MIDDLE TRIASSIC VOLCANISM IN THE BUDA MOUNTAINS

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Abstract

The volcanogenic materials, like pebbles of the Middle and Upper Eocene basal conglomerates in the Buda Mts. were considered as products of the neutral volcanism beginning in the Middle Eocene. But in the last years the andesite gravels are supposed to be Triassic lava products. The present paper shows the presence of other volcanites, like rhyolite, ignimbrite, trachyte and tuff. These may have originated from a volcanic cycle of Middle Triassic age. It is supported by a detailed petrographical-geochemical comparison with the Middle Triassic volcanogenic material of Inota. The studied volcanic activity is the same which has produced the so-called "pietra verde" tuffitic beds in the Transdanubian Central Range. According to the megatectonic relations, these results are compatible with the general magmatic data on the Middle Triassic of the Southern Alps.

Introduction

The Eocene basal conglomerate of the Buda Mts. lies unconformably on Middle or Upper Triassic rocks. It indicates Middle Eocene (at János hill) and Upper Eocene (Róka hill, Kálvária hill) transgressions (WEIN, 1977). The conglomerate itself and the overlying limestone and marl contains thin tuffitic layers. This is the common cause for the widespread opinion that the considerable amount of andesite pebbles in the conglomerate has originated from Middle Eocene and younger volcanism (HOFFMANN, 1871). SZÉKY-FUX and BARABÁS (1953) considered the pebbles as of the same age, on the grounds of the occurrence of Eocene volcanic rocks in the other parts of the Transdanubian Central Range. The Budaörs – 1 key borehole penetrated an andesite body within a Triassic sequence between 775,1 – 831,4 metres. This was considered as Eocene, too (NAGY et al., 1967). The andesite and rhyolite pebbles of the conglomerate are of Eocene origin, according to WEIN (1977). During the revision of the igneous rocks in Budaörs – 1 borehole, Upper Cretaceous alkali ultrabasite-dykes were found within the andesite, consequently the andesite volcanism is of Mesozoic, most probably of Triassic age (KUBOVICS, 1985).

The Triassic sequence of the Buda Mts. is known downwards until the upper part of Ladinian; this sequence does not contain any igneous rock, except an uncertain, Carnian tuffitic layer (WEIN, 1977). The "pietra verde" tuffitic beds are widespread in other parts of the Transdanubian

Central Range. These are of Late Anisian to Early Ladinian age, with potassiumtrachyte and rhyolite composition (SZABÓ and RAVASZ, 1970; RAVASZ, 1973). A sequence of the same age, containing also lava rocks, was found at Inota; these rocks form pebbles in an Upper Ladinian abrasion conglomerate (RAINCSÁK, 1980).

Geological investigations

This study is based on the examination of three exposures of the basal conglomerate in the Buda Mts. (Fig. 1). Grain-size frequency distribution analysis was measured at all localities. Taking lithology into consi-

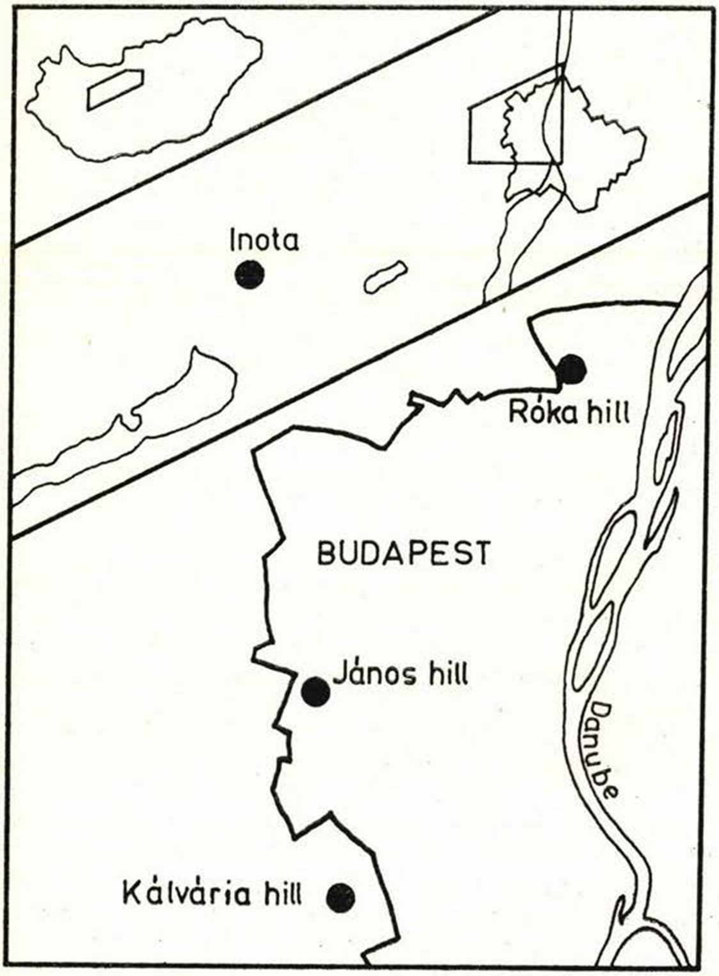

Fig. 1

deration, figure 2 summarizes these results. The dominant component of the clasts are carbonate rocks (Middle and Upper Triassic limestones and dolomites). The amount of volcanite pebbles at Kálvária hill is about 30, at János hill 15 and at Róka hill 5 percents. This relative decrease

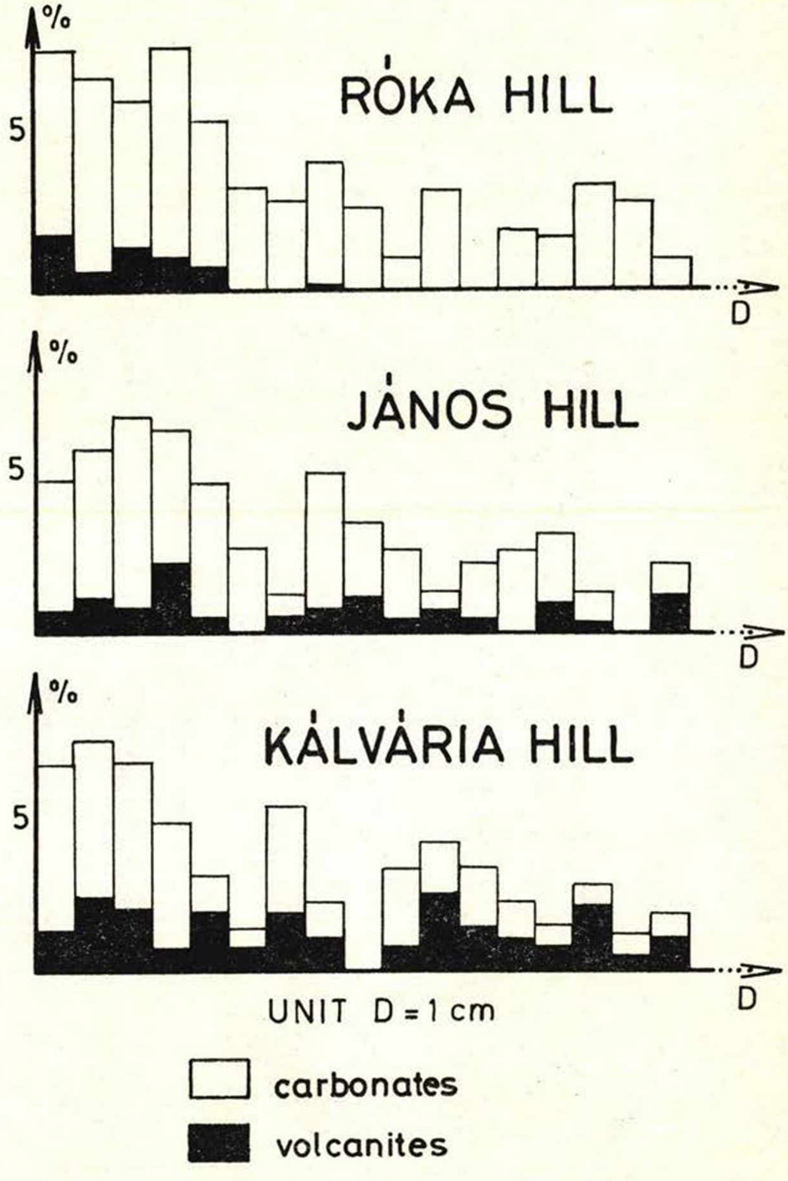

Fig. 2

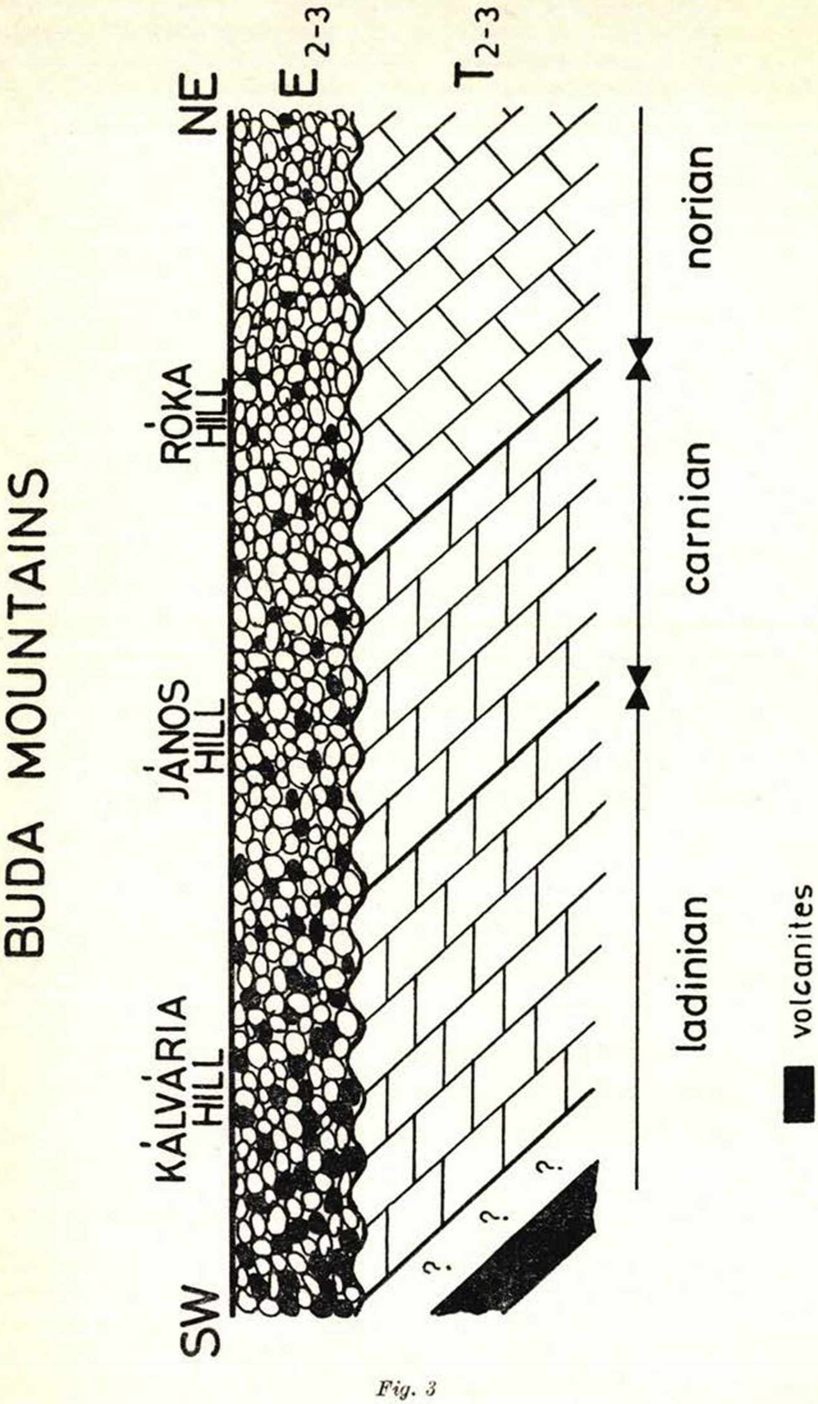
BUDA MOUNTAINS
SW
KÁLVÁRIA HILL
JÁNOS HILL
RÓKA HILL
NE
E_{2-3}
T_{2-3}
norian
carnian
ladinian
volcanites

Fig. 3

of volcanic material can be explained by supposing its origin from an Upper Anisian to Lower Ladinian volcanogenic level. It is well known that due to the Austrian tectonic event, the Triassic sequence of Buda Mts. is dipping to NE direction, therefore on the surface from SW to NE the formations are generally younger and younger. Thus the relative decrease in the amount of volcanite clasts is caused by the increase of stratigraphical distance, as it is shown in a very simple way on the figure 3. This is also supported by grain-size data because in the Southern outcrop (Kálvária hill) some of the boulders are over 40 cm in diameter, but in the Northern exposure (Róka hill) the maximal size is under 10 cm. Because of the presence of big boulders at the Kálvária hill, the source of this material might have been only some kilometers to south.

Since we have supposed a volcanic activity in the Buda Mts. of Middle Triassic age basing our hypothesis on the investigated volcanite pebbles, therefore it is necessary to make a comparison with a stratigraphically proven volcanogenic sequence of the same time. This occurence is at Inota. Here we have found a very similar volcanoclastic material as in the Buda Mts., so this was the basis for the detailed petrographical-geochemical comparison between the two areas.

Petrographical-geochemical investigations

Analytical procedures were: thin sections, chemical analyses, optical spectrography, X-ray diffractometry, neutron activation, K/Ar dating.

The main volcanic rock types are andesite, rhyolite, ignimbrite, trachyte and tuff in all studied exposures. Such volcanic association like this, is unknown from the Eocene.

a) *Andesite*

Black, brown or green rock, altered to a different extent. The kaolinitization of large-sized feldspars is very widespread. The originally presumably orthorhombic pyroxene shows completely glauconite-transformed feature. The biotite has limonitized and the ilmenite has suffered rutilization. The rock also contains apatite and rarely garnet. The groundmass consists of second generation plagioclase crystals, with an oligoclase-andesine composition. Secondary minerals are represented by quartz, chalcedony, opal, limonite, pyrite and calcite.

b) *Rhyolite*

Brownish-grey, with flow structure, its amount is less than the andesite. The flowage banding is typically marked by color differencies, the light colored bands are of quartz, opal and the dark colored bands are of biotite, limonite. The biotite phenocrystals, which have suffered magmatic resorption and limonitization show very significant preferred orientation. Also vesicular structure can be identified in some cases. Plagioclase-fragments with oligoclase composition of locally considerable quantity are found, in form of cumulates. Any distinction is not possible

Tab. 1.

All data by neutron activation. Analyst: J. Bérczi, Technical University of Budapest.
***: by the courtesy of Hungarian Geological Institute**

Sample number	1.	2.	3.	4.	(*) 5.	6.	7.	8.	9.	(*) 10.	11.	12.
Rock type Locality	Andesite Kálvária Hill	Andesite Kálvária Hill	Andesite Róka Hill	Andesite János Hill	Andesite Bő-1 Borehole	Ignimbrite Kálvária Hill	Rhyolite Kálvária Hill	Rhyolite Kálvária Hill	Rhyolite Inota	Rhyolite Inota	Rhyolite Inota	Trachyte Inota
La	17,9 ± 0,3	27,1 ± 0,5	20,2 ± 0,3	23,0 ± 0,3	25,0 ± 0,5	32,2 ± 0,4	32,8 ± 0,3	16,9 ± 0,3	17,5 ± 0,4	24,5 ± 0,5	31,9 ± 0,5	17,7 ± 0,5
Ce	49,5 ± 2,5	50,7 ± 1,7	40,2 ± 1,5	59,7 ± 1,8	58,6 ± 3,8	78,1 ± 1,3	37,3 ± 1,2	29,0 ± 1,6	43,7 ± 1,7	42,6 ± 2,0	73,5 ± 1,7	31,3 ± 1,3
Nd	25,6 ± 2,9	24,1 ± 2,0	22,8 ± 2,1	25,5 ± 1,7	25,5 ± 3,2	40,1 ± 2,3	12,4 ± 1,2	8,8 ± 1,4	11,9 ± 1,7	13,4 ± 1,0	25,8 ± 1,9	40,1 ± 2,4
Sm	5,0 ± 0,1	5,1 ± 0,1	6,4 ± 0,1	6,4 ± 0,1	8,5 ± 0,1	5,1 ± 0,1	5,8 ± 0,1	2,0 ± 0,1	2,9 ± 0,1	3,9 ± 0,1	4,0 ± 0,1	5,1 ± 0,0
Eu	0,68 ± 0,10	0,67 ± 0,09	0,47 ± 0,06	0,76 ± 0,07	0,93 ± 0,09	0,95 ± 0,09	0,32 ± 0,05	0,30 ± 0,08	0,48 ± 0,06	0,53 ± 0,04	0,97 ± 0,07	0,95 ± 0,1
Tb	1,2 ± 0,1	1,2 ± 0,1	1,1 ± 0,1	1,6 ± 0,1	1,0 ± 0,1	1,4 ± 0,1	0,6 ± 0,1	0,6 ± 0,1	0,7 ± 0,1	0,6 ± 0,1	1,5 ± 0,1	1,4 ± 0,1
Tm	0,4 ± 0,1	0,3 ± 0,1	0,5 ± 0,1	0,6 ± 0,1	0,3 ± 0,1	0,4 ± 0,1	0,2 ± 0,1	0,1 ± 0,1	0,2 ± 0,1	0,3 ± 0,1	0,8 ± 0,1	0,4 ± 0,1

Yb	3,0 ± 0,3	3,0 ± 0,3	3,0 ± 0,2	5,8 ± 0,2	3,2 ± 0,3	1,5 ± 0,2	2,2 ± 0,2	0,9 ± 0,3	1,5 ± 0,3	2,0 ± 0,2	5,4 ± 0,2	1,5 ± 0,2
Lu	0,40 ± 0,07	0,40 ± 0,06	0,40 ± 0,05	0,81 ± 0,05	0,53 ± 0,05	0,47 ± 0,06	0,11 ± 0,03	0,13 ± 0,04	0,19 ± 0,05	0,28 ± 0,02	0,77 ± 0,05	0,47 0,07
Th	4,2 ± 0,3	4,6 ± 0,3	4,8 ± 0,2	4,4 ± 0,2	11,5 ± 0,6	6,3 ± 0,4	5,3 ± 0,2	3,2 ± 0,2	4,3 ± 0,3	7,6 ± 0,4	3,4 ± 0,2	3,9 ± 0,2
Hf	0,9 ± 0,2	1,0 ± 0,2	1,1 ± 0,1	1,4 ± 0,01	4,5 ± 0,5	0,8 ± 0,2	0,8 ± 0,2	0,6 ± 0,2	0,7 ± 0,2	1,9 ± 0,3	0,5 ± 0,1	0,7 ± 0,1
Ta	0,2 ± 0,1	0,2 ± 0,1	0,2 ± 0,1	0,3 ± 0,2	0,8 ± 0,2	0,5 ± 0,2	0,3 ± 0,2	0,2 ± 0,1	0,5 ± 0,3	0,9 ± 0,1	0,5 ± 0,2	0,4 ± 0,3
Rb	15 ± 8	9 ± 8	15 ± 5	7 ± 6	124 ±20	14 ± 9	15 ± 6	3 ± 6	164 ± 22	190 ± 20	110 ± 10	136 ±12
Cs	3,5 ± 0,4	6,3 ± 0,4	0,7 ± 0,3	0,8 ± 0,3	23,2 ± 0,8	2,8 ± 0,3	2,6 ± 0,3	10,7 ± 0,3	2,0 ± 0,3	4,5 ± 0,3	5,3 ± 0,3	3,1 ± 0,3
Sc					17,0 ± 0,1					3,6 ± 0,1		
Cr					150 ± 7					30,0 ± 4		
Co					7,8 ± 0,3					4,7 ± 0,2		
Fe%					3,96 ± 0,07					2,26 ± 0,07		
U					2,0 ± 0,4					2,2 ± 0,4		

between the rhyolite samples from Inota and Buda Mts. according to the thin-section investigations, because of the great similarities between the two meterials.

c) *Ignimbrite*

Pale green, altered rock. Its relative amount is the same as of the rhyolite. The rock has a pale green matrix containing feldspar fragments (altered to kaolinite 1 T) and big lithic fragments (maximal diameter can be some cm) with typical "fiammé" form. Their material is mainly andesite mentioned above, consequently the ignimbritic volcanism is younger than the andesitic one. In the fluidal texture there are very many glass shards welding together. The chemical character of the rock is mainly rhyolitic. The amount of accesorial zircone and magmatic quartz is considerable locally.

d) *Trachyte*

Black, relatively unaltered rock, in very little amount. Its colour is deep green at Inota. Its common feature is the presence of large-sized feldspar crystals, whose unaltered specimens show a composition of oligoclase-andesine. The presence of augitic pyroxen and biotite is significant, groundmass consists of mainly potassium-feldspar, limonite, carbonate, clay-minerals, etc.

e) *Tuff*

The rock is generally of pale greyish-green colour, altered, fine-grained and made up for the most part by xenomorphic, isometric quartz grains. There are many glauconite-, chalcedony-filled cavities, attaining 5 mm in size. The mafic conponents have been replaced by secondary minerals. The feldspars have been affected by clay-mineralization. The rock also contains apatite and zircone. In some cases potassium-feldspar can be recognized. The limonitic patches are very widespread. On the ground of our investigations this rock is considered as "pietra verde".

The chemical analyses show high-grade alteration and effects of weathering. Therefore these data do not give enough information.

Since some trace elements, especially the rare earths are considered as relatively immobile during alteration and weathering, we have chosen them for the basis of comparison (Tab. 1). The chondrite-normalized (Haskin et al., 1968) curves of samples (Fig. 4) seem to be very similar at first, independently of the rock type and locality. This qualitative statement can be proved by quantitative, statistical methods. We have used nonlinear mapping (Sammon, 1969) and cluster analysis. The results are shown by the figures 5 and 6. Interpretations described in this discussion are tentative because of the small number of samples.

There are no characteristic differences among the andesite samples, since they form a well-separated group. Rhyolite samples are also relatively "together". This phenomenon in both cases can be explained by the genetic connection of volcanism in the Buda Mts. and at Inota. The

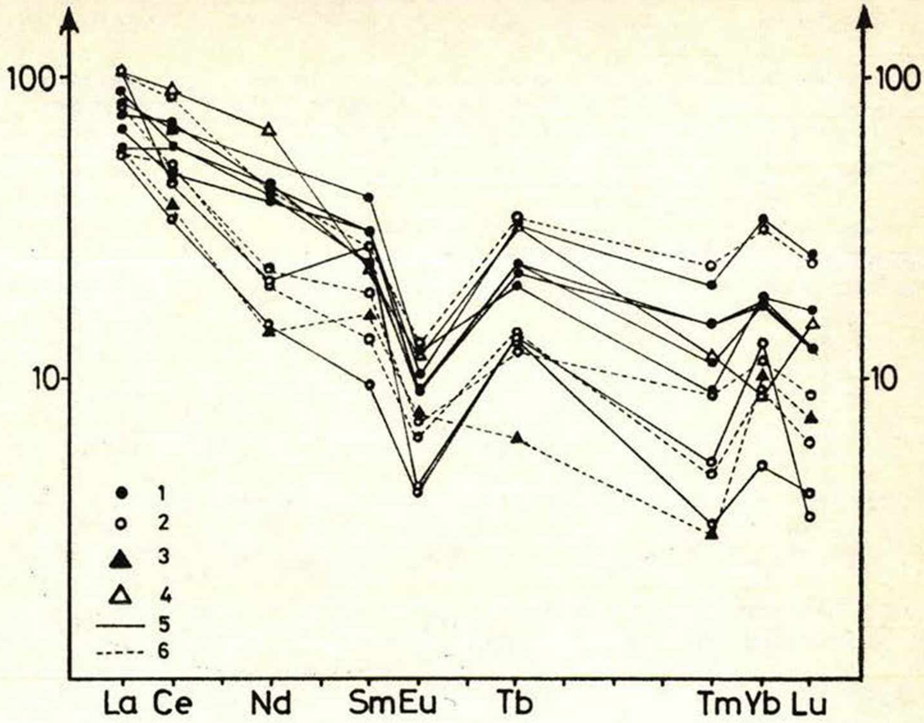

Fig. 4. 1. Andesite; 2. Rhyolite; 3. Trachyte; 4. Ignimbrite; 5. Buda Mts.; 6. Inota.

Tab. 2.

Analyst: K. Balogh, Institute of Nuclear Research of the Hungarian Academy of Sciences Debrecen

Rock name Locality	K (%)	$^{40}Ar_{rad}$ (cm³/g)(%)		K/Ar age in million years	Notes
Andesite Kálvária Hill	0,45	$6,3205 \cdot 10^{-7}$	3	36 ± 17	Strongly altered
Rhyolite Kálvária Hill	0,142	$4,075 \cdot 10^{-7}$	13	$72,5 \pm 8$	Altered
Andesite Róka Hill	0,466	$2,965 \cdot 10^{-6}$	59	157 ± 7	Altered
Trachyte Inota	4,57	$4,4775 \cdot 10^{-5}$	98	236 ± 9	

11. sample seems to be an exception, it has extremely high concentrations. The high negative Eu-anomaly is very significant in all cases, excepting 12. sample. This can be explained only by a complex, multi-stage magmatic process, according to the presence of neutral and acid lava products together. The volcanism, as a whole, has a calc-alkaline feature with alkaline affinity.

Referring to table 2 the radiometric ages of the studied volcanites are very different. It might have been caused by the alteration and weathering of different extent. In one case (4. sample) the method probably has provided the real age.

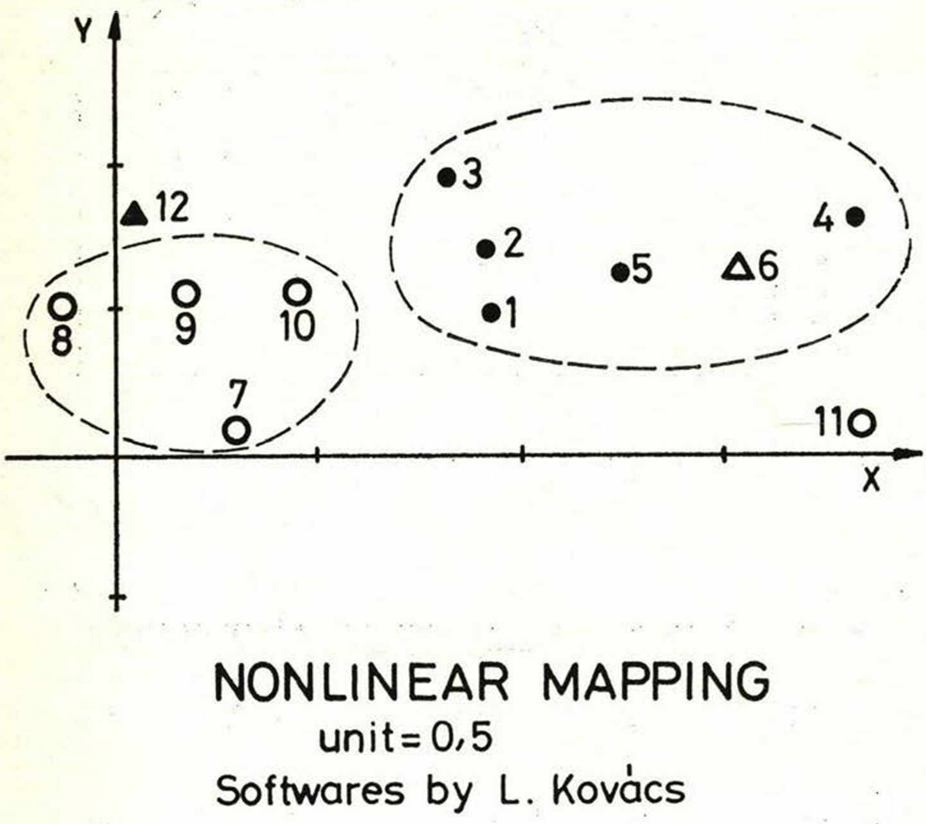

Fig. 5

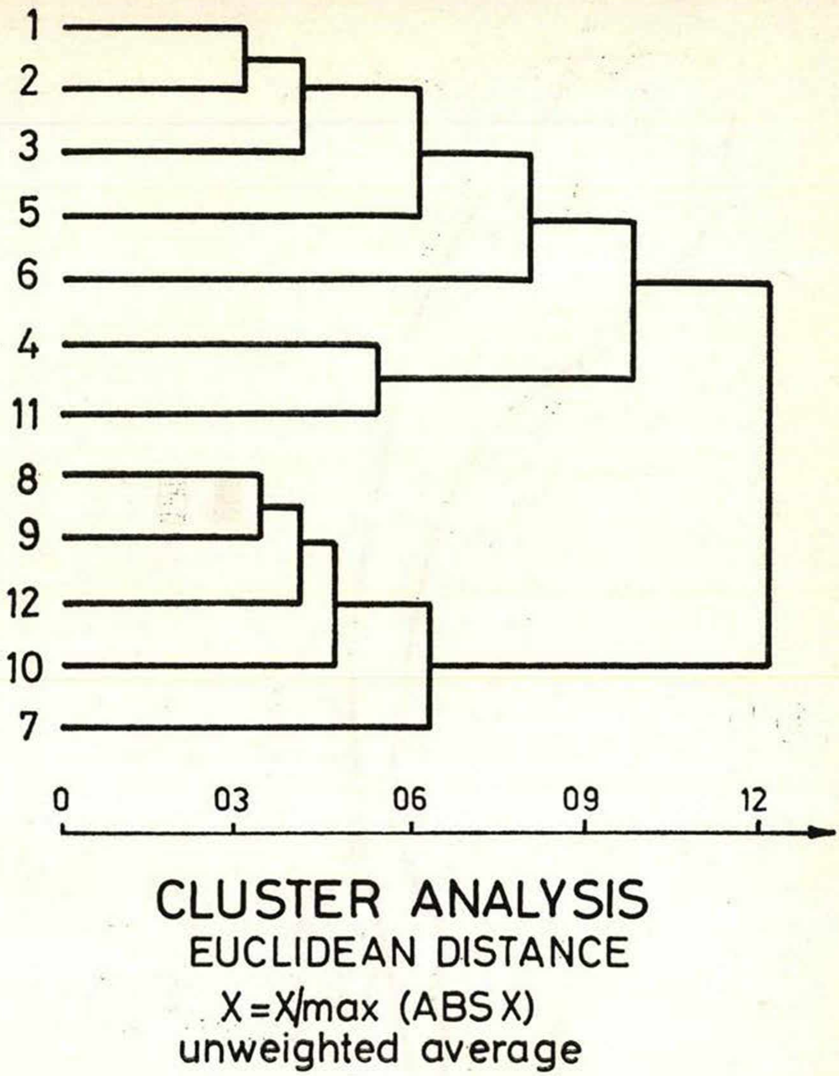

Fig. 6

Tectonic connections

The study of Cros and Szabó (1986) has shown the paleogeographic relations between the Aniso-Ladinian Alpine sequences and the Hungarian provinces in general, on the grounds of the tuffitic characters. According to Kázmér and Kovács (1985) the so-called Bakony-Drauzug unit shifted about 450 km to the east in the Paleogene. Since the studied volcanites

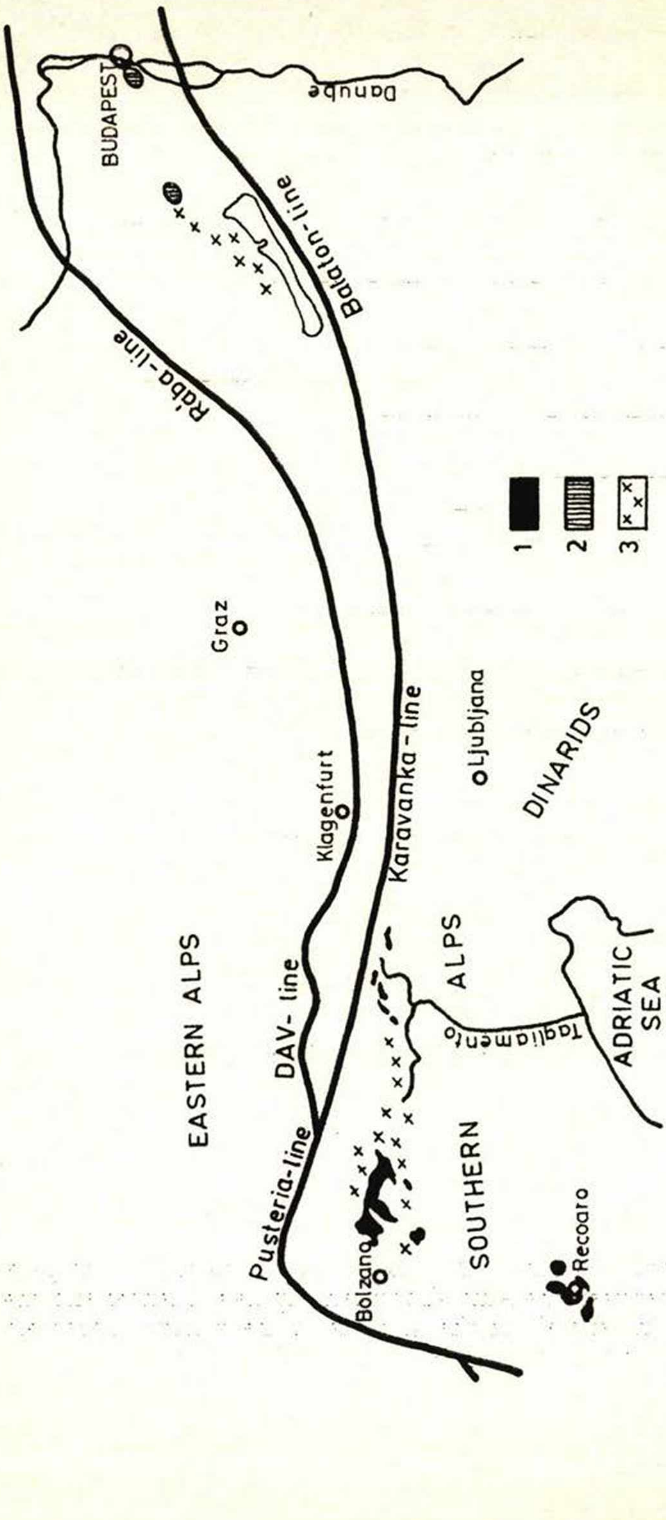

Fig. 7. 1. Middle Triassic magmatites; 2. (buried Middle Triassic magmatites (considered in this study); 3. Middle Triassic tuffs.

are in this tectonic unit, after the restoration the Transdanubian Central Range will be very close to the well-known Middle Triassic magmatic provinces in the Southern Alps (Fig. 7). The data on this magmatism (PISA, 1980) are compatible with the volcanism described in this paper, the genetic relationship between them will be proved later by a detailed comparative investigation.

Conclusions

a) The andesite, rhyolite, ignimbrite, trachyte and tuff pebbles of the Middle and Upper Eocene basal conglomerates in the Buda Mts. are eroded and redeposited products of an Upper Anisian to Lower Ladinian volcanic activity.

b) This is the same volcanism, which has produced the so-called "pietra verde" beds in the Transdanubian Central Range.

c) On the grounds of the investigations of volcanites, these have calc-alkaline feature with alkaline affinity.

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