

Apatite Enrichment in Nephelinite from Slánská Hora Hill, Central Bohemia

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ABSTRACT. The Cenozoic diatreme of Slánská hora Hill represents an extraordinary phosphorus anomaly (3.90–5.07 wt.% P_2O_5 ; 9.5–11.6 % of normative apatite) among alkaline volcanic rocks of the Bohemian Massif. The olivine-poor nephelinite (melanephelinite) from central part of the diatreme contains (i) large hydroxyl-fluorapatite crystals (up to 1.8 mm long) in digested harzburgite microxenoliths (about 2 mm in diameter), (ii) partly resorbed individual hydroxyl-fluorapatite (0.05–0.1 mm) in matrix derived from disintegrated microxenoliths and (iii) microcrystalline hydroxyl-chlorapatite inclusions (7–30 μm in size) in silicates of the nephelinite matrix. Apatite from the nephelinite dyke corresponds to hydroxyl-chlorapatite reflecting a change in Cl/F ratio. The apatite-rich ultramafic microxenoliths are likely related to metasomatized upper mantle source.

KEY WORDS: olivine-poor nephelinite, apatite, harzburgite xenolith, Bohemian Massif.

Introduction

The Cenozoic Alkaline Volcanic Subprovince of the Bohemian Massif (AVSBM) forming a part of the Central European Volcanic Province of Wimmenauer (1974) consists of various intraplate volcanic rock series (Ulrych et al. 1998a). Slánská hora Hill (330 m a.s.l.) located near the town of Slaný (*salty* in English) is a solitary diatreme with marginal part formed by vent breccia and a central neck consisting of olivine-poor hauyne nephelinite (referred to as nephelinite below) and petrographically characterized by Ondřej (1921). Whole-rock chemical analyses related to the neck show high phosphorus contents in the range of 4.03–4.22 wt.% P_2O_5 (Shrbený 1992; Vaněčková et al. 1993; Ulrych et al. 1998b). However, relevant explanation of the phosphorus anomaly bound to apatite and its origin has not been formulated. Vaněčková et al. (1993) suggest relation of the abundant apatite in nephelinite to contaminated crustal material rich in phosphorus. Ulrych et al. (1998b) explain the origin of apatite (both xenocrystic and microcrystalline) in olivine-poor nephelinite by exceptionally high apatite fractionation during crystallization of magma of silico-carbonatite affinity. The present paper suggests an association of the apatite enrichment with partial melting of the apatite-rich metasomatized mantle xenoliths and gradual contamination of magma.

Geological setting and volcanology

The erosional remnant of the diatreme is located in the town of Slaný (30 km west of Prague) on the N periphery of the Permo-Carboniferous Kladno Basin. The regional position of Slánská hora Hill is associated with the intersection of the ENE-trending Kladno Fault and transverse fault of the Slaný Fault System (NW–SE). The nearest volcanic manifestation is represented by the stratovolcano of Vinařická hora Hill north of Kladno (Kopecký 1959). From volcanological point of view, the composite diatreme at Slánská hora Hill includes: 1 – vent breccia formed in the first event of eruptive activity, 2 – dominant olivine-poor nephelinite intrusion forming the main edifice, and 3 – nephelinite dyke penetrating the olivine-poor nephelinite body.

Petrography and mineralogy

The studied samples come from an abandoned quarry on south-

ern slope of Slánská hora Hill. All samples are enriched in minute apatite-rich ultramafic microxenoliths, however, bigger ultramafic xenoliths have not been found yet. These microxenoliths are present also in nephelinite fragments in the volcanic breccia body and in the nephelinite dyke. They were, however, best documented in the main nephelinite body

Olivine-poor hauyne nephelinite, rich in apatite

The rock is dark grey to almost black in colour, massive with microporphyritic texture. Phenocrysts (0.5–0.7 mm) are represented by inexpressive zoned Al-salite (0.19–0.34 wt.% Cr_2O_3) and to a lesser degree by totally serpentinized olivine. Clouded hauyne (with 12 wt.% SO_3) containing nepheline relics ($\text{Ne}_{54-56}\text{Ks}_{23-25}\text{Q}_{19-21}$) is present, too. The holocrystalline matrix consists mainly of fassaite to Ti-fassaite, and of titanomagnetite impregnations with poikilitic nepheline and hauyne grains being subordinate. Broken apatite prisms (0.05–0.1 mm in size) originated from disintegrated harzburgite microxenoliths and occasional potash feldspar fragments (up to 0.3 mm) of unknown origin belong to xenocrystic population. Biotite, chlorite, pyrite, and droplets of volcanic glass (55.5 wt.% SiO_2 , $(\text{K}+\text{Na})/\text{Al} = 0.61$) occur as accessory phases. In addition, irregular apatite microinclusions (7–30 μm in size) were verified by backscattered electron images in the matrix silicates (Ulrych et al. 1998b). Among secondary minerals, zeolite, calcite, and Mn-bearing dolomite are present. On basis of both modal estimation and chemical composition the rock is classified as olivine-poor hauyne nephelinite; however, in special nephelinitic rocks classification as melanephelinite II (*sensu* Le Bas 1989). Microprobe analyses (JEOL JXA 50A with EDS PW 9400 analysis) of the rock-forming minerals are given in Table 1.

Apatite-rich ultramafic microxenolith of harzburgite composition

Partly molten and disintegrated ultramafic microxenoliths were found in variable proportion as an integral part of the nephelinite. Due to their small size (up to 2 mm) it is impossible to analyse them as a whole rock. Their cumulate origin from nephelinite magma can be excluded because of the spongy reaction rims between sintered microxenoliths and host nephelinite. How-

No.	1	2	3	4	5	6	7
SiO ₂	49.69	45.61	35.68	42.54	0.07	49.97	55.52
TiO ₂	2.23	3.65	-	0.32	15.85	0.28	1.22
Al ₂ O ₃	4.07	7.01	28.20	33.85	3.24	5.39	18.96
Cr ₂ O ₃	0.34	-	-	-	0.22	-	-
Fe ₂ O ₃	-	-	-	-	37.52	-	-
FeO	7.15	8.11	2.18	1.80	34.97	9.88	1.08
MnO	0.37	0.35	0.19	0.13	1.25	0.21	-
NiO	-	-	-	-	0.35	-	-
MgO	12.95	11.11	1.07	1.01	6.07	18.92	0.70
CaO	23.19	23.32	6.40	1.04	0.43	1.30	4.23
BaO	-	-	2.29	-	-	-	-
Na ₂ O	-	0.69	8.91	11.66	-	-	1.49
K ₂ O	-	0.14	2.54	7.64	-	0.47	8.40
P ₂ O ₅	-	-	-	-	-	-	0.40
SO ₃	-	-	12.19	-	-	-	-
Cl	-	-	1.34	-	-	-	-
	99.99	99.99	100.99	99.99	99.98	86.42	92.00
-O=Cl,S	-	-	-1.52	-	-	-	-
Total	99.99	99.99	99.47	99.99	99.98	86.42	92.00

Tab. 1. Representative microprobe analyses of minerals in nephelinite. 1 – Cr-bearing Ti-salite phenocryst; 2 – matrix titanite; 3 – hauyne phenocryst; 4 – nephelinite relics; 5 – titanomagnetite; 6 – serpentine mineral after olivine; 7 – droplets of volcanic glass.

ever, estimation of their modal composition corresponds to apatite-rich harzburgite. Its origin is most probably associated with the upper mantle source that was metasomatized prior to partial melting.

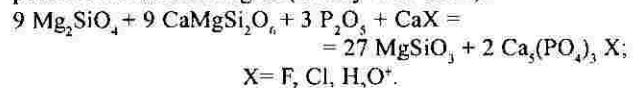
Dominant equigranular olivine (75 vol.%, 0.5–0.8 mm in size) is entirely replaced by Mg-serpentine and Mn-dolomite. Interstitial, slightly zoned orthopyroxene (bronzite) contains exsolution lamellae of Cr-Al-pigeonite, rare amphibole (cummingtonite) rims and accessory pyrope–almandine inclusions. Some of the orthopyroxene grains display opacitized margins passing to opaque Ti-Fe-oxide minerals. Titanomagnetite also occurs in individual grains (< 0.8 mm in diameter) with a gradual transition to Mg-Mn-bearing titanomagnetite in core.

Volatile-bearing and hydrous phases consist of hydroxyl-fluorapatite, secondary serpentine mineral, carbonate, and very

No.	1	2	3	4	5	6	7
SiO ₂	56.09	33.85	46.49	0.07	0.10	51.93	57.44
TiO ₂	0.43	0.48	2.14	13.83	15.50	0.22	0.20
Al ₂ O ₃	11.98	12.16	13.75	3.48	3.41	3.62	16.82
Cr ₂ O ₃	0.17	n.a.	-	0.23	0.24	-	-
Fe ₂ O ₃ *	-	-	-	40.93	37.87	-	-
FeO	12.16	32.32	20.68	24.34	34.78	8.14	0.83
MnO	0.19	1.03	0.41	11.26	1.56	0.09	0.22
NiO	-	-	-	-	0.19	-	-
MgO	17.08	11.16	9.37	5.57	6.03	21.33	0.22
BaO	-	-	-	-	-	-	0.94
CaO	1.50	8.81	2.32	0.27	0.29	0.87	0.42
Na ₂ O	0.39	-	1.71	-	-	-	0.22
K ₂ O	0.00	-	0.08	-	-	0.29	14.63
sum	99.99	99.81	96.95	99.98	99.98	86.49	91.92

Tab. 2. Representative microprobe analyses of minerals from harzburgite microxenoliths. 1 – bronzite; 2 – garnet (pyrope-almandine) inclusion in orthopyroxene; 3 – amphibole (cummingtonite) – rim; 4 – Mn-Mg-bearing titanomagnetite – core; 5 – titanomagnetite – rim; 6 – serpentine mineral; 7 – alkali-rich glass.

rare amphibole with glass inclusions. Euhedral, up to 1.8 mm long hydroxyl-fluorapatite crystals crystallizing in structural association with altered olivine and orthopyroxene along discordant cracks are considered to be a product of mantle metasomatism. Apatite precipitation in upper mantle conditions may be controlled by reaction of peridotite with carbonatite melt as possible metasomatic agent (Yaxley et al. 1991):



Hydroxylapatite crystals with acicular and prismatic habits often display secondary undulatory extinction and are pigmented due to abundant tiny fluid inclusions. Unusual alkali-rich glass of nephelinitic composition (57.4 wt.% SiO₂, 14.6 wt.% K₂O, K₂O/Na₂O = 0.94) infills thin channels occurring in margins of orthopyroxene. It differs in composition from droplets of volcanic glass in both the nephelinite matrix and reaction rim.

The ultramafic microxenoliths showing mosaic porphyro-

No.	1	2	3	4	5	6	7	8	9	10
P ₂ O ₅	40.53	40.06	40.12	39.82	40.11	39.89	43.03	40.10	39.51	38.80
SiO ₂	0.93	0.55	1.33	0.07	1.00	1.35	0.42	1.69	1.29	1.69
Al ₂ O ₃	0.46	-	0.63	0.16	0.06	0.59	-	0.23	0.42	0.23
FeO	0.52	0.46	1.07	1.58	1.14	0.78	0.33	0.64	1.12	0.64
MnO	0.13	0.14	0.13	0.34	-	-	0.26	0.17	0.25	0.17
MgO	0.45	0.45	0.33	0.51	0.30	0.36	0.27	0.30	0.09	0.30
CaO	54.16	55.00	53.55	54.97	54.64	54.02	53.72	55.96	53.87	53.96
Na ₂ O	0.13	0.51	-	0.17	0.13	0.15	0.36	0.53	0.32	0.53
K ₂ O	-	-	-	-	-	-	0.22	-	-	-
F	0.49	0.67	0.75	0.50	0.61	0.26	0.67	1.17	0.72	1.17
Cl	0.28	0.33	0.27	0.29	1.27	1.40	0.34	1.10	1.03	1.10
SO ₃	0.91	0.83	0.83	0.70	0.75	1.00	0.88	0.91	0.89	0.91
	98.99	99.00	99.01	99.11	100.01	99.80	99.50	99.50	99.51	99.50
-O=2F	-0.20	-0.28	-0.31	-0.21	-0.25	-0.11	-0.28	-0.49	-0.30	-0.49
-O=2Cl	0.06	0.07	-0.06	-0.06	-0.28	-0.31	-0.07	-0.25	-0.23	-0.25
Total	98.73	98.65	98.64	98.84	99.47	99.38	99.15	98.76	98.98	98.76

Tab. 3. Chemical composition of hydroxylapatite types. 1, 2 – hydroxyl-fluorapatite from microxenolith; 3, 4 – hydroxyl-fluorapatite xenocrysts from nephelinite; 5, 6 – hydroxyl-chlorapatite from nephelinite dyke; 7 – hydroxyl-fluorapatite from vent breccia; 8 to 10 – hydroxyl-chlorapatite microinclusions in the nephelinite matrix silicates.

Rock type wt. %	Olivine-poor nephelinite of the neck				Dyke nephelinite	Average nephelinite
	1	2	3	4	5	6
SiO ₂	31.82	31.50	33.16	33.00	36.65	38.48
TiO ₂	3.85	3.76	3.71	3.83	n.a.	4.36
Al ₂ O ₃	8.86	8.62	8.52	8.56	10.81	11.41
Fe ₂ O ₃	9.76	9.95	8.41	6.14	7.61	7.30
FeO	7.22	7.50	7.86	9.42	13.34	7.10
MnO	0.35	0.35	0.35	0.34	n.a.	0.25
MgO	8.70	8.95	7.94	8.23	5.10	7.04
CaO	16.86	16.76	16.55	17.29	17.04	14.50
Na ₂ O	2.23	1.80	2.77	2.83	3.81	2.96
K ₂ O	1.02	0.97	1.31	1.29	1.00	1.21
P ₂ O ₅	5.07	3.90	4.13	4.22	1.91	1.26
H ₂ O ⁺	-	-	2.21	1.65	-	2.24
LOI	3.55	5.08	-	-	2.82	-
CO ₂	-	-	1.58	1.96	-	0.65
C	-	-	0.03	-	-	-
F	-	-	0.08	-	-	0.13
Cl	-	-	-	-	-	-
S	-	-	0.12	-	-	0.07
H ₂ O ⁻	-	-	0.85	-	-	0.76
-O=2F,C,S	99.29	99.16	99.58	98.76	100.09	-
Total	99.29	99.16	99.58	98.76	100.09	99.72
Mg [#]	53.29	53.30	47.87	49.56	34.63	
CaO/Al ₂ O ₃	3.46	3.54	3.66	3.67	2.86	
Na ₂ O/Al ₂ O ₃	0.41	0.34	0.55	0.54	0.58	
P ₂ O ₅ /Al ₂ O ₃	0.41	0.32	0.37	0.35	0.12	

Tab. 4a. Chemical analyses of nephelinite. 1, 2 – analyst L. Mráz, Faculty of Science, Charles University; 3 – Shrbený (1995); 4 – Vaněčková et al. (1993); 5 – Ondřej (1921).

clastic texture (deformational features of altered olivine and slightly strained orthopyroxene and apatite) were equilibrated probably in high-pressure conditions. The spongy reaction rims between microxenoliths and host nephelinite (0.02–0.05 mm in width) consisting of Al-diopside and colourless volcanic glass were formed due to pyrometamorphic reaction.

Representative microprobe analyses of the rock-forming minerals are given in Table 2. Analyses of main textural types of hydroxylapatite are presented in Table 3.

Chemical composition of nephelinite

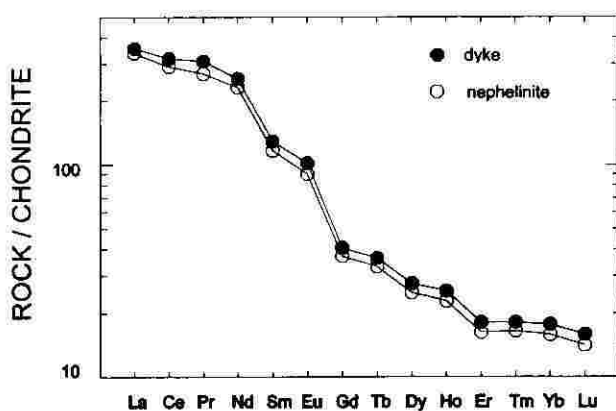


Fig. 1. Chondrite-normalized REE contents of nephelinite from Slánská hora Hill.

Major elements

In TAS diagram (Le Bas et al. 1986), the rock of Slánská hora Hill plots in the field of foidite. According to the C.I.P.W. norm it is nepheline-normative (13–16% *ne* and 3–5% *ol*). The nephelinite samples containing numerous ultramafic microxenoliths are more silica-undersaturated (31.5–33.0 wt.% SiO₂) than those containing rare microxenoliths with resorbed apatite xenocrysts. The Mg[#] (sensu Frey et al. 1978) varies from 51.1 to 53.3 in microxenolith-rich samples and from 47.8 to 49.5 in microxenolith-poor samples. High proportion of calcic clinopyroxene, apatite and secondary carbonate in nephelinite refers to high CaO/Al₂O₃ ratios (3.46–3.67, cf. aver. value of 1.99–5.22 for spinel peridotite xenoliths affected by carbonatite metasomatism, Yaxley et al. 1991). Bulk-rock chemistry is also consistent with Na₂O/Al₂O₃ values ranging from 0.34 to 0.55 (cf. 0.21–0.55 for metasomatized mantle xenoliths). The majority of incompatible trace elements contents manifest linear correlation with P₂O₅/Al₂O₃ ratio displaying not only contamination but also fractionation.

Compatible trace elements

Contents of characteristic elements such as Ni (23–31 ppm), Cr (8–12 ppm) and Sc (31 ppm) in the nephelinite are markedly lower if compared with average olivine nephelinite (e.g. from the České středohoří Mts., Shrbený 1995). Depletion in these elements is controversial especially in association with the digested ultramafic microxenoliths in nephelinite. Very low Mg[#] and low contents of compatible elements in the nephelinite are

probably due to mantle metasomatism of the source harzburgite and fractionation process.

Incompatible trace elements

Enrichment of the rock in incompatible elements such as P, Ba, Sr, Rb, LREE, Zr, and Th as well as above mentioned depletion in compatible elements relative to average olivine nephelinite are indicative of nephelinite II of Le Bas (1989), see Table 4b. P₂O₅ contents and variations in P₂O₅/Al₂O₃ ratios are unusually high and correlate slightly negatively with silica contents. Despite the high apatite solubility in basaltic melts (Watson 1980; Backer and Wyllie 1992) it is apparent that partly molten apatite grains contribute to the successive Ba, Sr and LREE enrichment of the originated magma. Therefore, the concentrations of LILE (Ba, Sr, Rb,) are positive correlated with P₂O₅/Al₂O₃ ratios.

Chondrite-normalized REE patterns for nephelinite have steeply negative slopes towards LREE and high (La/Yb)_N ratio (c. 18), see Fig. 1 and Tab 4b. The REEs are prevalently concentrated in apatite. The higher concentrations of Zr, P, Ce, Th, and Ti reported by Vaněčková et al. (1993) from the nephelinite of Slánská hora Hill and interpreted in association with progressive crustal contamination may be rather related to gradual contamination of apatite-rich harzburgite microxenoliths. Similar geochemical signatures are characteristic for nephelinites and related rocks occurring at localities adjacent to Slánská hora Hill. Prominent enrichment in P₂O₅, Sr, and Zr in nephelinites is shown in spidergram (Fig. 2).

Apatite mineral chemistry

With rare exceptions, nearly all apatites analysed are hydroxyl-fluorapatites, although their composition depends on their textural position within the rock: (i) apatite-rich metasomatized harzburgite xenoliths (type 1) and (ii) partly resorbed apatite xenocrysts occurring in both the nephelinite matrix and the vent breccia (type 2). Microcrystalline hydroxyl-chlorapatite inclusions in matrix silicates (type 3) and recrystallized hydroxyl-

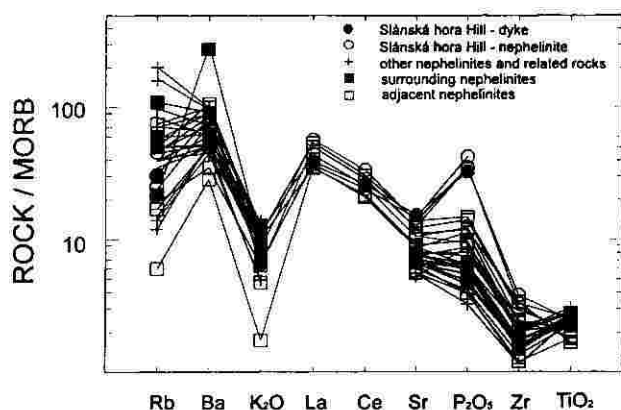


Fig. 2. Spidergram of nephelinite and related rocks of the Bohemian Cretaceous Basin and the České středohoří Mts. Apparent enrichment in P₂O₅, Sr and Zr in volcanic rocks of Slánská hora Hill (empty circles) and closely adjacent nephelinite localities (empty squares) relative to volcanic rocks from the wider surroundings (full squares) and České středohoří Mts. (crosses) is obvious. Data from Macháček and Shrbený (1970), Shrbený (1992) and Vaněčková et al. (1993).

ppm	1	2	3	4	average nephelinite
Ba	n.a.	n.a.	1005	1030	n.a.
Ce	252	275	n.a.	335	186.48
Co	40	40	n.a.	n.a.	53.86
Cr	8.1	8.5	12	n.a.	54
Cu	50	49	n.a.	n.a.	131
Ga	n.a.	n.a.	n.a.	24	n.a.
La	110.6	117.1	n.a.	171	104.95
Li	7.4	7.8	n.a.	n.a.	
Nb	n.a.	n.a.	198	187	131
Ni	29	29	25	31	36
Pb	< 2	< 2	n.a.	7	n.a.
Rb	31	30	31	46	41
Sc	n.a.	n.a.	n.a.	31	
Sr	1681	2093	1703	1873	1094
Th	n.a.	n.a.	n.a.	16	10.23
U	n.a.	n.a.	n.a.	1	3.16
V	368	373	n.a.	362	n.a.
Y	n.a.	n.a.	n.a.	52	33
Zn	204	198	n.a.	153	95
Zr	n.a.	n.a.	908	788	468
La	110.6	117.1			
Ce	252	275			
Pr	40.3	44.7			
Nd	145.8	160.6			
Sm	24.4	26.9			
Eu	6.8	7.67			
Gd	10.24	11.21			
Tb	1.65	1.81			
Dy	8.58	9.48			
Ho	1.76	1.96			
Er	3.66	4.08			
Tm	0.58	0.60			
Yb	3.49	3.90			
Lu	0.48	0.54			

Tab. 4b. Minor and trace elements contents of nephelinite. 1, 2 – analysts J. Košler (REE by ICP-MS), O. Šebek (other trace elements by AAS), Faculty of Science, Charles University; 3 – Shrbený (1995); 4 – Vaněčková et al. (1993).

chlorapatite xenocrysts hosted in nephelinite dyke (type 2a) are chemically indigenous to the nephelinite magma.

The site allocation method assumes the heterovalent S–Si–C substitution for P⁵⁺ and the isovalent F, Cl, and OH substitution (Sommenauer and Katz-Lehnert 1985). Ulrych et al. (1998b) reported increased SO₃ (0.35–1.00 wt.%), SiO₂ (0.16–1.84 wt.%) at almost constant CO₂ contents (0.28 wt.%) in hydroxylapatite from Slánská hora Hill.

It has been found that Cl/F ratio ranges from 0.23 to 0.31 and of 0.14 to 0.88 for large acicular hydroxyl-apatite crystals of type 1 and xenocrystic apatite population in both nephelinite and vent breccia (type 2a), respectively. In contrast, the repeatedly molten and recrystallized apatite xenocrysts in the dyke nephelinite, equilibrated with its surroundings, are apparently enriched in chlorine (Cl/F ratio being 1.1–4.4). Microcrystalline hydroxylapatites (type 3) with higher Cl/F ratio (0.94–8.2) indicate substantially increased activity of chlorine, too. The SO₃ concentrations are generally uniform in all hydroxylapatites analysed (0.6–0.9 wt.%).

Fe (0.062–0.228 p.f.u.) prevails over Mg (0.080–0.131

p.f.u.) and Mn (0.018–0.049 p.f.u.) in types 1 and 2. Concentrations of Al do not vary conspicuously. A low amount of Na in hydroxylapatite is likely connected with the presence of cezanite compound (Tazzoli 1983).

Discussion

Mantle-derived xenoliths anomalously enriched in apatite are rather exceptional worldwide being restricted to metasomatically altered regions of subcontinental mantle (Menzies and Murthy 1980; Exley and Smith 1982). The amphibole-bearing mantle xenoliths with abundant apatite are known from nepheline basanite dyke at Kiama, New South Wales, representing the amphibole-apatite series (Wass 1979, 1980). These xenoliths contain, in addition to dominant Ti-bearing pargasite and apatite: Al-augite, altered olivine, Mg-ilmenite, Mg-Al-bearing magnetite, carbonate, rutile and sulphides. The general geochemical characteristics of such xenoliths are low Si, Ni and Cr contents and high Fe and other incompatible elements such as Ti, K, P, REE contents. High concentrations of CO₂, Cl and F are most characteristic of the xenoliths. Their chemical composition is comparable with those for fractionated kimberlite enriched in Sc, Ti, V and Fe and strongly depleted in Cr and Ni. However, higher Sr and Ba contents are also consistent with those of carbonatite suite. Due to the dominance of modal apatite and amphibole, samples of mafic xenoliths are LREE-enriched and their chondrite-normalized patterns are comparable with those for carbonatite and/or kimberlite (Wada and Rogers 1980). The apatite itself is rich in Cl and F, with minor OH contents only. Similar xenoliths enclosed in alkaline lavas were described from the Eifel region, Germany, by Duda and Schmincke (1978) and Lloyd et al. (1991a) as well as from the East African rift system by Lloyd et al. (1991b). Salite-kaersutite cumulates (xenoliths?) in sodalite syenite from Zubrnice, České středohoří Mts. with high content of apatite (about 10 vol.%) were also described by Ulrych et al. (1998). From the genetic point of view, the incorporation of the metasomatized mantle xenoliths into silica-undersaturated magma generation demonstrates that phosphorus enrichment must have been present before their entrainment into host magma, i.e. in the mantle region. The decompressive melting and crustal contamination of the liquid during magma ascent played a local role.

Conclusion

A new interpretation of the phosphorus enrichment (9.5–11.6 % of normative apatite) of the olivine-poor nephelinite (melanephelinite) from Slánská hora Hill revealed magma contamination by apatite-rich mantle material as well as progressive magma fractionation. Both disintegrated and molten apatite-rich harzburgite microxenoliths and/or digested apatite xenocrysts were found disseminated in most volcanic rocks sampled from Slánská hora Hill. They dominate in nephelinite of the neck and are present to a lesser extent in glassy nephelinite fragments of the vent breccia and in dyke nephelinite. The microxenoliths are of harzburgite composition being in equilibrium with undersaturated melt and fluids.

Large hydroxylapatite crystals (type 1) and fragmented apatite xenocrysts (type 2a, 2b) derived from the above mentioned microxenoliths are responsible for anomalous phosphorus concentrations in host nephelinite. The volumetrically subordinate apatite of type 3, as apatite micro-inclusions (7–30 µm in size) is intimately associated with the matrix silicates. Speculation on their preservation during magma ascent is supported by the high magma explosiveness and by the relatively short interval

between eruption and magma mixing, despite of high apatite solubility in mafic alkaline liquids (Watson 1980; Baker and Wyllie 1992). The prevailing apatite types of (1) and (2a) are hydroxyl-fluorapatites displaying notable contents of F, Cl, and H₂O+ as well as uniform SO₃ and CO₂ concentrations. As a result of their chemical similarity these apatite varieties are likely comparable to hydroxylapatites from mantle source affected by carbonatite metasomatism (Yaxley et al. 1991). An important consequence of fluid re-speciation substantially affected by nephelinite melt upon magmatic evolution is the change of the Cl/F ratio within the nephelinite dyke indicated by hydroxyl-chlorapatite xenocrysts (type 2b) as well as by the origin of hydroxyl-chlorapatite inclusions (type 3).

The relationships between mineralogy, major- and trace element chemistry and significant phosphorus enrichment in the olivine-poor nephelinite should be, therefore, dependent on the presence of newly-found upper mantle microxenoliths. The presence of metasomatized source region of upper mantle is particularly significant beneath the central part of the Bohemian Massif.

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