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XENOLITHS FROM CRETACEOUS LAMPROPHYRES OF ALCSÚTDOBOZ—2 BOREHOLE, TRANSDANUBIAN CENTRAL MOUNTAINS, HUNGARY

Cs. SZABÓ*

ABSTRACT

Lower Triassic sediments of Alcsútdoboz-2 borehole (30 km W of Budapest (are cross-cut by alkaline lamprophyre dykes. These dykes contain xenoliths (megacrysts, ultramafic rocks, alkaline magmatite, quartzite inclusions and carbonatic evaporites) originated from different depths. Ultramafics contain phlogopite which is characteristic for lherzolite nodules of mantle origin. The alkaline magmatite xenoliths indicate contact of the melt with an alkaline intrusion in depth, which may bear significant economic importance.

INTRODUCTION

The Scythian (Lower Triassic) sediments of Alcsútdoboz-2 borehole are cross-cut by 12 middle Cretaceous (KUBOVICS, 1983) magmatic dykes *(Fig. 1)*. Contacts between the magmatites and the wall-rock are sharp or brecciated, dipping 10—65°. Apparent thickness of the dykes ranges from 5 cm to 2,5 m. 30—50 vol% of dykes IV and VIII consist of xenoliths; much less are contained in dykes II, VI, III, X and XII. Size of the xenoliths ranges from 0,5 to 2,5 cm. These are of irregular shape displaying resorbed outline.

PETROLOGY OF XENOLITH-BEARING MAGMATITES

Magmatites hit by Alcsútdoboz-2 borehole — as KUBOVICS presented in his 1980—81 lectures at the Hungarian Geological Society — are alkaline mafic rocks. Their texture is panidiomorphic granular. Mineral composition: olivine (phenocrysts only), Ti-augite and phlogopite. The ground mass contains carbonates, partly altered glass, sanidine, analcime, opaque minerals and apatite. Occurrence of ocella is characteristic.

The rocks may be ranged as monchiquite (alkaline lamprophyre) according to STRECKEISEN'S (1980) system, although amphiboles (kaersutite, barkevikite) are absent.

Average composition of monchiquite dykes of Alcsútdoboz-2 borehole — especially if reduced to dry rock — shows significant similarity to monchiquites of several localities on other continents. Some differences are the lower TiO_2 and higher volatile content and higher oxidation ratio.

Similar magmatites have been found in Vál-3, Budaörs-1, Zsámbék-23 and Csabdi-115 boreholes (the latter contains lamprophyre pebbles in Eocene conglomer-

* Department of Petrology and Geochemistry, L. Eötvös University, Budapest
H—1088 Budapest, Múzeum krt. 4/A, Hungary

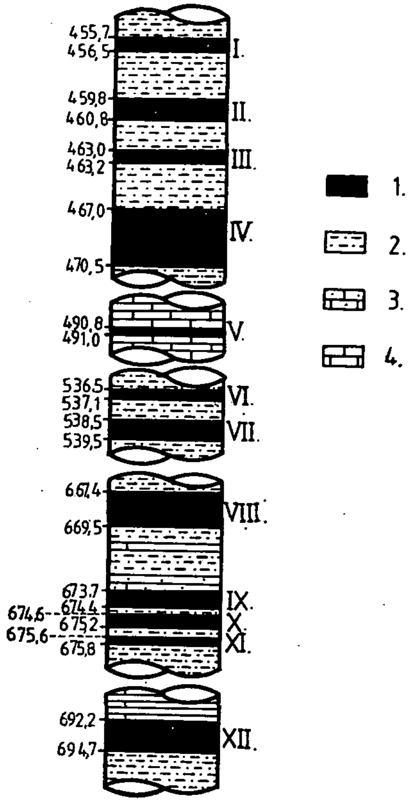

Fig. 1. Magmatites and their wall-rock in Alcsútdoboz-2 borehole (after KUBOVICS, 1981) 1 — monchiquite, 2 — aleurolite, 3 — sandstone, 4 — limestone (1 — Cretaceous, 2 to 4 — Lower Triassic)

ate only). Similar rocks have been reported by WÉBER (1962) from Nagykovácsi (Nagy-Kopasz-hegy), by HARRACH (1980) from Diósd-1 borehole and by HORVÁTH *et al.* (1983) from Sukoró-1 borehole *(Fig. 2)*.

PETROLOGY OF XENOLITHS FROM MONCHIQUITE DYKES

The following main groups were separated by microscopic examination:

A. Megacrysts (27 specimens)
B. Ultramafic xenoliths (46 specimens)
C. Alkaline rock inclusions (6 specimens)
D. Quartzite inclusions (6 specimens)
E. Calcitic evaporite (1 specimen).

A. Megacrysts

A.1. *Clinopyroxene* (21 specimens)

Most of them are black, some are dark green. Microscopically these are anhedral with tabular habit, uncoloured, having a violet tint in the thin syntaxial rim (like in clinopyroxenes of the lamprophyre). This rim often shows a saw-like form with zonal extinction (*Fig. 3*). Optically it is augite, having a Ti-augite rim. Some megacrysts contain rounded or elliptical calcite inclusions. Opaque minerals, euhedral phlogopite and orthopyroxene inclusions also occur. Clinopyroxenes are strongly fractured; calcitization can be observed in some places.

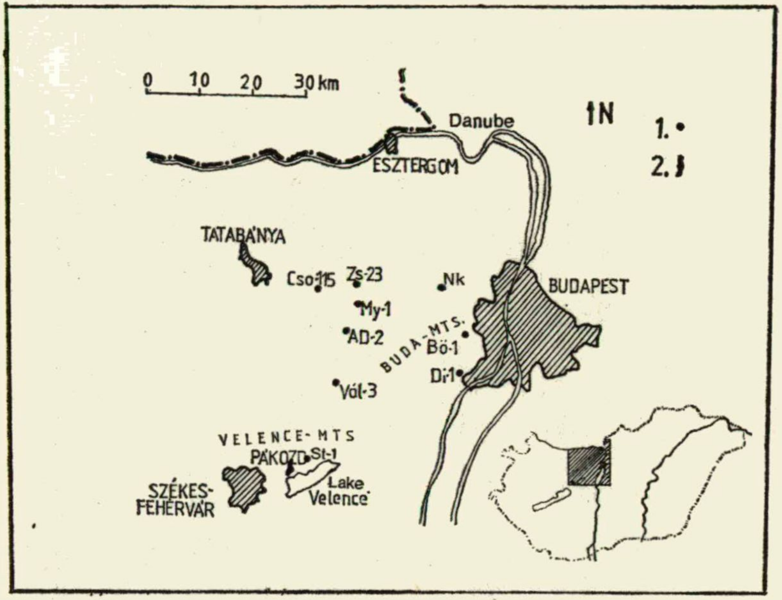

Fig. 2. Lamprophyre dyke localities in NE-Transdanubia. 1 — borehole; 2 — outcrop

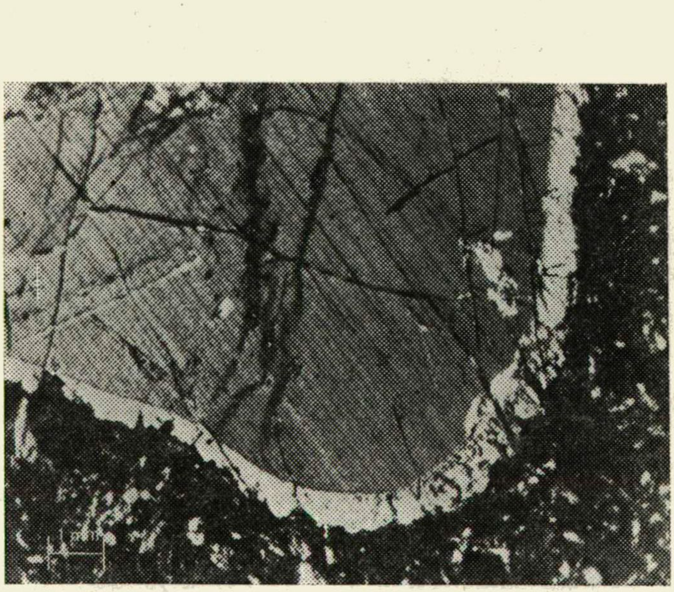

Fig. 3. Zoned clinopyroxene megacryst. +N

A.2. *Olivine* (2 specimens)

Dark green, microscopically uncoloured, anhedral, tabular forms with slightly undulatory extinction. Carbonatic alteration can be observed along rectangular cleavage planes and along the margins. Optical character is varied, so Fa-content fluctuates around 12,5%.

A.3. *Plagioclase* (2 specimens)

Rounded section with resorbed rims. Contains close twin lamellae, vanishing in the thin syntaxial rim *(Fig. 4)*. Optically the inner part is albite, the rim is potassium feldspar. The grains are fresh, cut by fissures with calcite filling.

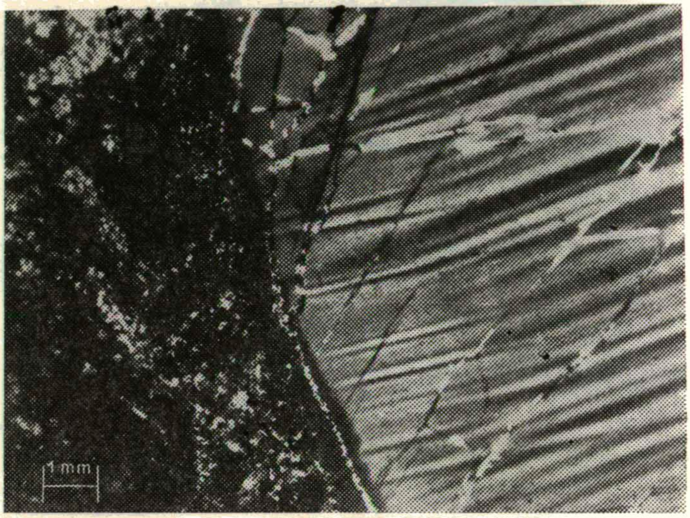

Fig. 4. Zoned plagioclase megacryst with twin lamellae. +N

A.4. *Opaque minerals* (1 specimen)

Subhedral, equate grains, probably of Ti-magnetite composition. It contains some apatite inclusions.

A.5. *Apatite* (1 specimen).

Heavily fractured, 3 mm long grain.

A.6. *Quartz* (1 specimen)

3 mm grain with resorbed rim.

B. Ultramafic xenoliths

B.1. *Classification of ultramafic xenoliths*

STRECKEISEN's classification (1974), according to modal composition, was followed. As often phlogopite occurs together with olivine, clinopyroxene and spinel, STRECKEISEN's olivine (Ol)—clinopyroxene (Cpx)—orthopyroxene (Opx) plot has been completed by an olivine (Ol)—clinopyroxene (Cpx)—phlogopite (Phl) plot to solve classification and nomenclature problems *(Fig. 5)*. Bulk modal composition and nomenclature of xenoliths is shown in Table 1. This is partly based on STRECKEISEN's nomenclature for peridotites and pyroxenites; partly it has been deduced from his amphibole—pyroxene—olivine plot, having substituted amphibole by phlogopite and pyroxene by clinopyroxene. This modification was necessary as we couldn't find an existing special nomenclature for this relatively rare group of rocks.

Fig. 5. and Table 1 present basic characters of ultramafic xenoliths of the lamprophyre:

- clinopyroxene and olivine are dominant components in the xenoliths;
- mica can be found — even monomineralically — in all groups except clinopyroxenite;
- common occurrence of large quantities of orthopyroxene and phlogopite is not characteristic.

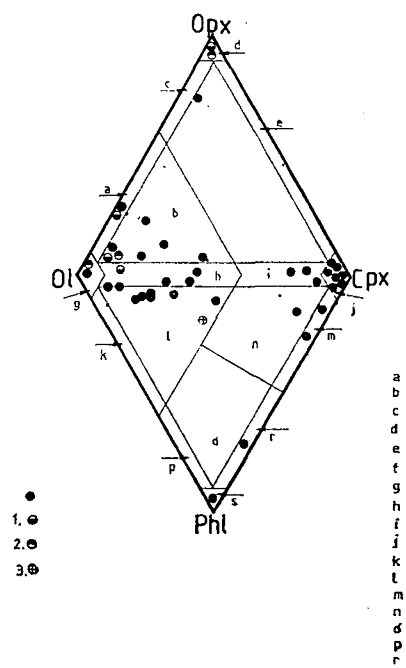

Fig. 5. Ol — Cpx — Opx and Ol — Cpx — Phl double plot of ultramafic xenoliths in dykes of Alcsútdoboz-2 borehole (Ol — Cpx — Opx plot of STRECKEISEN (1974), completed by an Ol — Cpx — Phl plot)

1 — Phl<5 vol%
2 — Phl>5 vol%
3 — Opx<5 vol%

a — harzburgite, *b* — lherzolite, *c* — olivine-orthopyroxenite, *d* — orthopyroxenite, *e* — websterite, *f* — olivine-websterite, *g* — dunite, *h* — wehrlite, *i* — olivine-clinopyroxenite, *j* — clinopyroxenite, *k* — phlogopite-peridotite, *l* — pyroxene-phlogopite-peridotite, *m* — phlogopite-pyroxenite, *n* — olivine-phlogopite-clinopyroxenite, *o* — olivine-clinopyroxene-phlogopitite, *p* — olivine-phlogopitite, *r* — clinopyroxene-phlogopitite, *s* — phlogopitite

TABLE 1

Modal composition and nomenclature of ultramafic xenoliths in dykes of Alcsútdoboz-2 borehole after STRECKEISEN *(1974), slightly modified*

Minerals vol%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Olivine	55.3—84.3	77.7	96.5—98.0	—	—	71.5—72.6	15.8	45.5—80.6	12.5—20.4	40.8—84.9	10.3	0.0—3.1	—	—	0.0—4.0
Clinopy-roxene	5.0—38.4	9.7	—	5.5	1.3	—	6.2	13.5—54.5	79.3—88.0	9.9—45.6	74.7	72.9—83.2	23.4	—	95.0—100
Orthopy-roxene	4.8—24.0	6.0	0.0—1.3	91.0	67.5	23.6—23.8	75.1	0.0—3.8	—	0.0—4.0	—	—	—	—	—
Phlogopite	0.0—0.1	6.0	0.0—1.6	3.2	28.3	0.0—4.3	1.0	0.0—3.8	0.0—1.0	4.2—18.8	14.5	13.3—26.9	71.6	100	0.0—5.0
Spinel	0.2—1.2	0.6	0.6—2.0	0.3	2.9	0.4—3.8	1.9	0.0—1.2	0.3—0.5	0.0—0.7	0.5	0.2—0.4	—	—	0.0—1.0
Apatite	—	—	—	—	—	—	—	—	—	0.0—1.0	—	—	—	—	0.0—1.0

1. Lherzolite (6 specimens)
2. Phlogopite-lherzolite (1 specimen)
3. Dunite (2 specimens)
4. Orthopyroxenite (1 specimen)
5. Phlogopite-orthopyroxenite (1 specimen)
6. Harzburgite (2 specimens)
7. Olivine-websterite (1 specimen)
8. Wehrlite (4 specimens)
9. Olivine-clinopyroxenite (3 specimens)
10. Clinopyroxene-phlogopite-peridotite (3 specimens)
11. Olivine-phlogopite-clinopyroxenite (9 specimens)
12. Phlogopite-clinopyroxenite (2 specimens)
13. Clinopyroxene-phlogopitite (1 specimen)
14. Phlogopitite (1 specimen)
15. Clinopyroxenite (12 specimens)

B.2. *Components of ultramafic xenoliths in the microscope*

Olivine. Large, subhedral, tabular and small, polygonal forms can be differentiated. Both types are colourless, having a positive optical character. Some of the tabular variety show undulatory extinction and mechanical twinning. This is characteristic for some lherzolite, wehrlite and clinopyroxene-phlogopite-peridotites only. Part of the olivine grains has been altered for carbonate, iddingsite and serpentine.

Clinopyroxene. Three types can be separated in the microscope.

a) Anhedral, tabular agglomeration. Colourless or may be light green, with undulatory extinction. Besides (110) cleavage close, transversal jointing is characteristic. Inclusions are rare; carbonatization may occur along cleavage or joint planes. Occurs in a part of lherzolite, wehrlite and olivine-websterite nodules.

b) Subhedral-anhedral, tabular variety. Large, colourless crystals bearing a slight violet rim contacting the lamprophyre. Shows undulating extinction and zonality on the margins. Its composition can be taken as the same as that of the clinopyroxene megacrysts, according to optical properties. It contains phlogopite and equant opaque mineral inclusions. Heavily fractured, rarely carbonatized or chloritized. It occurs in all clinopyroxene-containing ultramafic rock groups, like olivine-websterite, orthopyroxenite and lherzolite (in which the *a* variety is missing) as epitaxial growth on orthopyroxene.

c) Anhedral, tabular variety. It is green, pleochroic, sometimes the core of the grain only as larger or smaller spots. The rim contacting the lamprophyre shows violet tint. Extinction is mosaic-like and zonal corresponding with pleochroism. The green core can be aegirine-augite, the colourless field is augite and the violet rim Ti-augite according to the optical properties. Inclusions are mostly small grains indeterminable by the microscope, but some clinopyroxenes may contain apatite and equant opaque minerals, too. This type is characteristic for olivine-barren clinopyroxenites only.

Orthopyroxene. Two varieties can be separated: a larger, subhedral, tabular one and a smaller, polygonal one. Both show positive optical character and are of enstatitic composition. The tabular grains are brown due to frequent opaque mineral inclusions. Some sections show undulatory or mosaic extinction, sometimes folding or fracturing can be observed, too *(Fig. 6)*. Inclusions are opaque minerals and phlogopite. Part of them has been totally altered to carbonate and chlorite. It is a major component of lherzolite, olivine-websterite, orthopyroxenite, phlogopite-lherzolite, phlogopite-orthopyroxenite and dunite nodules. The polygonal variety is colourless, shows normal extinction, contains no inclusions and fresh. It occurs mostly in the surroundings of tabular orthopyroxenes *(Fig. 6)*. It is present in olivine-websterite and in part of the lherzolite nodules.

Mica. Anhedral, almost equant or subhedral, tabular forms bearing resorbed rims. Pleochroism: colourless or light yellow — yellowish brown. It is surrounded by a wide, more intensively pleochroic margin near lamprophyre contacts *(Fig. 7)*. Shows undulatory extinction. It can be taken as phlogopite due to optical angle of a few degrees and weak pleochroism. Elongated carbonate grains and haematite scales can be seen along cleavage planes. Micas are fractured and folded in monomineralic phlogopitite *(Fig. 8)*.

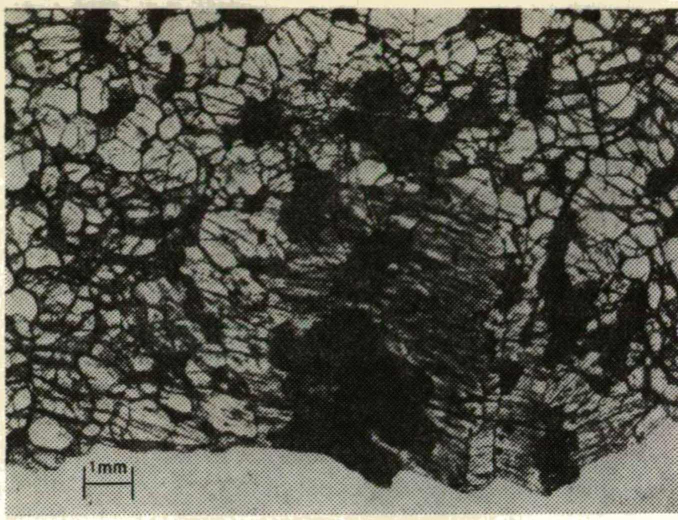

Fig. 6. Deformed, tabular and polygonal orthopyroxene (light) with clinopyroxene (dark) in lherzolite xenolith. // N

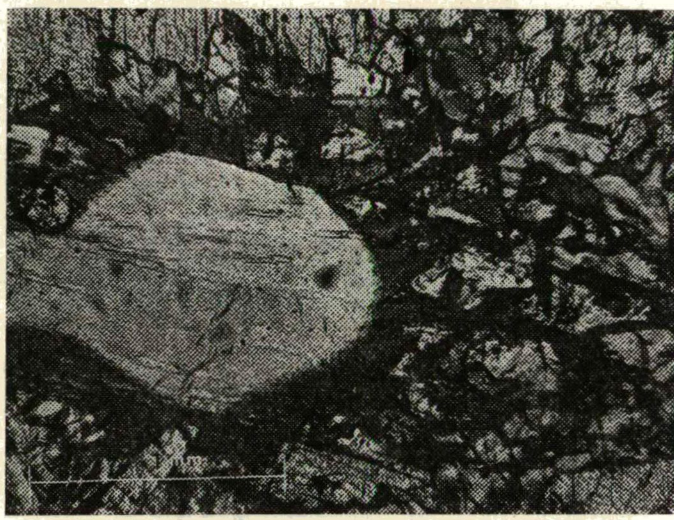

Fig. 7. Zoned phlogopite in clinopyroxene-phlogopite-peridotite. // N

Spinels occur as nearly equant grains among other components or as inclusions in pyroxenes. A variety forms agglomerations and occurs near clinopyroxenes or micas. The latter one is frequently translucent with reddish-brown tint. It is characteristic for lherzolite, phlogopite-lherzolite, phlogopite-orthopyroxenite nodules.

C. Alkaline magmatite inclusions

C.1. *Classification of alkaline magmatites* follows STRECKEISEN'S (1974) system, based on modal composition (Table 2).

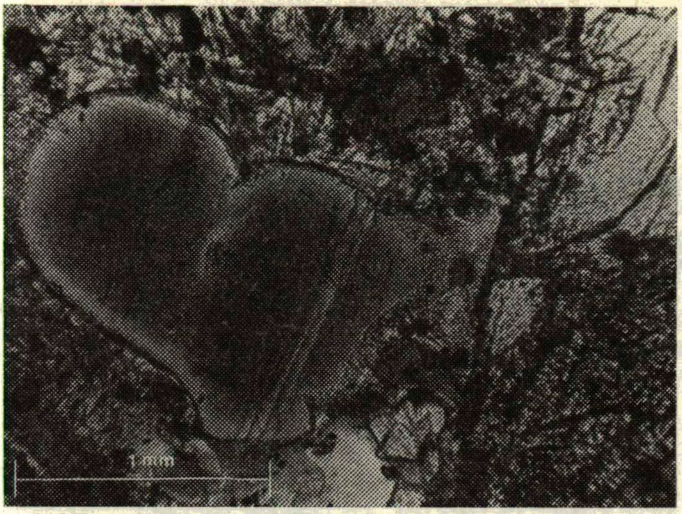

Fig. 8. Deformed, tabular phlogopite in phlogopitite xenolith. // N

TABLE 2

Modal composition of alkaline magmatite inclusions in dykes of Alcsútdoboz-2 borehole

Number of specimens	1	1	4
Mineral vol % \ Rock type	Melaalkali-syenite	Leuko-alkalisyenite	Alkaligranite
Potassium feldspar	11.7	54.3	21.6—72.3
Plagioclase	—	27.6	0.0—13.0
Clinopyroxene	73.6	18.1	0.9—5.6
Quartz	—	—	26.9—59.8
Apatite	13.4	—	—
Mica	1.0	—	—
Spinel	0.3	—	—

C.2. *Alkaline magmatite components in the microscope*

Potassium feldspar. Anhedral, bears resorbed rims. Cleavage in two directions can be well observed. Sometimes undulatory extinction, negative optical character; optical angle: about 30°. Optically it can be taken as sanidine. Grains are frequently surrounded by a zone of darker interference colour which may be isotropic as well.

Plagioclase. Anhedral, resorbed grains. Birefringence larger than in potassium feldspar. Close twin lamellae, positive optical character; optical angle: about 90°. Optically it can be taken as albite. The plagioclases are usually surrounded by irregular zones of darker interference colour. Optically this may be of sanidine composition.

Clinopyroxene. Subhedral, tabular or square-build, green grains showing weak pleochroism. Negative sign of elongation, positive optical character, undulatory extinction. Optically it can be taken as aegirine-augite. Inclusions are apatite *(Fig. 9)* and opaque minerals.

Quartz. Anhedral, resorbed, equant, colourless grains. Undulatory, sometimes mosaic like extinction. Often forms inclusions in potassium feldspar. Heavily fractured, devoid of inclusions.

Apatite. Subhedral-euhedral, square-build, columnar, fractured grains.

Mica. Anhedral, resorbed, tabular grains. Pleochroism: yellowish brown — dark greenish brown, fading towards the margins *(Fig. 9)*. It can be found in places where the lamprophyre melt penetrated xenoliths, consequently these are considered as foreign bodies.

Fig. 9. Zoned mica and apatite in clinopyroxene in alkalisyenite xenolith. // N

D. Quartzite xenolith in the microscope

Monomineralic xenolith. Quartz grains mostly form a mosaic-like order and are of similar size.

E. Carbonate evaporite in the microscope

3 mm long, ellipsoidal xenolith, formed by tabular gypsum and anhydrite, with calcite between and around them.

SIGNIFICANCE OF XENOLITHS IN THE DYKES
(Discussion)

The greatest significance is attributed to ultramafic xenoliths, alkaline magmatites and megacrysts among all inclusions.

The ultramafic xenoliths form two textural groups (besides mineral composition):

— nodules displaying deformation and recrystallization traces ("metamorphic" nodules)
— equigranular nodules displaying magmatic textures.

Sixteen ultramafic nodules display metamorphic characters based on microscopic investigations. These are positioned in the lherzolite, phlogopite-lherzolite, harzburgite, dunite, olivine-websterite, phlogopite-orthopyroxenite, orthopyroxenite, wehrlite and clinopyroxene-phlogopite-peridotite fields of *Fig. 3.* These nodules are characterized by mechanical twinning of olivine and orthopyroxene. According to MERCIER and NICOLAS (1975) this is a significant feature of nodules of upper mantle origin. These xenoliths display porphyroclastic and equigranoblastic texture (classification of HARTE, 1977). This means, that these xenoliths have suffered significant deformations and have been recrystallized. They have a "complex metamorphic record" (EMBEY-ISZTIN, 1977). Consequently, these xenoliths have been originated from the upper mantle, together with the enclosing magmatic melt.

Lherzolite nodules of similar texture have been found in Burgenland (RICHTER, 1971), in the Balaton Highlands (EMBEY-ISZTIN, 1977) and in the Nógrád—Gemer region (HOVORKA, 1978 and MOLNÁR, 1980) in Pliocene alkaline basalts of the Carpathian region. These authors have proven the upper mantle origin of the nodules by crystallization pressure and temperature values calculated from geochemical data.

However, ultramafic xenoliths from the Alcsútdoboz-2 lamprophyres show significant differences from those in Pliocene basalts in the Carpathian region, due to their phlogopite content. These xenoliths — considered as issued from the upper mantle on texture investigations — contain micas "built in" among other grains, as a primary component itself, also shown by coarse grain size (larger than 1 mm) and heavy deformation (disruption, folds, fractures) (*Fig. 8*). This means that phlogopite is a stable phase under upper mantle conditions, proven experimentally by KUSHIRO and AOKI (see RICHTER, 1971).

Few reports are known on mica-containing ultramafic xenoliths from alkaline basalt and basanite (e.g. RICHTER, 1971; SKEWES and STERN, 1979) but there is no one — as we know now — reporting them from lamprophyres. Phlogopite-bearing xenoliths of upper mantle origin are usually connected to kimberlites and carbonatites (DAWSON and Powell, 1969; DELANEY *et al.*, 1980; DAWSON, 1980; ARIMA and EDGAR, 1981).

Those ultramafic xenoliths in Alcsútdoboz-2 borehole, which show non-metamorphic, subhedral granular, rarely poikilitic texture can be taken as endogenous inclusions, together with clinopyroxene megacrysts separated from magma at great depths.

ROCK (1975) claims that ultramafic xenoliths rarely occurs in lamprophyres, since this magma does not ascend from great depths as primary melt but develops under low pressure, absorbing volatiles. High-pressure xenoliths of mantle origin become unstable under these conditions. Alkaline syenite—alkaline granite xenoliths, plagioclase, apatite and Ti-magnetite megacrysts and clinopyroxenite of aegirine-augitic composition found in Alcsútdoboz-2 borehole indicate that the lamprophyre melt "sampled" an alkaline magmatic body in depth.

Occurrence of lamprophyre and alkaline magmatic xenoliths may have economic value besides scientific importance, as similar rock sequences contain Th, REE, Nb, Ta and P deposits. The Nb, Sc, Th and U anomalies recorded by KUBOVICS (1960), WÉBER (1962) and HORVÁTH *et al.* (1983) in Velence and Buda Mts. suggest that re-evaluation of existing data and further exploration of this region is definitely necessary.

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