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PALEOGENE ANDESITE VOLCANISM AND ASSOCIATED ROCK ALTERATION (VELENCE MOUNTAINS, HUNGARY)

(Figs. 8, Tabs. 4)

Abstract: The Paleogene (E_{2-3} — Ol_1) volcanic rocks predominantly belong to the calc-alkaline suites. They are mostly andesites and basaltic andesites, but basalts, dacites and trachyandesites occur too in minor amounts. Regarding the petrological (e.g. phenocrysts), petrochemical (main and trace elements, REE composition) features, the alteration characteristics and the type of ore-mineralization developed, the Paleogene volcanism studied is intermediate between the active continental margin type and the oceanic island arc type volcanism, and it can be considered as belonging to the continental island arc and thin continental margin type.

Резюме: Палеогеновые (E_{2-3}-Ol_1) вулканические породы относятся преимущественно к известково-щелочным свитам. Они представлены главным образом андезитами и базальтовыми андезитами, но базальты, дациты и трахиандезиты появляются тоже в незначительном количестве. Что касается петрологических (напр. фенокристы), петрохимических (главные элементы, следы, состав р.з.э.) признаков, характеристики изменения и типа развившейся рудной минерализации, исследуемый палеогеновый вулканизм является промежуточным между вулканизмом типа активной окраины континента и вулканизмом типа океанической островной дуги и его можно считать частью типа континентальной островной дуги и тонкой окраины континента.

Megatectonic setting

The andesite volcanism in the E Velence Mountains belongs to a NE-SW-trending Paleogene volcanic arc in the centre of the Carpathian Basin (Fig. 1 A) (Csillag et al., 1980). Traceable in a total length a couple of hundreds of km over a width of about 50—70 km from Recsk in the NE as far as Zala in the SW. The Paleogene zone is for the most part buried under younger sediments, being known mainly from boreholes (Balázs et al., 1981).
The Eocene volcanics occur mostly near the S boundary line of the Paleogene zone, i.e. the Balaton-Darnó Line separating the Central Mountains and the Bükk Mountains units.

Geological setting

The reconstruction of the one-time andesite volcano of the Velence Mts. (Fig. 1 B), much of the andesite being buried under 50 to 250 m of Neogene clastics, was carried out on the basis of geophysical results (Dudko et al., 1982).

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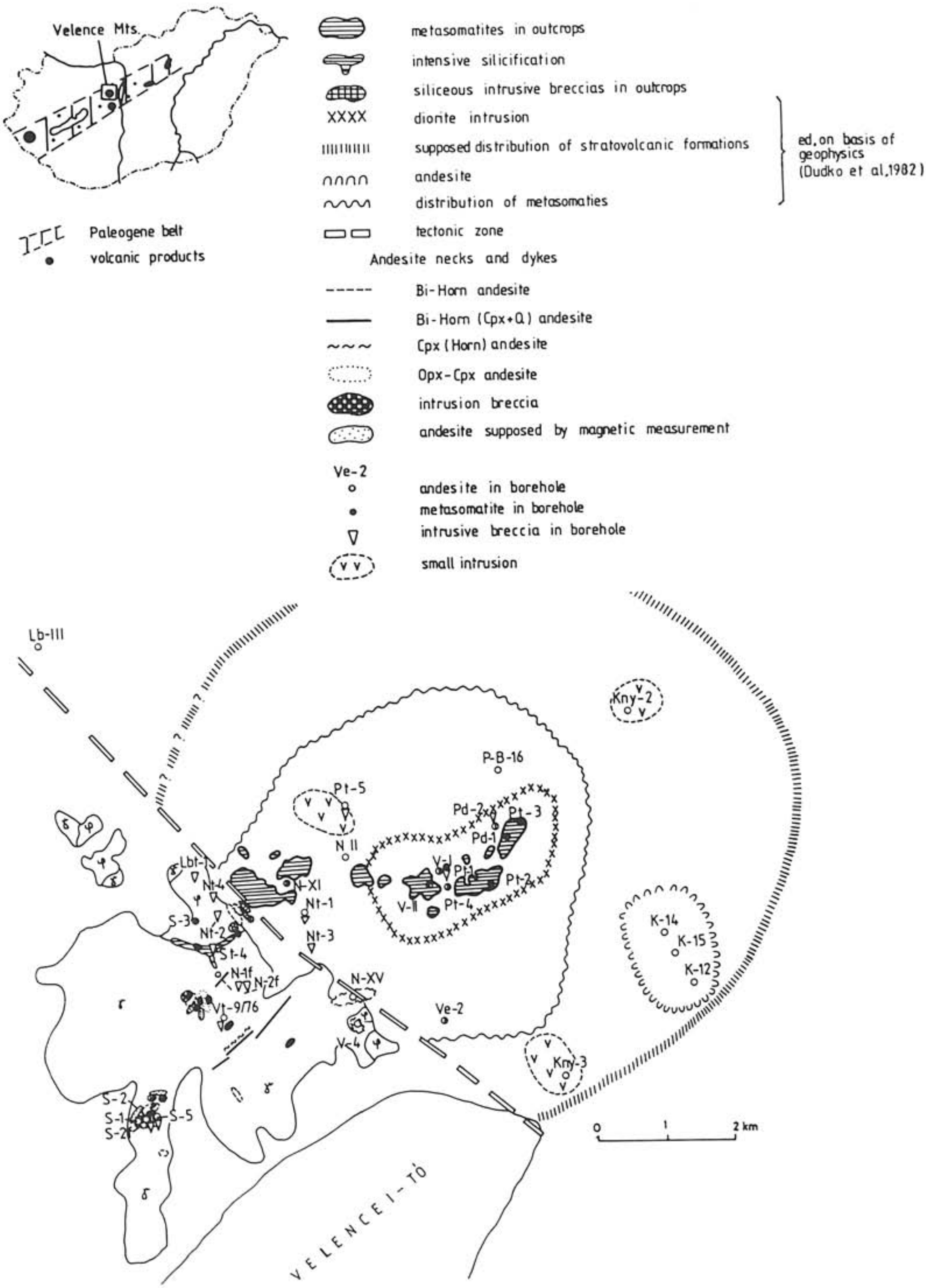

Velence Mts.
Paleogene belt
volcanic products
metasomatites in outcrops
intensive silicification
siliceous intrusive breccias in outcrops
XXXX
diorite intrusion
supposed distribution of stratovolcanic formations
andesite
distribution of metasomaties
ed, on basis of geophysics (Dudko et al,1982)
tectonic zone
Andesite necks and dykes
Bi-Horn andesite
Bi-Horn (Cpx+Q) andesite
Cpx (Horn) andesite
Opx-Cpx andesite
intrusion breccia
andesite supposed by magnetic measurement
Ve-2
andesite in borehole
metasomatite in borehole
intrusive breccia in borehole
small intrusion
Lb-III
Kny-2
P-B-16
Pt-5
Pd-2
Pt-3
Pd-1
N II
Lbt-13
Nt-4
N-XI
V-I
Pt-1
Pt-2
Nt-1
V-II
Pt-4
S-3
Nt-2
Nt-3
St-4
K-14
K-15
K-12
N-1f
N-2f
N-XV
Vt-9/76
Ve-2
V-4
Kny-3
S-2
S-1
S-5
0
1
2 km
VELENCEI-TÓ

About 12 km in diameter, the volcano has intersected Lower Paleozoic shales and Upper Carboniferous granites in the NW and Permian—Triassic carbonate deposits in the SE.

The paleovolcano was disintegrated along faults. The resulting tectonic blocks were eroded in different degrees. The area lying W of the large fault of NW-SE strike was uplifted and eroded down to its root. Here the anchimetamorphic schists and granites in outcrop are intruded by countless minor andesite dykes, necks and intrusive breccia bodies (Ó d o r et al., 1983).

In the E part, in the light of geophysical results, the presence over a large area of stratovolcanic rocks is supposed. So far these rocks have been cut only in borehole Kny-2. This drill penetrated into a part (980 m) of the stratovolcanic sequence and stopped at 1200 m (Fig. 2).

The upper part of the sequence is dominated by volcanic rocks (lava, lava-breccia, agglomerate and tuff). In the lower 300 m the redeposited pyroclastics (tuff-conglomerate, tuff-gravelite, tuff-sandstone) interrupted by agglomerate and lava layers and thin sedimentary intercalations (silt) gradually increase in abundance. Between 950 and 1000 m there is an intercalation including both unsorted volcanic and sedimentary material (argillaceous silt) which has been interpreted as lahar.

In the upper part of the stratovolcanic sequence there is a 360 m thick interval of basic composition and of rather uniform habit. The pyroclastics here are monomictic. This sequence is believed to be the result of a relatively short-lived parasitic activity which produced basaltic andesite and basalt material.

In the central area of the paleovolcano (Fig. 1 B), in a zone about 5 km in diameter, heavily altered rocks, metasomatites occur. Acidic metasomatites (secondary quartzite) are known to be found in a few larger outcrops striking E-W. In the area outlined by geophysical results (I. P., seismics), however, a multi-phase type of alteration, quite different in character, is known to appear, too (see later in this discussion) (D a r i d á n é et al., 1983). The parent (source) rock for the metasomatites may have been, as suggested by relicts of textural characteristics, intermediate volcanics, i.e. pyroclastics and lavas belonging to the stratovolcanic sequence in the W area and lavas or intrusives respectively in the central zone (E area).

In the zone of the volcanic centre there is a diorite intrusion of central position about 3 km in diameter. It was discovered by borehole Pd-2. Geophysical measurements (magnetic, seismic, gravitacional) have also detected some minor intrusions within the study area. Some of them have been chosen for the locations of boreholes (Pt-4, Pt-5 and Kny-3).

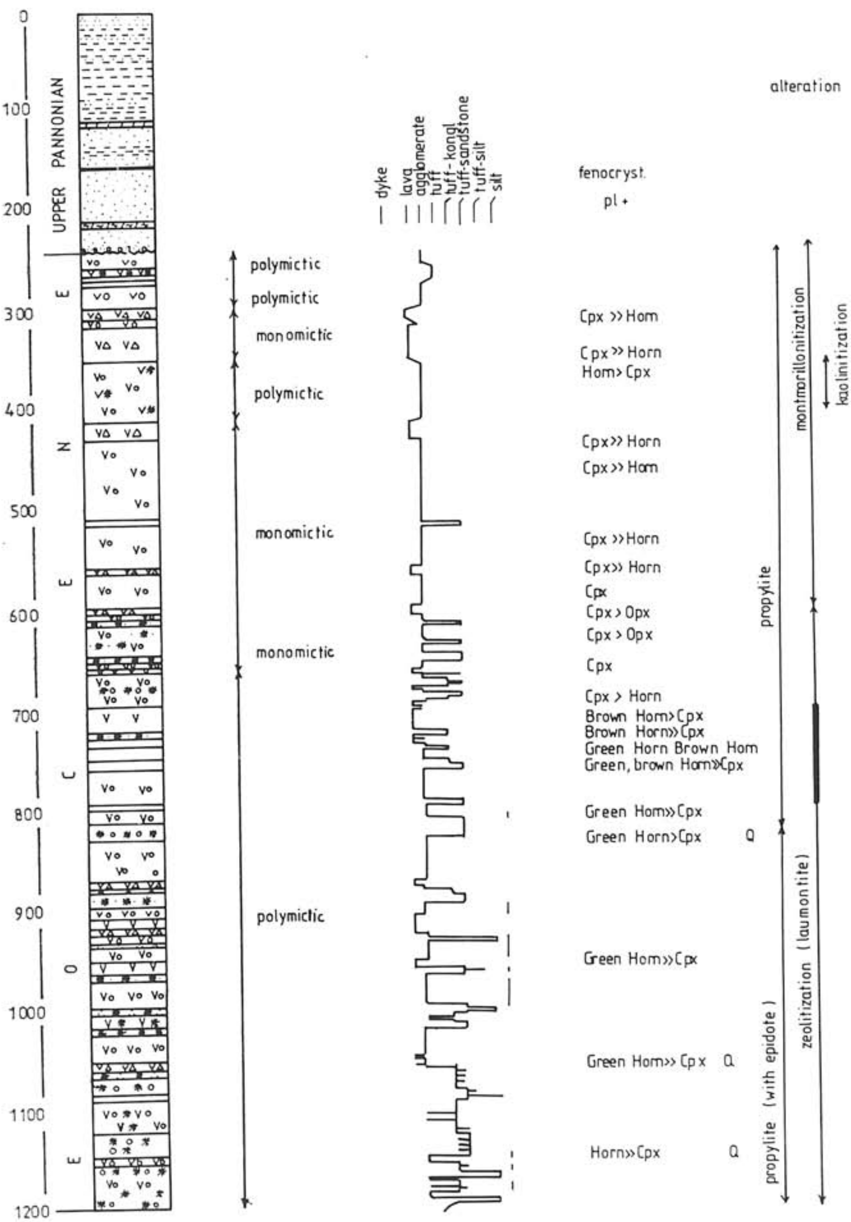
Age of volcanism

The date of the onset of volcanic activity is recorded by tuff horizons interbedded with shallow-water marine, carbonate and clastic deposits cut by boreholes put down in the wider neighbourhood (10—15 km) (boreholes Lb-II, Lb-III,

←

Fig. 1. Occurrence of andesites, intrusive breccia bodies and metasomatites in the eastern part of Velence Mts. (scheme).

Ad-3). As shown by the Foraminifera fauna, these belong to the upper Middle Eocene and the Upper Eocene, respectively. The culmination of the volcanism corresponds to Late Eocene time (NP 16-20; mainly NP 19/20 nannoplankton zone, Báldi — Beke, 1984). The volcanism persisted well in Early Oligocene time.



The tuff horizons interbedded with Lower Oligocene clays in borehole Ad-3 belong to the NP 23 nannoplankton zone, their K/Ar age being 30 ± 1 . 4 Ma (B a l o g h, 1985). From the andesites of the Velence Mountains, B a l o g h reported the following radiometric (K/Ar) dates:

Andesite dyke of Sukoró (total rock)	29 . 1 ± 1 . 2 Ma;
Pd-2 diorite (hornblende)	31 . 2 ± 1 . 4 Ma;
Pt-3 metasomatite (alunite)	32 . 9 ± 1 . 3 Ma.

Petrographic features

As evident from the mineralogical composition, the volcanic rocks studied are andesites with 30—50 % porphyric segregate (2—10 mm). The rocks of subvolcanic facies have a microholocrystalline- porphyric and porphyric-hyalopilitic texture, the lava rocks being porphyric-pilotaxitic in texture.

Among the porphyric constituents, plagioclase (of andesine-labradorite composition) is predominant. Mafic components are present in 8—12 %, being represented by hornblende (Hornb) (overwhelmingly green-hornblende, less frequently brown), biotite (Bi), clinopyroxene (Cpx) (augite), orthopyroxene (Opx) (hypersthene). In some rock varieties porphyric quartz grains (Q), less frequently 1 or 2 garnet (Gr) grains can also be observed. Based on mafic silicates, the following rock types have been distinguished: Bi-Hornb; Bi-Hornb (CPx + + Q ± Gr); Hornb; Cpx-Hornb; Cpx; Cpx-Opx andesites.

In the study area almost all rock types abound with endogenic inclusions of basic composition (poikilitic texture) 0 . 5—30 cm in diameter.

On the basis of the appearance of the individual rock types and their relation to one another in the explored succession can be established:

$$\text{Hornb, Cpx } (Q \pm Gr) \rightarrow \text{Hornb} > \text{Cpx} \rightarrow \text{Hornb (brown)} > \text{Cpx} \rightarrow \text{Cpx} \rightarrow \text{Cpx} > \text{Opx} \rightarrow \text{Cpx} > \text{Hornb}.$$

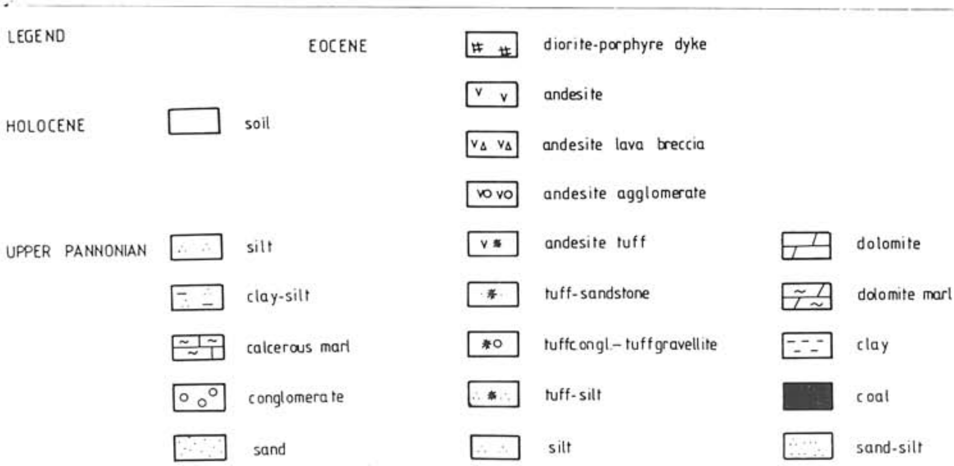


Fig. 2. Schematic lithological log of borehole KNY-2.

The magmatic contacts of the dykes and necks in the granite area and the occurrence of older types as inclusions (xenoliths) suggests the following sequence of intrussion: Bi-Hornb → Cpx → Bi-Hornb (Cpx, Q ± Gr) → Cpx-Hornb → → Cpx-Opx andesites.

On evidence of the foregoing an approximately acidic → basic trend can be proved to have been valid to the study area.

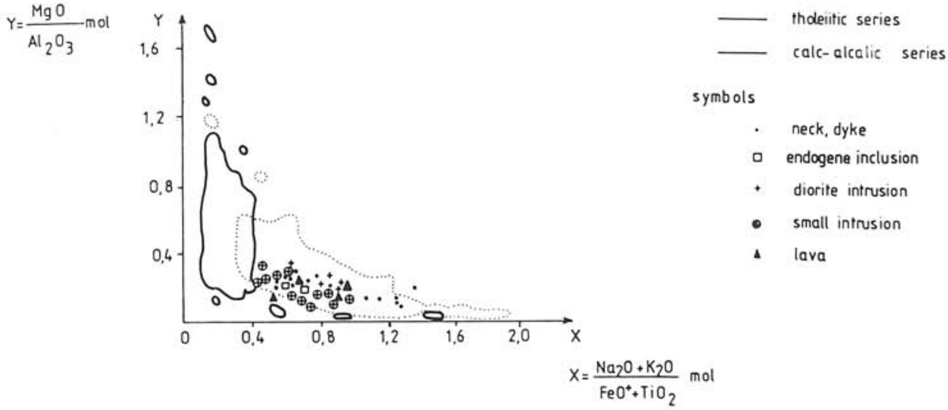


Fig. 3. The $\frac{MgO}{Al_2O_3}$ VS $\frac{Na_2O + K_2O}{FeO^+ + TiO_2}$ diagram (G r e e n, 1973) for Paleogene volcanics of Velence Mts.

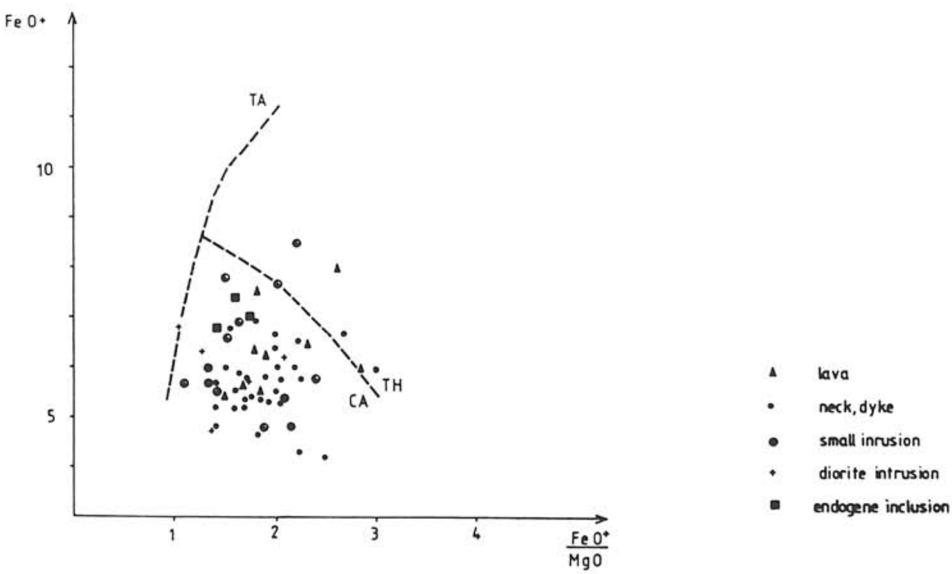


Fig. 4. Variation of FeO^+ and FeO^+/MgO (M i y a s h i r o, 1976) for the Paleogene volcanic rocks in the Velence Mts.

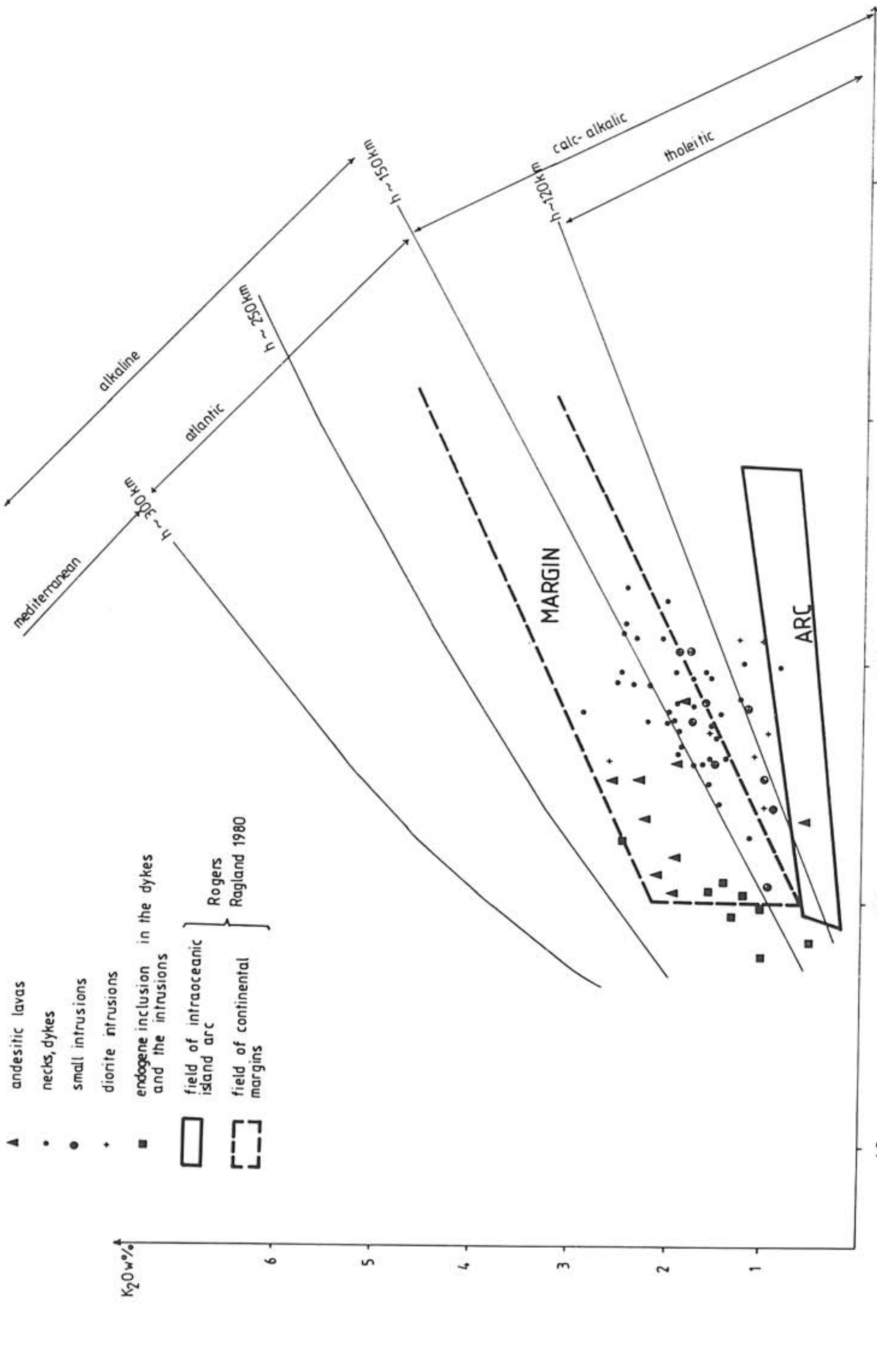


Fig. 5. The K_2O vs. SiO_2 (wt. %) diagram (N i k o v i c h — H a y s, 1971) of volcanic rocks from Velence Mts.

The course of the magmatic history is not properly understood as of yet. Relevant studies (isotopic composition, REE cont., microprobe analysis) are under way.

Petrochemical characteristics

In the light of the chemical analyses of the rocks and the different parameters (FeO/MgO, $Na_2O + K_2O$, etc.) the following conclusions can be drawn:
— In terms of the Gottini—Rittman (1970) diagram based on the relationship $\sigma = (K_2O + Na_2O)^2\, SiO_2 - 43$ $\tau = Al_2O_3 - Na_2O\ (TiO_2)$, the Velence Mountains volcanic rocks belong to the magmatism of the orogenic trends.

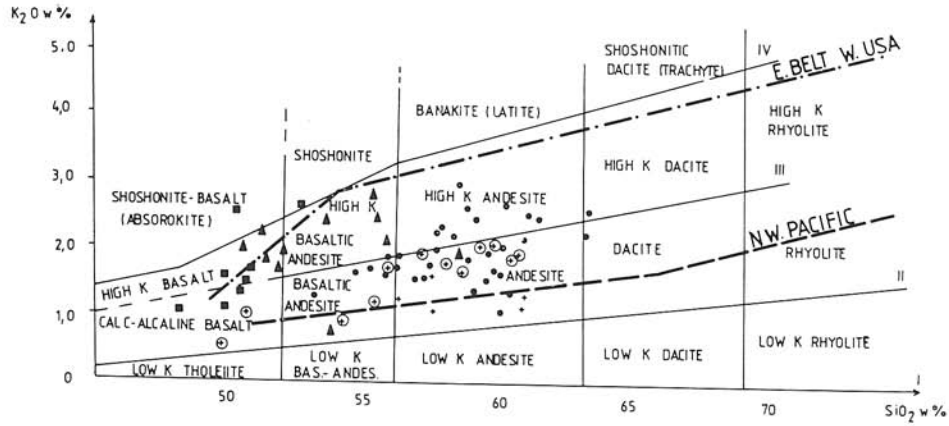


Fig. 6

symbols

- ▲ lava
- • neck,dyke
- ⊙ small intrusion
- + diorite
- ■ endogene inclusion
- I Low K series
- II calc-alkalic series
- III high K calc alkalic series
- IV shoshonitic series
- — · — / — — Plot of average values of K_2O v. SiO_2 for each rock type in the major tectonic regions (Ewart, LeMaitre 1980)

Fig. 6. The volcanic rocks of the Velence Mts. in the graph of K_2O against SiO_2 (in per cent by weight).

Explantions: The rock boundaries and nomenclature are taken from Peccerillo — Taylor, 1976; Ewart, 1979; Keller, 1982.

— As shown by the diagrams based on the essential element composition (SiO_2, FeO, MgO, Alk., K_2O) used for the distinction of the igneous rock series under consideration, the studied rocks are for the most part of calc-alkalic character (Figs. 3, 4). According to some classifications including that of Kuno, 1968. $Na_2O + K_2O$ vs. SiO_2; $\frac{FeO}{MgO}$ vs. SiO_2 (Miyashiro, 1974) and de la Roche de Laterrier, 1973 classifications based on indices derived from atomic numbers, they correspond to the calc-alkalic or, subordinately, to the tholeiitic range.

— According to different nomenclatures based on the chemical composition (Figs. 6, 7) and to the classifications proposed by Gill, 1978 (based on K_2O vs. SiO_2) and by IUGS 1984 (based on Alk. vs. SiO_2), the analyzed rocks are mostly andesites or basaltic andesites, respectively. In addition, basalts, dacites and trachyandesites occur in minor amounts. Similar results are arrived at by using the method based on the atomic numbers as proposed by Roche et al., 1980.

— As suggested by the K_2O vs. SiO_2 diagrams (Figs. 5, 6), the Paleogene volcanics from the Velence Mountains are intermediate between two main tectonic

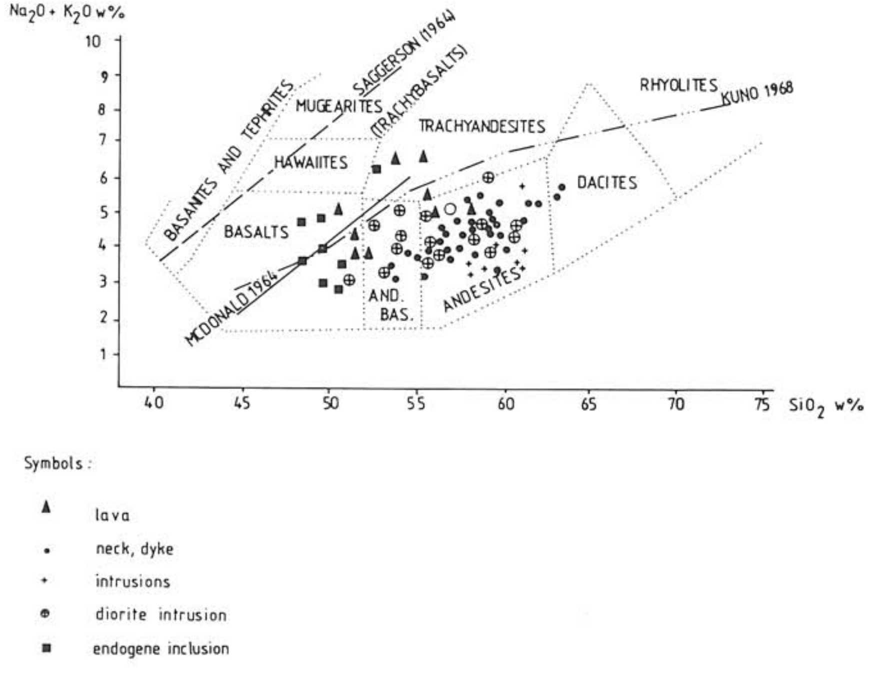


Fig. 7. The alkali-silica diagram for volcanic rocks in the Velence Mts.

Explanations: The generalized classification fields (light dashed lines) are from Cox et al. (1979); the boundary lines of the subalkaline, fairly alkaline and strongly alkaline rock types are from Mac Donald — Katsura (1964), Kuno (1968) and Saggerson — Williams (1964).

types: that of an active continental margin and that of an island arc underlain by an oceanic crust.

— The same results will be arrived at, when the rocks under study are examined according to the criteria based on a few essential elements and trace elements or phenocrysts, respectively, as proposed by J a k e š — W h i t e, 1972 (Tab. 1).

Table 1

Generalized difference between calc alkalic volcanic rocks of different tectonic settings (J a k e š — W h i t e, 1972)

	SiO_2% range	$\frac{Fe_2O_3+FeO}{MgO}$	$\frac{K_2O}{Na_2O}$	at the same K_2O and SiO_2						K/Rb	Th/U	Phenocrysts							sequence of phenocryst crystallization (hbe andesite)
				Rb	Ba	Sr	Th	V	Zr			Cpx	Opx	Mbe	Bi	Q	Gr	Co	
island arc	50 - 66	< 2,0	0,8	l	l	l	l	l	l	400	h	yes	yes	yes	rare	no	no	no	Cpx → Hornb → Cpx
continental margin (Andes)	56 - 75	> 2,0	0,6 1,1	h	h	h	h	h	h	230	l	yes	yes	yes	yes	rare	rare	rare	Hornb → Cpx → Opx
Velence Mts	50 - 63 (56,1)	1,98	0,61	h	h	h	h	h	h	342	h	yes	yes	yes	yes	rare	rare	no	Bi, Cpx → Hornb → Cpx

Table 2

Most sensitive discriminators on basis of the geochemical features for andesites from three orogen settings (B a i l a y, 1981)

	oceanic island arc Low K and	Other-and.	continental island arc	Andean	Paleogene volcanic rocks Velence Mts.	n
La ppm	3,0	11,2	17	28,5	27,3	(16)
Ce ppm	6,9	12	37	60,7	49,6	(16)
ΣREE ppm	35,2	74,2	94,4	146	154	(19)
La/Yb	1,2	6,4	8,9	16,5	16,4	(16)
La/Y	0,11	0,58	0,93	5,3	1,5	(13)
K/La	1950	1150	814	715	501	(13)
P/La	180	86	49	47	29	(13)
Th/U	1,7	2,7	3,6	33	4,7	(16)
Zr/Y	2,2	4,7	5,4	14,3	7,1	(13)
Hf/Yb	0,61	1,3	1,7	3,4	1,66	(16)
Ni/Co	0,29	0,52	0,95	1,4	0,74	(11)
Sc/Cr	3,8	0,8	0,6	0,36	0,33	(16)
Sc/Ni	3,4	2,0	1,1	0,55	2,07	(11)

REE analyses made by Bérczi J.

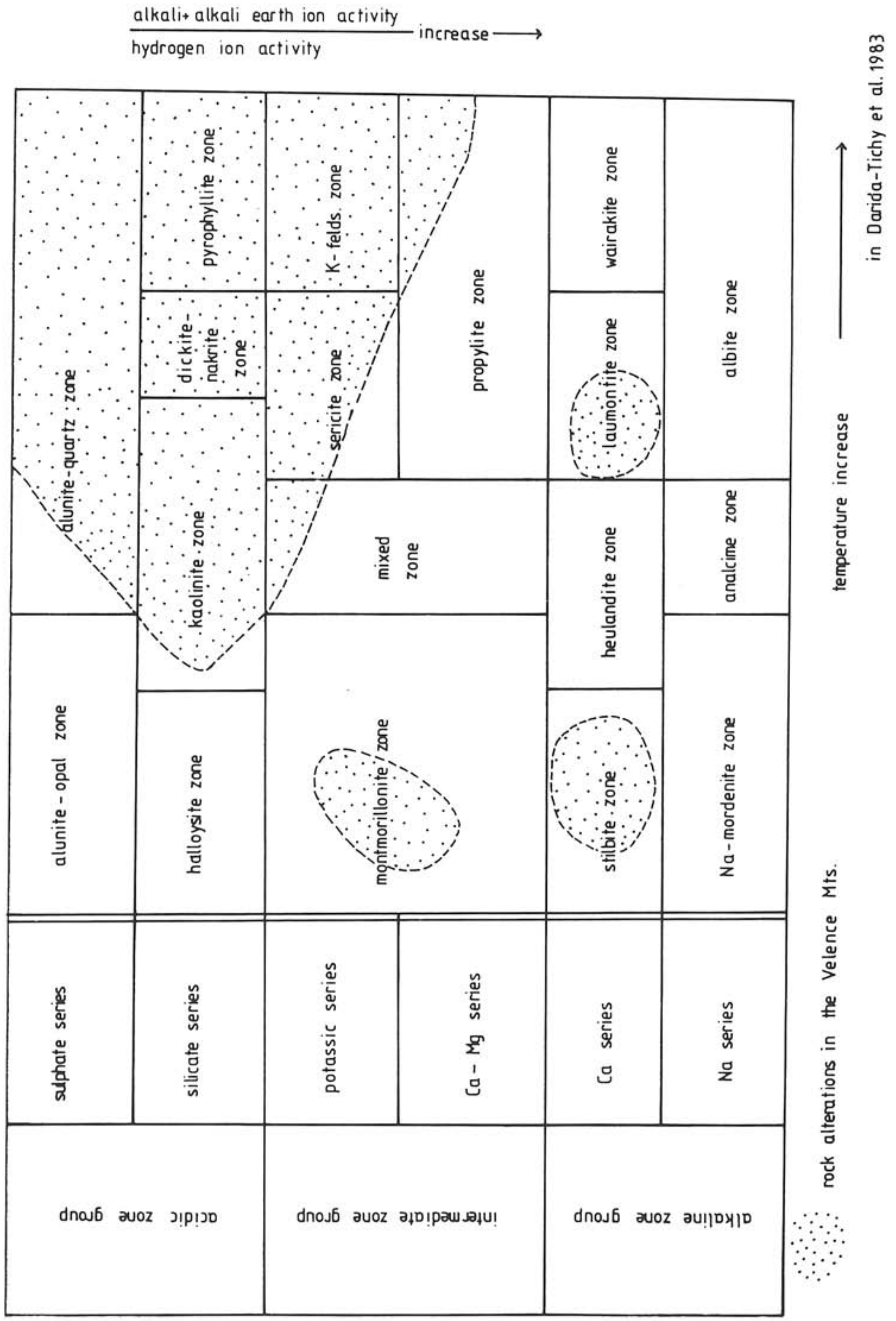
Similar conclusion can be drawn when the trace elements and the REE patterns are examined (Ó d o r et al., in preparation).

In terms of the immobile elements content (Ti, P, Zr and Y) (P a l a c i o s, 1983), the studied rocks are intermediate between the island arc- and the continental margin types.

— According to the diagrams based on the elements proposed by B a i l e y, 1981 (Cr, Ni, Sc, Yb, Y, La, Th, K and P), the Velence Mountains Paleogene volcanics belong most of all to a transition type which is associated with a thin continental margin and with an island arc underlain by continental crust (Tab. 2).

Table 3

Division of the zones of hydrothermal alteration after U t a d a (1980)


alkali+ alkali earth ion activity
hydrogen ion activity
increase
in Darida-Tichy et al. 1983
temperature increase
alunite-quartz zone
pyrophyllite zone
dickite-nakrite zone
kaolinite zone
K-felds. zone
sericite zone
propylite zone
mixed zone
wairakite zone
laumontite zone
heulandite zone
albite zone
analcime zone
alunite-opal zone
halloysite zone
montmorillonite zone
stilbite zone
Na-mordenite zone
sulphate series
silicate series
potassic series
Ca-Mg series
Ca series
Na series
acidic zone group
intermediate zone group
alkaline zone group
rock alterations in the Velence Mts.

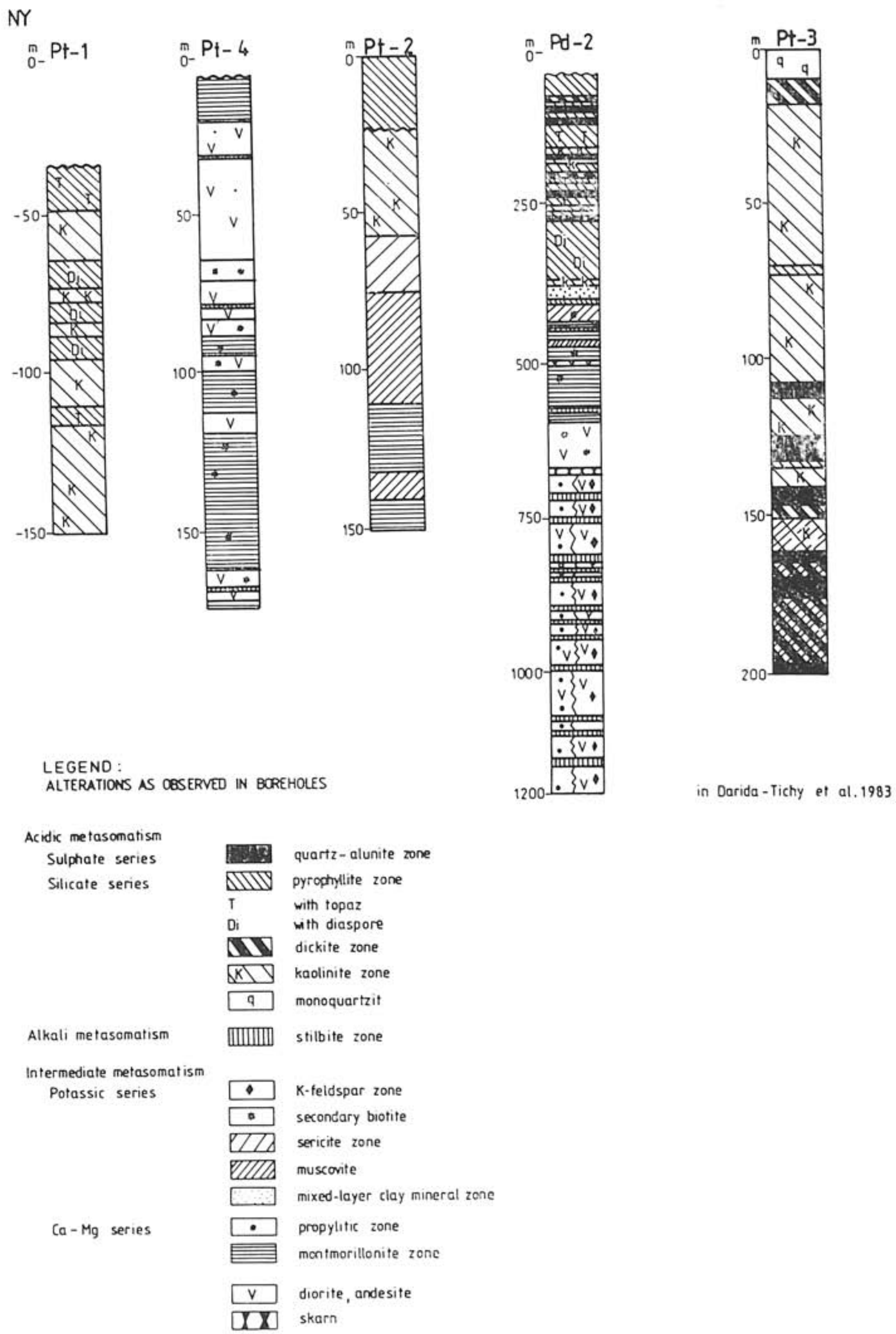


Fig. 8. Alterations as absorved in boreholes.

— A convincing assignation of the rocks studied cannot be achieved by using the REE distribution pattern either. These results suggest that the rocks under consideration are most closely related to the continental margin type (P a n t ó, 1980).
The studied rocks show a relatively marked negative Eu anomaly (Eu Eu* = = 0 . 2 — 0 . 3) which means that the magma being dealt with must be a strongly differentiated one.

Alteration

The Paleogene volcanism is accompanied by a metasomatism of high intensity. The drilling of boreholes in the study area led to the discovery of several alteration types and several metasomatic phases D a r i d a - T i c h y et al., 1983 (Tab. 3., Fig. 8.)
Listed in the chronological succession of their origin in terms of the nomenclature adopted (U t a d a, 1980), based on the formation temperature and the ratio of alkali and alkali earth ion activity to hydrogen ion activity (Tab. 3.), these are as follows:

1. The metasomatism of intermediate zone-group was developed in the central diorite intrusion. Propylitization belonging to the Ca series is characterized by the formation of quartz, chlorite, epidote, sericite, albite, calcite, magnetite, titanite and actinolite. This alteration is intertongued with a low-grade metasomatism belonging to the K series. At the base some K-feldspar formation is observed in form of veinlets and bands. In the upper segment it is represented by secondary biotite flake-aggregates and patches. Above this zone a sericitic zone has developed. In the above alteration types the formation temperature shows a trend of increase from the centre of the intrusion to the exterior.
2. The alterations of the alkalic zone-group in the study area are characterized by a low-grade carbonate-zeolite mineralization observable in 1—2 m zones. In the central area, desmine is found, while the stratovolcanic sequence (Kny-2) is characterized by the local occurrence of an intense laumontitization.
3. The acidic metasomatites are associated with structural zones. They show a rather intricate constitution, the higher-temperature varieties occurring in the zone of high-rate flow of solutions. Listed in a succession of decreasing formation temperature, the mineral association of the metasomatites belonging to the acidic silicate series is as follows:

quartz, topaz → quartz, pyrophyllite ± zunyite, diaspore → dickite,nacrite ± diaspore → kaolinite; along with a considerable amount (5—15 %) of pyrite and about 1 % rutile.

The latest metasomatic phase is a quartz-alunite mineralization belonging to the sulphate series of the acidic metasomatism in which, along the lithoclases, some native sulphur appears, too.

The above types of alteration are typical associates of the Cu-porphyric mineralization. The alteration types within the Cu-porphyric ore mineralizations of different tectonic situation are significant, too (Tab. 4.)
Comparing the Velence Mountains rocks with the two principal models, the diorite and the monzonite model, we find that they are closer to the continental margin — monzonite type.

Table 4
Generalized model for alterations of porphyry-copper formation

GENERALIZED MODEL FOR ALTERATIONS OF PORPHYRY-COPPER FORMATION Table 4

	LOWELL GUILBERT (1970) MODEL	HOLLISTER (1974)	VELENCE Mts.	
affinity to the tectonic setting	active continental margin	island arc	intermediate	
mineralization	Cu – Mo	Co - Au (Mo)	Cu, Mo, Au indication	
mineralized intrusion	quartz-monzonite, granodiorite	quartz-diorite, diorite, granodiorite	?	
alteration: central zone	Potassic zone: (K feld. Bi) quartz, K-felds., biotite, sericite, anhydrite	Potassic zone (Bi): quartz, biotite ± K-felds, chlorite	Potassic zone: quartz, biotite, K-felds	weak
	Phyllic zone: quartz, sericite, pyrite±chlor., hydr., rutile,	Phyllic z.?: quartz-seric.	Phyllic zone: quartz, sericite, pyrite, hydromica	weak
	Argillic zone: quartz, kaolinite, chlorit., montm. ± pyroph., dickite, topaz	Prophylitic zone: chlorite, sericite /or	Argillic zone: quartz, kaolinite, pyrophyllite, topaz, diasp, dickit	inten-sive
↓	Prophylitic zone: chlorite, epidote, calcite, adular, albite,	chlorite, epidote	Propylitic zone: chlorite, epidote, carb., sericite	inten-sive
outer zone				

Ore mineralization

No mineralization of commercial value has so far been detected in connection with the Velence Mountains Paleogene volcanism, but significant Cu-Mo and Cu-Au-Ag indications have been discovered.

Conclusion

The Paleogene (E_{2-3}-Ol_1) volcanic rocks predominantly belong to the calc-alkaline suites.

They are mostly andesites and basaltic andesites, but basalts, dacites and trachyandesites occur too in minor amounts. Regarding the petrological (e.g. phenocrysts), petrochemical (main and trace elements, REE composition) features, the alteration characteristics and the type of ore-mineralization developed, the Paleogene volcanism studied is intermediate between the active continental margin type and the oceanic island arc type volcanism, and it can be considered as belonging to the continental island arc and thin continental margin type.

Its formation must have connected with subduction. The megatectonic interpretation of the emplacement of the volcanism (to decide whether it was formed on an active continental margin or on an island arc underlain by a continental crust) is still to be given.

To judge the geological history and the megatectonic situation of the Paleogene formations under study requires further analysis.

Remark

The analyses used for the paper were carried out in the laboratories of he Hungarian Geological Survey, at the Technical University of Budapest and the Institute of Nuclear Physics (ATOMKI) at Debrecen.

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