GEOCHEMICAL INVESTIGATION OF OLIVINES FORM ALKALI BASALT AND THEIR XENOLITHES (NÓGRÁD-GÖMÖR REGION, HUNGARY)

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ABSTRACT

Neogene-Quaternary alkaline basalts in the Nógrád-Gömör region bear several kinds of inclusions and xenocrysts. Olivine appears in both the lherzolitic and wehrlitic series of the inclusions, is frequent among xenocrysts and appears in the host alkaline basalts as phenocrysts and in the groundmass. Deformation lamellae and subgrain boundaries in xenocrysts and in a wehrlite sample indicate a complex history of the inclusion before embedding in the host alkaline basalt. The REE-poor olivine with the highest mg-value is characteristic for lherzolite and dunite inclusions of the upper mantle origin. Main element composition of the xenocrysts is similar to that of the wehrlitic series (cumulate). Their mg-values indicate crystallization from a Fe-rich, tholeiitic magma; magma mixing (possibly assimilation) caused their embedding in the host alkaline basalt. REE spectra of individual grains suggest cognate phenocrysts and groundmass olivines from the alkaline basalts. High mg-values of phenocrysts indicate crystallization in the upper mantle, while groundmass olivines are products of near-surface process.

INTRODUCTION

Neogene- to Quaternary alkaline basalts and their pyroclastics are widely distributed within the Carpathian-Pannonian region (Balogh et al., 1981, 1982, 1986). in Steiermark and Burgenland (Austria), in the Little Plain and Balaton Highlands (Hungary) and in the Nógrád-Gömör region (Hungary and Czechoslovakia). These rocks contain mafic and ultramafic xenoliths and megacrysts (Dienes, 1968; Kurat, 1971; Richter, 1971; Embey-Isztin, 1976, 1977, 1984; Hovorka, 1978; Hovorka and Fejdi, 1980; Kurat et al., 1980; Scharbert et al., 1981; Jánosi, 1984; Dietrich and Poultidis, 1985; Kubovics et al., 1985; Bérczi and Bérczi, 1986; Forgáč et al., 1987).

Olivine appears in the so-called lherzolitic and wehrlitic series, and as xenocrysts, phenocrysts and in the groundmass of the alkaline basalts in the Nógrád-Gömör region.

Localities are shown in *Fig. 1;* the samples are listed in Table 1, together with the samples of Hovorka and Fejdi (1980), Jánosi (1984) and Forgáč et al., (1986).

TEXTURE ANALYSIS

The lherzolite and dunite xenoliths (Fig. 2) belong to the porphyroclastic, mosaic-porphyroclastic and equigranular texture types of Mercier and Nicolas (1975), Mercier and Carter (1975), Pike and Schwarzman (1977), Harte (1977). The

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wehrlite and olivine-clinopyroxénite are considered as hypidiomorphic cumulates (Fig. 2).

The ultramafic xenoliths and olivine xenocrysts display conspicuous traces of deformation in the microscope. We have observed deformation lamellae, subgrain boundaries as well as triple junctions after BOLAND et al. (1971), BOLAND and BUIS-KOOL—TOXOPEUS (1977), BUISKOOL—TOXOPEUS (1977), DEER et al., (1982), MERCIER (1983), NICOLAS (1984).

TABLE 1

Number of investigated olivines from the Nógrád-Gömör region

Locality	Lherzolite dunite	Wehrlite olcpxite	Xeno-cryst	Pheno-cryst	Ground-mass
THIS PAPER:					
Eresztvény-Nagybánya	1,7		21		
Eresztvény-Középbánya	12,13		18		
Bárna-Nagykő	3,4		17	30	33
Strázsahegy	6		22		
Fülek	9,10		16		
Magyarbánya	11	35,37	19		
Terbeléd (Trebeľ ovce	5,8				
Kercsiktető (Kerčik)	2		20		
Nagy-Salgó		36			
Medves	34				
Ajnácskő (Hajnačka)			24	28,29	
Pécskő			14		
Pogányvár (Pohansky)			23	27	
Tilic (Tilic)			15		32
Zabodakő (Zabda Skala)				25,26	
Fányakő				31	
JÁNOSI (1984):					
Maskófalva (Maškova)	+				
Nagy-Salgó			+		
HOVORKA and FEJDI (1980):					
Maskófalva (Maškova)			+		
Patakalja (Podrečany)			+		
Fülek (Fiľakovo)			+		
Sátoros (Šiatoros)			+		
FORGÁČ et al. (1986):					
Ajnácskő			+	+	
Bolgárom (Bulhary)			+	+	
Korláti (Konrádovce)			+	+	

Deformation lamellae form a set of long, parallel platelets of different extinction, made by cross-sliding *(Fig. 3)*. *The most favoured sliding surface is a function of* temperature and stress. Below 1000 °C the deformed olivines are characterized by translation lamellae, while these lamellae above 1000 °C easily move in the sliding plane, forming twinning seen in ultramafic xenoliths (CARTER and AVE LALLEMANT, 1970).

There are a lot of small, polygonal olivine grains around the large, porphyroclastic olivines and some xenocrysts of the porphyroclastic and mosaic-porphyroclastic ultramafic xenoliths *(Fig. 4);* these are called subgrains. The above mentioned authors consider that subgrains are formed when P—T conditions change around crystals, when magma mixing or incorporation in magma occurs and P—T changes produce
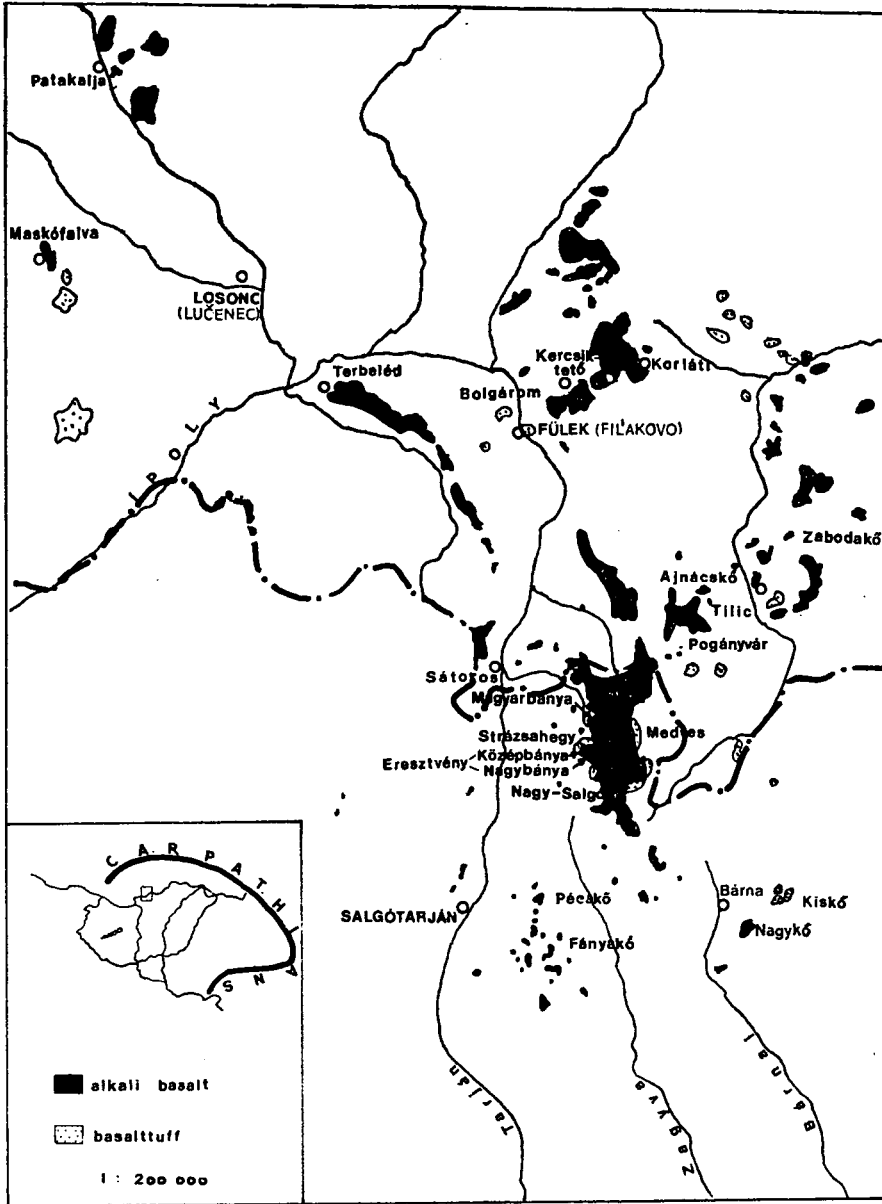
Fig. 1. Distribution of alkali basalt and basalt tuff in the Nógrád-Gömör region (after JÁNOSI, 1984).

multi-directed strain. The dislocations are expelled from the crystals or arranged in a plane. The dislocations can not move under low temperatures due to low diffusion, but these can be arranged in planes under high temperatures *(Fig. 5)* (GREEN and RADCLIFFE, 1972). These planes are the boundaries of subgrains where crystals are fractured and new grains are formed *(Fig. 4)*. The formation of substructures is due to complex deformation, which could be caused by flowing-mixing magma.
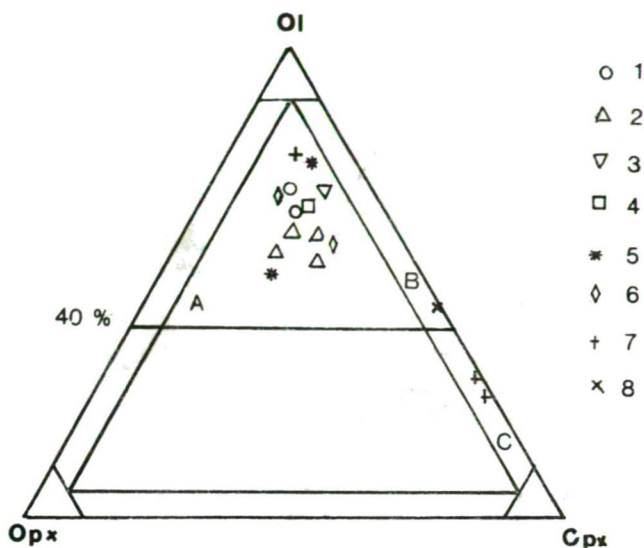
Fig. 2. Ol-Opx-Cpx plot of ultramafic xenoliths from the Nógrád-Gömör region; fields after STRE-CKEISEN'S (1974) classification of plutonic rocks.

Localities:
1 — Terbeléd
2 — Eresztvény-Nagybánya
    Eresztvény-Középbánya
3 — Strázsahegy
4 — Kercsiktető
5 — Bárna-Nagykő

6 — Fülek
7 — Magyarbánya
8 — Nagy-Salgó
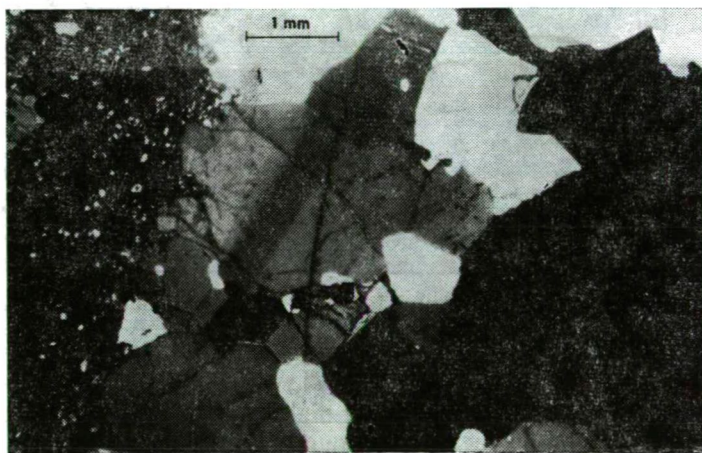A — Lherzolite
B — Wehrlite
C — Olivine-clinopyroxenite

Fig. 3. Photomicrograph of twinning olivine in a lherzolite xenolith from the Nógrád-Gömör region. Crossed nicols.

Fig. 4. Photomicrograph showing development of sugbrains in an olivine xenocryst from the Nógrád-Gömör region. Croossed nicols.
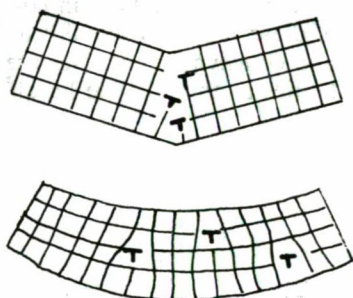

Fig. 5. Development of sugbrain in olivine.

The formation of triple junctions are made by recrystallization; these are more or less characteristic for the texture of the examined peridotite xenoliths.

Primary and secondary recrystallizations are known. In the former process energy is spent — within the crystals — to the elimination of dislocations, while during the latter one for decrease of surface energy. Secondary recrystallization in our ultramafic xenoliths is shown by mosaic texture, with slightly curved outline of grains and 120° triple junctions (NICOLAS, 1984). These deformations were found in the xenocrysts and olivines of some wehrlite samples, indicating a complex history of the xenocrysts and xenoliths before embedding in the host alkaline basalts.

GEOCHEMISTRY

Electron microprobe analyses were made by a JXA—50A microprobe (accelerating voltage 15 kV, 30 μA, electrobeam diameter: 1 μm). Olivine standard was applied. Minerals were checked for homogenity at five or more points. The representative data are presented in Table 1. Cation numbers were calculated on the basis of 4 oxygens.

Two groups of olivines were found in the ultramafic xenoliths. The lherzolite and dunite xenoliths with strongly deformed texture bear olivines with very low

FeO, MnO, low CaO contents and high mg-values (Table 2; *Fig. 6*). Data in Table 2 show fair correlation with those of olivines from lherzolite xenoliths in alkaline basalts in the Carpatho-Pannonian region (EMBEY-ISZTIN, 1976; KURAT *et al.*, 1980; DIETRICH and POULTIDIS, 1985; RICHTER, 1971). These olivines show no chemical inhomogenity or zonation and are in equilibrium with associated orthopyroxenes and clinopyroxenes. Data of DEER *et al.*, (1982) indicate that olivines in lherzolite xenoliths from the worldwide spread alkaline basalts show mg-values mostly between 89 and 92, like in our samples (Fig. 6).

KUBOVICS *et al.*, (1985) described olivines from ultramafic xenolithes from the Nógrád-Gömör region showing mg-values like above. These xenoliths were in equilibrium between 800—1000 °C under 1.0—1.5×10⁶ kPa pressure. The alkaline basaltic melt derived from 60—80 km depth. This value is in good correlation with the conditions of worldwide spread alkaline basalt source regions (e.g. WILKINSON, 1975; SKEWES and STERN, 1979; TAKAHASHI, 1980; PRESS *et al.*, 1986; etc.).

Olivines shows high FeO and MnO, but low CaO and very low MgO concentrations in cumulate-like olivine-clinopyroxenite and in wehrlitic xenoliths (see Table 2). The presented vol% data are similar to those of chrysolitic olivines of mafic plutonic rocks (DEER *et al.*, 1982). The two associated minerals in olivine-clinopyroxenite and wehrlite xenoliths (olivine and clinopyroxene) are in equilibrium with each other as seen in the microscope; but these are in disequilibrium with their environment, indicated by unclear grains, and concave outline. Despite displaying igneous texture, these xenoliths are foreign bodies in the alkaline basalts; the olivine compositions
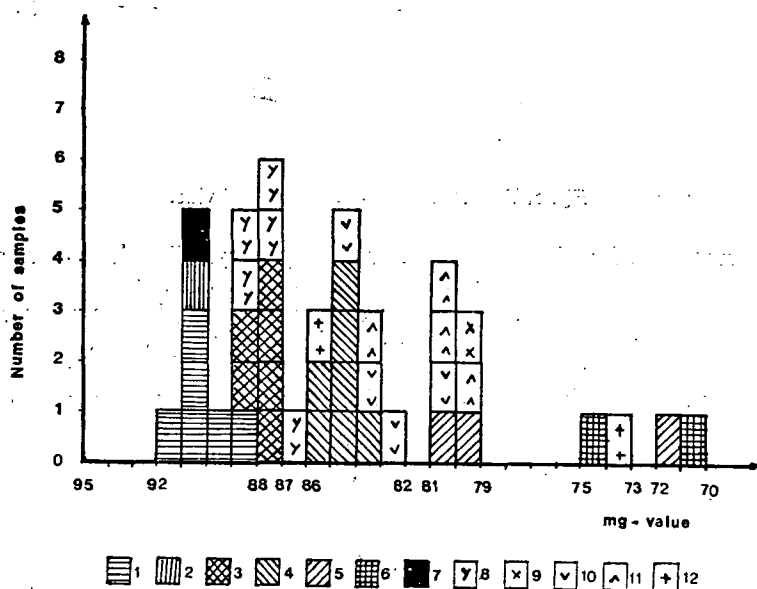
Fig. 6. Histograms of mg-values of olivines from the Nógrád-Gömör region

1 — lherzolite	7 — dunite (JÁNOSI, 1984)
2 — dunite	8 — phenocryst (FORGÁČ *et al.*, 1986)
3 — phenocryst	9 — xenocryst (JÁNOSI, 1984)
4 — xenocryst	10 — xenocryst (FORGÁČ *et al.*, 1986)
5 — wehrlite, olivine-clinopyroxenite	11 — xenocryst (HOVORKA and FEJDI, 1980)
6 — groundmass	12 — xenocryst (SZABÓ, 1984)

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indicate crystallization from a Fe-rich, mafic melt̃s in not too high témpèrature (low CaO-contents) (STORMER, 1973).

Composition of discrete olivine (resorbed outline, mostly deformed and larger than 2 mm grains, interpreted as xenocrysts after ÁRGYELÁN (1987), are well separeted in Table 2 and *Fig. 6* from the phenocrysts (euhedral, rarely skeletal, less than 2 mm grains). The xenocrysts contain more FeO and less MnO, but less MgO than the phenocrysts. Changes of mg-values in our samples display these characters very well *(Fig. 6)*. Considering the data of JÁNOSI (1984), HOVORKA and FEJDI (1980) and FORGÁČ *et al.*, (1986) some of the xenocrysts — described by us as megacrysts — shows strong chemical relationships with olivines of olivine-clinopyroxenite and wehrlite (Fig. 6). It means that part of the xenocrysts crystallized from the same Fe-rich melt, like the wehrlite and olivine-clinopyroxenite. This suggestion is supported by the CaO-FeO plot *(Fig. 7)*, where the points of xenocrysts (discrete inclusions called as megacrysts by HOVORKA and FEJDI, 1980; JÁNOSI, 1984; FORGÁČ *et al.*, 1986) are very near or within the field of tholeiites. Location of the field of mg-values of xenocrysts *(Fig. 6)* indicate that Fe/Mg ratio widely varied in the source melt. The phenocrysts are well separated from the xenocrysts (mg-values: 79—87) and from the mg-field of the olivine-clinopyroxenite and wehrlite, and display much less compositional variation *(Fig. 6)*.

This narrow mg-value field (87—88) indicates much more constrained crystallizations, than of the xenocrysts. We suggest 1200—1300 °C crystallization temperature (considering the low pressure experimental data of ROEDER and EMSLIE, 1970), which are similar to the alkaline lamprophyre data of KUBOVICS and SZABÓ (1987).

The olivine crystals of the groundmass from a well-separated group by their highest FeO, MnO and lowest MgO concentrations (Table 2, *Fig. 6*). These are located between the basanite and alkaline basalt fields of in the CaO-FeO plot *(Fig. 7)*. Their high CaO contents are characteristic for low-pressure olivines crystallized under near-surface conditions (SIMKIN and SMITH, 1970; STORMER, 1973).

Some xeno- and phenocrysts — of different size — bear barely perceptible zonation. Concentration changes of the most sensitive components: FeO, MgO, MnO and CaO were examined (Table 3), and two-way trends were shown *(Fig. 8)*.

Type I. (normal zonation) is represented by a xenocryst from Fülek and two phenocrysts — of different sizes — from Zabodakő. Composition of the rim zone of the xenocryst is located near the groundmass olivines, while phenocryst rims cross the field of xenocrysts and appear in the tholeiite field. The Fülek xenocryst shows steeply increasing CaO content, related to the fall of pressure. The unchanged CaO content of phenocrysts can be related to the decrease of crystallization temperature (STORMER, 1973).

The above characters unanimously prove that normal zonation can be formed by the change of different physical and/or chemical conditions, acting in different times. We noted that NAGY (1983) tried to determine the rate of cooling by the composition of the diffusion zone of phenocrysts, and to determine the equilibrium temperature by the olivine-spinel pair.

Type II. (reverse zonation) is represented by a xenocryst from Ajnácskő *(Fig. 8)*. A similar phenomenon was observed by NABELEK and LANGMUIR (1986) in a basalt sample from the Atlantic Ridge. *Fig. 7* shows that the zone of the xenocryst displays the same composition as the core of the phenocrysts. It clearly indicates that the zone was formed when the xenocryst was embedded in the melt of the host basalt. It means that xenocryst showing reverse zonation were crystallized from a Fe-rich tholeiitic melt, while the zones and the phenocrysts were formed due to the mixing of tholeiitic
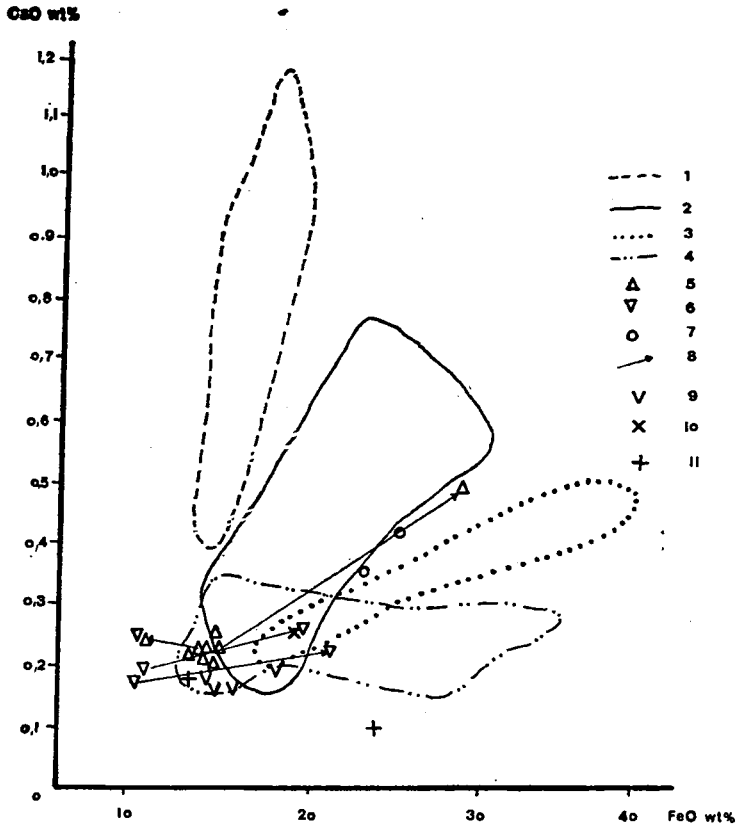
Fig. 7. CaO(wt%) versus FeO(wt%) in olivines from the Nógrád-Gömör region.

1 — nephelinite
2 — basanite
3 — alkali basalte } STORMER (1973)
4 — tholeiite
5 — xenocryst
6 — phenocryst

7 — groundmass
8 — core — rim trend
9 — xenocryst (HOVORKA and FEJDI, 1980)
10 — xenocryst (JÁNOSI, 1984)
11 — xenocryst (SZABÓ, 1984)

Fig. 8. Schematic profiles across normally zoned olivines (type I) and reversely zoned olivines (type II) from the Nógrád-Gömör region.

and Mg-rich magmas. JÁNOSI (1984) noted a similar magma mixing by a preliminary examination of pyroxene nodules of alkaline basalts from the Nógrád—Gömör region, proved by DOBOSI (1987) later.

DUDA and SCHMINCKE (1985), WÖRNER and WRIGHT (1984) suggested magma mixing in the alkaline volcanic complex at Laacher See by the geochemistry of xeno- and phenocrysts of similar composition.

REE GEOCHEMISTRY

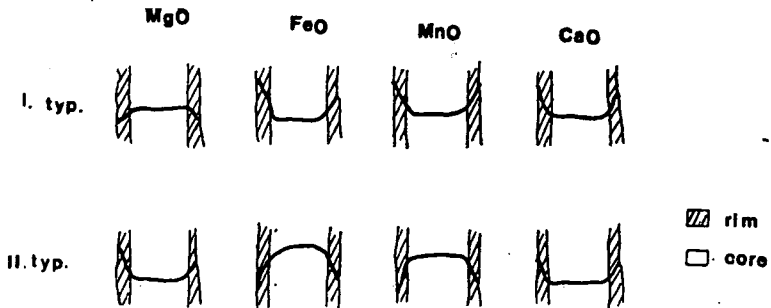REE and other trace element contents of separates of different olivine types (determined by optical and microprobe analysis) were determined by neutron activation analysis (Table 4).

Olivines of ultramafic xenoliths were shown to contain only Sc, Sm, La, Yb and rarely Ce, Lu and U. Comparing the resultes with a small number of samples from Graz (KURAT et al., 1980) and from the Balaton Highlands (BÉRCZI and BÉRCZI, 1986) we can say REE concentrations of these olivine types are extremly low and less diffe- renciated only. Sc, Sm and rarely La were determined in xenocrysts in similar amounts as in olivines of ultramafic xenoliths. Phenocrysts and especially groundmass olivi- nes are characterized by higher REE and trace element contents, except the two samp- les from Zabodakő (25, 26). The latter two ones are considered as phenocrysts (Table 1) or xenocrysts (Table 4). This contradiction shall be resolved by further investiga- tions.
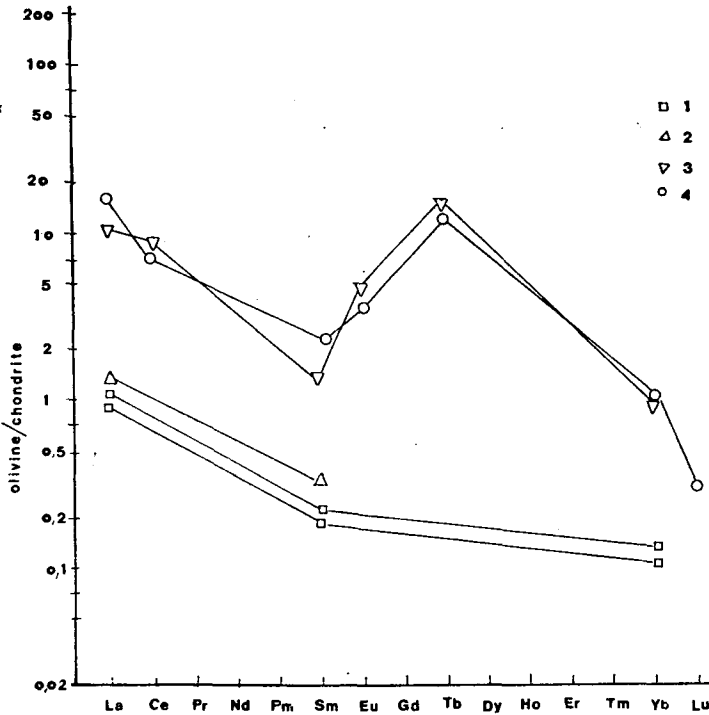

Fig. 9. REE pattern (normalised to chondrite, NAKAMURA, 1974) of olivines from the Nógrád-Gömör region. 1 — lherzolite; 2 — xenocryst; 3 — phenocryst ; 4 — groundmass

All olivine types were recognized at Nagykő near Bárna *(Fig. 1)*. The results clealy show the REE spectra of olivine crystals of different origin in the alkaline basalts of the Nógrád-Gömör region *(Fig. 9)*.

Compositions of zoned olivines

	Xenocrysts				Phenocrysts			
	16		24		25		26	
	core	rim	core	rim	core	rim	core	rim
FeO$_t$	15.2	26.9—30.5	14.7	11.3	11.6	17.7—19.7	11.8	18.3—22.1
MnO	0.22	0.97	0.20	0.18	0.17	0.42	0.17	0.22
MgO	45.0	35.0	45.2	48.0	47.4	42.0	47.5	40.5
CaO	0.23	0.48	0.21	0.26	0.17	0.23	0.20	0.23

The numbers of samples are listed in Table 1.

Ratios of some lantanides show parallel changes in the xenocrysts, lherzolites, phenocrysts and groundmass olivines despite their different concentrations. In the latter group the Eu shows a minor enrichment. The enrichment of Tb is unclear to us in absence of reference materials. Relationships of phenocrysts and groundmass olivines are clear, but similarities among xenocrysts and lherzolite olivines are considered to be random, due to dissimilarities in texture an chemical composition.

CONCLUSIONS

Three genetic groups were recognized among the olivine phases of the Nógrád-Gömör Neogene-Quaternary alkaline basalts:

1. REE-poor olivines of lherzolitic, dunitic inclusions displaying deformed texture are considered upper mantle components, well known from alkaline basalt xenoliths all over the Earth.

2. Genetic relationships among olivines of olivine-clinopyroxenite and wehrlite nodules on the one side and xenocrysts on the other are suggested by similarities in main element composition. We think that xenoliths and xenocrysts have been crystallized in a Fe-rich, differenciated tholeiitic melt under lower crust — upper mantle condition, and got to the host alkaline basalt by magma mixing (possibly assimilation). This event was recorded by the large amount of texture deformation, anhedral resorbed outline, revers zonation yielded by incorporation by a huge mass of high temperature more mafic melt.

3. The phenocrysts — together with groundmass olivine — are in relationship with the host alkaline basalt, supported by main element composition, REE distribution and absence of deformed texture. This host magma, being a mixed melt, was less differenciated that the system producing the xenocrysts, clinopyroxenite and wehrlite inclusions. After mixing — with upper mantle mg-values — the phenocrysts, and after ascending near the surface the groundmass olivines were crystallized.

ACKNOWLEDGEMENT

Main element contents of olivines from the Nógrád-Gömör region, in wt %

TABLE 2

	1	2	3	4	5	6	34	35	36	37	23	14	24	16	16	17	18	26	25	30	28	29	28	32	33
SiO_2	40.4	40.3	40.4	40.5	40.2	40.4	40.3	38.0	38.6	38.8	39.7	39.5	39.7	39.6	39.6	39.5	39.7	40.2	40.0	40.2	40.4	40.2	40.3	37.4	37.5
Al_2O_3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.05	na	na	na	na	0.03	0.03
FeO_t	10.8	10.5	9.30	8.90	9.50	8.90	9.16	25.6	15.4	18.4	14.0	13.6	14.7	15.2	15.2	15.0	15.0	11.8	11.6	11.7	11.8	11.3	11.3	23.1	25.9
MnO	0.16	0.16	0.12	na	0.13	0.12	0.12	0.30	0.29	0.29	0.19	0.18	0.20	0.22	0.22	0.21	0.20	0.20	0.17	na	0.18	0.18	0.18	0.61	0.70
MgO	48.6	48.9	50.7	50.1	49.6	50.0	49.1	35.7	41.6	42.3	45.8	46.0	45.2	44.6	45.0	45.4	45.2	47.5	47.4	47.7	47.5	48.0	48.1	37.9	35.5
CaO	0.10	0.16	0.07	0.20	0.06	0.06	0.12	0.04	0.06	0.04	0.23	0.21	0.21	0.21	0.23	0.22	0.20	0.20	0.19	na	0.25	0.26	0.26	0.33	0.41
Σ	100.06	100.02	99.79	99.50	99.49	99.48	98.80	99.64	95.95	99.83	99.94	99.53	100.04	99.97	100.28	100.36	100.33	99.90	99.39	99.60	99.43	99.94	100.14	99.37	100.04

nd = not detected; na = not analysed; FeO_t = total iron as FeO

	1	2	3	4	5	6	34	35	36	37	23	14	24	16	16	17	18	26	25	30	28	29	28	32	33
Si	0.994	0.992	0.991	0.993	0.990	0.992	0.996	1.007	0.991	0.993	0.994	0.991	0.996	0.997	0.993	0.989	0.994	0.996	0.995	0.997	0.998	0.994	0.994	0.987	0.996
Al	—	—	—	—	—	—	—	—	—	—	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	—	—	—	—	0.001	0.001
Fe	0.223	0.216	0.191	0.178	0.196	0.183	0.189	0.568	0.417	0.394	0.293	0.285	0.308	0.332	0.319	0.314	0.316	0.245	0.241	0.243	0.244	0.234	0.233	0.510	0.575
Mn	0.003	0.003	0.003	—	0.003	0.003	0.003	0.007	0.006	0.006	0.004	0.004	0.004	0.005	0.005	0.004	0.004	0.004	0.004	—	0.004	0.004	0.004	0.014	0.016
Mg	1.783	1.793	1.824	1.831	1.820	1.830	1.808	1.410	1.592	1.613	1.708	1.721	1.689	1.673	1.682	1.695	1.687	1.754	1.758	1.763	1.749	1.768	1.768	1.491	1.405
Ca	0.003	0.004	0.002	0.005	0.002	0.002	0.003	0.001	0.002	0.001	0.006	0.006	0.006	0.006	0.006	0.006	0.005	0.005	0.005	—	0.007	0.007	0.007	0.009	0.012
Fo%	89.0	89.2	90.7	91.1	90.3	91.0	90.3	71.0	79.0	80.1	84.9	85.4	84.2	83.0	83.6	84.0	83.9	87.4	87.5	87.9	87.3	87.8	87.9	73.7	70.0
mg-value	88.9	89.2	90.5	91.1	90.3	90.9	90.5	71.3	79.2	80.4	80.5	85.8	84.6	83.9	84.1	84.4	84.2	87.7	87.9	87.9	87.8	88.3	88.4	74.5	71.0

No. 1—6, 34 from lherzolite and dunite xenoliths; No. 35—37 from wehrlite, olivine-clinopyroxenite xenoliths
No. 14—23 xenocrysts; 25—30 phenocrysts; 32—33 groundmass
The numbers of the samples are listed in Table 1

Trace element contents of olivines from the Nógrád-Gömör region, in ppm

TABLE 4

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	26	25	27	28	30	31	32	33
Sc	2.55	3.73	3.35	5.93	4.80	4.94	2.06	1.94	4.08	1.92	4.58	3.61	1.77	3.83	3.72	3.37	3.71	3.37	3.43	2.65	2.40	3.49	3.74	3.66	3.80	4.64	4.39	4.57	5.18	4.95
Ta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hf	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.49	2.44	0.89	0.73	0.98	0.79
Th	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.75	3.52	1.38	1.22	4.29	1.32
U	—	—	0.04	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
La	0.84	—	0.38	0.24	0.77	0.48	0.55	—	0.44	0.32	0.78	0.11	0.62	1.16	—	—	0.39	—	0.76	—	—	—	—	—	—	0.31	0.53	0.19	0.73	—
Ce	—	—	—	—	—	—	0.08	—	—	—	—	—	—	—	—	—	—	—	—	—	0.48	—	0.99	1.60	2.205	2.600	3.22	1.88	4.34	4.90
Nd	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4.14	19.70	7.80	6.70	8.60	6.40
Sm	0.065	0.030	0.035	0.035	0.060	0.063	—	0.020	0.020	0.025	0.180	0.20	0.09	—	0.024	0.030	0.060	0.040	0.050	0.020	0.030	0.020	0.067	0.110	4.26	3.82	—	8.78	9.53	—
Eu	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.190	1.05	0.245	0.205	0.240	0.420
Tb	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.13	1.05	0.31	0.22	0.18	0.24
Yb	0.21	—	0.02	0.02	0.05	0.23	—	—	0.42	0.09	0.13	—	—	—	—	—	—	—	—	—	—	—	—	—	0.40	1.59	0.68	0.63	0.79	0.59
Lu	—	—	—	—	—	—	—	—	—	—	0.07	—	—	—	—	—	—	—	—	—	—	—	—	—	0.25	0.51	0.15	0.09	1.40	0.48
																									0.03	—	0.01		0.006	0.008

No. 1—13 from lherzolite xenoliths; No. 14—26 xenocryst; No. 27—31 phenocryst; No. 32—33 groundmass.
The numbers of samples are listed in Table 1.

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