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Shallow intrusive volcanic rocks on Mt. Raduha, Savinja-Kamnik Alps, Northern Slovenia

Plitve intruzivne vulkanske kamnine na Raduhi, Savinjsko – Kamniške Alpe

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Ključne besede: vulkaniti srednje sestave, intruzivni vulkaniti, Slovenija

Abstract

Volcanic rocks occurring in Ladinian (?) marls, interstratified with limestone (Solčava beds), at Grohat Alpine Meadow and Lipni plaz, Mt. Raduha, are shallow intrusives bodies with porphyric structure, and basaltic andesitic, acid andesitic and dacitic composition. Abundance of major oxides and trace elements in the studied rocks is similar to those observed in the Tertiary Smrekovec volcanic rocks suggesting contemporaneous formation and close genetic relationship.

Kratka vsebina

Vulkanske kamnine v ladinijskih (?) laporjih s tankimi vložki apnencev (solčavske plasti) na planini Grohat in Lipnem plazu na Raduhi predstavljajo plitva intruzivna telesa s porfirsko strukturo in bazično andezitno, kislo andezitno in dacitno sestavo. Vsebnosti glavnih oksidov in slednih prvin v raziskanih kamninah so močno podobne tistim v terciarnih smrekovških vulkanskih kamninah in kažejo na njihovo medsebojno časovno in genetsko povezanost.

Introduction

Marls with intercalations of thin limestone beds of Ladinian (?) age (Solčava beds) at Lipni plaz (fig. 1, loc. 1), Grohat Alpine Meadow (fig. 1, loc. 2) and Jež (fig. 1, loc. 3), north-western flanks of Mt. Raduha, locally include smaller bodies of coherent volcanics, emplaced concordantly with the sediment bedding (Plate 1 – fig. 1,2). Their thickness, however, is rather diverse – about 5 m at Grohat, and 0,5 at Lipni plaz. At Grohat, the body length amounts to about 30 m, and grades laterally into a weathered horizon.

Both, carbonate rocks and intrusive volcanic bodies have very similar dip towards the South-East (140/40). Location 1 is newly discovered, location 2 is marked only on Working map in the scale 1:25000 for Basic geological map of SFRJ, scale 1:100000, Sheet Ravne na Koroškem (Mioč & Žnidarčič 1983) as Oligocene tuffs and tuffites lying discordantly on Lower Triassic rocks. The same geological situation is presented on location 3.

East and South-East of the studied sites, in a distance less than 6 km, Tertiary Smrekovec volcanic complex occurs. It is composed of lavas and shallow intrusive bodies of andesitic and dacitic composition (Kralj, 1986), and extensive volcaniclastic deposits. Isolated outcrops of basal Tertiary conglom-

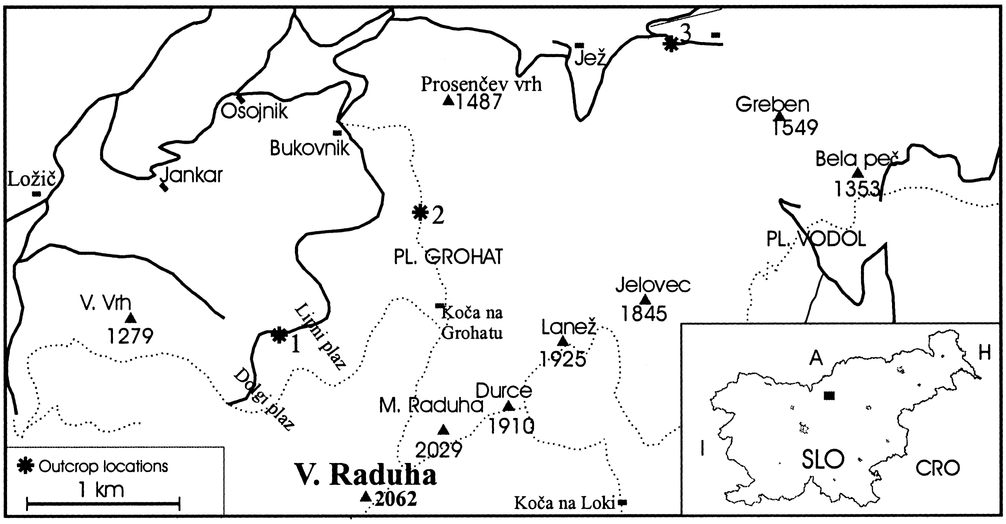


Fig. 1: Simplified map of the studied outcrops of shallow intrusive volcanic rocks on Mt. Raduha

erates overlie discordantly Upper Triassic limestone and were found on the top of Mt. Raduha. In the Durce area near by, there are tuffs and tuffites lying on Tertiary conglomerates (Celarc, current research)

Stanko Buser (personal communication) believes the presented volcanics are Ladinian sills and dykes, similar to those found in the Jezersko area (Buser & Cajhen 1977). Another possibility is, that volcanic rocks are of Tertiary age and are genetically related to Smrekovec volcanic complex. The distance is small, especially if Mt. Raduha is not thrusted. In this contribution, geochemical and petrological characteristics of shallow intrusive volcanic rocks at Grohat and Lipni plaz are presented, and the idea of their origin discussed.

Petrography and chemical composition

The samples from Mt. Grohat and Lipni plaz are very similar according to petrological characteristics, and they closely resemble the Smrekovec coherent volcanic rocks (Kralj, 1996). They are plagioclase-magnetite vitrophyres which consists of glassy groundmass, phenocrysts, microphenocrysts and microlites (Plate 1 – Fig. 3, 4). Seriate

Plate 1 – Tabla 1

1. Outcrop of shallow intrusive volcanic rock at Lipni plaz

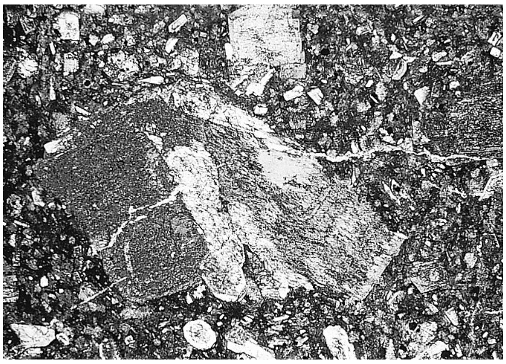
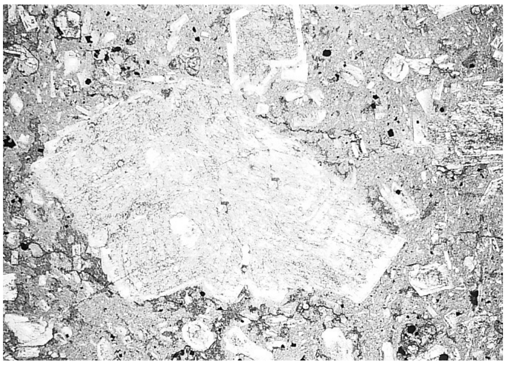
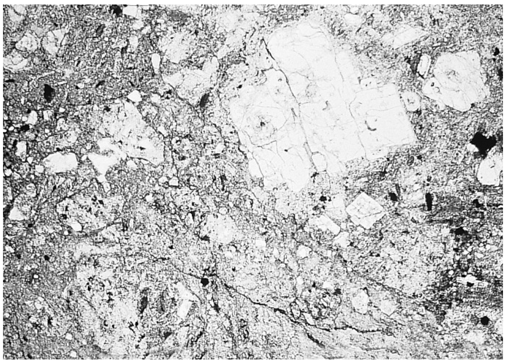
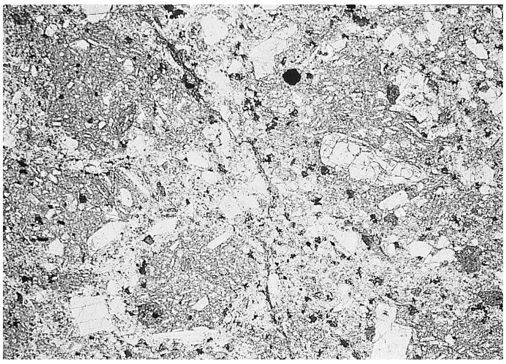
2. The same as Fig. 1, closer view

3. Shallow intrusive vocanic rock from Grohat under plane polarised light. The texture is volcanic, with glassy groundmass and plagioclase phenocrysts of various size. Plane polarised light, magnification 23 x

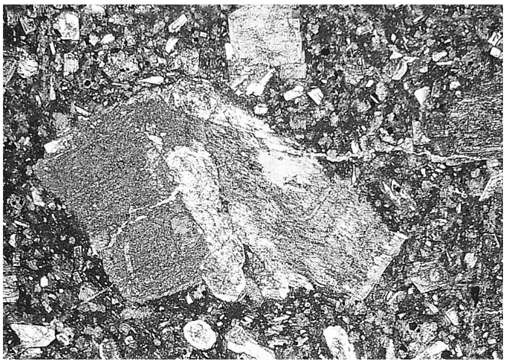
4. The same as Fig. 3, crossed nicols

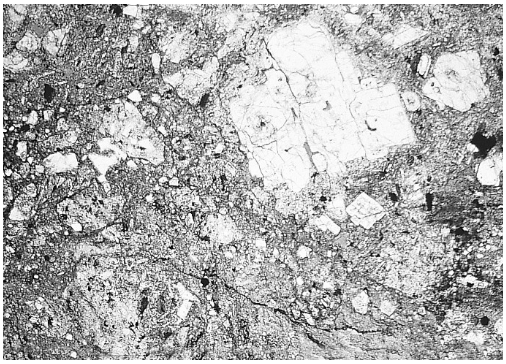
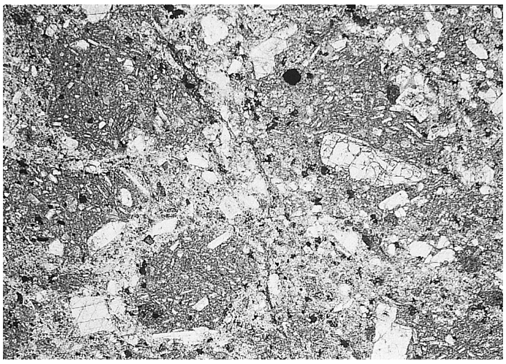
5, 6. Clastic character of the rock from Jež (location 3). The rock is probably a peperite. Plane polarised light, magnification 23 x



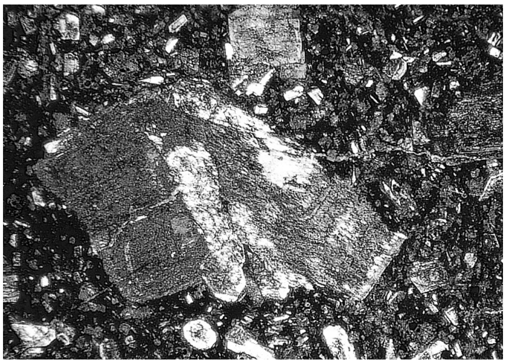
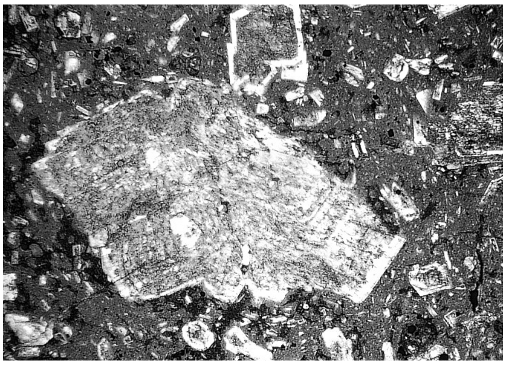
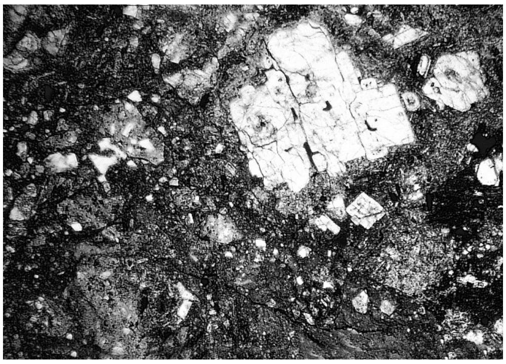
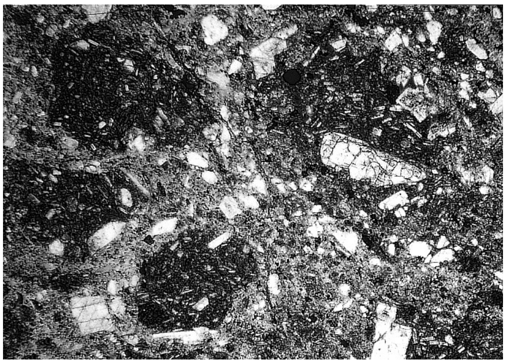











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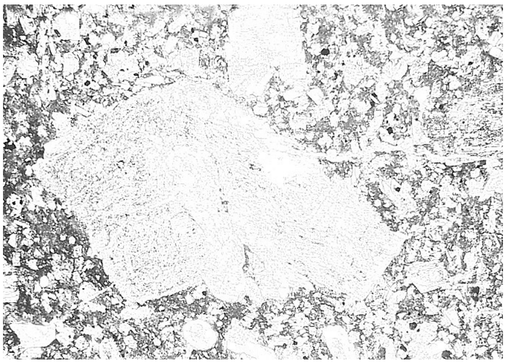

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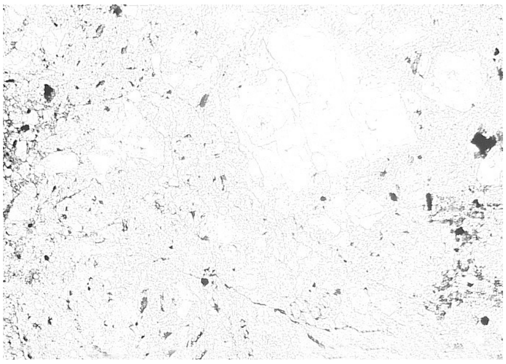

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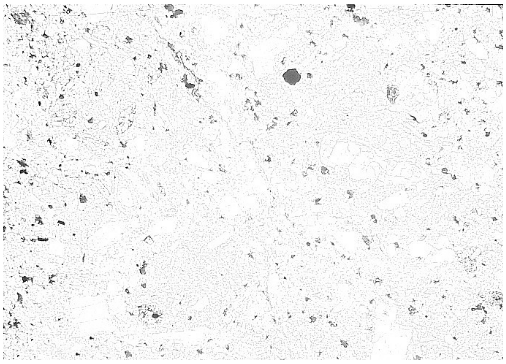

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texture is commonly observed. Phenocrysts are plagioclases, twinned and zoned, and extensively replaced by albite, less commonly to calcite and a filosilicate mineral, most probably interlayered chlorite/smectite. Glassy groundmass is devitrified and commonly replaced by authigenic albite, microcrystalline quartz and yellowish-green filosilicate minerals. Magnetite occurs as microphenocryst and some ten µm sized xenomorphic grains, dispersed throughout the rock.

The sample taken at Jež (location 3), along the road from Spodnje Sleme to the Bistra Valley, is just a fragment in a weathered rock and was not analysed chemically. The rock is probably an altered peperite (Plate 1 – Fig. 5, 6).

Chemical composition of the studied shallow volcanic rocks is shown in Table 1. At a glance, the rocks can be classified according to the silica content as andesites and dacite. Yet, a closer view to the ignition loss and high calcium and sodium content reveals the influence of rock alteration, particularly calcitisation and albitisation of the primary constituents.

Table 1:Chemical composition of shallow intrusive volcanic rocks. R1A – Lipni plaz, G2CA, G1B, Grohat.

Oxide/ Element	Unit	R 1A	G2Ca	G 1B
SiO_2	%	51,4	63,7	59,3
TiO_2	%	0,903	0,802	0,794
Al_2O_3	%	15,3	16,4	16,1
Fe_2O_3	%		4,78	5,45
FeO	%	3,6		
MnO	%	0,14	0,06	0,08
MgO	%	1,79	2,25	2,03
CaO	%	10,7	2,99	4,13
Na_2O	%	5,43	4,68	5,12
K_2O	%	0,45	1,47	1,22
P_2O_5	%	0,23	0,15	0,14
CO_2	%	6,83	0,66	2,00
L.O.I.	%	7,85	2,25	3,50
Li	ppm	68	77	89
Be	ppm	2,1	1,9	1,0
B	ppm	16	23	26
Sc	ppm	12,5	11,8	12,1
V	ppm	50	111	117
Cr	ppm	17	14	6
Co	ppm	12	17	20
Ni	ppm	5	3	5
Cu	ppm	4,5	9,1	8,8
Zn	ppm	61,3	55,2	53,6
Ga	ppm	9	12	10
Ge	ppm	<10	<10	10
As	ppm	2	<2	45
Se	ppm	<5	<5	<5
Br	ppm	1	1	1
Rb	ppm	12	37	29
Sr	ppm	435	441	514
Y	ppm	43	31	29
Zr	ppm	116	132	125
Nb	ppm	11	10	9
Mo	ppm	1	1	2
Ag	ppm	0,3	<0,2	<0,2
Element	Unit	R 1A	G2Ca	G1 B
Cd	ppm	<0,2	<0,2	<0,2
In	ppm	<0,5	<0,5	<0,5
Sn	ppm	4	4	4
Sb	ppm	0,4	<0,2	0,9
Cs	ppm	5	<3	8
Ba	ppm	166	251	221
La	ppm	23,7	20,7	20,9
Ce	ppm	47,1	37,7	39,2
Pr	ppm	6,7	4,6	4,8
Nd	ppm	27,9	20,1	20,0
Sm	ppm	5,9	4,4	4,6
Eu	ppm	2,00	1,01	1,14
Gd	ppm	5,5	3,9	3,8
Tb	ppm	1,0	0,7	0,7
Dy	ppm	6,9	4,9	4,2
Ho	ppm	1,53	0,97	0,98
Er	ppm	4,3	3,2	2,7
Tm	ppm	0,6	0,5	0,4
Yb	ppm	3,8	2,8	2,6
Lu	ppm	0,55	0,50	0,40
Hf	ppm	23	28	26
Ta	ppm	5	3	1
W	ppm	37	61	51
Au	ppm	<2	<2	9
Hg	ppm	<5	<5	<5
Tl	ppm	<0,1	0,1	0,1
Pb	ppm	<2	10	26
Bi	ppm	<5	<5	
Th	ppm	5,3	6,1	3,7
U	ppm	2,7	2,6	1,2

In the silica-total alkali diagram (Le Bas et al. 1986), the studied shallow intrusive rocks fall in the fields of basaltic trachyandesite, andesite and dacite (fig. 2). Based on classification using immobile elements Zr/TiO_2 – SiO_2 (Winchester & Floyd 1979), the rocks are andesites and dacite (fig.3), close to Tertiary volcanic rocks from the Smrekovec, Rogaška Slatina and Rogatec areas. Based on the diagram of K_2O/SiO_2 contents after Ewart (1979), the rock samples belong to calc-alkaline basaltic andesites, acid andesites and dacites.

In general, variations of trace elements and some of their ratios (table 2) are well in the variation span of orogenic andesites (Gill 1981), dacites (Ewart 1979), Tertiary volcanic rocks from the Smrekovec, Rogaška Slatina and Rogatec areas (Kralj, 1996; this volume), and South Pannonian basin (Pamić & Balen 2001). One outstanding exception is lithium, which is much higher than expected for andesites and dacites, although still in the variation span for dacites. We believe that lithium could originate from the action of deuteric fluids or partial incorporation of the enclosing marl in to magma during its emplacement to the host rock. Rubidium is relatively low with respect to the data for dacites (Ewart 1979), but closer to the data of Pamić & Balen (2001) for andesite formations in South Pannonian basin. Barium is low, too. Both, low rubidium and barium could be related to alteration of plagioclase feldspars. On the other hand, strontium is very high and suggests that it could be partially derived from an external source, probably carbonate.

Table 2: Some trace element ratios for intrusive volcanic rocks from Mt. Raduha

Ratio	R 1A	G2Ca	G1 B
K/Rb	308	330	348
Ba/La	7,0	12,1	10,6
Zr/Nb	10,5	13,2	13,9
La/Th	4,5	3,4	5,6
La/Nb	2,15	2,07	2,32
La/Yb	6,24	7,4	8,0
Ce/Yb	12,3	13,5	15,1

Zirconium, zinc and rare earth elements (REE) with yttrium are well in the variation span for andesites and dacites. Chondrite

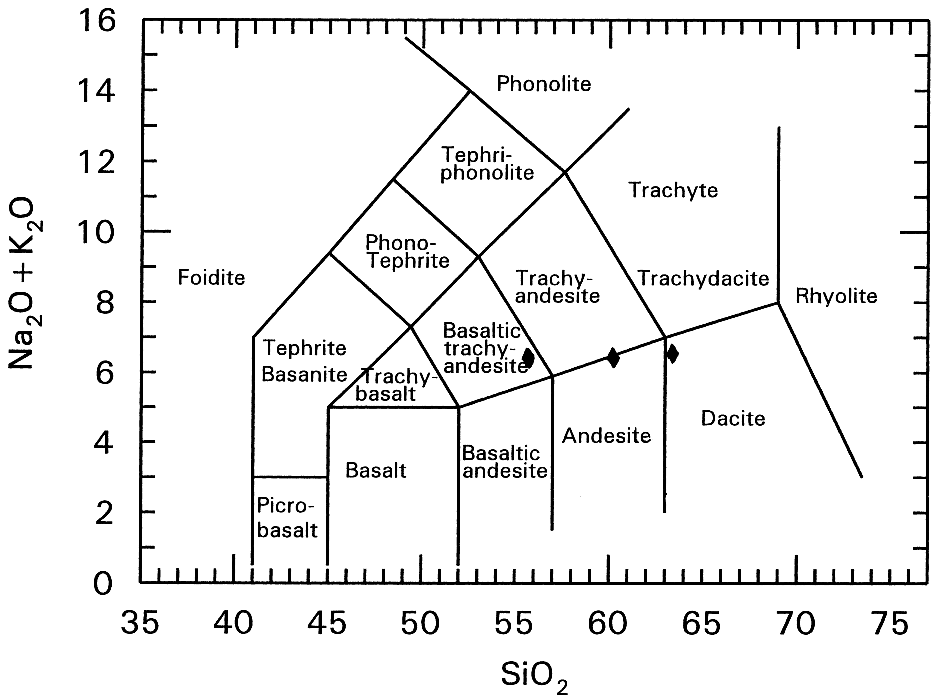


Fig. 2. The silica-total alkali diagram (Le Bas et al. 1986) for the studied shallow intrusive volcanic rocks from Mt. Raduha

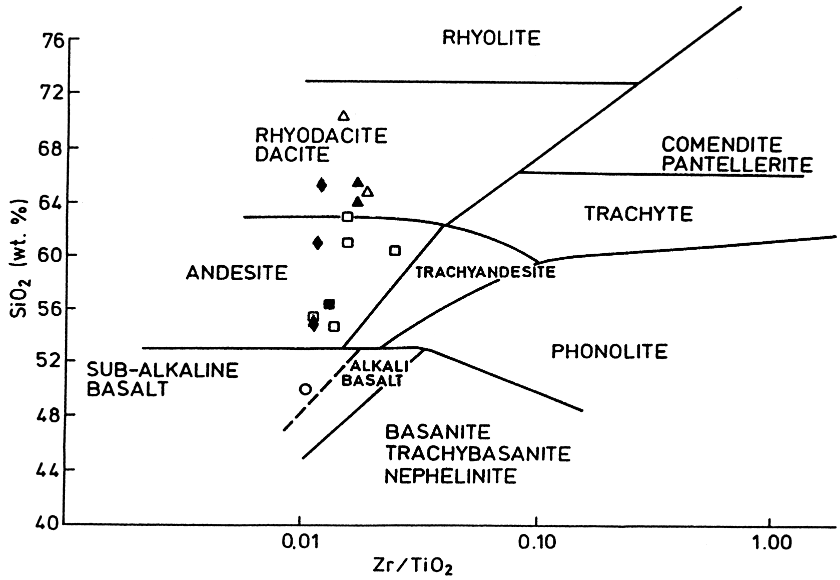
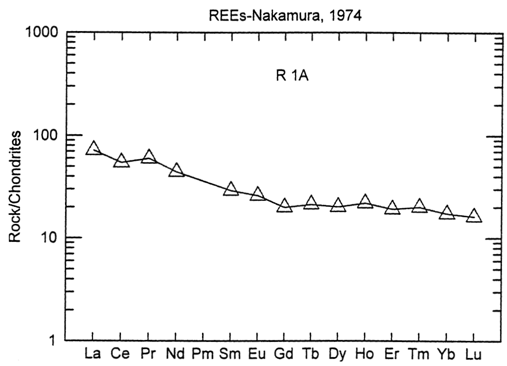


Fig. 3. Classification using immobile elements Zr/TiO_2 – SiO_2 (Winchester & Floyd 1977). Shallow intrusive volcanic rocks from Mt. Raduha – closed diamonds; Smrekovec volcanics – open circle, squares, triangles; Rogaška Slatina – closed square; Rogatec (Trlično) – closed triangles



normalised (Nakamura 1974) REE patterns are very similar for all analysed samples of shallow intrusive volcanic rocks (fig. 4, R 1A, G1 B, and G2Ca). Ligt rare earth elements (LREE) are moderately enriched with respect to heavy rare earth elements (HREE). Very small negative cerium and europium anomalies can be observed. The REE plots are similar to those observed for the Smrekovec volcanics (Kralj, 1996) and acid andesite from Zagaj at Rogaška Slatina (Kralj, this volume).

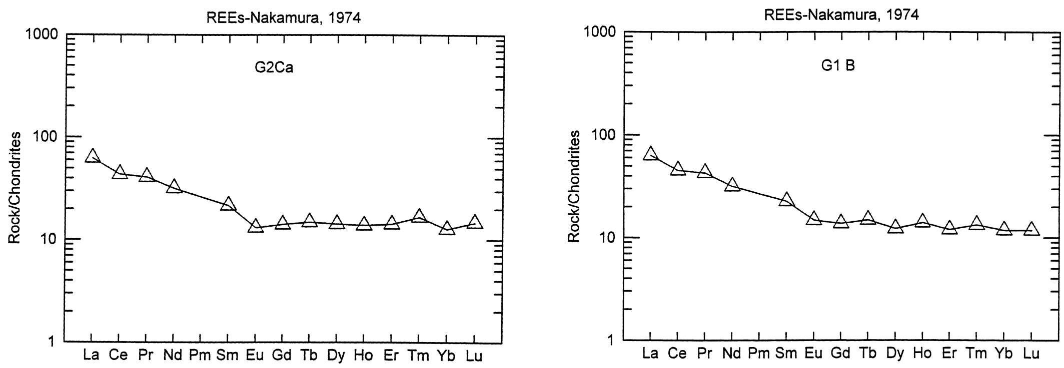


Fig. 4. Chondrite normalised REE abundance for the samples from Mt. Raduha. R 1A, Lipni plaz, G1 B and G2Ca, Grohat

In the Ce – Ce/Y diagram, volcanic rocks from Mt. Raduha are well aligned in the line for the Smrekovec volcanic rocks, and are different than acid andesite from Zagaj at Rogaška Slatina and dacite from Trlično at Rogatec (fig. 5).

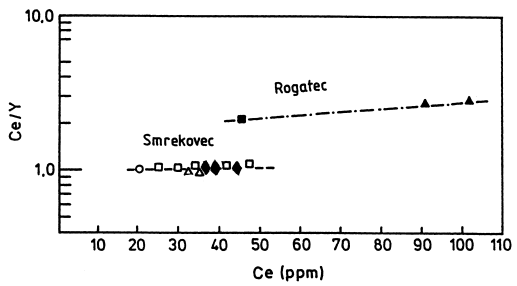


Fig. 5. The Ce/Y vs. Ce diagram with the volcanic rock samples from Mt. Raduha (closed diamonds), Mt. Smrekovec (open squares, open triangles and open circle), Zagaj at Rogaška Slatina (closed square) and Trlično at Rogatec (closed triangle)

Abundance of compatible trace elements Cu and Ni is low with respect to the data for dacites (Ewart 1979). Copper is low in comparison with the Smrekovec volcanics, too, but very close to the abundance observed in the lava from Trlično at Rogatec. Nickel is in the same variation range as in the Smrekovec, Rogaška Slatina and Rogatec volcanic rocks.

Conclusions

Shallow intrusive volcanic rocks from NW flanks of Mt. Raduha are classified as low potassium, calc-alkaline andesites and dacite. Trace element variations are consistent with the variation span for andesites (Gill 1981) and dacites (Ewart 1979) and are comparable with those observed in the Smrekovec, Rogaška Slatina and Rogatec volcanic rocks. Magmas seem to be emplaced in Ladinian (?) slaty marls during the Smrekovec volcanic activity owing to their week mechanical resistence and probably increasing lithostatic pressure. Shallow intrusives underwent alteration. In the early stage, it was very possibly related to the activity of deuteric fluids and is reflected in albitisation of plagioclases and somewhat higher sodium content than expected from the silica content. Late-stage alteration possibly involved calcitisation and the formation of clay minerals.

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