Acta Mineralogica-Petrographica, Szeged, XXXI, 25—42, 1990

MIDDLE TRIASSIC MAGMATIC SEQUENCES FROM DIFFERENT TECTONIC SETTINGS IN THE BÜKK MTS. NE HUNGARY

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ABSTRACT

In the Bükk Mts. (NE Hungary) two Middle Triassic magmatic event can be detected. In the first phase of the magmatism (Upper Anisian — Lower Lanidian) lava flows and pyroclastics with andesitic-rhyolitic composition were produced, while the younger magmatic horizon (Upper Lanidian — Lower Carnian) is represented by basaltic lava flows and subvolcanic intrusions, as well as some basic tuffs. On the basis of the major and trace element characteristics and the chemical composition of the clinopyroxenes, the first phase shows calc-alkaline orogenic, while the second has within-plate alkaline affinity.

INTRODUCTION

The whole Middle Triassic Eastern Bükk magmatic complex were considered by BALLA (1984,1987) as a single sequence and product of a shoshonitic-latitic type magmatism relating to subduction based on major elements chemistry published in the preceeding years (SZENTPÉTERY 1923—29, 1931—39,1950; BALOGH 1964).

DOBOSI (1986) in opposition to BALLA (1984,1987) suggested a slightly alkalinity and within-plate affinity of the Carnian Eastern Bükk metabasalts by chemical compositions of the pyroxenes appearing only in one sample. In this suggestion this alkaline volcanism may have been connected with the initial rifting of the continental shelf of Apulia (BALOGH *et al.* 1984).

The aim of this paper is to determine the geochemical affinity and the magmatectonic setting of the Middle Triassic Eastern Bükk magmatic sequence using new data and to solve the ambivalence of tectonic setting rised by previous examinations.

REGIONAL GEOLOGICAL SETTING, MODE OF OCCURRENCE, METAMORPHISM AND AGE

The Bükk Mts. located in the Igal—Torna—Bükk tectonic unit of the Pannonian region can be found in NE Hungary (*Fig. 1*). Numerous authors (BALOGH 1964; KÁZMÉR and KOVÁCS 1985; KOVÁCS 1982,1984,1989) suggested the relationship of this tectonic unit to the Dinarides and Southern Alps by stratigra

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phical and geodynamical investigations, which is also supported by the occurrence of the Middle Triassic "porphyrites and diabases" in the Bükk Mts. (e.g.: DERCOURT *et al.* 1984; CROS & SZABÓ 1984; KUBOVICS *et al.* 1990).

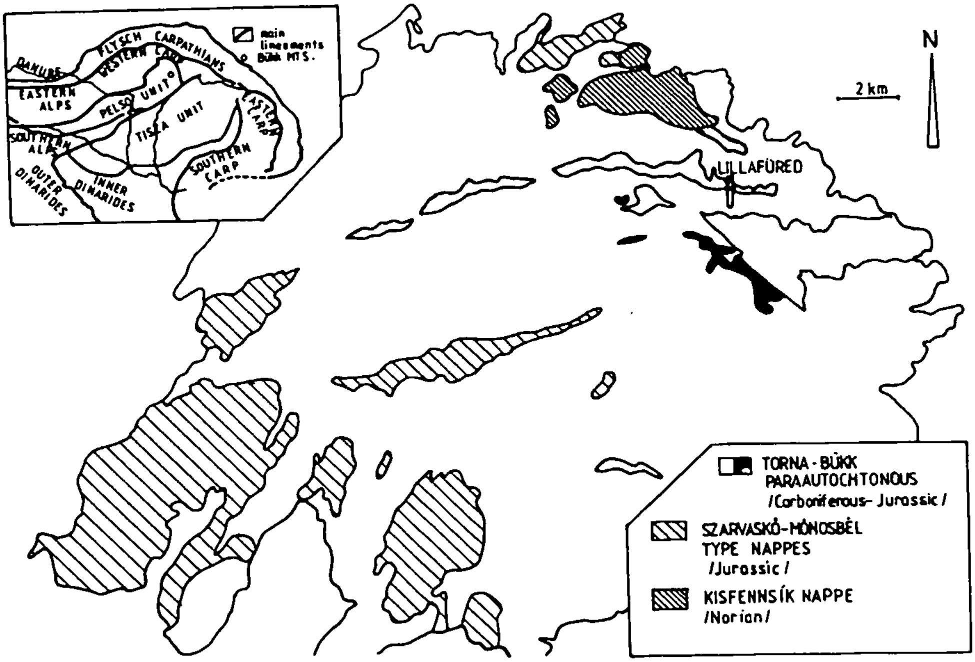

Fig. 1. Geological sketch of Bükk Mts. with the areal distribution of the Middle Triassic magmatites. — grey: Upper Anisian-Lower Ladinian intermediate-acidic metavolcanics; black: Upper Ladinian-Carnian metabasalts.

Triassic igneous rocks occur in three horizons of the largest tectonic unit (Bükk—Torna Paraautochtonous) of the Bükk Mts. (*Fig. 1—2*) (CSONTOS 1988). The Upper Anisian — Lower Lanidian, about 200 m thick, stratovolcanic sequence (Szentistvánhegy Fm.) formed partly at subareal and partly at submarine conditions consists of metaandesites, metarhyolites and its tuffs (SZENTPÉTERY 1923—29, 1931—39; PANTÓ 1951, 1961; BALOGH 1964).

The rocks of the following magmatic horizon (crop out in the surroundings of the Szinva Spring) Upper Lanidian — Lower Carnian age formed by submarine magmatic processes and consist of tuffits, basic tuffs and some basaltic lava flows (CSONTOS 1988).

The youngest magmatic event represented by a few, small subvolcanic, basaltic intrusions emplaced in cherty limestone (Lusta Valley) and in equivalent of the Raiblian shale (Létrástető) (BALOGH 1964; CSONTOS 1988).

This temporal evolution of the Eastern Bükk Middle Triassic magmatism is very similar to the Triassic volcanic activity in the Southern Alps (CASTELLARIN *et al.* 1980; PISA *et al.* 1980), i.e. a mainly subareal volcanism producing "acidic" lava flows and pyroclastic deposits changes into submarine basaltic magmatism.

Based on the secondary mineral assemblages of the magmatites, the composition ratio of the coexisting pumpellyite-chlorite-actinolite-epidote and the com-

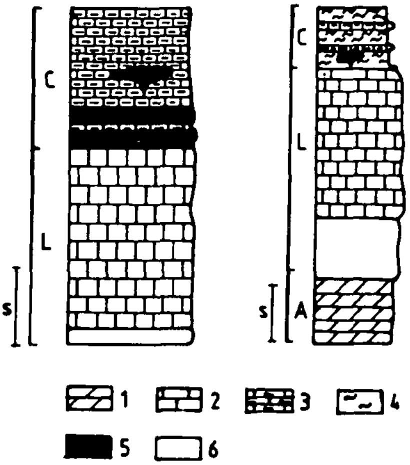

Fig. 2. Stratigraphical position of the Middle Triassic Eastern Bükk magmatites (after CSONTOS 1988) — 1. dolomite (deposited on outer shelf carbonate platform); 2. limestone (like at the dolomite); 3. cherty limestone (deposited in intraplatform basins); 4. shale (equivalent of the Raiblian shale); 5. U. Anisian-L. Ladinian intermediate-acidic volcanics; 6. U. Ladinian-Carnian basaltic volcanics and subvolcanic intrusions. s: 200 m.

position of pumpellyite ÁRKAI (1973, 1983) pointed out, that the Eastern Bükk magmatites were affected by an Alpine regional, high temperature pumpellyite-prehnite-quartz facies (WINKLER 1965) showing transition towards the greenschist facies metamorphism. This is why the attempts to determinate the magmatectonic setting of Eastern Bükk magmatites based on major-element geochemistry did not yield unequivocal results.

ÁRVA—SÓS *et al.* (1987) have determined the K/Ar age of some Eastern Bükk basic metatuffs and metarhyolites (quartz-porphyry) (Table 1). By reason of the recent petrographical investigations monomineralic phases (plagioclase and pyroxene-rich fractions) of the main metabasalt type were measured. As shown by the

TABLE 1.

K—Ar ages of the Eastern Bükk metamagmatites (measured by ÁRVA-SÓS).

		Phase measured	Potassium content	$^{40}Ar_{rad}$ (ncm^3/cm)	$^{40}Ar_{rad}$ (%)	K—Ar age (million years)
1.	Bag	w.r.	5.165	2.153 *E-5	97.0	104.0± 5
2.	Bag	w.r.	6.63	2.590 *E-5	87.0	98.0± 5
3.	Bag	w.r.	4.51	1.704 *E-5	98.0	95.0± 5
4.	Lil	w.r.	2.49	8.287 *E-6	93.0	84.4± 4
5.	Luv	py.	0.558	2.5627*E-6	66.4	114.0± 4.5
6.		pl.	21.029	8.9418*E-6	87.2	110.0± 4.2
7.	Szis	py.	0.115	7.1473*E-7	31.4	153.0±10.2
8.		s.m.	1.803	8.7824*E-6	86.5	121.0± 4.6
9.	Lét	py.	1.006	3.6689*E-6	73.1	91.5± 3.6
10.		pl.	2.479	7.3516*E-6	89.5	74.8± 2.8

w.r. — whole rock samples; pl. — phase abundant in plagioclase; py.— phase abundant in pyroxene; s.m. — phase abundant in secondary minerals — Bag—metarhyolite; Lil—metaandesite tuff; Luv—intrusion of Lusta Valley; Szis—lava flows at the Szinva Spring; Lét—intrustion of Létrástető
1.—4. ÁRVÁNÉ SÓS *et al.*, 1987.
5.—10. new data.

data (Table 1) obtained from whole-rock samples and monomineralic phases the radiometric ages indicate the Alpine regional metamorphic event (ÁRKAI 1973, 1983) probably connected to the Austrian (Upper Cretaceous) orogeny (ÁRVA—SÓS *et al.* 1987).

PETROGRAPHY

1. The older "andesitic-rhyolitic" sequence

The detailed petrographical descriptions were reported in works of SZENTPÉTERY (1923—29, 1931—1939), PANTÓ (1951, 1961), BALOGH (1964) and ÁRKAI (1973), therefore only the most relevant features of the fresh lava-types selected to the determination of the magmatectonic setting are briefly summarized here.

The metaandesites are strongly porphyritic and can be divided into two types. The first is characterized by plagioclase (An 10—30) phenocrysts and chlorite pseudomorphs after pyroxene microphenocrysts. The groundmass is strongly altered and made up of plagioclase, apatite, zircon, leucoxene and opaque minerals. The second type has chloritic-nontronitic-seladonitic pseudomorphs after orthorombic and monoclinic pyroxene phenocrysts and andesinic (rare labradoritic) plagioclase phenocrysts. The groundmass is composed of plagioclase and mafic mineral relics, leucoxene and opaques.

Fig. 3. Ignimbrite with flow texture — Flow structure formed around sanidine crystals.| II N, M:32x.

The studied metarhyolites are represented by a porphyritic and an ignimbritic type. In the first type weakly resorbed quartz and strongly resorbed alkali feldspar phenocrysts occur. The groundmass is totally recrystallized and consists of quartz and sericite. The ignimbritic type with flow texture contains crystalloclasts and lithoclasts, as well as some vitroclasts (*Fig. 3*). The crystalloclasts are sanidine, plagioclase, quartz, zircon and chloritic-hematitic pseudomorphs after amphibole (?); the lithoclasts are rhyolites-dacites with porphyritic texture and glassy or slightly crystallized groundmass. The matrix is strongly hematitized and devitrified glass.

2. The younger "basalts"

SZENTPÉTERY (1950a, b), PANTÓ (1951) and ÁRKAI (1973) published the petrography of the metabasalts from the Eastern Bükk, but the spatial distribution

1/ The temperature of the first metamorphic stage was quite uniform (mainly between 570 and 630 °C), and it was the pressure which had greater variation.

2/ The different samples with different recorded pressures represent equilibrium under different pressure conditions during either the top or the retrograde stage of the first metamorphism. In this case the p—T path may have been quite steep.

The pressure and temperature data of the first metamorphism do not seem to support the possibility of the formation of the sillimanite during this time, because neither of the p—T data was plotted within the stability field of the sillimanite.

The pressure and temperature conditions of the second metamorphic event is determined mainly by mineral equilibria. There are only two geothermo-barometric data determined by ÁRKAI *et al.* (1985), for the metamorphic terrain near the Somogy-Dráva Basin (534—536 °C, and about 200 Mpa), and two provided by this study for the Somogy-Dráva Basin (520—530 °C and 300—350 Mpa). These data indicate low pressure and temperature near the beginning of the medium grade. The pressure data are consistent with the observed andalusite-staurolite-sillimanite, and the andalusite-cordierite-sillimanite critical mineral assemblage, but the temperature was probably higher than those obtained from the hornblende-plagioclase geothermo-barometer. In compliance with the appearance of the sillimanite in the mineral assemblage, the temperature may have been about 600 °C (*Fig. 2*).

ACKNOWLEDGEMENTS

The author is wishes to thank N. POSPELOVA (Institute of Geology and Geochemistry of the Siberian Branch of the Academy of Sciences of the Sovietunion, Novosibirsk) for her kind help with the microprobe analyses, J. KÓKAI (Chief geologist of National Hydrocarbon and Gas Trust) for providing the samples. Thanks are also due to Prof. I. KUBOVICS, CS. SZABÓ (Department of Petrology and Geochemistry, Eötvös University) and to GY. BUDA (Department of Mineralogy, Eötvös University) for critical review of the manuscript, to ZS. KOVÁCS (National Hydrocarbon and Gas Trust) for providing the map with the localities of the boreholes and to Mrs. A. SZILÁGYI for drawing the figures.

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and the significant features of the main lava-types they described was not quite clear.

A. Lava flows at the Szinva Spring. This rock has schistose structure and mildly to strongly porphyritic texture (max 40%). The former is abundant in vesicles, but the latter does not have them. The deformed phenocrysts are: colourless augite and sericitic pseudomorphs after plagioclase (*Fig. 4*). The groundmass is totally altered and makes up of augite relicts, actinolite, chlorite, sericite and leucoxene.

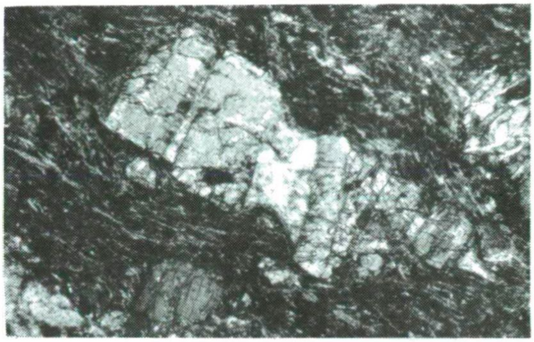

Fig. 4. Metabasalt with schistose structure and porphyritic texture (lava flow from Szinva Spring). — Aparted augite phenocrystal. x N, M:32x.

B. Intrusions emplaced in cherty limestone. This metabasalt has subophitic texture. The strongly coloured clinopyroxene phenocrysts have brownish pink to reddish brown dichroism, zoned and hour-glass structure. The clinopyroxenes partly enclose the plagioclase phenocrysts (they have completely sericitized) indicating that the crystallization of the plagioclases preceeded the formation of the clinopyroxenes. The totally destroyed groundmass consists of secondary minerals (chlorite, epidote, actinolite, opaques, leucoxene and albite).

C. Intrusions in the Raiblian shale — type formation. This is the most fresh Eastern Bükk metabasalt type, which has subaphyric texture. The very rare microphenocrysts (olivine) appear as replaced by calcite and chlorite. The groundmass consists of abundant augite and andesinic/labradoritic plagioclase (An 58—46), subordinate biotite, leucoxenized opaques and scarce apatite. Clinopyroxenes are weakly coloured (pale brownish yellow) and their zoned structure can be observed rarely as well.

GEOCHEMISTRY

The major elements determined by wet chemical analysis using atomic absorption method for Al, Mn, Mg, Ca, Na, K, flame-photometric method for Ti, P, and thermometric method for Si, Fe; Ni, Rb, Sr and Ba were determined by atomic absorption method (analyzed by L. HOFFMANN, Dept. of Petr. and Geochem., Eötvös University, Budapest). Y, Zr, and Nb were measured by quantitative spectrographic analysis (analyzed by J. NAGY-BALOGH, Dept. of Petr. and Geochem., Eötvös University, Budapest). Rare-earth elements, Hf, Ta, Th, Cr, Co and Sc were determined by INAA in the Nuclear Technical Institute of the Technical University, Budapest (analyzed by ZS. MOLNÁR).

1. Major-element geochemistry

A. Metaandesites and metarhyolites. Among the intermediate-acidic volcanics five groups were distinguished using Q-mode cluster analyses on major element chemical compositions (Table 2). As shown in the total alkalia-silica diagram (*Fig. 5*) the transition is continuous between the rock types, especially in the intermediate range. Due to the subsequent alkali enrichment the data-points trend to move towards the trachitic field. The AFM diagram (*Fig. 6*) indicates calc-alkaline trend to this volcanic sequence.

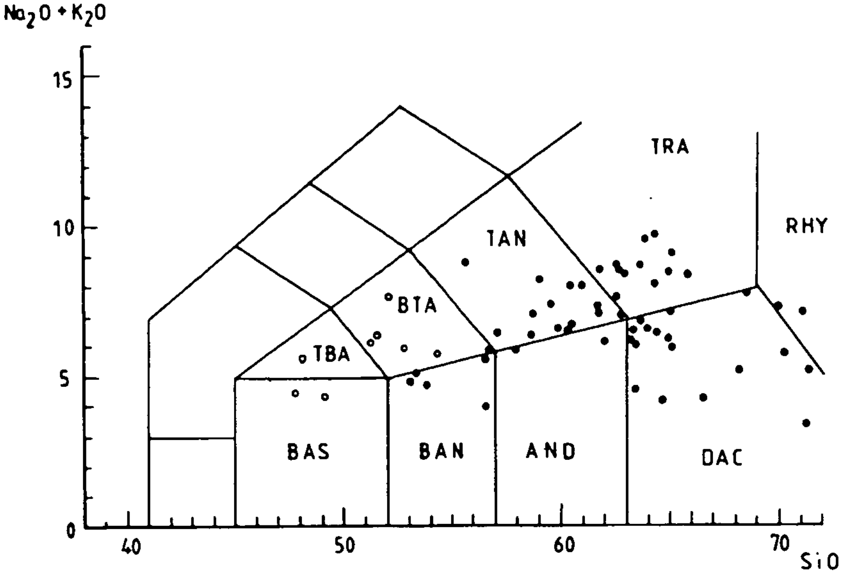

Fig. 5. TAS diagram for the Middle Triassic Eastern Bükk volcanic and subvolcanic rocks (open circles: "younger" metabasalts; solid circles "older" intermediate-acidic rocks).

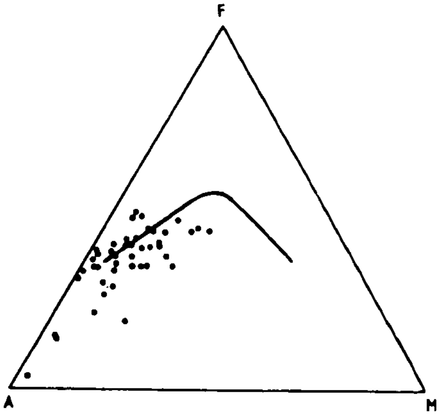

Fig. 6. AFM diagram for the Middle Triassic Eastern Bükk intermediate-acidic volcanics ("older" sequence).

TABLE 2.

The average major element and normative compositions of the Eastern Bükk intermediate–acidic volcanic groups ("older" sequence) distringuished by Q-mode cluster analyses.

	I		II		III		IV		V	
	a	b	a	b	a	b	a	b	a	b
SiO_2	76.33	76.78	72.53	72.69	63.75	65.36	58.73	60.41	54.12	55.84
TiO_2	0.08	0.08	0.12	0.12	1.43	1.47	1.50	1.54	1.52	1.57
Al_2O_3	11.85	11.92	13.75	13.78	16.32	16.73	19.19	19.74	17.71	18.27
Fe_2O_3	0.63	0.63	0.87	0.87	3.06	3.14	2.81	2.89	3.95	4.08
FeO	0.51	0.51	0.87	0.87	1.71	1.75	2.89	2.97	4.29	4.43
MnO	0.00	0.00	0.00	0.00	0.10	0.10	0.12	0.12	0.08	0.08
MgO	0.42	0.42	0.39	0.39	1.23	1.26	1.49	1.53	3.27	3.37
CaO	1.02	1.03	0.77	0.77	3.40	2.77	4.09	3.17	7.29	6.97
Na_2O	2.46	2.47	1.82	1.82	4.46	4.57	5.43	5.59	3.53	3.64
K_2O	5.77	5.80	8.44	8.46	2.41	2.47	1.82	1.87	1.57	1.62
P_2O_5	0.35	0.35	0.22	0.22	0.37	0.38	0.16	0.16	0.13	0.13
CO_2	0.00		0.00		0.55		0.79		0.42	
$+H_2O$	0.71		0.67		1.70		1.53		1.93	
$-H_2O$	0.10		0.11		0.14		0.09		0.44	
Sum	100.23	100.00	100.56	100.00	100.63	100.00	100.64	100.00	100.25	100.00
q	38.21		27.79		22.57		11.80		8.89	
c	0.54		0.75		2.41		3.15		—	
or	34.30		49.99		14.60		11.06		9.57	
ab	20.94		15.44		38.69		47.26		30.82	
an	2.79		2.39		11.25		14.66		28.73	
cpx	—		—		—		—		3.97	
di	—		—		—		—		3.20	
hd	—		—		—		—		0.77	
opx	1.34		1.66		3.14		4.57		8.83	
en	1.05		0.97		3.14		3.82		6.92	
fs	0.29		0.68		—		0.75		1.91	
mt	0.92		1.26		1.74		4.19		5.91	
il	0.15		0.23		2.78		2.93		2.98	
hm	—		—		1.94		—		—	
ap	0.83		0.52		0.90		0.39		0.32	
M	59.48		44.41		56.18		47.89		57.60	
DI	93.45		93.22		75.86		70.12		49.28	
SI	4.29		3.15		9.56		10.32		19.69	

Data are from SZENTPÉTERY (1923—39) and BALOGH (1964), partly analyzed by L. HOFFMANN (ELTE Dept. of Petr. and Geochem.). I—II.: metarhyolite, III.: metadacite, IV.: metaandesite, V.: basaltic andesite; a: raw data, b: volatile-corrected data.

Comparing the Eastern Bükk rock types with the volcanics of some orogenic areas (EWART and LE MAITRE 1980), the following substantial differences appear: the Eastern Bükk rhyolites have higher K_2O-contents (high normative orthoclase values) than the references, while the Eastern Bükk andesites and the basaltic andesites have higher TiO_2-, Al_2O_3-, Na_2O- (high normative corund values) and lower MgO-contents than the orogenic intermediate rocks.

B. The younger metabasalts. The analyses of the representative metabasalts samples are given in the Table 3. On the total alkalia-silica diagram (*Fig. 5*) data-points of the samples containing 4-5% volatiles concentrate in the field of trachybasalts and basaltic andesites. Based on the normative compositions of the metabasalts calculated from the volatile-free and Fe-corrected data, the lava flows occurring at the Szinva Spring may be considered as tholeiitic basalts (normative opx appears), while the intrusions of Lusta Valley and Létrástető, which have the highest S. I. and D. I. values show alkaline olivine basalt affinity (normative ne and ol in the norms) (Table 3).

2. *Trace-element geochemistry*

Analyses of the representative rock samples are given in the Table 4.

A. Metaandesites and metarhyolites. On the spiderdiagrams proposed by PEARCE (1982) some throughs and spikes appear (*Fig. 7*). In the case of primary basalts this phenomenon shows the nature of the source material and the partial melting process. Some of these geochemical features appearing in the basalt patterns can be extended to more evolved compositions, whereas others can be explained as the effect of fractional crystallization, volatile loss or crustal contamination (PEARCE 1982). For this reason trace element patterns of Eastern Bükk intermediate and acidic rocks are less suitable to determine the magmatectonic position of the older sequence. However, since the Nb and Ta behave as incompatible elements, the displayed low abundances of these elements in the Eastern Bükk metaandesithes-metarhyolites may reflect Nb-Ta depleted source indicating a

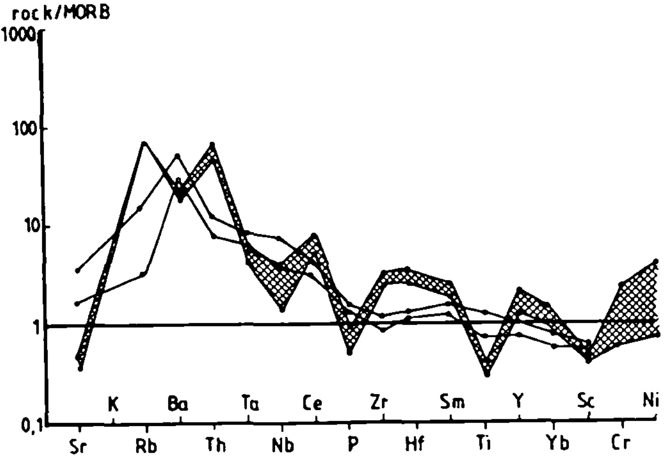

Fig. 7. Spiderdiagrams (PEARCE, 1982) of the Middle Triassic Eastern Bükk volcanic and subvolcanic rocks. (solid circles and dashed area: the "older" intermediate-acidic volcanics; area bordered by open circles: the "younger" basaltic volcanic and subvolcanic rocks).

TABLE 3.

Major element and normative compositons of the representative metabasalt samples (SZENTPÉTERY 1950/a; BALOGH 1964; analyzed by L. HOFFMANN).

	LUV		SZIS		LÉT	
	a	b	a	b	a	b
SiO_2	47.90	51.66	48.00	51.39	48.00	50.42
TiO_2	1.46	1.57	0.90	0.96	1.93	2.03
Al_2O_3	13.07	14.10	14.18	15.18	18.40	19.33
Fe_2O_3	4.59	1.57	7.84	1.66	3.39	1.67
FeO	4.17	7.87	1.48	8.32	6.13	8.33
MnO	0.10	0.11	0.11	0.12	0.17	0.18
MgO	8.68	9.36	9.57	10.25	4.90	5.15
CaO	7.35	7.18	6.74	5.85	5.58	5.66
Na_2O	2.93	3.16	2.68	2.87	4.86	5.11
K_2O	2.95	3.18	2.98	3.19	1.27	1.33
P_2O_5	0.21	0.23	0.20	0.21	0.76	0.80
CO_2	0.54		1.00		0.15	
$+H_2O$	4.44		3.81		3.44	
$-H_2O$	0.60		1.00		0.20	
Sum	98.99	100.00	100.49	100.00	99.18	100.00
c	—		—		1.10	
or	18.80		18.85		7.88	
ab	24.57		24.28		41.94	
an	14.88		19.12		22.87	
ne	1.18		—		0.68	
cpx	15.58		6.89		—	
di	11.11		4.82		—	
hd	4.47		2.06		—	
opx	—		3.58		—	
en	—		2.40		—	
fs	—		1.18		—	
ol	19.20		22.54		17.41	
fo	12.73		14.63		8.98	
fa	6.47		7.91		8.43	
mt	2.28		2.41		2.42	
il	2.99		1.83		3.85	
ap	0.54		0.51		1.89	
M	67.94		68.71		52.40	
DI	44.55		43.13		50.50	
SI	37.22		38.98		23.84	

a: raw data, b: volatile- and Fe^{+2} / Fe^{+3} corrected data. SZIS: Szinva Spring; LUV: Lusta Valley; LÉT: : Létrástető.

TABLE 4.
Trace element contents of the representative Eastern Bükk Middle Triassic volcanic and subvolcanic rocks.

	LÉT	LUV	SZIS	LIL	NIE	BÁN
La	35.00	18.50	19.00	28.50	36.00	39.50
Ce	62.00	40.00	42.00	57.00	62.00	85.00
Sm	5.00	4.87	4.25	6.54	7.04	8.75
Eu	1.10	1.61	1.63	1.00	1.00	1.10
Yb	2.20	2.20	2.04	3.10	2.40	4.60
Lu	0.35	0.28	0.30	0.48	0.45	0.72
Hf	3.80	3.20	2.80	6.30	7.00	9.00
Ta	3.10	1.40	1.20	0.80	1.10	1.00
Th	5.40	2.10	1.60	9.50	12.60	13.20
Cr	113.00	100.00	244.00	89.00	170.00	220.00
Co	16.00	38.10	36.00	9.70	10.30	5.60
Sc	16.00	22.50	25.00	16.60	9.60	19.20
Nb	51.00	27.00	13.00	5.00	5.00	14.00
Y	27.00	29.00	24.00	39.00	41.00	67.00
Zr	116.00	99.00	76.00	227.00	220.00	297.00
Ba	781.90	637.30	640.80	378.40	223.20	n.d.
Rb	27.30	12.70	6.60	154.20	10.10	n.d.
Sr	265.10	433.40	199.80	44.00	166.10	n.d.
Ni	179.80	242.50	224.10	69.10	125.50	n.d.

REE-elements and Hf, Ta, Cr, Co, Sc analyzed by ZS.MOLNÁR (Technical University, Budapest); Nb, Y, Zr analyzed by J. NAGY-BALOGH (ELTE Dept. of Petr. and Geochem.); Ba, Rb, Sr, Ni analyzed by L. HOFFMANN (ELTE Dept. of Petr. and Geochem.)
LÉT, LUV, SZIS: metabasalt (Létrástető, Lusta Valley, Szinva Spring).
LIL, NIE: metaandesite (Lillafüred, Nagy István erőse Hill).
BÁN: metarhyolite (Bánkút).

destructive plate margin origin (WILSON 1989) for these rocks. This suggestions seems to be supported by the La/Th (GILL, 1981) and by the Th-Hf/3-Ta (WOOD 1980) discrimination diagrams. In the former plot the Eastern Bükk metaandesites correspond the criteria of orogenic andesites ($2<La/Th<7$), while in the latter diagram (*Fig. 8*) data-points locate in the fields of the destructive plate margin-type basalts and their differentiates.

The chondrite-normalized rare-earth element (REE) patterns of the metaandesites-metarhyolites show strong negative Eu anomalies (Eu/Sm = 0.12-0.15), which reflect the fractionation of Eu into the feldspars in an earlier stage of the magma evolution (*Fig.* 9). (This fact corresponds to the low Sr abundances displayed on the spiderdiagram, although it had partly decreased by the metamorphism as well.)

B. The younger metabasalts. As shown on the spiderdiagrams (*Fig. 7*), the style of enrichment of some elements normalized to the MORB composition (PEARCE 1982) is highly similar to the trace element patterns of the transitional basalts formed in the within-plate areas.

In opposition to the older and more acidic sequence the data-points of the metabasalts fall in the field of within-plate basalts on the WOOD (1982) diagram

(*Fig. 8*), and they plot range along the **P**-type **MORB—WPA** boundary, which is also supported by their transitional to slightly alkaline character.

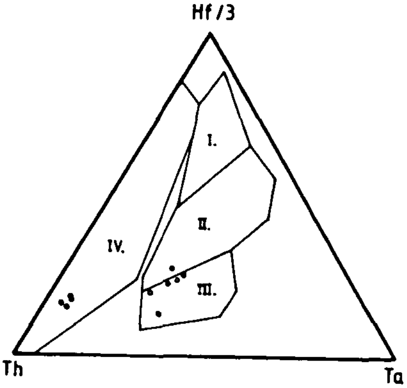

Fig. 8. Th-Hf/3-Ta discrimination diagram (WOOD 1980) for the Middle Triassic Eastern Bükk volcanic and subvolcanic rocks. (solid circles: the "older" intermediate-acidic volcanics; open circles: the "younger" basaltic volcanic and subvolcanic rocks).
I. **N-MORB.**: normal mid-ocean ridge basalts - II. **P-MORB.**: plume-MORB - III. **WPA**: within-plate alkaline basalts - IV. **DPMB**: destructive plate margin basalts and their differentiates.

The chondrite-normalized REE patterns of the Eastern Bükk metabasalts (*Fig. 9*) are only slightly light-REE enriched and have no Eu-anomaly except only those of the Létrástető intrusive rock (Eu/Sm = 0.22). With the strong enrichment displayed in the Ba-Pa range on its trace element patterns, this phenomenon indicates more evolved nature of the Létrástető intrusion compared to the other Eastern Bükk metabasalts.

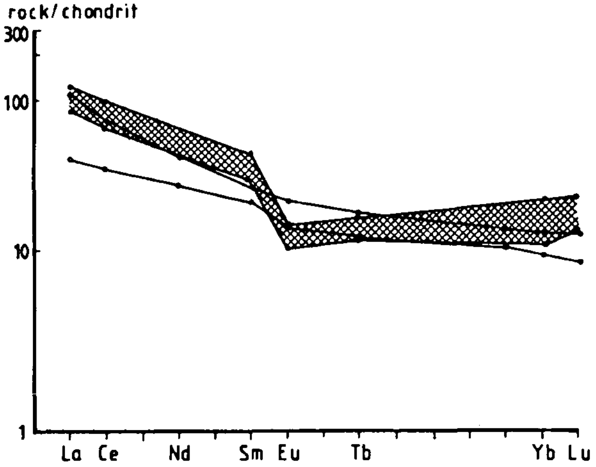

Fig. 9. Chondrite-normalized (NAKAMURA 1974) REE patterns of the Middle Triassic Eastern Bükk volcanic and subvolcanic rocks (solid circles and dashed area: the "older" intermediate-acidic volcanics; area bordered by open circles: the "younger" basaltic volcanic and subvolcanic rocks).

3. The chemical composition of pyroxenes

The chemical analyses of clinopyroxenes were performed with an AMRAY 1830I electron microprobe by M. JÁNOSI (Dept. of Petr. and Geochem. Eötvös University, Budapest) using 20 kV accelerating voltage and 20 nA beam current. Raw data were corrected by the on-line ZAF correction program.

The average compositions of the clinopyroxenes are given in the Table 5. *Fig. 10* illustrates the distribution of data-points on the Ca-Mg-Fe ternary. The LUV-pyroxenes (from the intrusions in the Lusta Valley) and LÉT-pyroxenes (from the Létrástető intrusion) can be classified partly as diopsides, but mainly as salites, while the SZIS-pyroxenes (from the lava flows occurring at Szinva Spring) proved to be salites, a part of them wollastonit-reach clinopyroxenes.

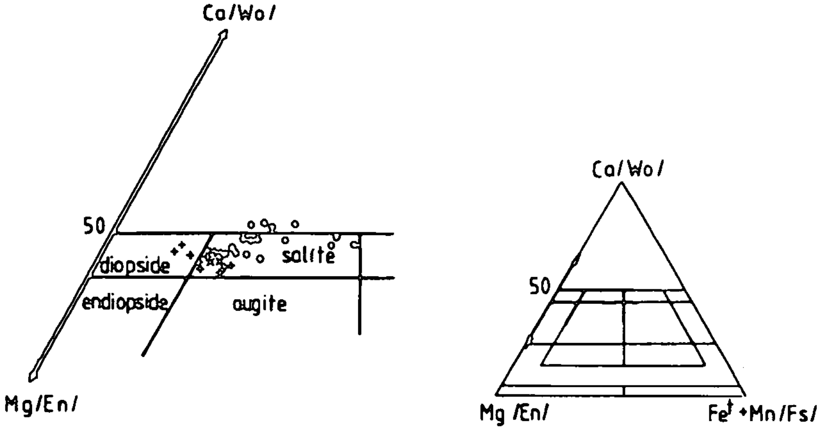

Fig. 10. Ca-Mg-Fe ternary for the clinopyroxenes from Middle Triassic Eastern Bükk metabasalts ("younger" sequence).
x: Létrástető; solid circles : Lusta Valley; +: Szinva Spring.

In the triangular diagram proposed by NISBET and PEARCE (1977) all pyroxene types show within-plate alkaline basalt (WPA) affinity.

On the plot of the discrimination functions F_1 against F_2 (NISBET and PEARCE, 1977) the data-points of the pyroxenes mostly fall on the boundary of the WPA-VAB-OFB fields, while the LUV-pyroxenes show an alkaline trend characterized by enrichment of TiO_2, Al_2O_3 and FeO from the core to the rim (*Figs. 11, 12*).

In the discrimination diagram based on Ti and Ca+Na content of clinopyroxenes (LETERRIER *et al.* 1982) (*Fig. 13*) the SZIS-pyroxenes show the less and the LUV-pyroxenes the most alkaline character, while the LÉT-pyroxenes have transitional position.

If we accept the assumption, that the two younger magmatic events (i.e. Upper Lanidian — Lower Carnian /Szinva Spring/; in the upper part of the Carnian /Lusta Valley, Létrástető/) producing the basaltic rocks form a single cogenetic sequence, we have to concede the slightly alkaline character indicating by SZIS-pyroxenes, i.e. they were formed from an evolved liquid with modified composition compared to the initial magma.

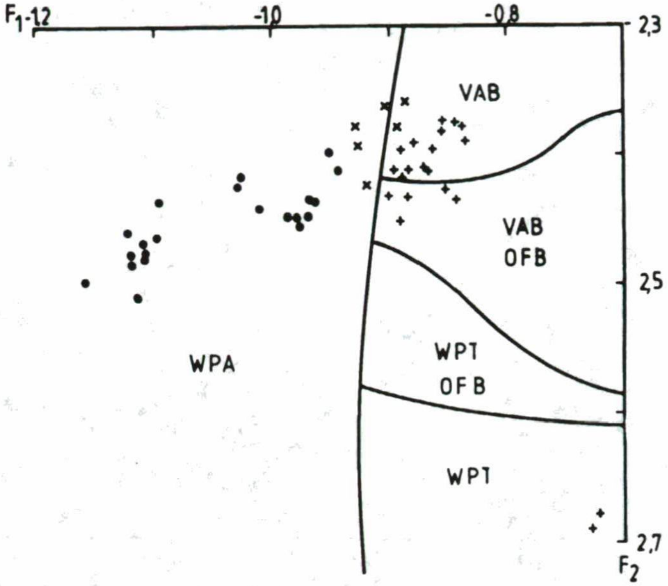

Fig. 11. Plots of discriminant function F_1 vs. F_2 (NISBET and PEARCE 1977) for the clinopyroxenes from Middle Triassic Eastern Bükk metabasalts ("younger" sequence).
VAB: volcanic arc basalts; **OFB**: ocean-floor basalts; **WPA**: within-plate alkaline basalts; **WPT**: within-plate tholeiitic basalts; x: Létrástető; solid circles : Lusta Valley; +: Szinva Spring.

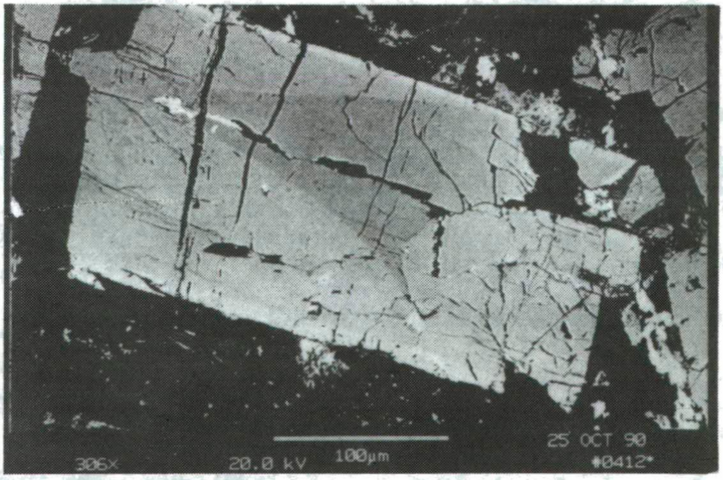

Fig. 12. Backscattered electron image of LUV-pyroxenes with hour-glass structure.

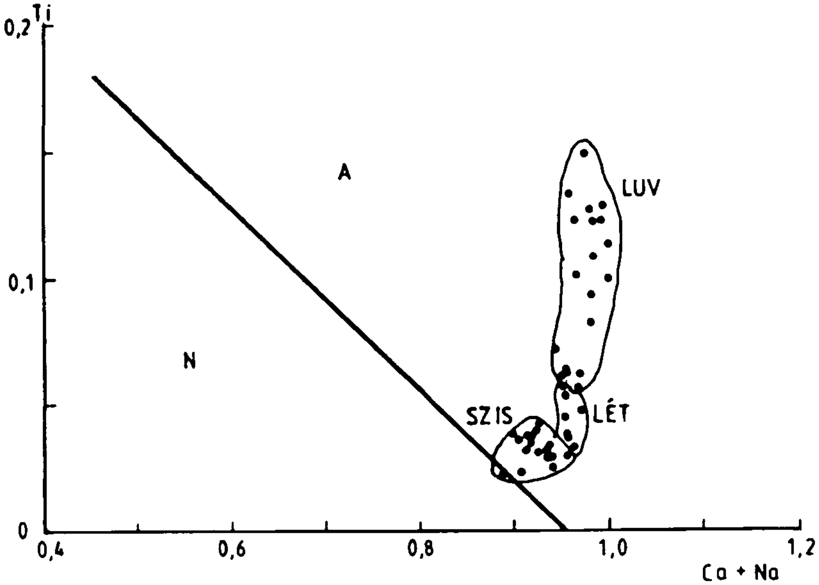

Fig. 13. Ti vs. Ca+Na discriminant diagrams (LETERRIER *et al.* 1982) for the clinopyroxenes from Middle Triassic Eastern Bükk metabasalts ("younger" sequence).
A: field of the alkaline basalts.
B: field of the non-alkaline basalts.
LÉT: Létrástető; LUV: Lusta Valley; SZIS: Szinva Spring.

SUMMARY

All geochemical patterns show, that the andesitic-rhyolitic lavaflows, tuffs and ignimbrites in the Upper Anisian - Lower Lanidian volcanic horizon erupted at a convergent plate margin and they have calc-alkaline character (*Fig. 14*).

In contrast with the former volcanism, the Upper Lanidian - Carnian volcanic (Szinva Spring) and subvolcanic (Létrástető, Szinva Valley) basalts formed by within-plate magmatic processes (*Fig. 14*). The lava flows in the volcanoclastic sequence at Szinva Spring erupted in the initial stage of the basic volcanism and have slightly alkaline or rather transitional character, while the subvolcanic intrusions (Létrástető, Szinva Valley) consist of alkaline basalt types according to their more differenciated nature.Although the Triassic igneous rocks in the Dinarides have been found by PAMIĆ (1984) as the products of a rifting episode, the magmatism also shows the geochemical ambivalence detected in the magmatic sequence of the Bükk Mts. as well. On the basis of the major-element geochemistry, the basic and some intermediate rocks in the Dinarides show tholeiitic nature, whereas some intermediate- and all acidic rocks show calc-alkaline affinity. Since the trace element patterns of the basic volcanics indicate within-plate character (like in the Bükk Mts.),therefore in the suggestion of PAMIĆ (1984) the whole Triassic magmatic sequence of the Dinarides is genetically related to the rifting of a stable continental realms.

TABLE 5.

Average compositions of clynopyroxenes from Middle Triassic Eastern Bükk metabasalts ("younger sequence").

	LÉT		LUV				SZIS			
	(n=6)		(n=3) a		(n=3) b		(n=4) a		(n=12) b	
SiO_2	49.15	(0.88)	48.40	(0.53)	44.32	(1.06)	51.53	(0.46)	49.22	(0.41)
TiO_2	1.45	(0.26)	2.18	(0.02)	4.37	(0.20)	0.73	(0.07)	1.18	(0.14)
Al_2O_3	3.69	(0.62)	4.40	(0.14)	7.93	(0.85)	3.45	(0.05)	5.24	(0.52)
Cr_2O_3	0.09	(0.19)	0.02	(0.02)	0.05	(0.04)	0.16	(0.12)	0.14	(0.09)
FeO_t	6.67	(0.57)	8.19	(0.15)	9.25	(0.46)	6.24	(0.36)	6.98	(0.92)
MnO	0.11	(0.07)	0.12	(0.03)	0.14	(0.03)	0.12	(0.03)	0.11	(0.07)
MgO	14.19	(0.40)	13.36	(0.07)	10.81	(0.23)	16.21	(0.55)	14.16	(0.54)
CaO	22.32	(0.07)	22.73	(0.29)	22.66	(0.60)	21.42	(0.40)	21.91	(0.32)
Na_2O	0.76	(0.11)	0.64	(0.16)	0.81	(0.11)	0.55	(0.07)	0.61	(0.,14)
Cation numbers on the basis of 6 oxygens										
Si	1.859		1.818		1.680		1.892		1.837	
Al_4	0.141		0.182		0.320		0.108		0.163	
Al_6	0.024		0.013		0.034		0.041		0.068	
Ti	0.041		0.062		0.125		0.020		0.033	
Gr	0.003		0.001		0.001		0.005		0.004	
Fe^{3+}	0.127		0.133		0.141		0.090		0.102	
Fe^{2+}	0.084		0.124		0.153		0.101		0.116	
Mn	0.004		0.004		0.004		0.004		0.004	
Mg	0.800		0.748		0.611		0.887		0.788	
Ca	0.905		0.915		0.920		0.843		0.876	
Na	0.056		0.046		0.060		0.039		0.044	
K	0.000		0.000		0.000		0.000		0.000	
Ac	5.57		4.63		5.97		3.93		4.44	
Jd	0.00		0.00		0.00		0.00		0.00	
TiTs	4.12		6.15		12.46		2.00		3.32	
CrTs	0.26		0.05		0.13		0.47		0.41	
CaTs	2.41		1.29		3.36		4.14		6.76	
FATs	7.13		8.72		8.08		5.06		5.73	
Wo	38.27		37.64		33.99		36.30		35.68	
En	40.00		37.40		30.53		44.36		39.38	
Fs	4.38		6.38		7.84		5.25		5.98	
mg	0.79		0.74		0.68		0.82		0.78	

n=number of analysis; standard deviations are given in the parenthesis; analyzed by M. JÁNOSI (ELTE Dept. of Petr. and Geochem.)

LÉT: Létrástető - The average of all analysis.

LUV: Lusta Valley - Composition of the core (a) and the rim (b) of a representative grain presented on the *Fig. 12*.

SZIS: Szinva Spring - a: Average core-composition of some clinopyroxenes. — b: Average composition of the non-zoned clinopyroxenes and the rim of the grains listed in file a.

	Variation plot	Spider	Th—Hf—Ta	Chem comps of clinopyroxenes
metabasalts	———	WPA—WPT TRANSITIONAL	WPA	ALKALINE
Szinva Spring			slightly	slightly
Lusta Valley			slightly	slightly
Létrástető			stronger	stronger
metaandesites metarhyolites	OROGENIC (La—Th)	CONVERGENT PLATE MARGIN	CONVERGENT PLATE MARGIN CA	———

Fig. 14. Summary of the magmatectonic setting determination for the Middle Triassic Eastern Bükk metamagmatites
WPA: within-plate alkaline, **WPT**: within-plate tholeiitic, **CA**: calc-alkaline character.

Despite the within-plate affinity of the Eastern Bükk metabasalts, they may have been formed even at a convergent plate margin following the formation of the calc-alkaline andesite-rhyolite magmatism, like in the volcanic assemblages found in Japan and in the Andes. However an independent continental rift-type formation for the Eastern Bükk metabasalts cannot be unambiguously excluded.

The study of genetical relationship between the older intermediate-acidic and the younger basaltic formations as well as the magma-generation in the Middle Triassic convergent plate area (Southern Alps—Outer Dinarides—Bükk Mts.) (e.g. BÉBIEN *et al.*, 1978) is in progress using further geochemical and geodynamical investigations.

ACKNOWLEDGEMENTS

The author wish to thank: SZ. HARANGI and CS. SZABÓ (Eötvös University) for fruitful discussions on the chemical and petrological data; Á. SZILÁGYI—PRITZ for the figures; M. JÁNOSI, J. NAGY BALOGH, L. HOFFMANN (Eötvös University), E. ÁRVA SÓS (ATOMKI, Debrecen) and ZS. MOLNÁR (Technical University, Budapest) for their readiness to help.

This work was supported by OTKA Nº3390313, a grant of Hungarian Academy of Sciences to prof. I. KUBOVICS.

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Manuscript received, 15 November, 1990