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TEXTURAL FEATURES AND MODES OF ULTRAMAFIC XENOLITHS FROM SITKE, LITTLE PLAIN (HUNGARY)

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ABSTRACT

Several upper mantle xenoliths from Sitke (Little Hungarian Plain) have been studied. This locality is one of the important sites of the Early Tertiary volcanic activity in the Little Hungarian Plain. The Sitke's volcanic apparatus is consisting of a tuff-ring which is characterized by the occurence of fragments of olivine nephelinitic host rock. The tufaceous layers and fragments are often including nodules consisting generally of spinel lherzoliths, while dunitic and harzburgitic composition occur rarely. Two special xenoliths, one with a pure spinel-vein and another with considerable amphibole and clinopyroxene content, have been found, as well.

Based on the textural investigation it can be proved that the porphyroclastic and equigranularic textures prevail and the transitional textures between them also exist. The two specific nodules are considered to be metasomatically originated in the upper mantle.

INTRODUCTION

A typical within plate basaltic activity (EMBEY-ISZTIN, 1980) took place during Pliocene in the Carpatho-Pannon region and this volcanic event lasted until the Pleistocene (JÁMBOR *et al.*, 1981; BALOGH *et al.*, 1986). The basaltic volcanism shows an alkaline character, its products contain many inclusions originated in the upper mantle and lower crust. The nodules are distributed in the following areas: (1) Graz Basin (KURAT *et al.*, 1980; DIETRICH and POULTIDIS, 1985), (2) Little Hungarian Plain (RICHTER, 1971; EMBEY-ISZTIN, 1978; SZABÓ, 1982; KUBOVICS *et al.*, 1985; EMBEY-ISZTIN *et al.*, 1989). (3) Balaton Highland (EMBEY-ISZTIN, 1976/a, 1978, 1984; BÉRCZI and BÉRCZI, 1986; EMBEY-ISZTIN *et al.*, 1989, (4) Nógrád-Gemer (Gömör) (HOVORKA, 1978; HOVORKA—FEJDI, 1980; KUBOVICS *et al.*, 1985, 1988), (5) PERSANY (PERSÁNYI) Mts. (MALDARESCU *et al.*, 1983; BÉRCZI, 1988) *(Fig. 1)*.

This paper presents the first part of a set of petrographical, petrological and geochemical studies. It describes the large suite of ultramafic xenoliths and their host rock from Sitke (Little Hungarian Plain) carrying useful information about the the nature, and the compositional feature of the upper mantle and its processes.

LOCALITY

The Sitke volcanism producing large amounts of pyroclastics *(Fig. 2)* belongs to the Little Hungarian Plain (LHP) volcanic field. Its eruptive centres are situated close to the Rába-line and in a N—S zone between Pauliberg (Pálhegy) and Güssing (Németújvár) (JUGOVICS, 1972).

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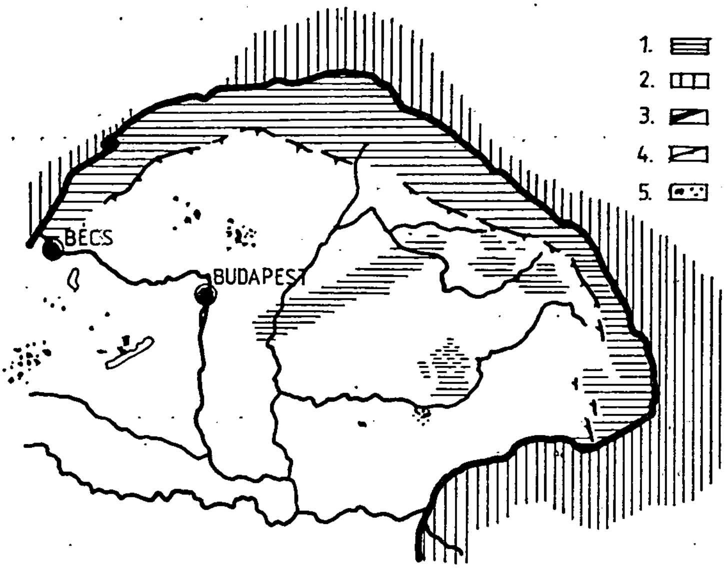

Fig. 1. Distribution of the Pliocene-Pleistocene alkaline basalt including upper mantle xenoliths in the Carpatho-Pannon region.
1 — flysh, 2 — Carpathian foredeep, 3 — contour of the Carpathian fold system, 4 — Klippen belt, 5 — alkaline basalt with upper mantle xenoliths

The Sitke volcanic activity started at least 4,25 M. y. ago. Lava flows and dikes were recognized only on the Hercseghegy *(Fig. 2)* that can be considered one of the eruptive centres (JUGOVICS, 1972). The pyroclastic series overlie the Upper Pannonian micaceous sandy and clay beds. This superposition indicates a correlation between the stratigraphical situation and radiometric data (JUGOVICS, 1972; JÁMBOR *et al.*, 1981).

The Sitke volcanic building can be studied in numerous quarries on the Belsőhegy and Hercseghegy *(Fig. 2)*. As the xenolith associations show the greatest quantity and highest variability in the Belsőhegy quarry *(Fig. 2)* we focused our investigations on this site. It is regarded as a representative outcrop of the Sitke tuffring.

The locality is a 7 m high and about 120 m long quarry front. The well-bedded host pyroclastic series (grain size is less than 4 cm) are devided into two levels by a 50 cm thick lavabreccia layer which appears in the middle part of the wall. The layers are subhorizontal. The lavabreccia consists of fragments of host rock and a lot of ellipsoidal to spheroidal shaped ultramafic xenoliths. The nodules have generally a mean size of 7 cm in diameter but they sometimes can reach 12 cm, too. Most of the lava fragments indicate high degree of carbonatization containing grains of calcite in the cracks, pores and amygdals. In addition, some small-sized (0.5 cm) olivine-rich inclusions have been recognized, as well. The series settled over and under the lavabreccia are built up by unconsolidated tuffic pyroclsatics, which are nearly barren in xenoliths, except the uppermost level where greater dimension (9 cm) nodules can be found. The nodules derived from the various levels do not show any substantial difference.

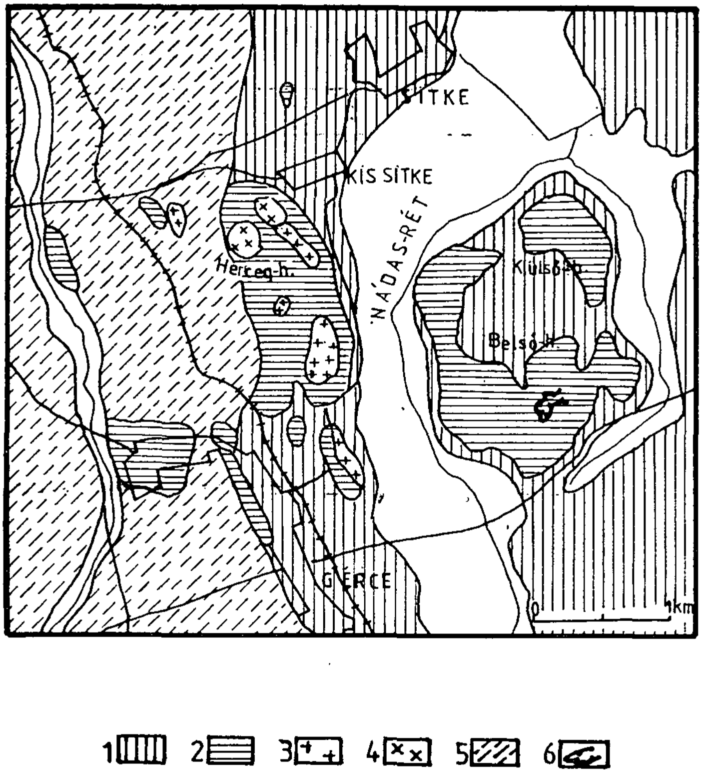

Fig. 2. Geological map of Sitke and adjacent area (Jugovics, 1972) 1 — Upper Pannonian sand and clay, 2 — basaltic tuffs, 3 — massiv basaltic rock, 4 — vesicular basaltic rock, 5 — Pleistocenian pebble, 6 — sampling points

HOST ROCK

Fragments of the fresh massive lava collected for the analytical purpose have a porphyritic texture with trachytic character. Proportion of the phenocrysts is 13—17 vol% and a third of them is clinopyroxene. The remaining porphyroclasts are made up olivine which is partly euhedral—hedral, partly kinked. In addition, some unhedral grains of quartz (less than 2 vol%) with undulatory extention occur in every sample. This feature proves that they originated by contamination. The mesostasis commonly contains elongated, strongly zoned crystals of augite-titanaugite. Opaque minerals are rare in the glass-rich groundmass.

The Table 1 shows the major element composition of two representative Sitke samples compared with the average of other basalt localities from the LHP.

In the *Fig. 3* the Sitke samples (Belsőhegy, Hercseghegy) appear in the tephrite and basanite field in accordance with their modal mineralogical composition, while the averages of some well-known occurences (Pálhegy, Somló, Sághegy) from the LHP fall in the trachybasalt field.

The Belsőhegy sample shows an extremly high alkali character (Table 1 No 1) and considering its high normative nepheline and olivine contents it can be regarded

TABLE 1

Major element composition, CIPW norms and some petrochemical parameters of basaltoid rocks from Sitke

	1	2	3	4	5
SiO_2	45.98	48.97	48.23	43.36	46.30
TiO_2	3.60	2.54	2.06	2.31	2.30
Al_2O_3	12.33	14.98	15.58	16.28	14.34
Fe_2O_3	7.05	2.70	4.04	1.73	4.33
FeO	4.57	6.90	5.94	7.91	6.10
MnO	0.17	0.14	0.18	0.14	0.21
MgO	8.87	7.61	6.75	10.87	8.67
CaO	9.83	8.54	8.48	9.28	9.19
Na_2O	3.27	3.68	3.71	3.07	3.83
K_2O	1.89	1.92	1.85	2.19	2.56
P_2O_5	0.97	0.47	0.70	0.15	1.17
CO_2	0.00	0.00	0.00	0.00	0.00
$+H_2O$	0.98	1.49	2.77	3.19	1.00
$-H_2O$	0.00	0.00	0.00	0.00	0.00
Sum	99.51	99.94	100.29	100.48	100.00
		CIPW norms			
or	11.17	11.35	10.93	12.94	15.13
ab	23.13	27.45	29.56	3.36	17.02
an	13.38	18.69	20.40	24.17	14.38
ne	2.46	2.00	0.99	12.25	8.33
cpx	22.61	16.53	13.64	16.76	18.70
ol	8.14	12.61	10.61	20.56	12.08
mt	4.85	3.91	5.86	2.51	6.28
il	6.84	4.82	3.91	4.39	4.37
hm	3.71				
ap	2.30	1.11	1.66	0.36	2.77
M	62.01	62.90	59.13	70.69	64.00
D. I.	36.76	40.80	41.48	28.55	40.48
S. I.	34.58	33.36	30.28	42.18	34.01

1 — Belsőhegy, Sitke
2 — Hercseghegy, Sitke (JUGOVICS, 1976)
3 — Pálhegy, (10 samples, MAURITZ, 1948; SCHARBERT *et al.* 1981; POULTIDIS and SCHARBERT, 1986)
4 — Somló, (13 samples, JUGOVICS, 1976)
5 — Sághegy, (22 samples, JUGOVICS, 1976)

as an olivine nephelinite composition. Whereas its petrochemical patameters (Table 1, mg-value, D. I., S. I.) resemble to that of more evolved basaltoid rocks of Pálhegy, Somló and Sághegy and show a lot of differences from the primitive, undifferentiated Hercseghegy sample (Table 1 No 2). The above-mentioned apparent contradiction can be explained by effect of the qartz grains originated by contamination in the Belsőhegy sample, that increased the normative orthoclase and albite content. A neglecting proportion of the quartz grain in the Belsőhegy olivine nephelinite can be found this rock may have been derived from a primitive, undifferentiated melt similar to lavas which are characteristic at the Hercseghegy.

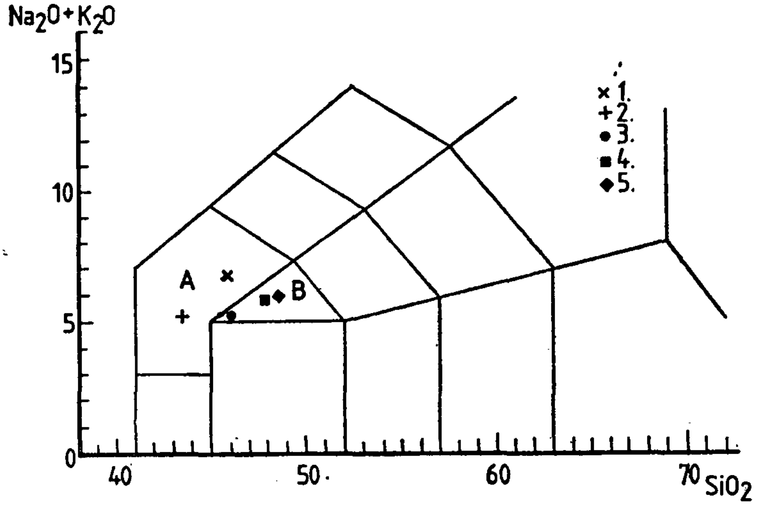

Fig. 3. TAS-diagram of the Little Hungarian Plain basaltoid rocks A — Tephrite and basanite. B — Trachybasalt, 1, 2, 3, 4, 5 symbols as in Table 1

PETROGRAPHY OF THE ULTRAMAFIC XENOLITHS

We have collected about 150 xenoliths from the Sitke tuffring situated south from the village. This sampling was completed by some specimens from Hercseghegy and from Gérce *(Fig. 2)* where some nodules have been previously studied by EMBEY-ISZTIN (1978, 1984), SZABÓ (1982), EMBEY-ISZTIN *et al.* (1989). A large amount (99%) of the studied samples described in this paper are derived from the quarry of Belsőhegy.

Modal compositions of about 40 representative xenoliths were calculated from least-squares analyses of bulk rock. The nodules display a relatively limited mineralogical variation (Table 2) and they are principally made up of olivine (40—80 vol%), orthopyroxene (9—36 vol%), clinopyroxene (5—17 vol%) and spinel (<5,5 vol%). This composition resembles to Cr-diopside group (Type I) of xenoliths (WILSHIRE and SHERVAIS, 1975), except for 3 dunites (sample No BH—60, —78, —79) and a

TABLE 2

Modal composition of some representative xenoliths from Sitke

Sample Texture	BH—04 Porphyr	BH—09* Equigr	BH—15 Equigr	BH—55 Porphyr	BH—60 Second	BH—81 Equigr	BH— 58 Porphyr
Ol	53	20	68	68	85	30	48
Opx	36	72	11	16	12	7	34
Cpx	7	4	17	8	2	36	11,5
Sp	4	4	4	8	1	10,5	4
Amph	—	—	—	—	—	6	0,5
Glass	—	—	—	—	—	10,5	2

* without spinel-rich vein.

special spinel- rich composite xenolith (sample No BH—09). In addition we have found 4 nodules (sample No BH—74, —81, —85, —90) containing amphibole grains. In the BH—81 ample the quantity of amphibole reach >6 vol%. No trace of primary plagioclase neither relic garnet were observed in the studied xenoliths.

The majority of analysed xenoliths is spinel lherzolite and harzburgite; other rock types [dunites (BH—60, —78, —79), composite xenoliths (BH—09) and amphibole-rich material (BH—81)] are rare *(Fig. 4).*

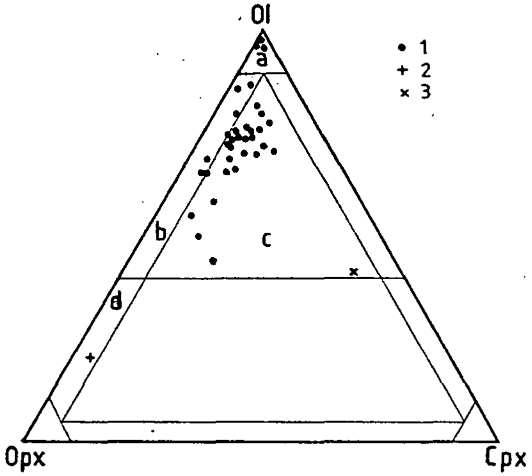

Fig. 4. Ol—Opx—Cpx diagram (Streckeisen, 1974) of ultramafic xenoliths from Sitke, 1 — common xenolith, 2 — composite xenolith, 3 — amphibole lherzolite xenolith, a — dunite, b — harzburgite, c — lherzolite, d — olivine orthopyroxenite

Among the secondary minerals calcite and hematite are common in the Sitke xenoliths, but the quantity of these materials is restricted. Hematite is found as a film around olivine and pyroxene grains, whereas calcite can mostly replaces a part of the olivine crystals. Both of these secondary minerals are the products of subsequent alteration.

The xenoliths commonly show an evidence of minor partial melting process along some grain boundaries or in patches. These melted zones consist of euhedral clinopyroxene and olivine crystals with euhedral spinel and yellow or red glass *(Fig. 5);* plagioclase microlites, calcite and xenomorphic amphibole are very subordinate. The above-mentioned minerals and glass may be common in the ultramafic xenoliths (Frey and Printz, 1978) and result from melting of amphibole (or phlogopite) during the rapid eruption of the host magma (Frey and Green, 1974; Best, 1974).

Based on the textural studies of spinel peridotite xenoliths derived from the upper mantle four principal types were usually identified (Mercier and Nicolas, 1975; Pike and Schwarzman, 1977; Harte, 1977): (1) protogranular or allotriomorphic-granular or coarse, (2) porphyroclastic, (3) equigranular or granuloblastic, and (4) secondary recristallized. (In this paper we used the Mercier-Nicolas's classification.) The main characters which permit distinction among their textural types are the following: grain size, presence or absence of porphyroclasts and their deformation, grain boundary of the silicate phases (linear, curved, ragged), shape and position

Fig. 5. Photomicrograph showing in melted zone glass, euhedral fine clinopyroxene, olivine, spinel and resorbed amphibole (amph) [BH—85, Sitke]. 1N, M=33x

of the spinel grains. Textures of the Sitke xenoliths are porphyroclastic, equigranular and transitional between these two types. In addition secondary recrystallized textures also exist. Embey-Isztin (1978) described xenoliths have protogranular-porphyroclastic transitional texture, but we have not recognized this type yet.

36% of the xenoliths display a typical porphyroclastic texture *(Fig. 6)* which is wide-spread type in upper mantle peridotites. Porphyroclasts of olivine and orthopyroxene are up to 6 mm in diameter; boundaries of these minerals are ragged and curved. Olivines have kink bends or undulatory extenction. Orthopyroxenes are usually strained and often show fine clinopyroxene exsolution lamellae in the inner part of the grains *(Fig. 7)*. Sometimes a few small euhedral olivines are enclosed by large sized othopyroxenes resembling to poicilitic texture. Neoblasts of olivine and orthopyroxene also appear in the equigranular matrix (which contains clinopyroxene and spinel). The grain boundaries of the neoblasts are linear, and the triple point

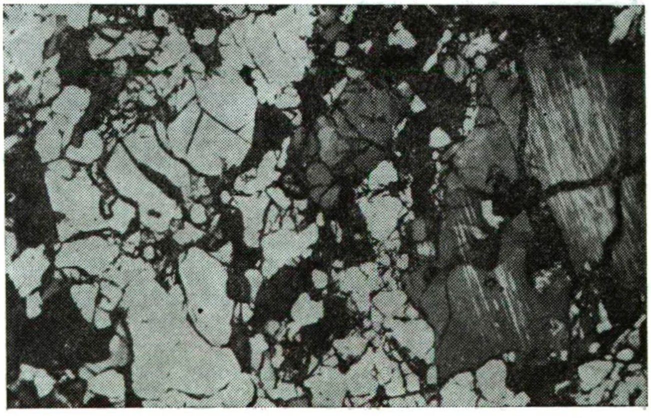

Fig. 6. Photomicrograph showing porphyroclastic texture in spinel lherzolite xenolith from Sitke [BH—74]. +N, M=20x

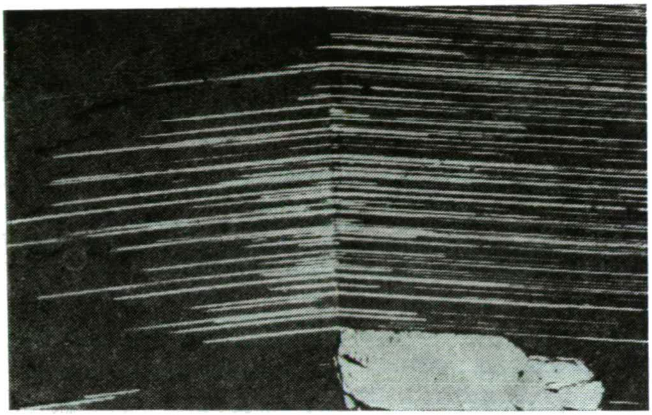

Fig. 7. Photomicrograph showing clinopyroxene exsolution lamellae and olivine inclusion in orthopyroxene in spinel lherzolite xenolith from Sitke [BH—04]. +N, M=33x

junction is characteristic. This texture appears to be the result of a polygonisation and recrystallization of the coarser grained assemblages. These minerals are very rarely strained. Spinels are chestnut brown and form holly-leaf shaped grains in the interstitial position. Xenoliths with this mentioned texture type comprise a few grains of probably pargasitic amphibole.

Relatively high ratio (22%) of the studied inclusions exhibit a typical granuloblastic texure *(Fig. 8)*. In these nodules minor olivine and/or orthopyroxene porphyroclasts occur. These grains have similar textural features to those which have been described at the previous textural groups. Excluding the rare porphyroclasts (flattening character), the average grain size of these nodules is generally less than 1.0 mm. Neoblasts of olivine and orthopyroxene have straight or smoothly curved borders and often show 120° triple point junctions. Such a feature (strain-free grains) indicate the recristallization after strong deformation. Spinel forms generally small near-spherical opaque or redbrown grains in the silicate phases, however, some of

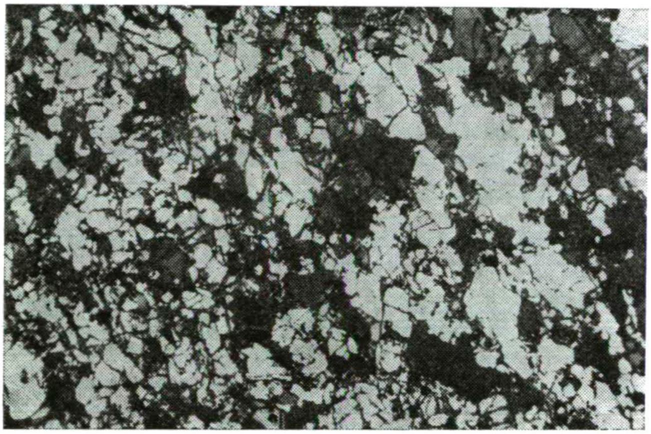

Fig. 8. Photomicrograph showing equigranular texture in spinel lherzolite xenolith from Sitke [BH—33]. +N, M=20x

them can occur as translucent holly-leaf shaped crystals surrounded with an opaque rim in the interstitial position, associated with the melted areas containing unhedral spongy clinopyroxene grains as well. In some of equigranular xenoliths the mineral grains define a weak foliation and show two dimensions markedly more flattened than the third one. So it means that the equigranular nodules can be divided into two groups: tabular and mosaic equigranular ones.

22% of the xenoliths show transitional features between porphyroclastic and equigranular types. Grain size of the strained olivine and orthopyroxene is smaller than those of porphyroclastic textured xenoliths. These nodules display no signs of foliation. The neoblasts have curvilinear boundaries and the triple point junctions are characteristic.

The proportion of pure secondary recristallized nodules compared to the primary types is subordinate (18%). Grain-size of olivine and orthopyroxene is less than 2 mm and these crystals are generally unstrained. Mineral borders are curved and linear with triple junctions. Small grains of spinel constitute spherical inclusions in olivines and orthopyroxenes. Larger spinels show amoeboid-like shape and appear in interstitial position.

Only two nodules display conspicuous differences in mineralogical composition and textural features. One is a composite xenolith (BH—09), in which an olivine orthopyroxenite is intruded by a spinel-rich vein. The olivine orthopyroxenite has mosaic equigranular texture. Among the polygonal neoblasts we found only a few strained orthopyroxene porphyroclasts with fine clinopyroxene lamellae. Several small opaque grains of spinel appears as spherical inclusion in the silicate phases. Large opaque spinel crystals form a fine vein (its width is about 1 cm) crosscutting and consuming the host peridotite *(Fig. 9)*.

The other special xenolith (BH—81) contains abundant amphibole crystals. This amphibole lherzolite has a characteristic equigranular texture with typical olivine and orthopyroxene porphyroclasts and neoblasts *(Fig. 10)*. Grains of clinopyroxene are polygonal and have sometimes display twinning and inclusion of Cr-rich spinel. The grain-size of amphiboles is less than 1.2 mm. They are brown colour and anhedral in shape. They appear in intersitial position defining nearly parallel bands. These bands also contain spinel and considerable clinopyroxene and their

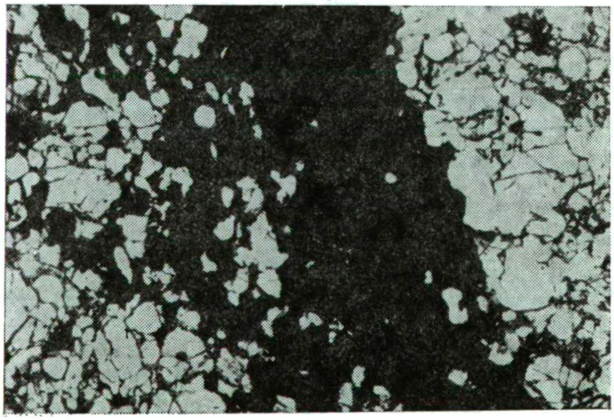

Fig. 9. Composite xenolith [BH—09], showing thin spinel vein in olivine orthopyroxenite xenolith from Sitke. 1N, M=20x

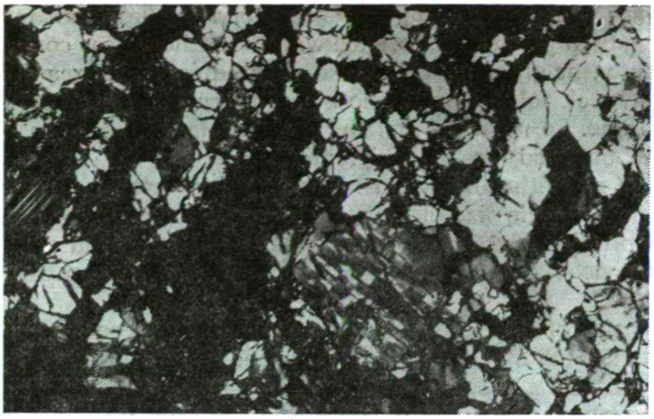

Fig. 10. Amphibole lherzolite xenolith [BH—81], showing olivine porphyroclast and nearly parallel band consisting mainly of amphibole, clinopyroxene and spinel in a typical equigranular texture. 1N, M=20x

position suggests close textural relationships. The spinels are brown. The large amoeboid shaped grains (about 2 mm) are covered by a fine opaque rim. Large amount of spinel occur close to the amphiboles; the interstitial spinel is typically absent in this amphibole lherzolite. The overprinting of these bands on the normal recrystallized texture indicates that the amphiboles were formed after the polygonization and recrystallization of this xenolith.

These two special nodules can be considered as an evidence of modal metasomatism (HARTE, 1983; DAWSON, 1984) in the upper mantle. This metasomatism has already been proved beneath the Carpatho-Pannon region by EMBEY-ISZTIN (1976/b), KURAT *et al.* (1980) based on the young basaltoid suite and by SZABÓ (1985), KUBOVICS *et al.* (1989) based on the Early Cretaceous lamprophyre.

CONCLUSIONS

The Sitke tuffring encloses four textural types of upper mantle xenoliths.

Textural analyses of the xenoliths show that high porportion of the nodules has porphyroclastic and equigranular texture. We have found many transitional textures as well, proving that the nodules are products of a continous metamorphic process (MERCIER and NICOLAS, 1975). Textural relationship of these inclusions confirms NICOLAS and MERCIER's theory suggesting that a volcanic vent carries out one predominant nodule-type.

The strained elements in the texture indicate that the upper mantle had a long, complex previous deformational history. The straining may has occurred during the development of the diapir (COISY and NICOLAS, 1978) or during the shearing due to the decoupling of the mantle from the crust. Mantle diapirs in Neogene are demonstrated by geophysical methods (STEGENA *et al.*, 1975). Development of upper mantle diapir beneath the LHP has also been proposed by EMBEY-ISZTIN (1984).

Two special types of xenoliths were collected. One contains bands rich in amphibole, clinopyroxene and spinel and the other is a composite nodule with spinel-vein. They suggest that the upper mantle beneath the LHP has been undergone a modal metasomatism after the deformation. This process has facilitated the formation of the basaltic melt. The amphibole-bearing (Cr-diopside group) mantle nodules are wide-spread in the world (e.g. WHITE, 1966; BEST, 1974; FREY and GREEN, 1974; FRANCES, 1976; TAKAHASHI, 1980; WILSHIRE *et al.*, 1980) and occurence of them are regarded as an important volatile-containing phase within the upper mantle (e.g. OXBURGH, 1964; DAWSON and SMITH, 1982). It should be mentioned that some amphibole lherzolites have been recognized in the Carpatho-Pannon region by EMBEY-ISZTIN, (1974); KURAT *et al.*, (1980); KUBOVICS *et al.*, (1989).

The Sitke xenoliths may have contained more amphiboles than at present and some part of them may have been partially melted during the ascent to the surface in the host magma.

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