0.19	0.32	13.95	10.62
Ab	77.05	78.92	4.12	4.21	84.65	88.96
Or	1.96	1.70	95.04	95.17	1.09	0.32

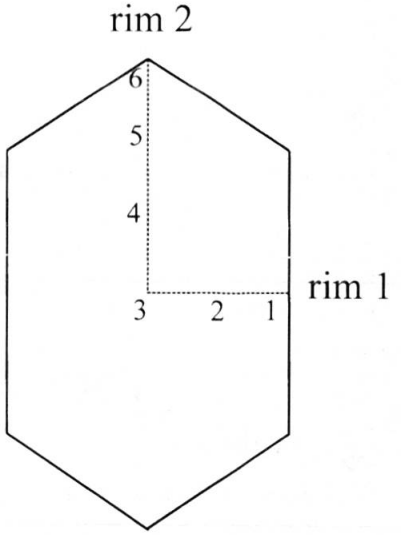


Fig. 4 Distribution of measuring points of microprobe analysis on plagioclase mantled K-feldspars in porphyry syenite.

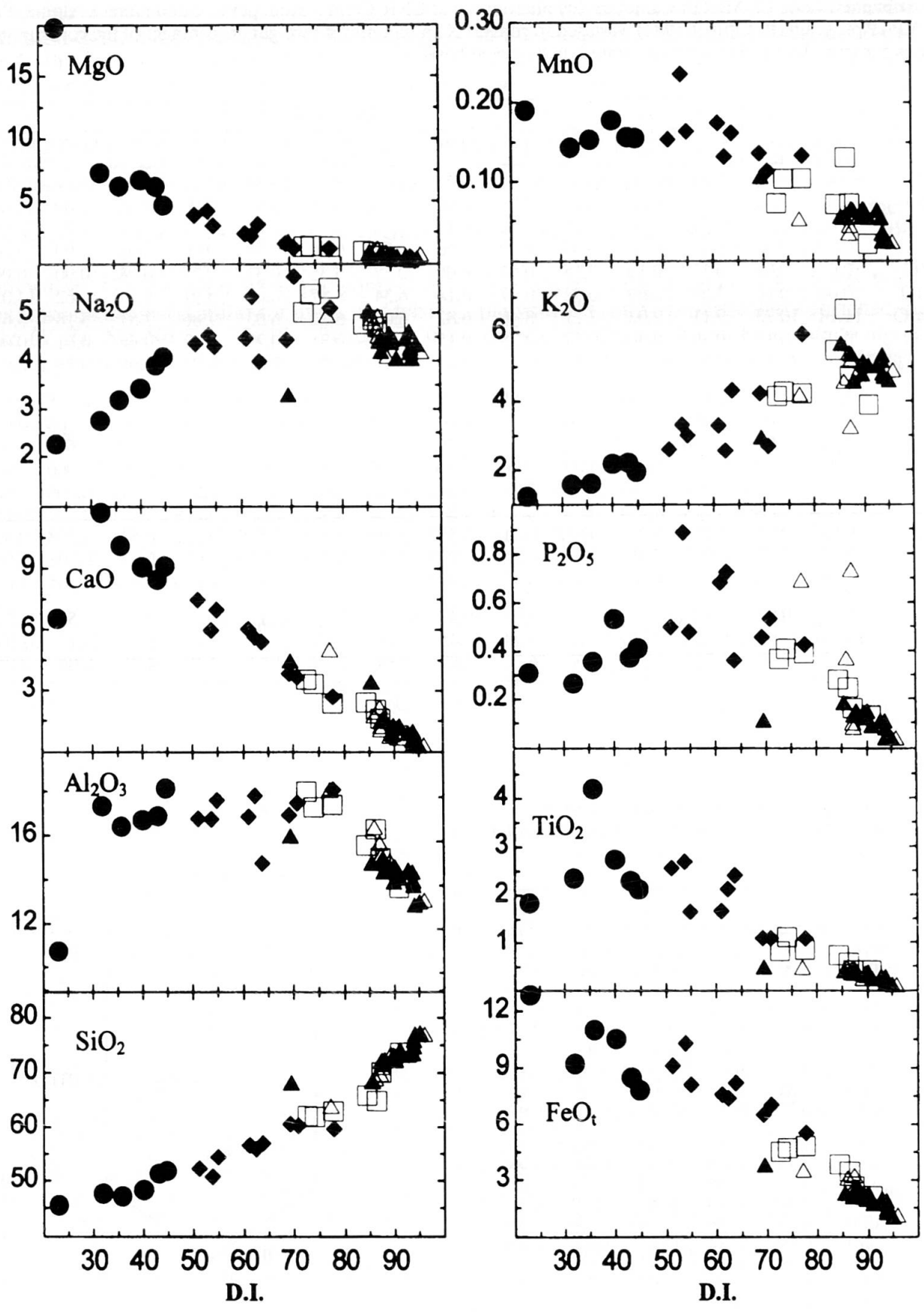


Fig. 5 Major elements (wt%) vs. D.I. for rocks of the KGB. FeOt as total FeO. Values recalculated to $Sum_{Ox} = 100\%$. Symbols as in figure 2.

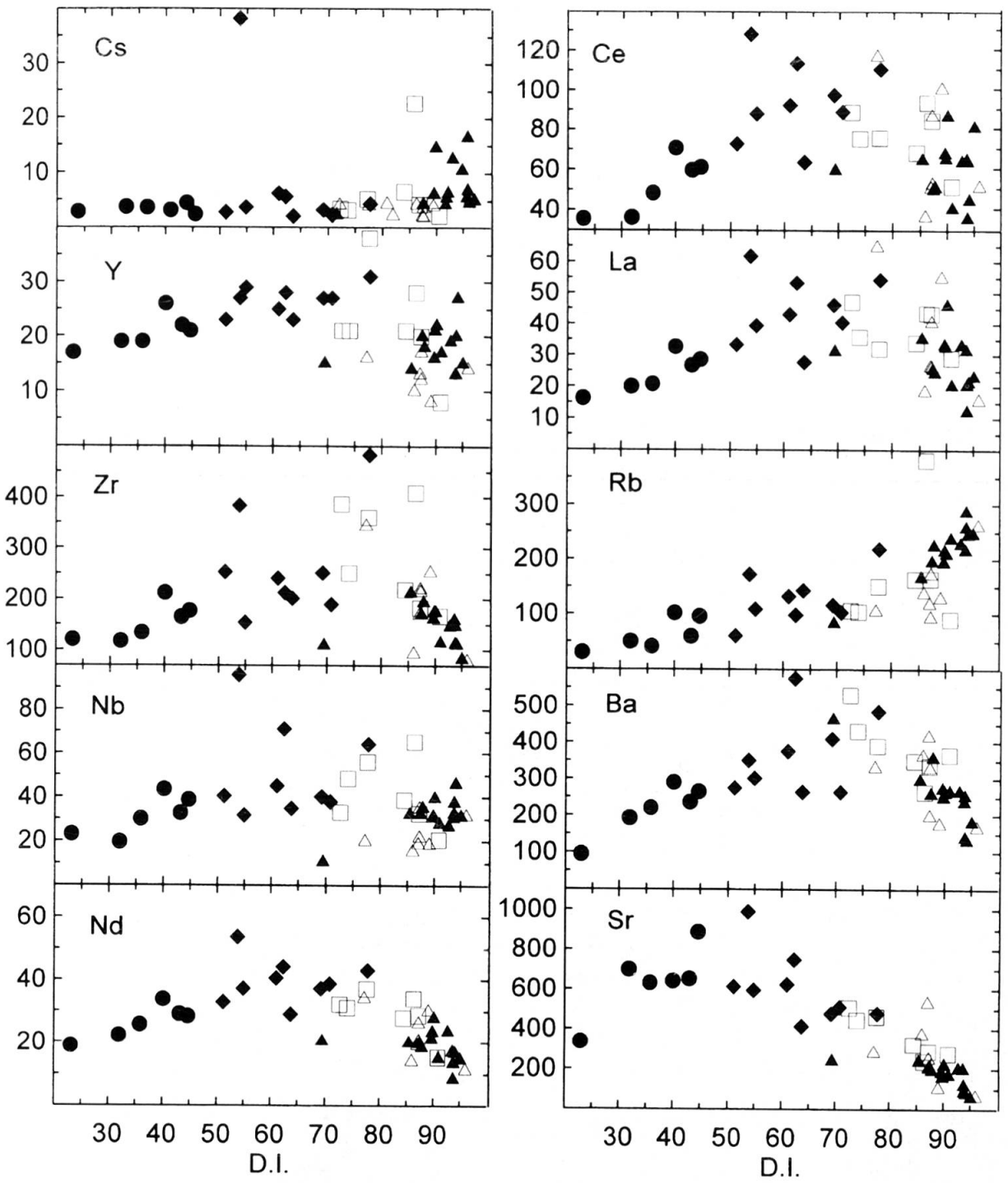


Fig. 6 Trace elements (ppm) vs. D.I. for rocks of the KGB. Symbols as in figure 2.

REE patterns (Fig. 7) also support the hypothesis of hybrid rock formation. The mafic and intermediate rocks with obvious signs of hybridization are enriched in REE with respect to the mafic rocks with no signs of hybridization. The enrichment is higher for HREE and lower for LREE. Mafic to intermediate hybrid rocks also show slight negative Eu anomaly (Eu/Eu* = 0.68 –0.97), wich is absent in non-hybrid mafic rocks (Eu/Eu* = 0.99–1.12). On the other hand felsic hybrid rocks are depleted in LREE with respect to non-hybrid felsic rocks and exhibit small negative to positive Eu anomaly (Eu/Eu* = 0.67–2.03) exept for three samples, with negative Eu anomaly similar to non-hybrid felsic rocks. In porphyry rocks, REE values are similar to non-hybrid felsic rocks values, but less fractionated in HREE part and exhibit smaller negative to slight positive Eu anomaly (Eu/Eu* = 0.62–1.22) with respect to non-hybrid felsic rocks.

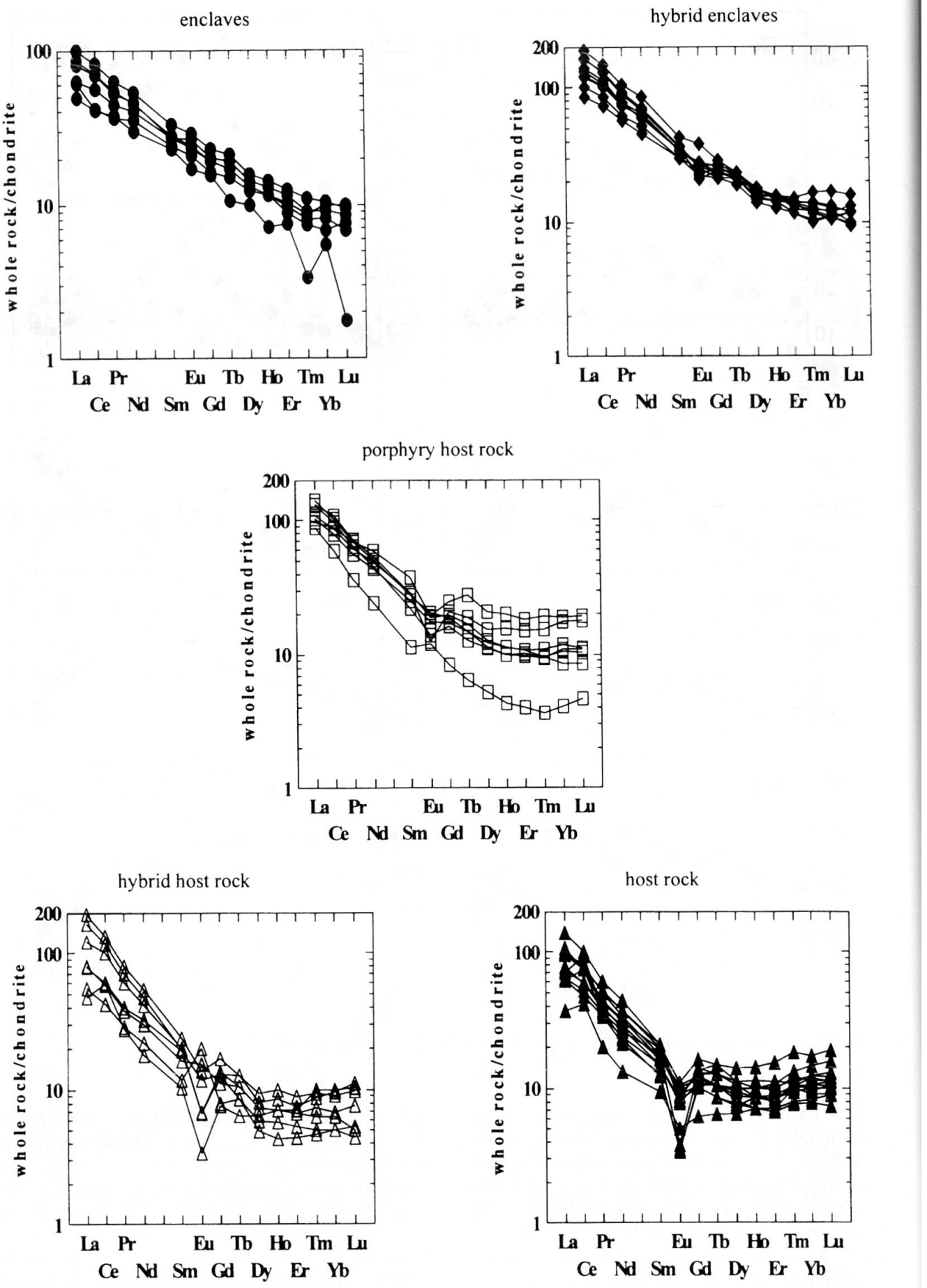


Fig. 7 Chondrite-normalized REE patterns for rocks of the KGB. Chondrite values from NAKAMURA (1974). Symbols as in figure 2.

5.1. MAFIC ROCKS

On the basis of field, petrographic and geochemical evidence we can devide the mafic rocks of the Karavanke Granitic Belt into two groups:

(1) the rocks without signs of hybridization (gabbro),

(2) hybrid rocks (monzogabbro, monzonite, monzodiorite).

Mineral and geochemical characteristics of the mafic rocks suggest the origin of the mafic magma in partial melting of the upper mantle. Relatively flat mafic rocks REE MORB normalized pattern from Nb to Yb (Fig. 8) indicate a common mantle source and the LIL enrichment is a relatively common feature in within-plate basalt provinces (BONIN 1990, 1997).

With respect to trace elements only some of the mafic rocks could be linked by the process of crystal fractionation. For La enrichment in mafic magma from 20.8 (M2a – the most mafic non-cumulative sample) up to 61.8 (M19a – the highest La value), about 72% of crystallization is needed, which would produce a residual liquid with SiO_2 content higher then 49.67%. Calculation was made for gabbro normative modal composition and mineral/melt partition coefficients from literature (ROLLINSON, 1993). The La enrichment might be reasonably explained by the process of crystall fractionation for the La value upto 28.6 (M21a – D.I. = 45). All other mafic and intermediate rocks probably underwent hybridization.

5.2. FELSIC ROCKS

Felsic rocks of Karavanke Granite Belt – syenogranite – are meta- to peraluminous (A/CNK = 0.85–1.2), transsolvus (mesoperthitic alkali feldspar + K-feldspar + albite) (BONIN, 1991, SHAND in CLARKE, 1992).

In the PEARCE et al. (1984) Rb/Y+Nb discrimination diagram for the tectonic interpretation of granitic rocks (Fig. 9), the pathway of non-hybrid mafic rocks could be ascribed to fractional crystallization of mantle derived magma, that would result in WPG field for felsic rocks. But felsic rocks of KGB plot in the vicinity of the WPG/

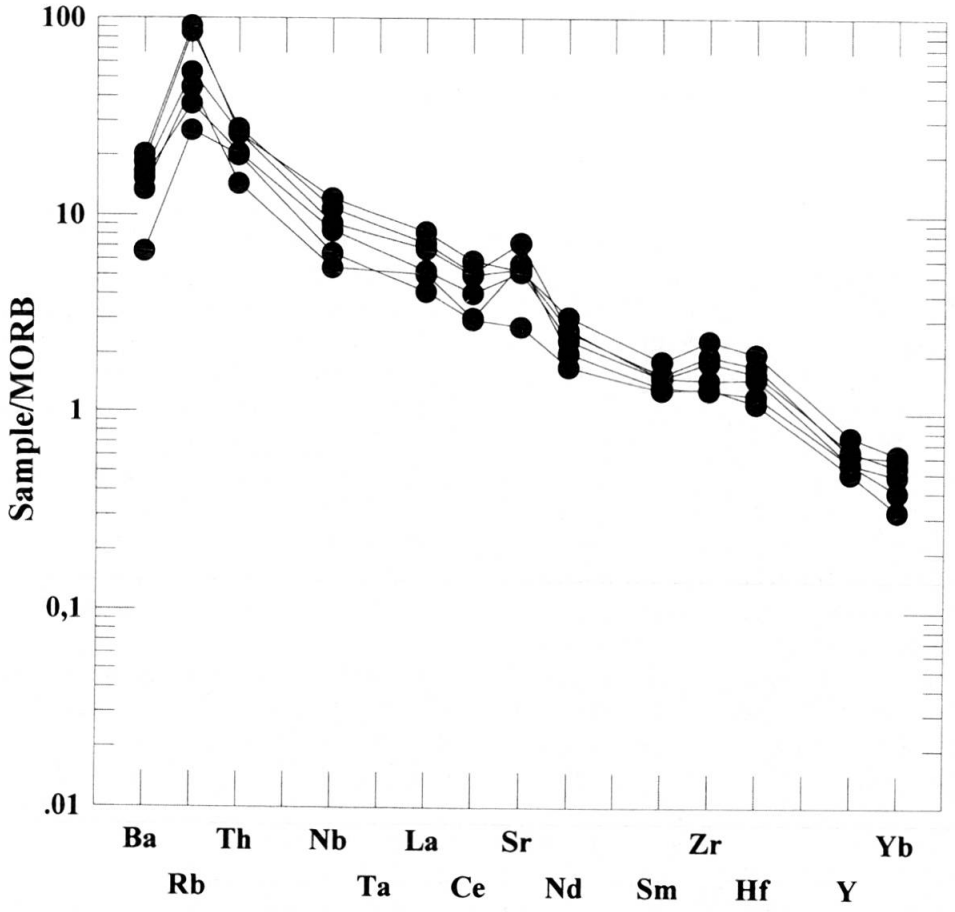


Fig. 8 MORB normalized spidergram of KGB mafic rocks.

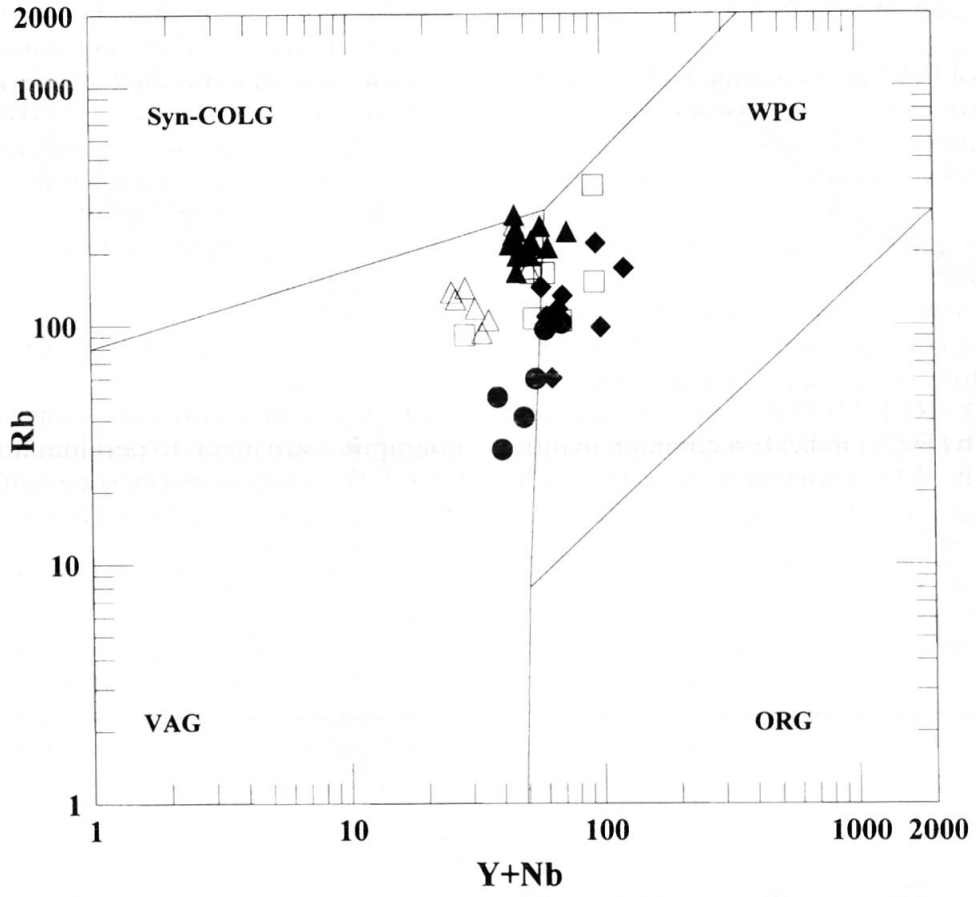


Fig. 9 Rb/Y+Nb discrimination diagram for the tectonic interpretation of granitic rocks (PEARCE et al., 1984). Symbols as in figure 2.

VAG border, partly in WPG and partly in VAG field, yielding extensive crustal contamination. ORG normalized spider diagrams with negative Ba anomaly (Fig. 10), enrichment in LIL and depletion of HFS elements, and Fe rich mica mineral chemistry suggest an early anorogenic tectonic setting (BONIN 1990, 1997; BONIN et al., 1998)

The variation diagrams of major elements vs. D.I. for syenogranite series show regular trends wich can be interpreted as Liquid Lines of Descent. This indicates a leading role of fractional crystallization with some, less significant episodes of mixing. Because of the mass ratio of felsic and mafic magma (the mafic rocks represent about 20% of the whole belt), the interaction processes between the two magmas must have influenced the felsic magma as well, thus producing some hybrid syenogranite and syenite.

The field and petrographic signs of hybridization in felsic rocks are not as obvious as in mafic rocks. Hence, if we consider the behaviour of trace elements in felsic rocks, we can see that some syenogranite display important differences as higher Sr and lower Rb, Nb, Y contents. This may indicate their hybrid nature and is in good agreement with the selective mechanism of contamination for the hybridized mafic rocks, characterized by lower Sr and higher Rb, Nb and Y contents with respect to non-hybrid enclaves.

This interpretation is also supported by the behaviour of REE patterns where the differences exist between hybrid and non-hybrid syenogranites. The depletion of REE content in hybrid syenogranite relative to non-hybrid one is in agreement with the enrichment observed in hybrid mafic rocks.

6. Conclusions

The rocks of the Karavanke Granitic Belt range in composition from olivine gabbro to syenogranite without a compositional gap. Field, petrographic and geochemical evidence indicate that they do not represent the result of a crystal fractionation process, nor of a simple bulk mixing process. Only some of the more mafic and some of the more felsic rocks could be consistently linked by crystal fractionation. Rocks of intermediate composition are the results of a different degree of interaction between the two end-member magmas.

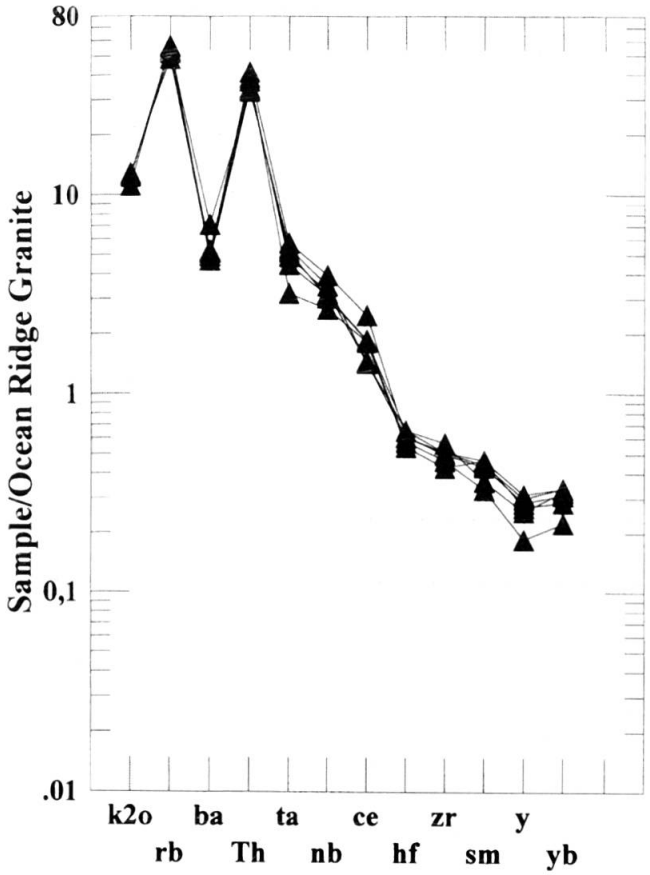


Fig. 10 ORG normalized spidergram of KGB syenogranite.

Chemical and mineralogical compositions indicate that the mafic rocks represent the mantle derived magma. Rising and fractional crystallization of mafic magma probably produced the heat necessary to trigger the melting of crustal material, which lead to the formation of the felsic magma, as suggested by initial Sr isotopic data (DOLENEC, 1994).

The highly contrasted felsic-mafic relationships and the alkaline character of rocks fit an anorogenic to post-orogenic tectonic setting according to PITCHER (1993).

Late Permian to Triassic early anorogenic A-type plutonic-volcanic complexes constitute a part of the Western Mediterranean province. The large alkaline magmatic activity of the Western Mediterranean province was related both to post-orogenic continental consolidation of the European plate, containing fragments of Gondwana accreted to Laurasia and to precursory stages of the formation of Meso-Tethys oceanic basin created from the Paleo-Tethys ocean and propagating westwards within the Gondwanaland (BONIN et al. 1987, 1998; BONIN, 1997). The Triassic (245–200 Ma) is marked by the onset of the Tethys ocean basin spreading with the development of a large rift system and emplacement of volcanic-plutonic complexes related to strike-slip fault zones (BONIN et al., 1998).

The Triassic early anorogenic bimodal alkaline plutonic complex of the Karavanke Granitic Belt is consistent with the regime of incipient rifting suggested by BONIN et al. (1987) for the Western Mediterranean Magmatic province, thus indicating that the Triassic Karavanke Granitic Belt is also part of the same magmatic province.

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