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Upper Cretaceous - Palaeogene Tholeiitic Basalts of the Southern Margin of the Pannonian Basin: Požeška gora Mt. (Croatia)

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Abstract

According to the geological relationships in the region of Požeška gora Mt. (the southern margin of the Pannonian Basin, northern Croatia), basic eruptive rocks are considered to be of Upper Cretaceous - Palaeogene age. Detailed petrographic examination, based on physiographic description, the chemical composition of major and trace elements, rare earth elements and stable isotopes, indicates that these primary tholeiitic basalts have variable structural-textural characteristics, and were postmagmatically affected by metamorphic processes. Tholeiitic basalts originated from the upper mantle, and were placed in the form of subaquatic effusions in the extensional zones within continental crust.

1. INTRODUCTION

Požeška gora Mt. is located in the transitional zone between the Tisia tectonic megaunit and the Inner Dinarides (Fig. 1; KOVÁCS et al., 1989; HAAS et al., 1990; ŠIKIĆ, 1995; HERAK et al., 1990). Basic rocks represent part of the magmatic complex of the NE part of the Požeška gora Mt., which is also composed of alkali-feldspathic granites and rhyolites (Fig. 2).

Petrographic examinations of the basic magmatic rocks of the Požeška gora Mt. have previously been incomplete, comprising part of investigation of the magmatic complex as a whole (KOCH, 1917; TUĆAN, 1919; BARIĆ & TAJDER, 1942; TAJDER, 1947, 1955, 1959; ŠPARICA et al., 1979, 1980; MAJER & TAJDER, 1982). PAMIĆ et al. (1990) concluded that basalt magmas originated from the upper mantle, and that they are connected with continental areas. They included basic rocks within the bimodal volcanic association.

On the basis of geological data KOCH (1917, 1919), TAKŠIĆ (1944) and ŠPARICA et al. (1979, 1980) determined that the volcanic rocks are of Tertiary age. However, discovery of "scaglia" limestone layers within the basalts led PAMIĆ & ŠPARICA (1983) to their conclusion of an Upper Cretaceous age. HALAMIĆ et al. (1990) interpreted these limestone occurrences as enclaves, which together with structural measurements, was used as an argument for a Post-Maastrichtian, i.e. Post-Laramian age for the basic volcanic rocks of the Požeška gora. However, MAJER & TAJDER (1982) proposed that these rocks represent an allochtonous block, and that they are, according to their similarity with the rocks in the other parts of the Dinarides, of Triassic age. Isotopic K-Ar analyses undertaken by PAMIĆ et al. (1988) determined the age of the acid magmatic rocks within the bimodal volcanic association as 71.5 ± 2.8 Ma, thus reaffirming an Upper Cretaceous age.

2. BASIC GEOLOGICAL DATA

The magmatic complex of the Požeška gora is bounded on the northern margin by Neogene and Quaternary sediments, in a partly tectonic and partly erosional-tectonic contact (Fig. 2). Their southern margin is characterised by a tectonic contact with Upper Cretaceous deposits (Fig. 2). Acid eruptive rocks, which are the major part of the magmatic rocks, are represented by alkali-feldspathic granites, i.e. alaskites and alkali-feldspathic rhyolites (PAMIĆ, 1988; PAMIĆ et al., 1990).

Basic rocks mostly occur southeast of Požega, between the Vidovci and Komušina villages, where along the northern margin they are in the contact with rhyolites and rhyolitic tuffs, and to the south are covered by Neogene sediments (Fig. 2). Furthermore, these rocks have been found southwest of Požega, south of Drškovci village, where they are in tectonic contact with granites and rhyolites.

A major part of the basalt body is composed of more or less altered basalts of different structural and textural varieties, which are presented as a single unit on the geological map, since it was not possible to divide them into units appropriate for geological mapping. At some localities pillow lavas have been found, proving that the

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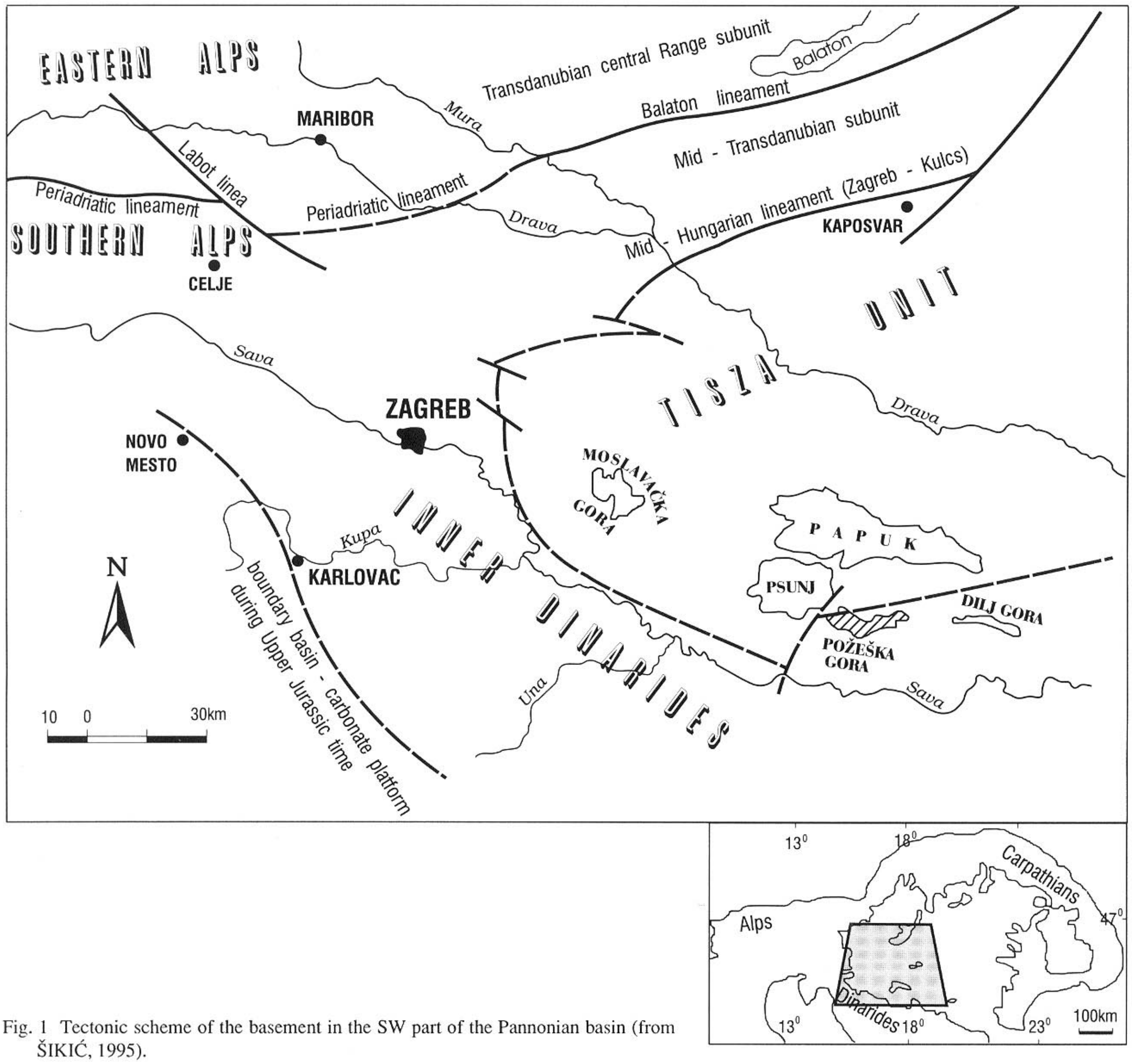

Fig. 1 Tectonic scheme of the basement in the SW part of the Pannonian basin (from ŠIKIĆ, 1995).

basaltic rocks originated from subaquatic effusions (Fig. 3a). The second group of basic rocks of the Požeška gora is composed of hypoabyssal rocks, i.e. diabases and subordinate gabbrodiabases. They are rather frequently represented as veins in granites (Fig. 4a) and rhyolites (Fig. 4b). Diabase veins have also been found in the Upper Cretaceous sediments north of Bodliš (Fig. 2). In addition basic effusives and vein rocks, volcanic agglomerates, and basic tuffs have been discovered.

In the basaltic body there are several occurrences of reddish to gray-reddish pelagic limestones which are up to 1.5 m thick, and of restricted lateral extent (Fig. 3b). These rocks are mostly sandy biomicrites, micrites and sparites. Non-carbonate detritus comprises quartz grains, fine-grained muscovite, opâque minerals and a clayey-haematitic substance. Findings of globotruncanid foraminifera indicate their Upper Cretaceous age (PAMIĆ & ŠPARICA, 1983). At several localities along the Nakop creek, limestones are accompanied by acid tuffs. Boundaries between sedimentary rocks and basaltic lavas are almost always sharp and without load casts, and reactional boundaries are characterized by the recrystallization of limestones and loss of their haematitic component, as well as a decrease in grain size of the basalts ("frozen margin"). On this basis we may conclude that these limestones were enclaved during effusion of lava on the sea bottom, and that the basic effusives are younger than the sediments.

3. PETROLOGY

The analysed samples were collected during work on the Geological map of the Republic of Croatia (scale 1:50.000) during 1989 and 1990.

The modal composition was determined by optical and X-ray diffraction methods. Major elements were analysed in the Institute of Geology, Zagreb, by gra-

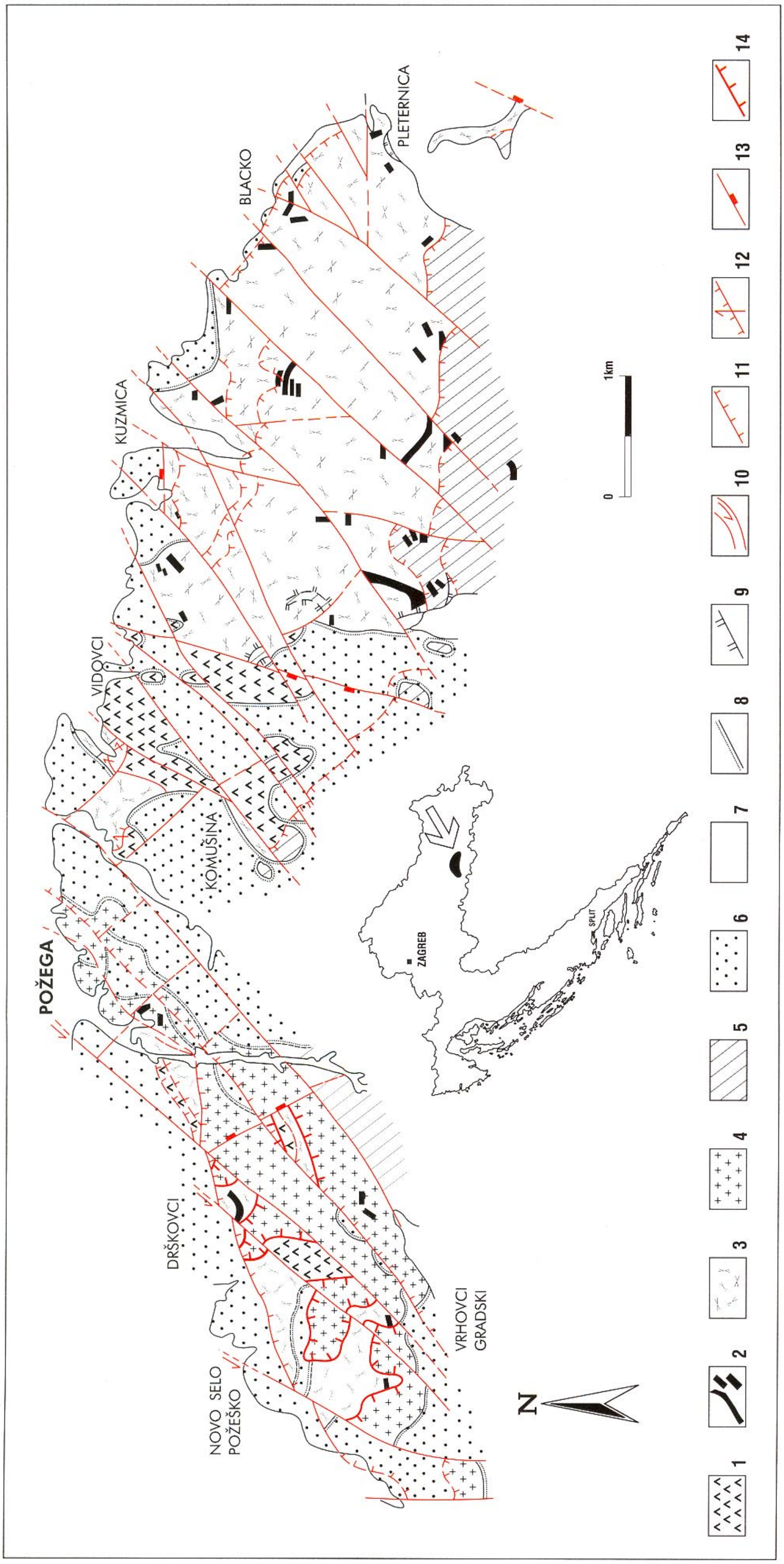

Fig. 2 Geological map of the magmatic complex of Požeška gora Mt. Legend: 1) basalts; 2) diabase veins; 3) rhyolites; 4) granites; 5) Upper Cretaceous sedimentary rocks; 6) Tertiary sedimentary rocks; 7) Quaternary; 8) discordant boundary; 9) boundary of effusive volcanic body; 10) fault: normal, transcurrent; 11) reverse fault; 12) gravitational sliding; 13) relatively subsided block; 14) gravitational overthrust.

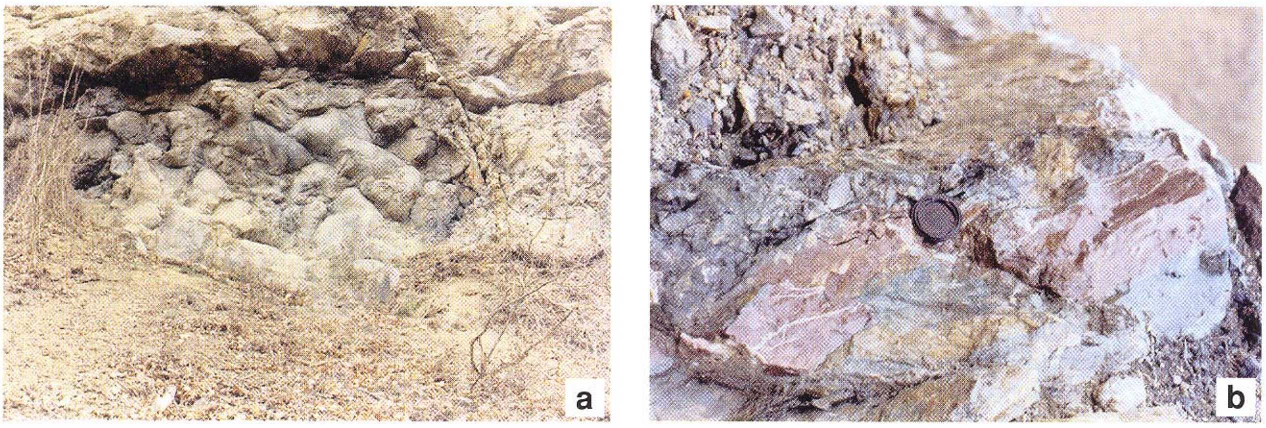

Fig. 3 a) Pillow lavas in the Nakop quarry; b) enclaves of Upper Cretaceous pelagic limestones in basalts in the Pako quarry.

vimetry, spectrophotometry and flame photometry, and some of the samples were analysed by XRF at the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) in Hannover (Table 1). Trace elements were determined at the Ruđer Bošković Institute in Zagreb, and at BGR in Hannover by XRF (Table 2). The accuracy of the determinations was tested with international standards and was in all cases better then ±5%. Rare earth contents were determined by inductively coupled plasma mass spectrometry (ICP-MS) at BGR Hannover (Table 3). The accuracy of these analyses is also better than ±5%.

The diagrams of STRECKEISEN (1967, 1978) were used for classification of the basic volcanic rocks. Three different basic rocks were determined: a) basalts, b) diabases and gabbrodiabases, and c) volcanic agglomerates and basic tuffs.

a) **Basalts** are composed of basic plagioclase (labradorite), albite and pyroxene. Secondary components, besides albite, are chlorite, epidote, calcite, prehnite, pumpellyite, sericite, quartz and zeolite, and accessory are ilmenite, magnetite and apatite. Basic plagioclase is completely altered into acid plagioclase in approximately 80% of the analysed rocks, while in 20% of basalts basic plagioclase is preserved, but rarely unaltered, because of prehnitization and sericitization.

On the basis of structural and textural characteristics basalts are divided into several groups: fine-grained, medium-grained, coarse-grained, porphyritic and vesicular.

Fine-grained basalts with grains up to 0.5 mm in size mostly have typical ophitic texture, while those with subophitic, intergranular, divergent-radial, skeletal-arborescent and hyalopillitic texture are not so frequent. Their structure is homogeneous and vesicular.

Medium-grained basalts are composed of grains ranging in size from 0.5 - 1 mm. Their texture is ophitic, intergranular and subophitic, and structure homogeneous, infrequently vesicular.

Coarse-grained varieties have grains coarser than 1 mm, ophitic texture and homogeneous structure.

Porphyritic basalts are characterized by porphyritic texture and a homogeneous or vesicular structure. In the fine-grained matrix, composed of any of these textural varieties of fine-grained basalts, are phenocrysts of plagioclase and clinopyroxene, up to 3 mm in size, which are present either as isolated grains or as agglomerates.

Vesicular basalts are characterized by their vesicular structure, which is macroscopically visible. Vesicles are 0.15 - 3 mm in size, usually of circular or slightly elliptical shape. Monomineralic vesicles are filled with calcite, infrequently with chlorite and very rarely with quartz. Polymineralic vesicles are filled with the miner-

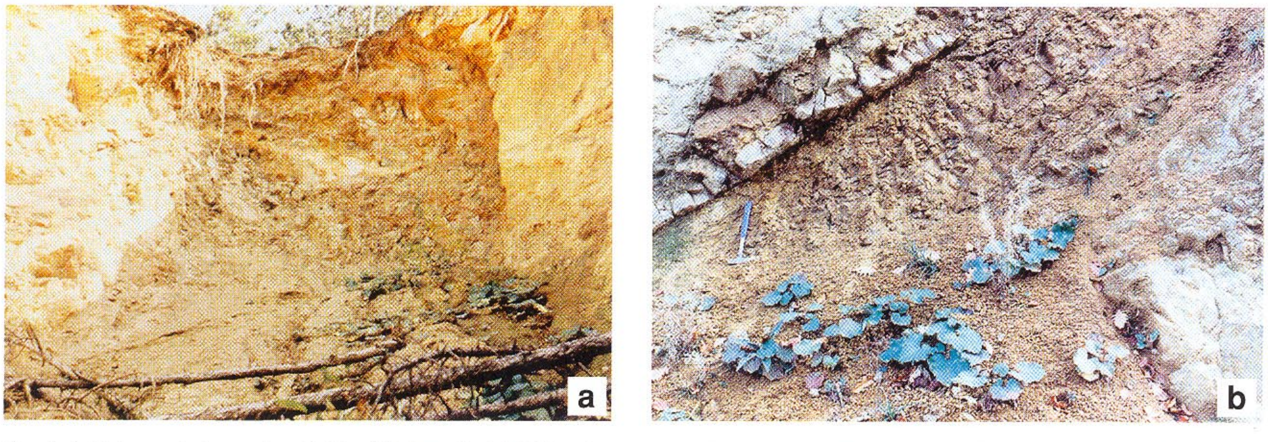

Fig. 4 a) Diabase vein in granites (1.2 km NE from Gradski Vrhovci village); b) diabase vein in rhyolites (2 km SW from Kuzmica village).

sample	1 (NG8[1])	2 (NJ5[1])	3 (35[1])	4 (755)	5 (2810)	6 (PC7)	7 (NA3)	8 (NJ-2)	9 (VDA2)	9A 9A	10 (74[1])	11 (782)	12 (MC1)	13 (1318A)	14 (PC-1)	15 (PD-12)	16 (VDA4)	17 (KB1)	18 (NM1)	19 (845)	19A
SiO_2	49.04	45.43	50.93	44.73	45.14	45.96	49.11	55.06	47.66	48.12	43.62	47.91	46.2	47.28	44.41	45.51	47.19	46.44	50.97	47.20	46.67
TiO_2	2.86	3.16	2.86	2.31	2.53	1.24	1.77	3.04	1.65	2.38	1.44	1.93	1.85	1.75	1.48	1.00	2.07	1.75	1.89	0.53	1.57
Al_2O_3	15.03	14.57	14.73	15.60	14.53	15.94	17.85	15.43	14.79	15.38	12.83	14.92	16.58	16.52	13.26	20.78	17.02	15.43	17.60	16.19	16.11
Fe_2O_3	11.78[2]	15.13[2]	11.70[2]	5.50	7.92	3.97	5.59	2.73	7.60	5.27	7.32[2]	7.14	6.08	5.68	5.89	5.12	9.09	7.53	4.53	5.10	5.95
FeO	-	-	-	6.08	5.97	5.05	6.28	5.61	4.24	6.47	-	5.60	5.30	6.20	3.13	3.12	1.52	4.54	4.55	5.29	4.46
MnO	0.15	0.20	0.17	0.18	0.17	0.14	0.10	0.22	0.17	0.16	0.1	0.18	0.17	0.20	0.14	0.12	0.11	0.18	0.13	0.16	0.16
MgO	3.42	5.55	3.60	3.83	3.53	7.25	1.71	3.53	4.93	4.15	1.41	4.03	3.32	5.74	3.22	6.15	1.51	5.54	4.04	5.54	4.05
CaO	6.74	6.51	6.02	9.01	9.93	9.25	6.72.	5.47	8.27	7.54	18.24	10.77	11.02	8.07	15.68	10.23	10.11	9.25	7.71	12.46	11.35
Na_2O	4.50	2.32	3.24	3.04	4.25	4.61	4.26	4.69	4.96	3.98	2.73	3.60	3.60	3.18	2.43	2.54	3.62	2.80	1.89	3.22	2.96
K_2O	0.43	0.92	1.07	0.38	0.30	0.58	1.92	0.99	0.19	0.75	0.59	0.58	1.10	0.83	0.30	0.30	0.03	0.32	1.41	0.80	0.64
P_2O_5	0.34	0.37	0.29	0.56	0.71	-	-	-	0.70	0.49	0.16	0.48	0.75	0.39	0.55	-	0.96	0.49	-	0.37	0.51
LOI	5.72	5.28	4.85	8.76	4.91	5.75	4.25	2.91	4.38	5.20	11.15	2.81	4.02	3.92	9.41	4.85	6.65	5.54	4.84	3.04	5.65
total	100.01	99.44	99.55	99.98	99.89	99.74	99.56	99.68	99.54	99.89	99.59	99.95	99.99	99.76	99.90	99.72	99.98	99.89	99.53	99.90	100.08
CO_2	2.47	1.80	3.09	3.89	3.90	-	-	-	2.65	-	7.60	0.00	2.41	1.48	7.22	-	2.78	2.41	-	0.83	-
H_2O	2.80	3.58	0.96	4.87	1.01	-	-	-	1.73	-	3.55	2.81	1.61	2.44	2.19	-	3.87	3.13	-	2.21	-
Chemical analyzes calculated on H_2O and $CaCO_3$ free basis																					
SiO_2	53.80	49.44	56.16	51.85	50.14	48.89	51.52	56.89	51.92	52.29	55.36	49.32	49.73	50.32	54.61	47.97	52.6	50.92	53.82	49.26	51.39
TiO	3.14	3.44	3.11	2.67	2.81	1.32	1.86	3.14	1.79	2.58	1.83	198	1.99	1.86	1.81	1.05	2.30	1.91	1.99	0.55	1.73
Al_2O_3	16.49	15.86	16.03	18.08	16.14	16.96	18.73	15.94	16.11	16.70	16.28	15.35	17.84	17.58	16.30	21.9	16.97	16.91	18.58	16.89	17.66
Fe_2O_3	12.92	16.46	12.73	6.37	8.80	4.22	5.86	2.82	8.27	5.60	9.29	7.35	6.54	6.04	7.24	5.39	10.13	8.25	4.78	5.32	6.43
FeO	-	-	-	7.04	6.63	5.37	6.59	5.79	4.62	6.78	-	5.76	5.70	6.59	3.84	3.28	1.69	4.97	4.80	5.52	4.75
MnO	0.16	0.22	0.18	0.21	0.19	0.15	0.10	0.23	0.18	0.18	0.12	0.18	0.18	0.21	0.17	0.13	0.12	0.19	0.14	0.17	0.16
MgO	3.75	6.04	3.92	4.43	3.92	7.71	1.79	3.65	5.37	4.50	1.78	4.15	3.57	6.10	3.95	6.48	1.68	6.07	4.26	5.78	4.38
CaO	3.95	4.60	2.27	4.71	5.52	9.84	7.05	5.65	5.34	5.43	10.89	11.08	8.55	6.58	8.00	10.77	7.33	6.77	8.14	11.89	9.0
Na_2O	4.94	2.52	3.52	3.52	4.72	4.90	4.47	4.85	5.40	4.31	3.46	3.70	3.87	3.38	2.98	2.67	4.03	3.07	1.99	3.36	3.25
K_2O	0.47	1.00	1.16	0.44	0.33	0.62	2.01	1.02	0.21	0.80	0.62	0.59	1.18	0.88	0.36	0.32	0.03	0.35	1.48	0.83	0.66
P_2O_5	0.37	0.40	0.31	0.65	0.79	-	-	-	0.76	0.54	0.20	0.49	0.80	0.41	0.67	-	1.07	0.53	-	0.38	0.56
$FeO^*/FeO+MgO$	1.03	0.90	1.02	1.17	1.46	0.73	1.48	0.91	1.29	1.12	1.16	1.32	1.32	0.99	1.42	0.88	3.00	1.19	1.05	0.95	1.32
$Fe_2O_3:FeO$	0.62	0.47	0.63	0.90	1.32	0.78	0.88	0.49	1.79	8.87	0.62	1.27	1.14	0.91	1.88	1.64	5.90	1.65	0.99	0.96	1.69
CaO/Na_2O+K_2O	0.77	1.30	0.48	1.19	1.09	1.78	1.08	0.96	0.95	1.06	2.67	2.58	1.69	1.54	2.39	2.16	1.80	1.97	2.34	2.83	2.19
Q	8.1	8.9	19.5	10.7	-	-	-	7.6	-	-	11.1	-	-	-	12.2	-	10.6	4.4	11.2	-	-
C	1.5	3.2	5.6	4.8	-	-	-	-	-	-	-	-	-		-	-	1.5	0.4	-	-	-
Or	2.8	5.9	6.9	2.6	1.9	3.6	11.9	6.0	1.2	-	3.6	3.5	6.9	6.9	2.1	1.9	0.2	2.0	8.8	4.9	-
Ab	42.1	21.5	30.2	29.8	40.1	24.5	37.9	41.0	45.9	-	229.5	31.4	32.8	28.6	25.3	22.7	34.2	26.1	16.9	23.7	-
An	17.3	20.4	9.3	19.2	21.4	22.5	25.1	18.7	19.2	-	27.2	23.6	27.9	30.0	30.1	47.0	29.5	30.3	37.4	28.6	-
Ne	-	-	-	-	-	9.2	-	-	-	-	-		-	-	-	-	-	-	-	2.5	-
Di	-	-	-	-	0.3	21.3	8.4	7.5	2.0	-	18.8	23.5	7.8	-	4.3	5.4	-	-	2.4	23.1	-
Hy	14.4	35.0	14.7	20.1	-	-	0.2	9.0	15.4	-		2.3	10.69	26.3	15.9	8.7	11.4	26.7	14.2	-	-
Ol	-	-	-	-	21.4	12.2	7.9	-	6.2	-	-	5.6	2.9		-	8.6	-	-	-	11.9	-
Mt	6.8	7.2	6.7	6.1	6.23	4.1	5.0	4.1	4.7	-	4.8	5.0	5.0	4.8	4.8	3.8	5.5	4.9	5.2	2.9	-
Hm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Il	6.0	6.6	5.9	5.0	5.3	2.5	3.5	6.0	3.4	-	3.5	3.8	3.7	3.5	3.4	2.0	4.3	3.6	3.8	1.0	-
Ru	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ap	0.8	0.9	0.7	1.5	1.8	-	-	-	1.7	-	0.4	1.1	1.8	0.9	1.5	-	2.4	1.2	-	0.9	-
Pl norm	29.1	48.6	23.6	39.1	35.3	36.0	39.8	31.3	29.4	-	48.0	42.9	45.9	51.1	54.3	67.3	46.2	53.7	68.9	50.5	-
C.I.	27.2	38.8	27.5	31.3	33.5	40.0	25.0	26.5	32.0	-	26.1	40.2	30.3	34.7	28.5	28.4	21.3	35.3	25.7	39.1	-
D.I.	53.0	36.4	56.6	39.1	42.7	37.4	49.8	54.6	47.0	-	44.3	34.9	39.8	34.1	39.7	24.5	45.0	32.6	36.8	31.3	-

[1] XRF, BGR; [2] total Fe as Fe_2O_3

Table 1 Major element contents and CIPW norms. Legend: 1-8) metabasalt; 9) metadiabase; 9A) average composition of metabasalts and metadiabases; 10-16) basalt; 17-18) diabase; 19) gabbro - diabase; 19A) average composition of basalts and diabases.

	1 (NG8[1])	2 (NJ5[1])	3 (35[1])	4 (755)	5 (2810)	9 (VDA2)	10 (74[1])	11 (782)	12 (MC[1])	13 (1318A)	14 (PC1)	16 (VDA4)	17 (KB1)	19 (845)
Ba	124	164	111	154	112	107	81	78	238	136	282	175	165	354
Co	38	45	40	-	-	-	26	-	-	-	-	-	-	-
Cr	67	160	140	-	-	-	189	-	-	-	-	-	-	-
Cu	28	18	24	-	-	-	27	-	-	-	-	-	-	-
Ga	30	28	23	-	-	-	26	-	-	-	-	-	-	-
Hf	18	18	18	-	-	-	18	-	-	-	-	-	-	-
Mo	4	4	4	-	-	-	4	-	-	-	-	-	-	-
Nb	20	21	19	-	-	-	12	-	-	-	-	-	-	-
Ni	23	26	34	-	-	-	23	-	-	-	-	-	-	-
Rb	14	28	35	27	5	5	15	12	32	27	5	9	5	23
Sn	30	35	39	36	31	52	49	29	35	50	31	41	30	29
Sr	175	147	202	199	165	234	139	181	251	181	265	206	225	353
V	341	337	315	198	300	159	238	150	266	196	73	174	238	92
Y	37	48	39	20	41	34	17	26	31	21	23	37	21	18
Zn	111	123	108	96	119	113	34	114	111	80	84	120	99	64
Zr	214	235	189	78	205	227	105	97	182	180	114	194	120	66

Table 2 Trace elements contents (in ppm). Table 1 is the numeration key for samples.

al association ± calcite ± chlorite ± epidote ± quartz ± prehnite ± pumpellyit ± haematite ± zeolite.

b) **Diabases and gabbrodiabases** only occur as dykes and sills which cut both the entire magmatic complex, and sedimentary rocks of Upper Cretaceous age. Diabases have ophitic texture, a homogenous structure, and could be divided, on the basis of their textural and structural characteristics into medium-grained, coarse-grained and weakly-porphyritic types. Major mineral components are basic plagioclase or albite and clinopyroxene. Secondary components include albite, chlorite, epidote, calcite, prehnite and sericite, while accessory components are opâque minerals and apatite.

	74	NG8	NJ5	35
La	6.8	16	17	15
Ce	16	38	43	35
Pr	2.2	5	5.7	4.7
Nd	11	23	27	22
Sm	3.3	6.1	7.6	6.5
Eu	1.2	2	1.9	1.6
Gd	2.9	6.2	7.1	5.7
Tb	0.52	0.96	1.2	0.96
Dy	3.9	6.9	8.3	6.9
Ho	0.69	1.3	1.6	1.3
Er	2.1	3.1	4.78	3.8
Tm	0.33	0.56	0.72	0.59
Yb	2.4	4.3	5.3	4.4
Lu	0.35	0.61	0.80	0.64

Table 3 Rare earth elements contents (in ppm). Table 1 is the numeration key for samples.

Gabbrodiabases are characterized by hypidiomorphic texture and homogeneous structure. The major mineral components are plagioclase and hornblende, secondaries include chlorite, epidote and calcite, while magnetite and apatite are accessories.

c) **Volcanic agglomerates and basic tuffs** occur much more infrequently than other types of basic rocks. Volcanic agglomerates have psephitic texture and massive structure. Clasts of different textural-structural types of basalts, or subordinate rhyolite, are 10-100 cm in size. The matrix is composed of weakly cemented tuffaceous material.

Basic tuffs are represented by thinner beds within the succession of basalts and volcanic agglomerates. They were divided into vitrocrystalline, crystallóvitrophitic and vitrophitic types.

4. MINERALOGY

Plagioclase (labradorite) has a prismatic shape, is usually prehnitized or sericitized, only infrequently fresh. Its modal component in basalt and diabase is approximately 55%. The mean content of anorthite was determined by optical measurement as 57.9%. The mean normative composition of plagioclase is 52.8% an (Table 1). Therefore, optical and normative values indicate that the plagioclase is a labradorite, what is also confirmed by roentgen analysis indicating neutral to basic plagioclase.

The clinopyroxene (augite) is of short-prismatic, articulated or feather-like form. It is one of the major mineral components of basalt and diabase, with a modal content of up to 30%.

Hornblende is the major mineral component of gabbrodiabase dykes, while only in one type of basalt it does represent a late-magmatic mineral.

Ilmenite, magnetite and apatite are accessory minerals in all basic effusive rocks of Požeška gora Mt.

Albite is the most important mineral in altered basalts and diabases, since there are almost no samples of basic magmatic rocks showing no evidence of albitization. It is most frequently of prismatic, twig-like and needle-like form, and is inhomogeneous, with inclusions of epidote/clinozoisite and chlorite. The mean anorthite component determined by optical measurements is 5.5%, and by roentgen diffraction it was determined as acid to neutral plagioclase. The mean value of normative composition is 34.4% an (Table 1). Normative values are not in concordance with the results of optical determinations. This could be explained by including one part calcium from the postmagmatic minerals epidote, prehnite and pumpellyite into normative plagioclase. Also, there is a possibility that the albitization process is not complete, but it was not possible to prove this optically because of the very small number of plagioclase grains appropriate for theodolitic measurements.

Chlorite was found in all samples of the basic rocks. It is present in small veins, vesicles or in intergranular spaces in the form of very fine aggregates. The approximate formula of chlorite which occurs in veinlets in basalts from Nakop creek was calculated from X-ray powder diffraction data following the procedure proposed by NIETO (1997). According to the obtained formula

$$(Mg_{2.99}Fe_{1.78}Al_{1.13})(Si_{3.07}Al_{0.93})O_{10}(OH)_8$$

and valid division of the chlorite group minerals (NEWMAN & BROWN, 1987) this chlorite could be determined as ferroan clinochlore.

Epidote is present as an inclusion in acid plagioclase, in the matrix as grainy aggregates or in fissure systems in the rocks where it represents the most common mineral. On the basis of the diffractogram of the epidote from veins in the basalts of Pako and Nakop creeks, unit cell dimensions were calculated, and using the equation of CARBONIN & MOLIN (1980) the following formulae of these two epidotes were obtained:

$$Ca_2(Al_{2.40}Fe_{0.60})(Si_2O_7)(SiO_4)O(OH), \text{ and}$$
$$Ca_2(Al_{2.23}Fe_{0.77})(Si_2O_7)(SiO_4)O(OH).$$

Calcite most frequently fills vesicles in the rock, but is also present in small joints and as irregular aggregates. In the rock matrix it is usually agglomerated with epidote and chlorite. In open fissures colourless calcite crystals up to 1 cm in size were found, with hexagonal prism surfaces and basal pinacoids.

Prehnite substitutes plagioclase, and in some samples plagioclase is completely prehnitized. It is also present in the form of small veins. It was determined by both optical and roentgen methods.

Sericite is uncommon and substitutes plagioclase.

Quartz usually fills small veins, more rarely vesicular fabrics, and very infrequently interstitial spaces.

Pumpellyite was found in small veins and vesicles in metabasalts, and was determined by the optical and roentgen diffraction methods.

Haematite fills veins and was found in irregular aggregates in the form of a soil-like substance, and was determined by optical and roentgen diffraction methods.

Pyrite is present along fissures in the form of small agglomerates, while coarser crystals were found in basalt dykes.

Zeolite fills only vesicles in some varieties of metabasalts from Majdan creek, and was determined by optical measurement.

5. GEOCHEMISTRY

From the results of chemical analyses presented in Table 1 it is obvious that the major element contents show a certain amount of variability, most frequently caused by different contents of secondary calcite and by other secondary processes.

In chemical analyses calculated to 100%, without ignition loss and $CaCO_3$ (Table 1), the SiO_2 content varies from 47.97 - 56.89% ($\bar{x}$=51.84%). Therefore some rocks could be determined as neutral, and most of the rocks as basic according to STRECKEISEN (1978). Total Fe oxide content is rather more uniform, with certain variations ($\bar{x}$=11.48%). The mean value of Fe_2O_3:FeO ratio is 1.28 (Table 1). Total Fe oxide contents is higher than the MgO contents, which is more variable (1.79 - 7.71%). Alkali content is variable, mostly depending on the degree of the albitization of the rock, and Na_2O contents ($\bar{x}$=3.78%) is higher than the K_2O content (0.73% on average). TiO_2 content is interesting, ranging from 0.55% in a gabbrodiabase vein to 3.44% in some varieties of basalt. Harker's diagrams indicate that an increase of SiO_2 also increases the alkali content, and decreases CaO and P_2O_5 content, while an increase of MgO slightly decreases the CaO, Na_2O and P_2O_5 values. Petrochemical characteristics of major elements, trace elements and CIPW normative composition indicate that analyzed rocks belong to the tholeiitic basalts.

A geochemical model of values normalized on MORB (PEARCE, 1983) indicates higher normalized contents of K, Rb and Ba (Fig. 5). Incompatible elements are enriched, except Y and Yb, whose relation is similar to N-MORB. Such a model has normalized trace elements similar to continental tholeiitic basalts.

A geochemical model of values normalized on chondrite (THOMPSON, 1982) shows relatively high

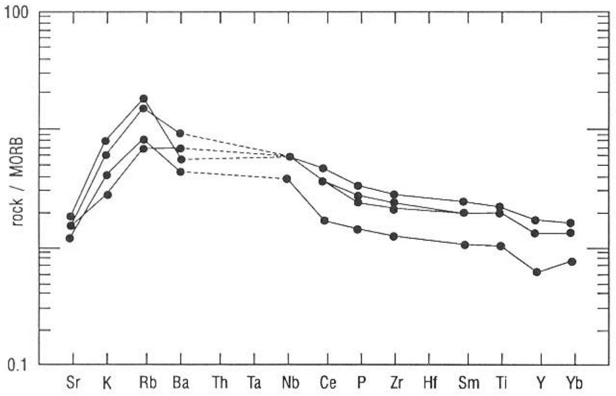

Fig. 5 Diagram of trace elements normalized on MORB (PEARCE, 1983).

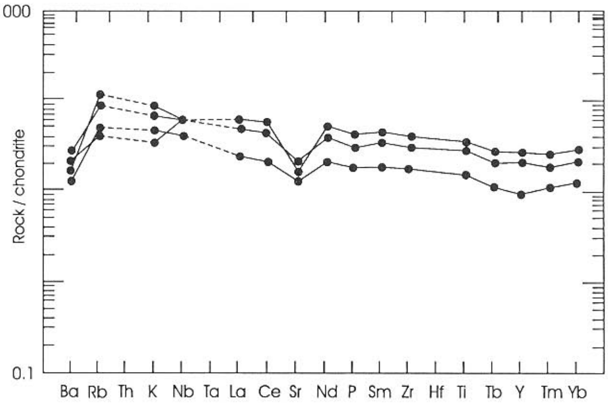

Fig. 6 Diagram of trace elements normalized on chondrite (THOMPSON, 1982).

ratios of Rb and K, and a clearly expressed negative anomaly of Sr (Fig. 6). A decrease in Sr could be explained by low-pressure fractionation of plagioclase, while the geochemically normalized model indicates that the primary magma originated from the enriched mantle or crustal contamination of magmas.

The Zr/Nb ratio in analysed samples ranges from 9.75 - 10.7 (average 10.1), indicating that the magma originated from an enriched mantle, as the values for N-MORB are higher than 30 (WILSON, 1989).

A three-component diagram for basalts La/10-Y/15-Nb/8 (CABANIS & LECOLLE, 1989) indicates that basalts of the Požeška gora Mt. belong to the E-type of MORB (Fig. 7).

For study of the geotectonic position, a discrimination diagram Ti/100-Zr-Y (PEARCE & CANN, 1973) was used, where points of basic volcanites from Požeška gora fall within the D field, i.e. in the field of within-plates basalts (Fig. 8).

On an Nbx2-Zr/4-Y diagram (MESCHEDE, 1986), the analysed basic volcanites fall in the field of within-plates tholeiites, which is also the field of basalts of the volcanic arc (Fig. 9). Values of Ti and V were plotted on the diagram (after SHERVAIS, 1982), where points indicate a trend of oceanic island basalts (Fig. 10).

A geochemical model of the rare earth elements normalized on chondrite (Fig. 11) shows La contents approximately 50 times greater than in chondrites with a gentle negative inclination of the curve (Ce/Yb_N approximately 2), while intensely calcitized basalt has a 20 times higher content of La than chondrites with a gentle negative inclination of the curve (Ce/Yb approximately 2). Samples NJ-5 and 35 have weakly expressed

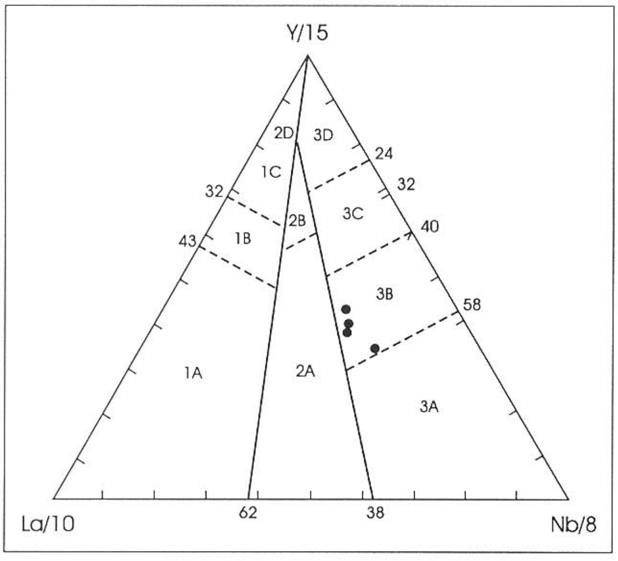

Fig. 7 Diagram La/10-Y/15-Nb/8 for basalts (CABANIS & LECOLLE, 1989). Legend: 1) volcanic-arc basalts (1A - calc-alkali basalts; 1B - an area overlap between 1A and 1C; 1C - volcanic-arc tholeiites); 2) continental basalts (2A - continental basalts; 2B - back-arc basin basalts); 3) oceanic basalts (3A - alkali basalts from intercontinental rift; 3B - E-type MORB-enriched; 3C - E-type MORB-weakly enriched; 3D - N-type MORB).

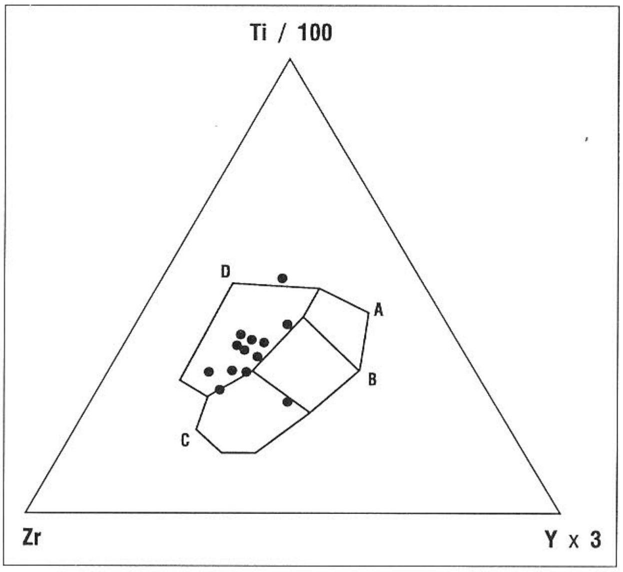

Fig. 8 Three-component Ti/100-Zr-Yx3 diagram for basalts (PEARCE & CANN, 1973). Legend: A) island-arc tholeiites (IAT); B) middle-oceanic rift basalts (MORB) and IAT; C) calcium-alkalic basalts (CAB); D) within-plate basalts (WPB).

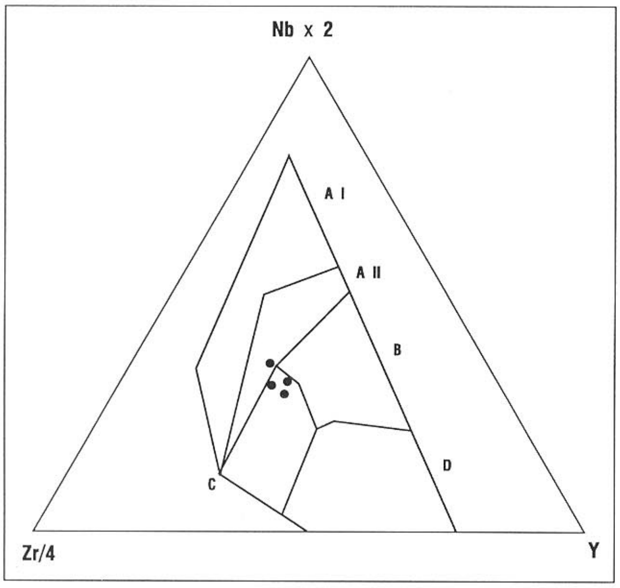

Fig. 9 Three-component Nbx2 - Zr/4 - Y diagram for basalts (MESCHEDE, 1986). Legend: AI) within-plate alkali basalts; AII) within-plate basalts and within-plate tholeiites; B) E-type MORB; C) within-plate and volcanic-arc basalts; D) N-type MORB and volcanic-arc basalts.

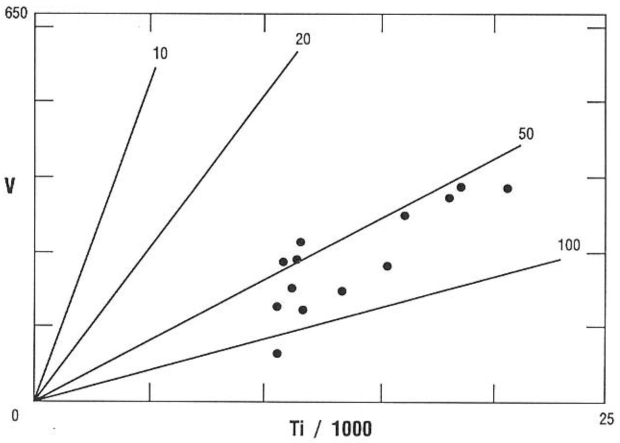

Fig. 10 Diagram Ti/1000 - V for basalts (SHERVAIS, 1982). Legend: Ti/V ratios between 10 and 20: island-arc basalts; Ti/V ratios between 20 and 50: MORB, continental flood basalts and back-arc basalts; Ti/V ratios between 15 and 50 with a near-vertical trend: calc-alkaline basalts.

negative Eu anomaly (Eu/Eu* = 0.79 and 0.71, respectively; Eu/Eu* = $Eu_N/\sqrt{(Sm_N \times Gd_N)}$, and sample 74 a weakly expressed positive Eu anomaly (Eu/Eu* = 1.19). Negative Eu anomaly may indicate existence of the "magma chamber" where cumulate gabbroid rocks with positive Eu anomaly were formed. Samples with a slight negative Eu anomaly may have fractionally crystallized plagioclase or may have been in equilibrium with plagioclase-bearing mantle source (WILSON, 1989). A geochemical model of REE normalized on chondrite is comparable to continental tholeiites.

PAMIĆ et al. (1988) have performed isotopic determinations of ^{18}O and $^{87}Sr/^{86}Sr$ on several basalt samples, and PAMIĆ (1993) has determined the K-Ar age on three samples of fresh basalts (Table 4). The $^{87}Sr/^{86}Sr$ ratio indicates that basaltic magmas were formed by partial melting of upper mantle rocks (TAYLOR & SHEPPARD, 1986). Discrimination diagrams $^{87}Sr/^{86}Sr$ - SiO_2 and Ba/Y - $^{87}Sr/^{86}Sr$ (MANTOVANI et al., 1985) also indicate that basalts of the Požeška gora Mt. belong to the high-titanium tholeiitic volcanic series with a magmatic origin in enriched mantle. Differences in oxygen isotopic composition argue that the basalts were affected by postmagmatic, hydrothermal metamorphism of the oceanic floor (SPOONER et al., 1974; COLEMAN, 1977).

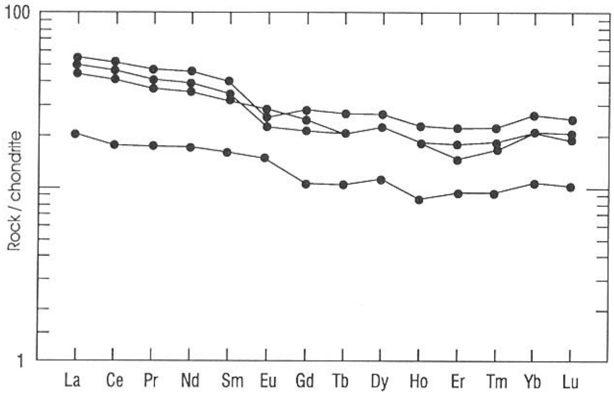

Fig. 11 Diagram of the rare-earth elements normalized on chondrite.

6. DISCUSSION AND CONCLUSION

Požeška gora Mt. is mostly composed of altered basalts and altered diabases, with subordinate fresh basalts, diabases, gabbrodiabases, volcanic agglomerates and tuffs. Normative composition and petrochemical characteristics of major elements, trace elements, and rare earth elements (REE) together with the isotopic composition indicate that the analysed rocks belong to the high-titanium tholeiitic basalts, the magma for which originated from the upper mantle. Rocks were affected by hydrothermal metamorphism, as indicated by mineral parageneses and isotopes; therefore in approximately 80% of analysed rocks basic plagioclase is completely substituted by albite, and in others partial

Rock	$\delta^{18}O$	$^{87}Sr/^{86}Sr$	K-Ar-ages (Ma)
fresh basalt	5.3	0.70570 ± 16	
altered basalt	7.3	0.70403 ± 250	
altered basalt	6.3	0.70435 ± 5	
additional 3 samples of basalts			66.0 ± 3.9 54.5 ± 2.7 48 ± 1.5

Table 4 $\delta^{18}O$ content, $^{87}Sr/^{86}Sr$ ratio and K-Ar ages.

albitization is present. The secondary mineral paragenesis according to ERZINGER (1989) belongs to the TYPE III: High-temperature (>200°C) sea water-basalt alteration at reducing conditions and medium to low water/rock ratios. However, it should be pointed out that secondary minerals albite, chlorite, epidote, prehnite, sericite, pumpellyite and zeolite are also typical for the very low degree of regional metamorphism (WINKLER, 1979).

Gathered K-Ar ages of basic rocks from the Požeška gora Mt. range from 66-48 Ma (from the Upper Cretaceous/Palaeocene boundary to the Middle Eocene) (PAMIĆ, 1993). The position of the magmatic body is presented on the geological map (Fig. 2); it is discernible that veins of basic rocks cut the Upper Cretaceous granite-rhyolite complex, as well as Upper Cretaceous clastic rocks. Furthermore, within the basalt body numerous decimetre-metre size outcrops of pelagic limestones and shales occur (Fig. 3), and some of these were determined as being of Upper Cretaceous age (Upper Santonian to Lower Maastrichtian - PAMIĆ & ŠPARICA, 1983). These rocks show no signs of more intense contact-metamorphic changes, except recrystallization, probably because of the more abrupt cooling of lava during submarine effusion. Since contact planes between basalts and sediments are sharp, without load casts, it may be supposed that these sediments were enclaved after lithification. However, the possibility that some sedimentary rocks represent layers between two effusional events, cannot be excluded. On the basis of aforementioned, compatible geological and isotopic data, we may conclude that the basic rocks of the Požeška gora Mt. are of Upper Cretaceous - Palaeogene age, and that they are younger than the granite-rhyolite complex and Upper Cretaceous clastic rocks.

Subduction processes during the Early Cretaceous, together with the Eoalpine orogenesis (BELAK et al., 1995) had caused emersion in the marginal part of the Northern Dinarides; therefore in this area there are no deposits of this age. Subduction was either minimized during the Upper Cretaceous, or was completed, i.e. there was a closure of Tethys in this part of the Dinarides. Postsubduction tectonic processes (continental rifting or pseudorifting) have caused rhyolite volcanism along deep faults. Rifting or pseudorifting-extensional processes caused the Upper Cretaceous transgression, which was registered in all marginal parts of the Dinarides (ŠPARICA et al., 1980), and formation of the Upper Cretaceous - Palaeogene marginal basin.

Basic rocks of the Požeška gora Mt. are, therefore, a consequence of extensional processes during the Upper Cretaceous and Palaeogene along the northern margin of the Dinarides. On the basis of geological and isotopic data it may be concluded that the first process was effusion of the rhyolites, and crystallization of smaller masses of its intrusive equivalents. Rhyolite magma was formed by partial melting of the continental crust (PAMIĆ et al., 1990). Partial melting, which produced acid crustal magma, was facilitated by positioning of high-temperature basic magma in higher levels of the lithosphere (SUNESON & LUCCHITTA, 1983). Similar geodynamical evolution of some areas in the western part of the USA, resulting in bimodal volcanic association, was proposed by LIPMAN (1980).

By the Upper Cretaceous basic volcanism occurred in deeper parts of the already formed basin, and lasted until the closure of the basin (Pyrenean tectonic phase in the Eocene). In the geodynamic interpretation of these areas it should be stated that rhyolites were placed along the marginal parts of the Upper Cretaceous-Palaeogene basin, since they were not genetically related to the sediments in this basin, while basalts were placed in the deeper parts of the basin. Consequently, acid and basic volcanic rocks were, during effusion, spatially separated, and were positioned in their present mutual position by tangential tectonic transport during the Tertiary.

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