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ROCK-FORMING MINERALS OF ALKALINE VOLCANIC SERIES ASSOCIATED WITH THE CHEB-DOMAŽLICE GRABEN, WEST BOHEMIA

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ABSTRACT

The Middle to Late Miocene intraplate alkaline volcanism of W Bohemia is associated with the uplift of the NE flank of the Cheb-Domažlice Graben. Two coexisting cogenetic volcanic series have been recognised: (i) weakly alkaline series basanite – trachybasalt – (basaltic) trachyandesite – trachyte – rhyolite (15.9-11.4 Ma) and (ii) strongly alkaline series olivine nephelinite – tephrite (16.5-8.3 Ma). The chemistry of the minerals characteristically reflects the differentiation development of the above rock series. Early crystallization in the mafic rocks is manifested by olivine phenocrysts (Fo_{66-76}), melilite, Ti-magnetite and (Ti,Fe^{3+})-diopside to fassaite; in the intermediate rocks by diopside; and in the felsic rocks by (Mn,Ti)-magnetite, diopside, and high-temperature K-oligoclase (phenocryst cores). Continuing to late crystallisation in mafic to intermediate rocks is represented by kaersutite, nepheline (at T <700°C; also occurs with melilite in ijolite pegmatoidal segregations) and labradorite to andesine, with K-andesine to K-oligoclase rims in transitional rocks. In the felsic compositions, ongoing crystallisation is characterised by Mn-magnesioriebeckite, Mn-winchite and Mg-biotite; feldspars are prevalently anorthoclase (perthite), which occasionally mantles K-oligoclase and is succeeded by Na-sanidine (matrix or rare rims to anorthoclase phenocrysts). Feldspars and quartz in the matrix of the felsic rocks terminate crystallization. Late magmatic minerals are analcime, replacing plagioclase and nepheline, carbonates and barite in the mafic rocks. Mn-oxyhydroxide, nontronite, rare sulphur and organic matter reflect crystallization in the postmagmatic stage.

ABBREVIATIONS USED IN THE TEXT:

CDG – Cheb-Domažlice Graben
WAS – weakly alkaline series associated with the Cheb-Domažlice Graben
SAS – strongly alkaline series associated with the Cheb-Domažlice Graben

INTRODUCTION

The Cenozoic alkaline volcanism of the Bohemian Massif is an integral part of the Central European Volcanic Province, which extends from France to Germany, Czech Republic and Poland (Wimmenauer, 1974). It is a surface manifestation of a large, sheet-like region of up welling found in the upper mantle from the eastern Atlantic Ocean to central Europe and the western Mediterranean (sensu Hoernle et al., 1995).

Contrasting associations of weakly alkaline (silica undersaturated to oversaturated) and strongly alkaline (undersaturated) magmatic series are known from many continental intraplate volcanic provinces (Wilson et al., 1995). Alkaline magmas may follow simultaneously either a silica saturated to oversaturated differentiation trend (rhyolites, Q-trachytes), or an undersaturated one (phonolite), reflecting the individual differences in chemistry of the primary magma (Foland et al., 1993). However, assimilation-fractional crystallisation processes, centred in the lower-crust magma chamber, play the decisive role in the development of both series, but especially of WAS (Wilson et al., 1995). Similar alkaline rocks series are known from Siebengebirge (Vieten et al., 1988), Westerwald (Schreiber et al., 1999), Hocheifel (Huckenholz and Büchel, 1988) and in particular from Cantal, Massif Central (Downes, 1989; Wilson et al., 1995) within the Cenozoic European Volcanic Province. The Euganean Magmatic Complex in the hinterland of the Alpine Orogen also reveals geochemical similarities in particular in felsic members of the rock series (Milani et al., 1999).

GEOLOGICAL SETTING

Cenozoic volcanism in W Bohemia is associated with the uplifted northeastern flank of the young CDG (NNW-SSE striking, 150 km long and 5-10 km wide) formed by the Tepelská vrchovina Highland and Slavkovský les Mts. The ENE-WSW trending Ohře Graben occurring to the north is limited by the CDG. By convention (Wohnig, 1904), the Střela river valley defines the boundary between the volcanics of the Tepelská vrchovina Highland and those of the Doupovské hory Mts. in the Ohře Rift.

From the early beginning of the 20th century geologists were intrigued by W Bohemian rocks of exceptional petrographical composition ("andesitic character" of Wohnig ,1904), some of them within the Tertiary Volcanic Subprovince of the Bohemian Massif. Shrbený (1979) noted "silica higher-saturated" types. Subsequently, Ulrych et al. (1999) identified two contrasting rock groups, a weakly alkaline series (WAS) and a strongly alkaline series (SAS).

Tertiary volcanic rocks of both series are concentrated in the Teplá Crystalline Complex; the WAS is associated with the unit exclusively. They occur rarely also in the Mariánské Lázně Metabasite Complex (e.g., Podhorní vrch Hill near Mariánské Lázně) and the Slavkovský les Crystalline Units (e.g., Buková Hill near Horní Slavkov). Geochemical distribution of the young volcanics within the SE flank of the CDG lacks obvious zonation (Fig. 1). The undifferentiated products (e.g., olivine nephelinite to basanite of Podhorní vrch, Polom and Lysina Hills) are above all spatially associated with faults belonging to the Mariánské Lázně Fault Zone (Ulrych et al., 2000a). Nevertheless, the most primitive rocks of melilite-bearing olivine nephelinite composition are present only in the area of Český Chloumek (16.5 Ma - Wilson et al., 1994). These volcanic rocks can be associated with some younger NE-SW trending faults (Litoměřice Deep Fault Zone) that spatially coincide with the Variscan major thrust of the Mariánské Lázně Metabasite Complex over the Saxothuringian para-autochthonous domain (Kachlík, 1993). The melilite-bearing volcanics are commonly characteristic of the main fault zones limiting the Ohře Rift, in W Bohemia region mostly associated with the Krušné hory Fault Zone (Kopecký, 1978; Ulrych et al., 1999; Ulrych et al., in press a). However, rare older volcanic products (29.5 Ma) also occur in the area of the NE flank of the CDG (leucite basanite from Polikno – Ulrych et al. in press b).

The differentiated products of the WAS (concentrated in the Teplá, Toužim and Manětín areas) are generally characteristic of the outer parts of the CDG. The rare trachytic occurrences as Špičák, Stěnský vrch hills and "Mordloch" have been described by Wohnig (1904), Berounský vrch Hill and reclassification of Stěnský vrch Hill trachyte as rhyolite by Pivec et al. (in press), Dobrá Voda and Kojšovice localities (trachyte accompanied by rhyolite) by Vrána (2000).

Špičák Hill is a trachytic extrusive bulbous dome. The nearby Stěnský vrch Hill can be interpreted as a laccolith with a gneissic roof

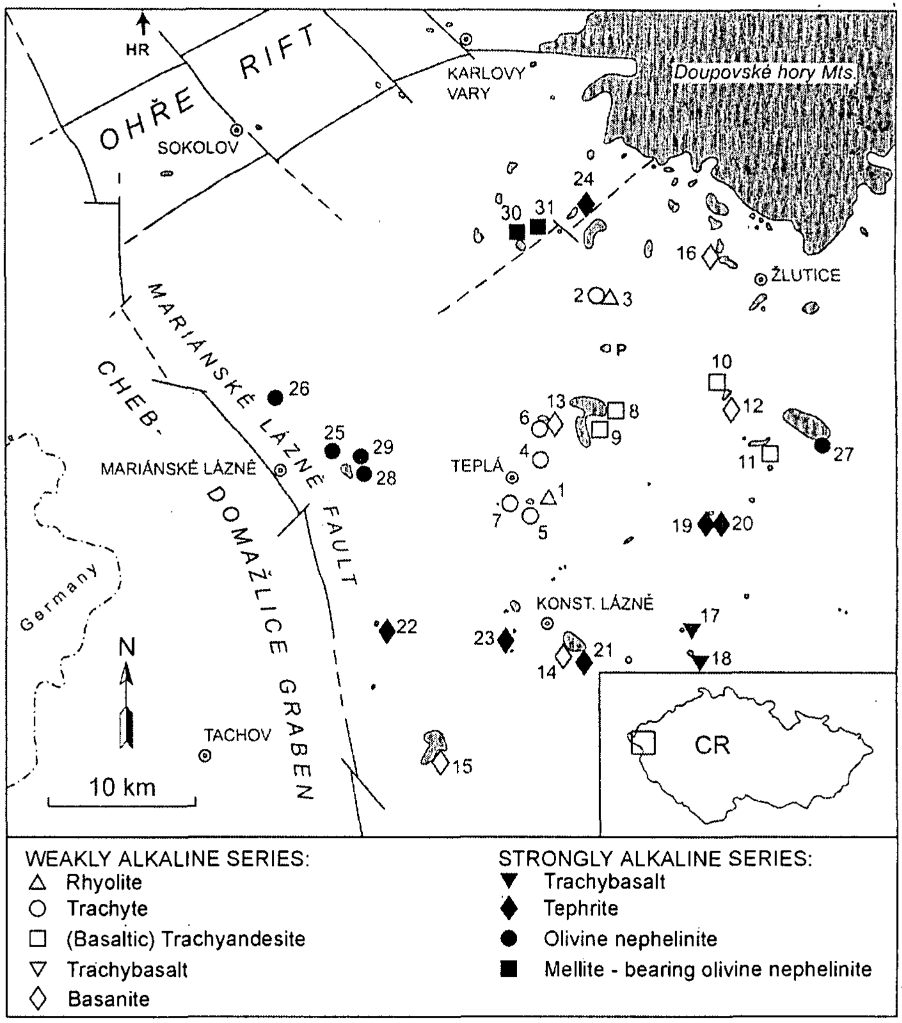

Fig. 1. Geological sketch of the NE flank of the Cheb-Domažlice Graben with marked out occurrences of the Tertiary volcanics and sampling

preserved (Ulrych et al., 1991). Basaltic trachyandesites and trachybasalts form variable groups of flows (typically developed at Doubravický vrch Hill). Zbraslavský vrch Hill consists of two lava flows and a feeding channel filled by agglutinate, giving an asymmetric "flag-form" volcanic structure (Fediuk, 1995). A horseshoe-shaped group of hills is formed by Třebouňský vrch Hill, which represents a relict of feeder channel filling, and the Branišovský vrch Hill lava flow. The Okrouhlé Hradiště Hill is a relict of a large flow(s). Vlčí hora Hill is a large composite volcano (Ulrych, 1986; Ulrych et al., 2000c).

Volcanic rocks of the SAS are more abundant in comparison to the WAS forming mostly smaller intrusions such as stocks and diatremes (for comparative overview see Fig. 1). A major locality is the large polyphase volcano Podhorní vrch (Cajz, 1992; Ulrych et al., 2000c). The melilite-bearing olivine nephelinites from Chloumecký kopec Hill are relicts of a volcanic edifice with preserved rim of Upper Eocene Staré Sedlo Formation. Chlumská hora Hill is the largest relict of an olivine nephelinite flow (4 by 1.2 km) occurring together with other characteristic "table mountains", e.g., Vladař Hill south of the formal boundary (see above) of the Doupovské hory Mts. Pekelský vrch Hill Nečtiny is a relict of a composite volcano with products of trachybasalt-tephrite composition.

SAMPLING AND ANALYTICAL METHODS

Thirty one representative rock samples were used for the geochemical (Ulrych et al., in press b) and the present mineralogical study. The sampling covers the elevated block of the CDG (Fig. 1). Sampling sites are presented together with their geological characteristics, petrography and modal mineralogy of the rocks in

Table 1. Rock samples were prepared for the study by use of common methods described, e.g. in Ulrych et al. 2000c and Ulrych et al. in press b).

K-Ar isotope measurements were taken in the Institute of Nuclear Research of the Hungarian AS, Debrecen. An Ar extraction and its measurement were made on the mass spectrometer by the method of isotope dilution ^{38}Ar according to procedure described by Balogh (1985) and Odin et al. (1982).

Rock-forming minerals were analysed in the Institute of Geology, AS CR, Prague with a JXA 50A electron microprobe with spectrometer EDAX PV 9400, using an accelerating voltage of 20 kV, beam current of $1.5\ 10^{-9}$ A, beam diameter of 2 µm and counting time of 120 s per analysis (analyst A. Langrová). Standards employed are natural mineral (olivine, kaersutite, jadeite, diopside, leucite, apatite, barite) and synthetic phases (SiO_2, TiO_2, Fe_2O_3, Cr_2O_3, MgO) and the ZAF correction method was used.

AGE RELATIONS OF VOLCANIC SERIES

The new K-Ar data and a review of the published data (Wilson et al., 1994; Ulrych et al., in press a, b and Pivec et al.

Table 1. Geological and petrological characteristic of the representative rocks of the weakly and strongly alkaline series

Locality	Sample No.	Root name in TAS* classific.	Sub-root name	Normative characteristic	Mineral composition	Country rock (xenoliths)	Structure texture	Volcanic form
WEAKLY ALKALINE SERIES								
Stěnský vrch Hill	202	rhyolite		Q-, Ns-normative	anorthoclase quartz magnesioriebeckite	gneiss	holocrystalline porphyritic with trachytic matrix	dome (laccolith?)
Špičák Hill	180	trachyte	high K-type	Q-normative	anorthoclase, sanidine, oligoclase, quartz, winschite, biotite, Ti-magnetite, titanite, apatite, Mn-oxyhydroxide, sulphur	gneiss	holocrystalline porphyritic with trachytic matrix	dome
Prachometský vrch Hill	186	trachyte	high K-type	Q-normative	sanidine, anorthoclase diopside-hedenbergite-augite series, Ti-magnetite, titanite, apatite	amphibolite	holocrystalline fine-porphyritic with trachytic matrix	dome
Třebouňský vrch Hill	251	trachy-andesite	latite	Ne-, Ol-normative	andesine, anorthoclase diopside-augite series kaersutite, nepheline, Ti-magnetite, titanite, apatite	mica schist	holocrystalline porphyritic with trachytic matrix	lava flow
Doubravický vrch Hill	256	basaltic trachy-andesite	sho-shonite	Ne-, Ol-normative	bytownite, anorthoclase diopside-augite series nepheline, Ti-magnetite, titanite, apatite, zeolite, carbonate, barite	PermoCarboniferous sediments	holocrystalline pilotaxitic, vesicular	lava flow
Zbraslavský vrch Hill	255	trachybasalt	hawaiite	Ne-, Ol-normative	andesine, sanidine, kaersutite, diopside, Ti-magnetite, titanite, apatite, carbonate	gneiss and PermoCarboniferous sediments	holocrystalline fine porphyritic with pilotaxitic matrix "sonnenbrand"	lava flow
Prachomety II	Z-13	basanite		Ne-, (Ol-) normative	ferrisalite-ferrifassaite, labradorite, (andesine), K-oligoclase, serp.olivine, Ti-magnetite, apatite, (analcime)	mica schist	porphyritic with holocrystalline matrix	intrusion (partly brecciated)
Vlčí hora Hill,	P-1	basanite - analcimized		Ne-, Ol-normative	ferrisalite-ferrifassaite, kaersutite, Ti-magnetite,apatite	phyllite to mica schist	porphyritic in holocrystalline matrix, magacrysts: kaersutite, diopside, olivine	complex volcano

Table 1. continued

Locality	Sample No.	Root name in TAS* classific.	Sub-root name	Normative characteristic	Mineral composition	Country rock (xenoliths)	Structure texture	Volcanic form
STRONGLY ALKALINE SERIES								
Vinice Hill	Z-22	trachybasalt	hawaiite	Ne-, Ol-normative	kaersutite, ferrisalite, phenocrysts, labradorite-andesine, K-oligoclasse, ferrisalite in matrix	phyllite to mica schist	holocrystalline fine porphyritic	intrusion
Pekelský vrch Hill	Z-24	tephriete		Ne-, (Ol-) normative	ferrisalite-ferrifassaite, phenocrysts, labradorite, K-andesine Ti-magnetite, apatite in matrix	mica schist	fine porphyritic holocrystalline fluidal matrix	small volcano
Okrouhlé Hradiště Hill	Z-19	tephrite		Ne-, Ol-normative	(olivine), ferrifassaite, labradorite, analcime,	phyllite to mica schist, xenolite: pyroxenite and dunite with glassy rims	holocrystalline fine-porphyritic	differentiated lava flow(s)
Polom in Mariánské Lázně	Z-15	olivine (contam.)		Ne-, Ol-normative	olivine, ferrifassaite, labradorite, serp. olivine, Ti-magnetite, apatite	granite xenoliths: granite with glassy rims, pyroxenite	porphyritic with holocrystalline matrix	intrusion (partly brecciated)
Lysina Hill	Z-14	olivine nephelinite(contam.)		Ne-, Ol-normative	olivine, ferrifassaite, nepheline, Ti-magnetite,apatite	granite xenoliths: granite	porphyritic with holocrystalline matrix	intrusion
Český Chloumek	Z-16	melilite-bearing olivine nephelinite		Ne-, Ol-normative (melilite)	olivine, ferrifassaite, nepheline, melilite, Ti-magnetite	Miocene sediments and granite, xenoliths: wehrlite?	holocrystalline microporphyritic	dyke-like intrusion

in press) are presented in Table 2A, B together with chemical analyses of the rocks. Based upon this data and the distribution scheme of Cenozoic volcanism in the Bohemian Massif (Ulrych et al., 1999), two coexisting volcanic series of Middle to Late Miocene age associated with the NE flank of the CDG were recognized (Fig. 2):

(i) Weakly alkaline series - WAS (15.9-11.4 Ma), cf. Pivec et al. (in press);

(ii) Strongly alkaline series - SAS (16.5-8.3 Ma) developed to a limited degree only.

The ultimate development of the volcanism of the NE flank of the CDG was at about 12 Ma. However, the onset of the volcanism (16-17 Ma) is characteristic of the more distal regions of the CDG. This activity of the CDG NE flank provides a link between the Oligocene-Miocene strongly alkaline series of the Western Ohře Rift (24-16 Ma, average 22 Ma) (Ulrych et al., in press a) and the Pliocene to Quaternary (0.43-0.11 Ma) primitive alkaline volcanics occurring at the intersection of the OR and CDG structures in the vicinity of Cheb (Wilson et al., 1994; Wagner et al., 1998). From K-Ar data of Wilson et al. (1994) and Ulrych et al. (in press a) on basanitic rocks (Hory in Karlovy Vary -15.5 Ma and Horní Rotava in the Krušné hory Mts. - 14.8 Ma) it follows that the Middle Miocene volcanism in W Bohemia was not restricted to the CDG area only.

The age-related Group of Late Miocene Intrusives (13-9 Ma; sills and dykes) represents the final volcanic episode of

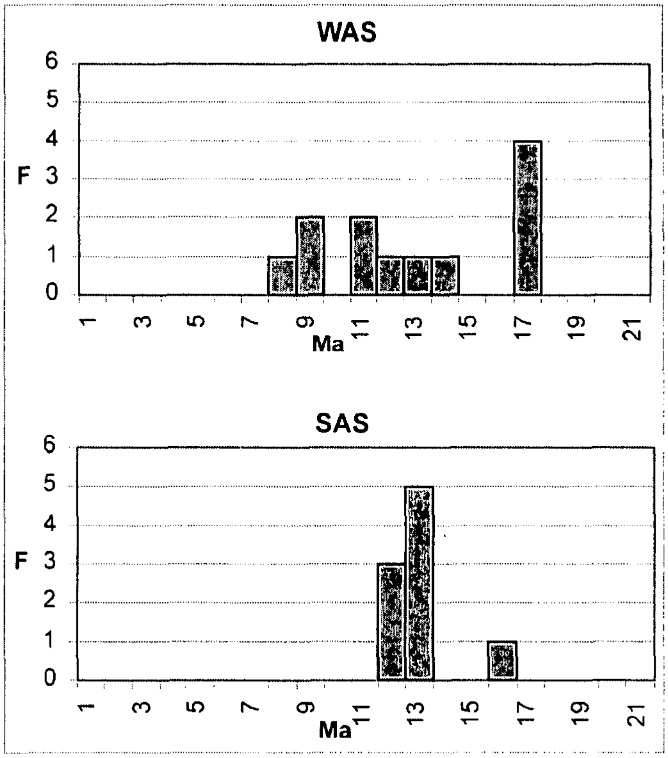

Fig. 2. K-Ar age distribution of the rocks of the weakly and strongly alkaline series associated with the Cheb-Domažlice Graben. For data see Table 2a, b. Vertical axis – frequency of K-Ar experimental data

the České středohoří Mts. Area. It was described from a block of coal-bearing basinal Ohře Rift sediments in the Bílina-Most area (Cajz et al., 1999). Products of a similar final episode (13 Ma) of the volcanic cycle are known from many areas of the CEVP such as Heldburger Gangschar, Rhön, Hessian Basin, Vogelsberg and Westerwald (11-6 Ma, Lippolt 1983).

The recurrence of volcanism and changes in its chemical characteristics coincide with tectonism (Downes, 1996), causing principal changes in tectonic settings and character of magmas from calc-alkaline to alkaline in the Carpathians. This change reflects Late Miocene E-W compression in the Alpine Orogeny linked to entry of continental crust into the subduction zone. Volcanism of the CDG NE flank thus parallels the development of the graben structure, as revealed by the minimal Middle Miocene (?) relict of a sedimentary fill in the Lažany-Vlčí hora Hill area (Zartner, 1939) preserved below the underlying basanite flow (11.7 Ma – Wilson et al., 1994).

Table 2A. Chemical analyses of rocks of the weakly alkaline series

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	202	ZC-30B	ZC-30A	ZC-20A	180	186	203	251	251a	255a	256	255	Z-13	P-3	P-1	P-19
Rock type	RY	RY	TR	TR	TR	TR	TR	TA	TA	TA	BTA	TB	BA	BA	BA	BA
SiO_2(wt.%)	70,18	74,45	65,66	65,39	65,77	62,91	62,90	53,46	55,17	55,57	51,83	45,24	42,24	42,91	43,81	41,43
TiO_2	0,03	0,08	0,24	0,40	0,31	0,55	0,30	1,67	1,41	1,76	1,68	2,68	2,46	3,37	3,11	3,90
Al_2O_3	15,12	13,76	17,98	17,82	17,57	18,20	19,14	18,22	17,70	17,75	18,83	16,33	12,64	11,99	12,49	11,27
Fe_2O_3	1,23	1,29	1,51	1,43	1,93	1,08	2,99	4,64	3,28	5,10	5,29	6,21	5,14	5,12	4,59	5,02
FeO	0,08	0,05	0,07	0,13	0,08	0,14	0,10	1,92	3,00	1,56	2,18	4,50	5,99	5,88	6,56	7,21
MnO	0,04	0,02	0,05	0,06	0,24	0,12	0,10	0,18	0,19	0,17	0,22	0,21	0,22	0,18	0,20	0,22
MgO	0,05	0,16	0,06	0,10	0,14	0,06	0,12	2,36	1,82	1,63	2,02	4,22	11,19	11,11	9,60	9,25
CaO	0,41	0,20	0,80	1,25	0,76	2,13	1,03	5,63	5,60	6,09	6,81	9,73	11,54	13,97	13,30	14,61
Na_2O	6,60	3,06	7,39	6,79	6,27	7,40	6,49	5,15	5,02	4,98	4,85	3,79	3,85	2,39	3,16	2,98
K_2O	4,48	4,91	5,92	6,00	5,56	4,91	5,55	3,74	4,09	3,50	3,02	1,47	1,41	1,70	1,77	1,74
P_2O_5	0,03	0,09	0,03	0,06	0,07	0,10	0,04	0,55	0,43	0,50	0,62	0,79	0,82	0,57	0,69	0,75
H_2O^+	1,17	1,20	0,44	0,30	0,42	1,24	0,67	1,28	1,26	0,86	1,11	2,01	2,02	0,59	0,29	1,32
H_2O^-	0,04	0,22	0,12	0,09	0,32	0,34	0,63	0,82	0,40	0,28	0,96	1,43	0,52	0,21	0,27	0,22
F	0,03	0,06	0,04	0,06	0,06	0,03	0,04	0,11	0,07	0,02	0,09	0,12				
Cl	0,01				0,02	0,02		0,11			0,13	0,01				
CO_2	0,19	0,03	<0.01	0,05	0,40	0,44	<0.10	0,05	0,01	0,02	0,04	0,91	0,03	0,13	0,07	0,20
	99,69	99,58	100,31	99,93	99,92	99,67	100,10	99,89	99,45	99,79	99,68	99,65	100,07	100,12	99,91	100,12
O=2F	-0,01	-0,03	-0,02	-0,03	-0,03	-0,01	-0,02	-0,05	-0,03	-0,01	-0,04	-0,05				
O=2Cl								-0,02			-0,03	-0,05				
Total	99,67	99,55	100,29	99,90	99,89	99,66	100,08	99,82	99,42	99,78	99,61	99,55	100,07	100,12	99,91	100,12
Rb (ppm)	436	282	153	213	191	133	162	110	90	102	83	61	49	39	40	39
Cs	6,5	6,2	2,8	2,6	2,2	1,5	1,40	1,9	1,3	0,9	0,87	0,78	0,94	0,57		
Sr	126				128	1270	480	1338	1189	1040	1287	1069	1002	728	877	941
Ba	420	215	143	564	434	1546	1242	1455	1290	1451	1258	906	828	487	580	788
Ga	34				35	28	25	18	17	14	16	14				
As	6				6	11		4	5	4	3	2	3,1			
Sc	0,3	5,6	1,6	1,2	1,4	6,7	0,9	6,3	6,9	7,9	6,2	16	23	34	17	33
Y	35				35	36	25	40	34	34	39	31	21	22	26	21
La	84	10	156	101	132	171	131	144	160	140	121	95	114	121	137	113
Ce	115	21	216	155	220	152	186	251	241	218	228	176	177	180	211	171
Nd	16,0	10,0	40,0	37,0	71,0	14,0	54,0	102,0	99,0	100,8	106,0	87,0	78,3	79,0	84,0	75,1
Sm	2,8	2,2	2,9	4,3	9,2	4,4	5,9	14,3	14,7	15,3	15,6	13,7	11,4	13,3	16,9	13,9
Eu	0,3	0,2	1,0	1,2	1,9	1,5	1,6	4,2	3,8	3,6	4,6	4,2	3,4	3,4	4,4	3,7
Gd	2,7				6,2	4,1	5,0	12,3	10,2	9,4	12,5	12,1	13,8	10,9	12,1	11,6
Tb	0,47	0,40	0,50	0,50	0,95	0,71	0,59	0,85	1,43	1,36	1,60	1,40	1,06	1,44	1,58	1,22
Yb	3,7	3,6	3,3	2,8	3,7	3,1	2,8	2,9	3,9	3,9	3,4	2,6	2,19	3,01	4,50	3,00
Lu	0,51	0,43	0,48	0,41	0,58	0,45	0,47	0,51	0,38	0,44	0,58	0,45	0,33	0,33	0,41	0,38
Th	72,3	9,0	33,0	33,0	26,3	21,4	27,6	15,6	14,1	15,9	14,0	10,2	13,2	10,0	12,0	13,0
U	5,4	7,0	7,1	6,3	7,8	5,1	3,4	4,0	4,5	6,6	3,2	2,7	3,2	2,1	1,9	1,0
Zr	380				517	661	626	460	505	363	512	322	252	243	288	299
Hf	14,5	2,9	11,7	13,2	12,8	14,6	14,9	12,4	11,8	10,5	11,5	9,2	6,8	9,9	9,4	8,9
V							15						198	301	310	330
Nb	139				160	133	126	122	154	123	149	116	89	70	85	117
Ta	8,7				10,2	9,1	8,8	10,5	10,1	7,7	9,2	6,8	5,4	6,1	7,1	7,6
Cr	7				12	10	4	11	26	21	16	15	219	175	230	258
Co	0,5	3,7	0,5	1,1	0,6	1,2	1,0	5,7	11	14	3,6	5,0	51	54	45	41
Ni	5				5	5	5	6	10	17	7	13	237	157	120	99
Cu	5				5	5	0,2	37	17	29	11	21		155	87	150
Zn	115	56	72	46	63	200	98	137	95	143	195	129	128	70	90	95

Table 2A. continued

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	202	ZC-30B	ZC-30A	ZC-20A	180	186	203	251	251a	255a	256	255	Z-13	P-3	P-1	P-19
Rock type	RY	RY	TR	TR	TR	TR	TR	TA	TA	TA	BTA	TB	BA	BA	BA	BA
K/Rb	85,28	144,51	321,15	233,80	241,61	306,41	284,35	282,20	377,19	284,80	302,00	200,02	238,84	361,79	367,28	370,31
Rb/Sr	3,46				1,49	0,10	0,34	0,08	0,08	0,10	0,06	0,06	0,05	0,05	0,05	0,04
Sr/Ba	0,30				0,29	0,82	0,39	0,92	0,92	0,72	1,02	1,18	1,21	1,49	1,51	1,19
Zr/Nb	2,73				3,23	4,97	4,97	3,77	3,28	2,95	3,44	2,78	2,83	3,47	3,39	2,56
Y/Nb	0,25				0,22	0,27	0,20	0,33	0,22	0,28	0,26	0,27	0,24	0,31	0,31	0,18
La/Nb	0,60				0,83	1,29	1,04	1,18	1,04	1,14	0,81	0,82	1,29	1,73	1,62	0,96
Th/U	13,40	1,29	4,65	5,24	3,37	4,20	8,12	3,90	3,13	2,41	4,38	3,78	4,13	4,76	6,32	13,00
Zr/Hf	26,20				40,39	45,27	42,01	37,10	42,80	34,57	44,52	35,00	37,06	24,55	30,64	33,60
Nb/Ta	15,98				15,69	14,62	14,32	11,62	15,25	15,97	16,20	17,06	16,48	11,48	11,97	15,39
SREE	225,48	47,80	420,21	302,16	445,53	351,26	587,36	532,06	534,51	492,71	493,28	392,45	402,27	412,49	472,36	392,65
$(La/Yb)_N$	16,28	1,99	33,91	25,87	25,59	39,57	33,56	35,62	29,45	25,67	25,53	26,21	37,47	28,86	21,89	26,97
Eu/Eu*	0,33	0,41	1,87	1,41	0,73	1,06	0,88	0,94	0,90	0,85	0,97	0,98	0,83	0,84	0,89	0,85
#Mg	8,12	21,70	8,09	12,89	13,91	10,17	8,27	44,81	39,07	35,73	37,90	46,73	68,85	68,96	65,32	62,32
Gd/Gd*	0,13	0,00	0,00	0,00	0,16	0,15	0,15	0,28	0,24	0,24	0,31	0,39	0,44	0,34	0,32	0,38
Age (Ma)	12,4				12,5	11,9		12,1		11,4	12,9		12,8		11.7*	15.9*

1-202 rhyolite, Stěnský vrch Hill near Teplá, AQ
2-ZC30B rhyolite, Kojšovice (Vrána 2000), B
3-ZC30A trachyte, Kojšovice (Vrána 2000), B
4-ZC20A trachyte, Dobrá Voda (Vrána 2000), B
5-180 trachyte, Špičák Hill near Teplá, Q
6-186 trachyte, Prachometský v. Hill near Teplá, AQ
7-203 trachyte, Berounský v. Hill near Heřmanov, B
8-251 trachyandesite, Třebouňský v. Hill near Teplá, AQ
9-251a trachyandesite, Branišovský v. Hill near Teplá Shrbený 1979), AQ
10-255a trachyandesite, Zbraslavský v. Hill near Manětín (Shrbený 1979), AQ
11-256 basaltic trachyandesite, Doubravický v. Hill near Manětín, AQ
12-255 trachybasalt?, Zbraslavský vrch Hill near Manětín, AQ
13-Z13 basanite, Prachomety II near Teplá, AQ
14-P3 basanite, Okrouhlé Hradiště Hill near Konstantinovy Lázně, AQ
15-P1 basanite, Vlčí hora Hill near Černošín, AQ
16-P19 basanite, Holý v. Hill near Ratiboř, Q

Explanations: Q - active quarry, AQ - abandoned quarry, NO - natural outcrop, B - boulders

Table 2B. Chemical analyses of rocks of the strongly alkaline series

Sample No.	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Z-20	Z-22	Z-23	Z-24	Z-19	P-2	P-4	Z-26	Z-15	Z-14	226	M-1	M-2	P-16	Z-16
Rock type	TB	TB	TB	TE	TE	TE	TE	TE	ON	ON	ON	ON	ON	MON	MON
SiO_2 (wt.%)	47,32	45,66	45,89	44,91	45,55	40,27	41,59	44,98	43,67	43,98	40,99	39,58	40,60	40,90	39,19
TiO_2	2,55	2,89	2,86	2,85	3,07	3,91	3,66	1,99	3,51	2,10	4,18	1,98	1,95	2,20	2,70
Al_2O_3	16,14	15,80	15,28	15,83	15,20	13,65	14,79	12,04	13,87	12,21	13,76	10,20	10,87	11,60	11,39
Fe_2O_3	4,80	6,12	4,77	4,99	4,93	4,80	5,17	2,48	5,62	4,18	7,51	6,39	4,34	4,08	3,99
FeO	5,65	5,25	6,45	6,45	6,14	8,12	8,93	8,05	5,40	6,33	7,56	5,85	6,83	7,10	7,99
MnO	0,22	0,23	0,23	0,23	0,21	0,24	0,25	0,17	0,18	0,17	0,23	0,22	0,21	0,19	0,20
MgO	4,00	4,34	5,41	5,41	6,11	7,90	6,25	12,46	6,98	13,02	6,42	15,02	14,52	12,50	12,49
CaO	9,81	9,93	10,73	10,73	11,05	12,39	12,02	11,22	11,80	11,33	11,24	12,45	12,13	13,59	15,81
Na_2O	4,24	4,23	3,59	3,59	3,65	3,49	3,97	2,62	3,69	3,33	3,75	3,93	3,64	2,74	3,00
K_2O	1,90	1,13	2,21	2,21	2,19	2,22	0,87	1,31	0,72	0,94	1,89	1,33	0,97	1,10	1,11
P_2O_5	1,00	1,08	0,94	0,94	0,74	0,92	0,90	0,60	0,51	0,52	0,94	0,97	0,88	0,82	0,88
H_2O^+	2,06	1,73	1,01	1,01	0,95	0,50	1,09	1,69	2,23	1,69	0,80	1,23	1,78	2,64	1,12
H_2O^-	0,21	0,61	0,34	0,34	0,35	0,02	0,20	0,14	0,79	0,26	0,20	0,82	0,51	0,33	0,31
CO_2	0,07	0,02	0,04	0,04	0,07	0,49	0,37	0,07	0,02	0,13	0,03	0,08	0,28	0,07	0,03
Total	99,97	99,02	99,75	99,53	100,21	98,92	100,06	99,82	98,99	100,19	99,50	100,05	99,51	99,86	100,21
Rb	52	53	50	46	51	55	65	32	70	52	47	31	27	52	37
Cs	0,79	0,86	0,73	1,10	0,71	0,80	0,41	0,5	1,70	1,90	0,57	0,42	0,44	3,30	3,30
Sr	1046	979	858	967	829	1088	1190	594	895	600	1254	988	836	816	1151
Ba	814	787	718	644	642	691	731	501	616	611	985	849	627	964	1005
Ga												11	11		
As	1,9	1,7	2	1,6	1,4			1,8	2,3	1,5					
Sc	14	16	19,7	20	25	22	16	26,4		28	25	24	24	28	27
Y	31	29	22	20	21	31	30	17	21	16	32	23	20	17	25
La	106.7	106,1	84,5	83,3	81,9	99,2	118,9	43,6	70,4	52,9	110,0	99,4	83,1	76,9	89,7
Ce	185	182	144,0	146,0	142,9	138,9	166,2	71,8	122,4	85,6	181,1	142,0	126,0	122,4	137,1
Nd	92,0	89,1	70,3	72,1	70,0	66,0	73,2	37,1	64,7	43,7	73,2	55,7	53,1	61,9	66,0
Sm	14,5	14,7	11,9	11,7	11,5	12,5	14,1	6,94	10,4	7,48	16	9,1	9,1	10,3	12,8
Eu	4,1	4,2	3,46	3,52	3,33	3,31	3,57	2,26	3,08	2,35	3,62	2,73	2,52	3,18	2,64
Gd	13,1	13,3	11,8	11,8	11,6	10,7	11,0	7,8	9,6	8,9	8,7	8,7	6,7	11,2	10,1
Tb	1,45	1,45	1,17	1,16	1,11	1,19	1,19	0,89	1,03	0,88	1,52	1,03	0,92	1,07	1,09
Yb	3,3	3,5	2,49	2,49	2,42	2,66	2,91	1,50	1,87	1,68	2,48	1,66	1,66	1,71	1,79
Lu	0,49	0,49	0,36	0,34	0,34	0,28	0,33	0,25	0,32	0,24	0,31	0,25	0,27	0,22	0,18

Table 2B. continued

Sample No.	17 Z-20	18 Z-22	19 Z-23	20 Z-24	21 Z-19	22 P-2	23 P-4	24 Z-26	25 Z-15	26 Z-14	27 226	28 M-1	29 M-2	30 P-16	31 Z-16
Rock type	TB	TB	TB	TE	TE	TE	TE	TE	ON	ON	ON	ON	ON	MON	MON
Th	9,7	9,5	9,4	8,4	8,6	16,0	9,0	5,0	6,5	6,4	8,1	10,5	9,3	9,3	14,0
U	3,1	2,7	2,5	2,4	2,4	1,0	1,0	0,9	1,7	1,6	1,9	5,2	4,8	1,9	1,9
Zr	426	403	285	280	279	361	366	138	230	135	243	177	159	283	231
Hf	10,9	10,8	8,2	8,2	8	8,1	8,5	4,1	7,1	4,1	8,9	3,9	3,8	5,4	7,0
V	166	202	212	210	240	321	389	158	278	179	288	133	150	192	233
Nb	89	88	74	73	71	122	112	43	55	48	104	85	76	102	144
Ta	6,0	6,0	5,6	5,7	5,4	7,0	6,4	2,8	4,1	3,5	6,1	5,2	4,6	6,5	6,1
Cr	22	27	45	48	62	44	33	422	67	370	354	410	445	324	271
Co	16	21	24	25	30	41	40	56,0	38	55	42	52	55	49	56
Ni	11	13	17	17	30	57	37	162	45	249	207	236	271	173	222
Cu						81	66				73	83	67		77
Zn	143	150	139	160	115	117	112	103	94	101	116	69	93	108	115
K/Rb	303,27	176,96	366,86	398,76	356,41	335,02	111,09	339,78	85,37	150,04	333,77	356,10	298,19	175,58	249,00
Rb/Sr	0,05	0,05	0,06	0,05	0,06	0,05	0,05	0,05	0,08	0,09	0,04	0,03	0,03	0,06	0,03
Sr/Ba	1,29	1,24	1,19	1,50	1,29	1,57	1,63	1,19	1,45	0,98	1,27	1,16	1,33	0,85	1,15
Zr/Nb	4,79	4,58	3,85	3,84	3,93	2,96	3,27	3,21	4,18	2,81	2,34	2,08	2,09	2,77	1,60
Y/Nb	0,35	0,33	0,30	0,27	0,30	0,25	0,27	0,28	0,38	0,33	0,31	0,27	0,26	0,17	0,17
La/Nb	1,20	1,21	366,86	1,14	1,15	0,81	1,06	1,01	1,28	1,10	1,06	1,17	1,09	0,75	0,62
Th/U	3,13	3,52	0,06	3,50	3,58	16,00	9,00	5,56	3,82	4,00	4,26	2,02	1,94	4,89	7,37
Zr/Hf	39,08	37,31	34,76	34,15	34,88	44,57	43,06	33,66	32,39	32,93	27,30	45,38	41,84	52,41	33,00
Nb/Ta	29,67	29,33	19,47	26,07	26,30	17,43	17,50	30,71	26,19	28,24	17,05	16,35	16,52	31,88	23,61
SREE	420,62	414,38	329,98	332,41	325,10	334,74	391,40	172,13	283,79	203,68	396,95	320,56	283,39	288,88	321,40
$(La/Yb)_N$	22,98	22,06	24,34	24,00	24,28	26,75	29,31	20,85	27,00	22,59	31,82	42,95	35,91	32,26	35,95
Eu/Eu*	0,88	0,90	0,88	0,91	0,87	0,85	0,84	0,94	0,93	0,88	0,85	0,93	0,94	0,90	0,69
#Mg	45,69	45,83	34,76	50,91	54,78	57,11	49,11	71,76	58,33	73,01	48,46	73,08	73,93	70,88	69,34
Gd/Gd*	0,40	0,41	0,46	0,45	0,46	0,43	0,37	0,60	0,44	0,58	0,27	0,35	0,30	0,52	0,42
Age (Ma)	10,4	13,5	13,0	10,5	9.0* 6,5	11.8*	8.3*	16.5*		16,2			12.4* 17,0	16.5*	

17-Z20 trachybasalt, Skupečský v. Hill near Konstantinovy Lázně, AQ
18-Z22 trachybasalt, Vinice Hill near Konstantinovy Lázně, AQ
19-Z23 trachybasalt, Pekelský v. Hill near Nečtiny, Q
20-Z24 tephrite, Pekelský v. Hill near Nečtiny, Q
21-Z19 tephrite, Okrouhlé Hradiště Hill near Konstantinovy Lázně, AQ
22-P2 tephrite, Homole Hill near Planá, AQ
23-P4 tephrite, Krasíkov Hill near Konstantinovy Lázně, NO
24-Z26 olivine nephelinite (crystalline rocks and magnetite xenoliths), Číhaná AQ
25-Z15 olivine nephelinite (granite xenoliths), Polom in Mariánské Lázně, AQ
26-Z14 olivine nephelinite (granite xenoliths), Lysina Hill near Kynžvart, NO
27-226 olivine nephelinite, Chlumská hora Hill near Manětín (Shrbený 1979), AQ
28-M1 olivine nephelinite (massive), Podhorní v. Hill near Mariánské Lázně, NO
29-M2 olivine nephelinite (brecciated), Podhorní vrch Hill near Mariánské Lázně, AQ
30-P16 melilite-bearing olivine nephelinite, Chloumecký kopec Hill near Č. Chloumek, NO
31-Z16 melilite-bearing olivine nephelinite, Český Chloumek q, AQ

Ages designated by asterisk (Wilson et al. 1994) other (K. Balogh and E. Árva-Sós, Debrecen).

PETROGRAPHY

A survey of the principal rock types, localities, their geological and petrographical characteristics, main modal mineralogy and geochemistry are shown in Table 1. For more detailed petrographic and geochemical characteristic of the rocks see Shrbený (1979), Ulrych et al. (2000c, in press b) and Pivec et al. (in press).

Rock-forming minerals

Quartz occurs as interstitial grains in the matrix (<0.4 mm in size) and as prismatic euhedral crystals (up to 5 mm in size) in fissures in rhyolite and trachyte from Špičák Hill. In trachyte it occurs in paragenesis with Mn-oxyhydroxide coatings and with an organic matter of white colour. Wohnig (1904) also described quartz in vesicles of trachyte from Prachometský vrch Hill.

Feldspars are broadly distributed in the felsic rocks as phenocrysts and matrix minerals. They commonly reveal characteristic ternary composition due to a higher content (>5 mol.%) of the third component (sensu Barth, 1969; Table 3; Fig. 3).

Alkali feldspars dominate in rhyolite and trachytes, reaching 80-90 vol.%. Where anorthoclase is the sole feldspar, as in the rhyolite of the Stěnský vrch Hill, it forms phenocrysts (up to 8 mm). Zoned hypautomorphic phenocrysts (up to 12 mm) of alkali feldspar occur in trachyte from Špičák and Prachometský vrch hills. The phenocrysts of trachyte from Špičák Hill (antiperthites or perthites) are – in optimum examples – formed by (i) a high-temperature K-oligoclase core ($Ab_{70-75}An_{16-21}Or_{09-11}$) or its diffuse relicts of Ca-anorthoclase composition ($Ab_{60}An_{16}Or_{24}$), (ii) ubiquitously mantled by anorthoclase with perthitic texture ($Or_{31-43}Ab_{47-63}An_{05-11}$), and with (iii) rare Na-sanidine rims similar in composition to the matrix (K>Na)-phase. The disordered sanidine structure was checked using optical method. Matrix feldspar is Na-sanidine

($Or_{59}Ab_{40}An_{01}$) and K-oligoclase ($Or_{07}Ab_{80}An_{13}$) compositions. The sanidine is in composition identical with the feldspar of trachyte from Drachenfels ($Or_{62}Ab_{36}An_{02}$), cf. Vieten et al. (1988).

Anorthoclase (Table 3, No. Z-13) in basanite, (No. 256/28) in basaltic trachyandesite, (No. 251/20) in trachyandesite, or sanidine (255/40) in trachybasalt are probably of xenocrystic origin and may indicate some magma mixing between mafic and felsic compositions. Sanidine in trachybasalt has appreciable BaO contents (max. 3.75 wt.%). Wilson et al. (1995) reported higher BaO contents (about 1 wt.%) in K-feldspar of the trachytes in Cantal. Rare anorthoclase laths (Or_{20-22}) occur in the matrix of intermediate and basic rocks.

The presence of ternary feldspars with anhydrous ferromagnesian minerals in rhyolites and Q-normative trachytes indicate high temperatures of origin (Nekvasil, 1992). As recognised by Carmichael (1963) and Nekvasil (1990) the most common reaction in these rock types would be the crystallisation of alkali feldspars through the reaction of older plagioclases with melt. This explains the presence of partially resorbed cores of high-temperature ternary plagioclases and/or ternary alkali feldspars (generally

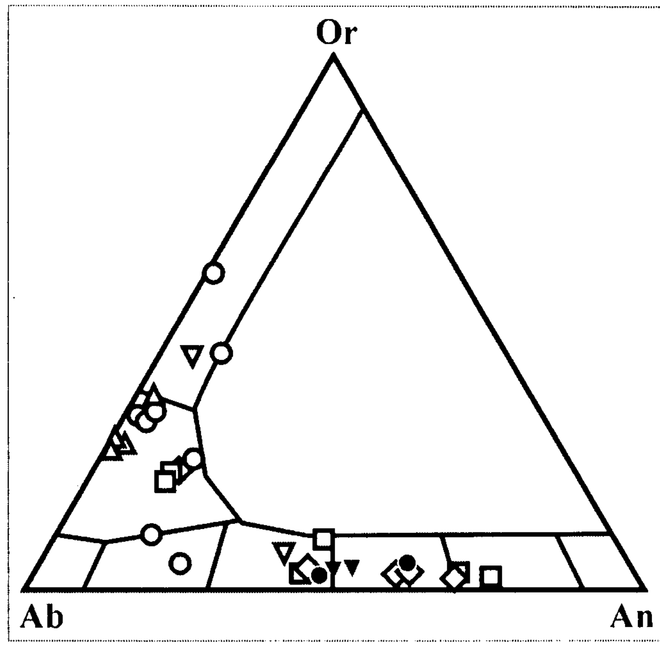

Fig. 3. Feldspars in An-Ab-Or diagram (mol.%). Symbols as in Fig. 1.

Table 3. Representative chemical analyses of feldspars

Sample	202/	202/	202/	180/	180/	180/	180/	180/	180/	186/	186/	251/	251/	256/	256/	256/	256/
No.	9C	10R	18M	23C	24R	25C	26R	27M	28M	12C	13R	23C	20	30C	29C	27R	28
Rock type		RY				TR				TR		TA			BTA		
SiO_2	67,52	67,36	68,33	65,21	66,59	66,61	65,75	64,21	67,22	63,78	68,59	57,31	64,79	50,31	51,15	59,30	62,37
TiO_2								0,08		0,01	0,04	0,07	0,03	0,01	0,11	0,08	0,03
Al_2O_3	18,57	17,95	16,78	20,04	18,54	19,58	18,93	22,53	17,05	22,65	17,91	26,35	21,50	31,65	31,08	23,86	22,68
FeO	0,36	0,16	0,47	0,20	0,20	0,25	0,47	0,33	0,38	0,09	0,06	0,03	0,07	0,08	0,05	0,06	0,01
MnO	0,11	0,03		0,14	0,07	0,13	0,01	0,03	0,01			0,04	0,01	0,00	0,05		
MgO								0,02				0,03		0,02	0,04		
BaO			0,09		0,23	0,01	0,26			0,23	0,18			0,05	0,19	0,41	0,23
CaO	0,57	0,67	0,19	3,34	1,09	3,25	2,16	2,62	0,17	4,72	0,44	8,84	2,82	14,62	13,65	8,55	2,95
Na_2O	8,24	7,16	8,52	7,00	7,01	8,27	5,60	9,01	4,51	8,18	7,39	6,06	7,78	2,61	3,07	5,06	7,83
K_2O	4,91	6,61	4,68	4,25	5,86	1,70	7,17	1,15	10,14	0,78	5,58	0,49	3,58	0,32	0,45	1,93	4,05
P_2O_5	0,06			0,06	0,06	0,06	0,06		0,11								
Total	100,3	99,94	99,06	100,2	99,65	99,86	100,4	99,98	99,59	100,4	100,1	99,22	100,5	99,67	99,84	99,25	100,1
							Number of ions per 32(O)										
Si	11,99	12,07	12,27	11,63	11,96	11,78	11,82	11,35	12,21	11,25	12,17	10,35	11,48	9,19	11,58	10,75	11,19
Al	3,888	3,790	3,551	4,214	3,926	4,083	4,013	4,695	3,650	4,709	3,745	5,608	4,487	6,811	4,314	5,097	4,793
Ti								0,011		0,001	0,005	0,010	0,004	0,001		0,011	4,000
P	0,009			0,009	0,009	0,009	0,008		0,170						0,042		
Fe^{2+}	0,053	0,024	0,071	0,030	0,030	0,037	0,071	0,049	0,058	0,013	0,008	0,005	0,010	0,012		0,009	2,000
Mn	0,017	0,005		0,021	0,011	0,019	0,002	0,004	0,002	0,000	0,000	0,006	0,002	0,000			
Mg								0,005		0,000	0,000	0,008	0,000	0,005			
Ba			0,006		0,016	0,001	0,018			0,016	0,013			0,004	0,270	0,029	0,016
Ca	0,108	0,129	0,037	0,638	0,210	0,616	0,416	0,496	0,033	0,893	0,084	1,712	0,535	2,862	0,199	1,662	0,567
Na	2,838	2,489	2,966	2,421	2,442	2,837	1,953	3,089	1,588	2,800	2,544	2,123	2,674	0,925	1,901	1,780	2,724
K	1,113	1,512	1,072	0,967	1,343	0,384	1,645	0,259	2,350	0,176	1,264	0,113	0,809	0,075	1,664	0,447	0,927
Z	15,89	15,86	15,82	15,85	15,89	15,87	15,84	16,06	16,03	15,96	15,92	15,96	15,97	16,00	15,90	15,85	15,98
X	4,129	4,159	4,152	4,077	4,052	3,894	4,105	3,902	4,031	3,899	3,918	3,977	4,034	3,884	4,105	3,938	10,23
Ab	69,9	60,3	72,7	60,1	60,9	73,9	48,4	80,3	40,0	72,1	65,1	53,8	66,6	23,9	47,1	45,4	64,3
An	2,7	3,1	0,9	15,9	5,2	16,1	10,3	12,9	0,8	23,0	2,2	43,4	13,3	74,0	4,9	42,4	13,4
Or	27,4	36,6	26,3	24,0	33,5	10,0	40,8	6,8	59,2	4,5	32,4	2,9	20,1	1,9	41,2	11,4	21,9
Cn			0,1		0,4	0,0	0,5	0,2		0,4	0,3	0,0	0,0	0,1	6,7	0,7	0,4

Table 3. continued

Sample No.	Z22/1	Z22/2	Z22/3M	255/32	255/40	P1/1C	P1/1R	P1/2M	Z-13C	Z-13R	Z-13	Z14/1	Z14/2
Rock type		TB		TB			BA			BA		ON	
SiO_2	55,69	55,78	56,08	58,96	62,98	52,87	52,39	52,70	53,04	55,47	63,07	52,98	54,85
TiO_2	0,31	0,38	0,34	0,08			0,15	0,26	0,23	0,33	0,22	0,31	0,35
Al_2O_3	27,50	27,01	27,03	25,22	19,91	29,79	29,38	29,22	29,62	28,00	22,05	28,81	27,81
FeO	0,94	0,79	0,65	0,09	0,27	0,56	0,84	1,27	0,64	0,70	0,70	0,66	0,78
MnO		0,08		0,03		0,09	0,14	0,28	0,05	0,08	0,25		0,22
MgO	0,03	0,04	0,03	0,00		0,06	0,05	0,04	0,06	0,05	0,06	0,08	0,10
BaO	0,26	0,25		0,95	3,75	0,25	0,39	0,23	0,33	0,26	0,37		
CaO	10,19	9,14	9,95	8,03	1,01	12,57	11,89	11,63	10,94	9,06	2,85	12,18	9,97
Na_2O	4,97	5,47	5,48	6,07	5,33	4,12	4,00	4,14	4,64	5,98	7,07	4,10	4,98
K_2O	0,62	0,55	0,51	1,13	7,09	0,29	0,56	0,37	0,41	0,66	3,81	0,81	0,43
P_2O_5		0,25	0,12				0,46	0,48	0,45	0,28	0,52	0,31	0,34
Total	100,51	99,74	100,19	100,56	100,34	100,60	100,25	100,62	100,41	100,87	100,97	100,24	99,83
						Number of ions per 32 (O)							
Si	10,038	10,099	10,105	10,581	11,587	9,570	9,529	9,548	9,588	9,956	11,217	9,620	9,923
Al	5,842	5,764	5,740	5,330	4,314	6,355	6,298	6,239	6,311	5,923	4,622	6,166	5,930
Ti	0,042	0,052	0,046	0,011			0,021	0,035	0,031	0,045	0,029	0,042	0,048
P		0,038	0,018		0,042		0,071	0,074	0,069	0,043	0,078	0,048	0,052
Fe^{2+}	0,142	0,120	0,098	0,014		0,085	0,128	0,192	0,097	0,105	0,104	0,100	0,118
Mn		0,012		0,005		0,014	0,022	0,043	0,008	0,012	0,038		0,034
Mg	0,008	0,011	0,008			0,016	0,014	0,011	0,016	0,013	0,016	0,022	0,027
Ba	0,018	0,018		0,067	0,270	0,018	0,028	0,016	0,023	0,018	0,026		
Ca	1,968	1,773	1,921	1,544	0,199	2,438	2,317	2,258	2,119	1,742	0,543	2,370	1,932
Na	1,737	1,920	1,914	2,112	1,901	1,446	1,411	1,454	1,626	2,081	2,438	1,443	1,747
K	0,143	1,127	0,117	0,259	1,664	0,067	0,130	0,086	0,095	0,151	0,864	0,188	0,099
Z	15,923	15,953	15,909	15,911	15,901	15,925	15,918	15,896	15,999	15,966	15,947	15,876	15,952
X	4,016	3,981	4,059	4,012	4,105	4,083	4,048	4,060	3,984	4,123	4,029	4,123	3,957
Ab	44,9	50,0	48,4	53,0	47,1	36,4	36,3	38,1	42,1	52,1	63,0	36,1	46,2
An	50,9	46,2	48,6	38,8	4,9	61,4	59,6	59,2	54,9	43,6	14,0	59,2	51,1
Or	3,7	3,3	3,0	6,5	41,2	1,7	3,3	2,2	2,5	3,8	22,3	4,7	2,6
Cn	0,5	0,5		1,7	6,7	0,5	0,7	0,4	0,6	0,5	0,7		

C - core, R - rim (of phenocrysts), P - phenocryst, M - matrix

anorthoclase rimmed by sanidine) in K-feldspars phenocrysts in the trachytes (Table 3). Trachyte crystallisation need not lead to complete resorption of plagioclase Nekvasil (1992). The extent of resorption of plagioclase will depend upon pressure, bulk H_2O and the bulk chemistry of the melt. Partial to complete resorption of plagioclase can occur in Q-normative trachytes under H_2O buffered conditions, particularly if silica saturation is not attained until the later stages of crystallisation.

Plagioclases predominate in the more basic members of the WAS (trachyandesite and basaltic trachyandesite). They prevail in the matrix (up to 50 vol.%), as phenocrysts they are more rare. Partially resorbed oligoclase cores (to anorthoclase) in trachyte have been discussed above. Plagioclase composition in the intermediate rocks (trachyandesite, basaltic trachyandesite) is andesine (An_{43-42}). and in basanite, tephrite and trachybasalt is labradorite (An_{64-51}) with low contents of Or- and Cn-components (Table 3). Plagioclases in trachybasalts show a minimum variability in An-content within the range of andesine. Rare plagioclase is K-andesines (Table 3, No. 255/32R) in trachybasalt. This, together with the zero "ordering index" (Oi), indicates their high-temperature origin. They are characterised by high BaO content (up to 1 wt.%).

Nepheline was only detected in WAS rocks in the matrix of trachyandesite from Třebouňský vrch and basaltic trachyandesite from Doubravický vrch Hills. The nepheline compositions (Table 4) plotted in the ternary diagram Ne-Ks-Qz-H_2O system at 700 °C and 1 kbar p_{H2O} (Fig. 4) are not so far from the "Barth join", which denotes the compositional trend for natural nephelines (Dollase and Thomas, 1978). In accordance with the criteria of Wilkinson and Hensel (1994) the studied nephelines crystallised at temperatures lower than 700°C. In contrast to the WAS, nepheline is common in the matrix of olivine nephelinite, basanite and tephrite. Both sparse homogeneous microphenocrysts ($Ne_{70-72}Ks_{24}Q_{03-05}$) and interstitial patches of nepheline are characteristic for melilite-bearing olivine nephelinite from Chloumecký vrch Hill. Large crystals (up to 12 mm in size) enriched in Ne-component ($Ne_{76-79}Ks_{19-20}Q_{02-04}$) occur in the ijolite pegmatoidal segregations in the melilite-free olivine nephelinite of Podhorní vrch Hill (Ulrych et al., 2000c). The nephelines reflect host rock chemistry. The proximity to the Ne – Ks join, higher Ks and lower Qz of nephelines from the ijolite is consistent with the segregation bulk chemistry compared with parent rocks (cf. Fig. 4). SAS nepheline is relatively richer in Ks-component and distinctly lower in Q-component (<5) (Fig. 4). Analcimization is confined to crystal rims and cleavage, only.

Table 4. Representative chemical analyses of nephelines and analcimes

Sample No.	251/1	251/2	256/1	29/C	29/R	29/C	29/R	Z14/1	Z14/2	Z16/1V	Z16/2M	Z19/1
Rock type	TA		BTA	ON		Ijolite in ON		BA		MON		TE
SiO_2	44,48	44,26	45,09	42,30	42,21	41,89	41,13	42,66	42,95	42,11	42,09	56,24
TiO_2	0,00	0,00	0,06	0,05	0,08	0,05	0,03	0,18	0,25	0,19	0,11	
Al_2O_3	33,01	33,01	32,61	33,69	33,12	33,42	33,98	32,52	32,96	33,47	32,31	22,26
Fe_2O_3	0,78	0,95	0,92	1,62	1,09	1,17	1,11	0,93	0,88	0,82	1,29	0,40
MnO						0,02	0,03					0,01
MgO						0,05	0,04	0,57	0,54	0,76	0,71	0,07
CaO	1,15	1,28	1,07	0,51	0,52	0,15	0,14	2,18	1,86	1,60	3,23	5,34
Na_2O	16,87	16,45	16,65	16,11	16,18	16,38	16,56	15,78	15,76	14,42	14,45	7,38
K_2O	3,56	3,70	3,52	5,80	5,89	6,29	6,36	4,47	4,10	7,37	6,06	1,20
Total	99,85	99,65	99,92	100,08	99,09	99,42	99,38	99,29	99,30	100,74	100,25	92,90
	Number of ions per 4 (O)											48 (O)
Si	2,117	2,112	2,141	2,020	2,056	2,039	2,014	2,063	2,067	2,028	2,037	32,518
Al	1,852	1,857	1,825	1,878	1,901	1,918	1,943	1,853	1,870	1,900	1,843	15,169
Ti			0,002	0,002	0,003	0,002	0,001	0,007	0,009	0,007	0,004	
Fe^{3+}	0,028	0,034	0,033	0,059	0,040	0,043	0,041	0,034	0,032	0,030	0,047	0,174
Mn						0,001	0,001					0,005
Mg						0,004	0,003	0,041	0,039	0,055	0,051	0,060
Ca	0,059	0,065	0,054	0,027	0,027	0,008	0,007	0,113	0,096	0,083	0,167	3,308
Na	1,557	1,522	1,533	1,522	1,528	1,546	1,572	1,479	1,471	1,346	1,356	8,273
K	0,216	0,225	0,213	0,361	0,366	0,391	0,397	0,276	0,252	0,453	0,374	0,885
Z	3,997	4,003	4,001	3,959	4,000	4,002	3,999	3,956	3,977	3,964	3,931	47,861
X	1,832	1,813	1,800	1,910	1,921	1,950	1,980	1,909	1,857	1,936	1,949	12,526
Ne (mol.%)	77,85	76,82	75,43	75,80	76,30	76,42	78,60	80,54	78,42	72,28	70,39	
Ks	10,81	11,37	10,49	18,00	18,30	19,33	19,85	15,01	13,42	24,31	24,44	
Qz	11,34	11,81	14,08	6,20	5,40	4,25	1,55	4,45	8,15	3,41	5,17	

Analcime patches mainly result from a low-temperature transformation of nepheline or plagioclase in the matrix of basanites (Okrouhlé Hradiště, Polom, Vlčí hora and Lysina hills) and basanite of Prachomety II (for analyses see Table 4). Analcime occurs rarely in vesicles.

Melilite is present in matrix of melilite-bearing olivine nephelinite at Český Chloumek (Table 5). Anomalous, large rusty crystals (up to 18 mm in length) occur in the ijolite pegmatoidal segregations in the melilite-free olivine nephelinite of Podhorní vrch Hill (Ulrych et al., 2000c). Melilite of the ijolite is characterized by appreciable amount of soda-melilite and ferroåkermanite end-members, accompanied by åkermanite molecule (Table 5) in comparison to usual chemical composition of melilite in the matrix (cf. Pivec et al., 1998). Such replacement of Ca (Mg,Al) by Na (Fe^{2+},Fe^{3+}) in melilite structure causes a marked lowering of the melting point of the magma (Yoder, 1973).

Olivine occurs in olivine nephelinite and basanite as (i) xenocrysts from disaggregated mantle xenoliths (>2-3 mm, Fo_{88-90}), (ii) euhedral phenocrysts (about 10 vol.%, 0.5-1 mm, Fo_{66-76}) and (iii) rare irregular matrix grains. Olivine of all types is mostly substantially altered (iddingsitisation and serpentinization). Phenocryst olivine in olivine nephelinite has a restricted compositional range (Fo_{81-84}, CaO = 0.3-0.7 wt.%), in contrast with the groundmass (Fo_{59-68}), which is often serpentinised (Table 6). The exceptional accessory olivine of tephrite from Okrouhlé Hradiště Hill is Fo-rich poor (Fo_{49-52}, CaO = 0.8-0.9 wt.%).

Clinopyroxene occurs in minor to substantial amounts in major rocks of the WAS. It occurs as phenocryst and in groundmass of in trachyte occurring in Prachometský vrch Hill.

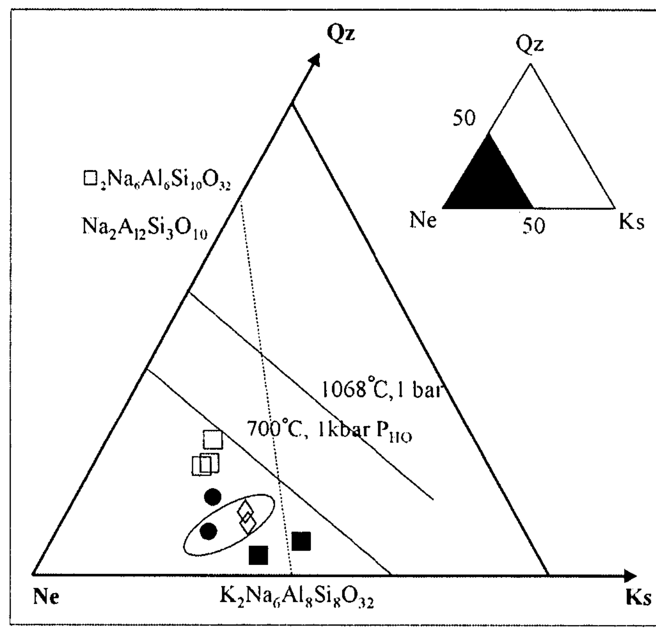

Fig. 4. Nephelines in Ne-Ks-Qz diagram. The dashed line ("Barth join") denotes the composition of natural nephelines (Dollase and Thomas 1978); the full line solution of feldspar in nepheline at 1068 °C, 1 bar (Donnay et al. 1959, Wilkinson and Hensel 1994); the dashed-dot line marks the limit of solid solutions at 700 °C (Hamilton 1961). Shaded area corresponds to nepheline composition of coarse-grained nepheline-clinopyroxene-melilite/leucite + K-feldspar exsolution in olivine nephelinite of Podhorní vrch Hill (Ulrych et al. 2000c). Symbols as in Fig. 1.

Phenocryst in all the rocks occurs as hypautomorphic, columnar crystal (0.2 to 2 mm in size) showing weak concentric and/or sectoral zoning (e.g., in the trachybasalt of Zbraslavský vrch Hill). Their compositions (Table 7) are diopside (Morimoto, 1988; Fig. 5), they often plot above the (Wo>50) boundary of the "fassaite" field, reflecting high Ti, Al, and Fe^{3+} contents. Clinopyroxene megacrysts (up to 50 mm in size) from basanite and tuffs from Vlčí hora Hill reveal the same composition (Ulrych and Kašpar, 1977). Clinopyroxenes in trachyte from Prachometský vrch Hill and in most trachyandesitic rocks are relatively enriched in Fs-component, more so than clinopyroxenes from trachytic rocks of Siebengebirge (Vieten, 1979, 1980). Both WAS and SAS clinopyroxenes contain minor Na_2O and MnO, which are highest in trachyte (maximum = 1.75 and 2.56 wt.%, respectively).

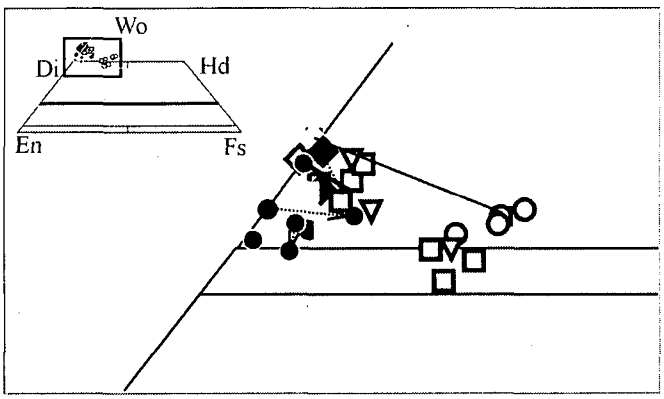

Fig. 5. Clinopyroxenes in Morimoto's ed. (1988) classification diagram. Dashed lines join core and rim, arrows point to the rim. Symbols as in Fig. 1.

Table 5. Representative chemical analyses of melilite

Sample No.	Z16/1C	Z16/2R	M2/C	M2/R
Rock type	MON		Ijolite segr. in ON	
SiO_2	42,86	43,75	42,89	40,77
TiO_2	0,26	0,21	0,16	0,16
Al_2O_3	7,07	7,97	6,36	7,37
FeO	4,23	4,06	5,79	7,16
MnO	0,23	0,18	0,10	0,22
MgO	7,58	6,81	7,07	4,74
BaO			0,02	0,05
CaO	34,38	33,04	32,13	33,90
Na_2O	3,02	3,25	5,61	5,10
K_2O	0,27	0,30	0,09	0,10
Total	99,90	99,57	100,22	99,57
	Number of ions per 14 (O)			
Si	3,907	3,968	3,939	3,821
Al	0,760	0,852	0,688	0,814
Ti	0,018	0,014	0,011	0,011
Fe	0,322	0,308	0,445	0,561
Mn	0,018	0,014	0,008	0,017
Mg	1,030	0,921	0,968	0,662
Ca	3,358	3,211	3,162	3,404
Ba			0,001	0,002
Na	0,534	0,572	0,999	0,927
K	0,031	0,035	0,011	0,012
Na mel	26,88	29,03	32,75	39,96
Geh	5,69	7,12	14,8	8,54
Aker	62,54	46,55	46,07	32,5
Di mel	5,17	13,25	6,38	19
Wo	0,28	4,06		

Table 6. Representative chemical analyses of olivine

Sample No.	Z13/1	Z13/2	P1/1	P1/2	Z15/1	Z15/2	Z14/P	Z14/2M	Z14/3M	Z16/1	Z19/1C	Z19/1R	Z19/2
Rock type	BA		BA		ON		ON			MON	TE		
SiO_2	38,18	38,70	39,63	39,30	38,20	39,54	39,49	39,08	39,36	39,91	39,13	39,13	38,85
TiO_2	0,25	0,26	0,37	0,24	0,26	0,21	0,29	0,31	0,24	0,12	0,23	0,38	0,23
Al_2O_3	0,48	0,40	1,07	1,23	0,53	0,61	0,37	0,56	0,62	0,44	1,59	2,09	2,24
FeO	22,58	20,73	26,63	25,22	21,80	22,41	22,08	22,69	22,42	14,67	35,33	34,90	35,95
MnO	1,05	0,79	0,78	0,88	0,49	0,73	0,64	0,77	0,75	0,34	0,90	0,97	1,01
NiO	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0,30	0,19	n.d.	n.d.	n.d.	n.d.
MgO	37,05	38,44	30,53	31,74	37,73	37,32	36,57	35,96	36,10	41,41	22,03	21,74	20,84
CaO	0,47	0,31	0,71	0,61	0,56	0,53	0,43	0,33	0,30	0,53	0,80	0,80	0,88
Total	100,06	99,63	99,72	99,22	99,57	101,35	99,87	100,00	99,98	97,42	100,01	100,01	100,00
	Number of ions per 4(O)												
Si	1,995	2,009	2,101	2,083	1,995	2,027	2,051	2,037	2,047	2,051	2,153	2,147	2,144
Al^{IV}	0,005				0,005								
Al^{VI}	0,025	0,024	0,067	0,077	0,027	0,037	0,023	0,034	0,038	0,027	0,103	0,135	0,146
Ti	0,010	0,010	0,015	0,010	0,010	0,008	0,011	0,012	0,009	0,005	0,010	0,016	0,010
Fe	0,987	0,900	1,181	1,118	0,952	0,961	0,959	0,989	0,975	0,631	1,625	1,601	1,659
Mn	0,046	0,035	0,035	0,040	0,022	0,032	0,028	0,034	0,033	0,015	0,042	0,045	0,047
Ni								0,010	0,008				
Mg	2,886	2,974	2,413	2,508	2,937	2,852	2,831	2,795	2,798	3,173	1,807	1,778	1,715
Ca	0,026	0,017	0,040	0,035	0,031	0,029	0,024	0,018	0,017	0,029	0,047	0,047	0,052
Fo	73,2	76,3	65,8	67,8	74,5	73,6	73,7	72,6	73,0	82,5	51,5	51,2	49,4
Fa	25,0	22,6	32,2	30,2	24,2	24,8	25,0	25,7	25,5	16,4	46,2	46,1	47,8
Te	1,2	0,6	1,0	1,1	0,6	0,8	0,7	0,9	0,9	0,4	1,2	1,3	1,4

Table 7. Representative chemical analyses of clinopyroxenes

Sample No.	186/ 7C	186/ 9R	186/ 8M	186/ 1M	251/ 3C	251/ 4R	251/ 2C	251/ 1R	256/ 1C	256/ 2R	256/ 7M	256/ 5M	255/ 1C	255/ 2R	255/ 3R	255/ 7M
Rock type	TR				TA				BTA				TB			
SiO_2	49,81	49,36	49,97	49,36	48,59	47,77	49,88	45,87	50,53	45,92	49,51	45,07	51,01	44,37	47,50	41,71
TiO_2	0,54	0,91	0,84	1,06	1,57	1,92	1,75	2,49	0,42	3,12	1,93	3,34	0,39	3,47	1,95	5,29
Al_2O_3	2,70	1,48	1,70	2,49	4,77	4,50	5,18	8,12	2,47	5,78	3,54	6,94	2,22	6,80	5,68	9,41
FeO	12,81	15,10	15,13	14,80	8,42	8,63	9,99	10,54	13,17	9,17	7,96	9,32	12,45	8,66	8,73	8,52
MnO	1,31	2,51	2,56	2,22	0,21	0,23	0,35	0,34	0,35	0,26		0,21	0,69	0,11	0,17	0,22
MgO	10,55	8,50	8,15	8,76	12,25	12,61	12,07	11,06	10,69	11,30	13,29	10,43	10,68	11,11	11,95	10,92
CaO	21,43	20,24	20,70	20,20	22,78	22,97	20,68	20,49	20,54	22,79	21,91	22,43	20,39	23,71	22,76	21,88
Na_2O	1,00	1,75	1,73	1,68	1,20	1,08	0,78	0,80	1,16	1,11	1,26	1,47	1,74	0,81	0,79	1,36
K_2O						0,09			0,12	0,16	0,11	0,15	0,13	0,15	0,20	0,19
Total	100,15	99,85	100,78	100,57	99,79	99,80	100,68	99,71	99,45	99,54	99,51	99,46	99,70	99,19	99,73	99,50
Number of ions per 4 cations and 6 (O)																
Si	1,882	1,893	1,902	1,875	1,806	1,777	1,854	1,724	1,917	1,723	1,839	1,695	1,921	1,673	1,774	1,564
Al^{IV}	0,118	0,067	0,076	0,111	0,194	0,197	0,146	0,276	0,083	0,256	0,155	0,305	0,079	0,302	0,226	0,416
Fe^{3+}		0,040	0,022	0,014	0,000	0,026	0,000	0,000	0,000	0,021	0,006	0,000	0,000	0,024	0,000	0,021
Al^{VI}	0,003				0,015		0,081	0,084	0,028			0,003	0,019		0,024	0,000
Ti	0,015	0,026	0,024	0,030	0,044	0,054	0,049	0,070	0,012	0,880	0,054	0,094	0,011	0,098	0,055	0,149
Cr															0,000	0,000
Fe^{3+}	0,157	0,184	0,178	0,188	0,177	0,198	0,024	0,109	0,122	0,189	0,149	0,227	0,171	0,196	0,159	0,246
Fe^{2+}	0,247	0,260	0,282	0,268	0,085	0,044	0,287	0,222	0,296	0,077	0,093	0,065	0,221	0,052	0,114	0,001
Mg	0,594	0,486	0,462	0,496	0,679	0,699	0,669	0,620	0,605	0,632	0,736	0,585	0,600	0,625	0,665	0,610
Mn	0,042	0,082	0,083	0,071	0,007	0,007	0,011	0,011	0,011	0,008		0,007	0,022	0,004	0,005	0,007
Ca	0,868	0,832	0,844	0,822	0,907	0,915	0,824	0,825	0,835	0,916	0,872	0,904	0,823	0,958	0,911	0,879
Na	0,073	0,130	0,128	0,124	0,086	0,078	0,056	0,058	0,085	0,081	0,091	0,107	0,127	0,059	0,057	0,099
K						0,004			0,006	0,008	0,005	0,007	0,006	0,007	0,010	0,009
Wo	50,7	52,7	53,2	51,8	53,6	55,2	44,9	47,8	47,4	56,4	51,3	58,1	49,5	58,6	53,1	59,0
En	34,7	30,8	29,1	31,3	40,3	42,1	36,4	35,9	34,3	38,9	43,3	37,6	36,1	38,2	38,8	41,0
Fs	14,4	16,5	17,7	16,9	5,0	2,7	15,6	12,9	16,8	4,8	5,5	4,2	13,3	3,2	6,6	0,0
Jd	0,2	0,0	0,0	0,0	0,9	0,0	3,1	3,4	1,6	0,0	0,0	0,2	1,2	0,0	1,4	0,0

Table 7. continued

Sample No.	Z13/1 C	Z13/1 R	Z13/2 M	Z19/1	Z19/2 M	P1/ 1C	P1/ 2C	Z15/1	Z15/2	Z24/1 C	Z24/1 R	Z24/2 M	Z14/1 C	Z14/1 R	Z14/2 M	Z16/1 C	Z16/1 R	Z16/C
Rock type	BA			BA		BA		ON		ON			ON			MON		
SiO_2	45,13	46,24	43,57	45,30	46,47	44,03	42,12	44,90	45,13	47,48	44,98	42,43	50,81	48,98	49,63	45,36	49,37	45,18
TiO_2	3,92	2,80	3,23	2,63	2,54	3,73	4,42	3,33	3,92	2,16	3,24	4,14	0,97	1,13	1,53	2,92	1,32	2,68
Al_2O_3	6,75	5,69	7,68	7,66	7,42	6,84	8,77	7,46	6,75	4,77	6,49	9,66	5,53	6,91	4,68	7,02	2,17	7,30
Cr_2O_3	0,15	0,25	0,23	0,36	0,42	0,23	0,27	0,10	0,15	0,35	0,37	0,24	1,17	1,56	0,79	0,34	0,30	0,27
FeO	7,13	9,03	8,87	6,70	6,31	7,62	7,99	7,46	7,13	8,55	8,00	8,90	4,60	4,87	5,29	7,89	12,98	7,22
MnO	0,32	0,41	0,27	0,31	0,23	0,17	0,16	0,34	0,32	0,45	0,34	0,37	0,37	0,35	0,44	0,29	0,39	0,43
MgO	11,90	12,10	11,45	12,15	12,45	11,89	11,17	11,90	11,90	12,56	11,59	10,67	14,55	13,18	13,70	11,62	9,76	11,26
CaO	23,30	23,45	23,10	24,27	23,75	23,93	24,13	23,68	23,30	23,41	23,93	22,27	21,11	21,16	22,09	23,82	23,07	24,50
Na_2O	1,18	0,60	1,04	0,69	0,70	0,88	0,84	0,92	1,18	0,60	1,01	1,20	1,14	1,41	1,07	0,96	0,61	0,85
K_2O	0,17	0,03	0,17	0,11	0,05	0,12	0,11	0,01	0,17	0,00	0,15	0,13	0,25	0,18	0,08	0,18	0,21	0,12
Total	99,95	100,60	99,61	100,18	100,34	99,44	99,98	100,10	99,95	100,33	100,10	99,94	100,40	99,73	100,00	100,40	100,18	99,81
Number of ions per 4 cations and 6 (O)																		
Si	1,678	1,720	1,629	1,677	1,715	1,649	1,573	1,667	1,678	1,767	1,675	1,584	1,848	1,800	1,838	1,682	1,880	1,685
Al^{IV}	0,296	0,249	0,339	0,323	0,285	0,302	0,386	0,326	0,296	0,209	0,285	0,416	0,152	0,200	0,162	0,307	0,097	0,315
Fe^{3+}	0,026	0,030	0,032	0,000	0,000	0,000	0,000	0,006	0,026	0,024	0,040	0,000	0,000	0,000	0,000	0,011	0,023	0,000
Al^{VI}	0,000	0,000	0,000	0,011	0,038	0,000	0,000	0,000	0,000	0,000	0,000	0,009	0,085	0,099	0,043	0,000	0,000	0,006
Ti	0,110	0,078	0,091	0,073	0,070	0,105	0,124	0,093	0,110	0,060	0,091	0,116	0,026	0,031	0,043	0,081	0,038	0,075
Cr	0,004	0,007	0,007	0,010	0,012	0,007	0,008	0,003	0,004	0,010	0,011	0,007	0,034	0,045	0,023	0,010	0,009	0,008
Fe^{3+}	0,192	0,160	0,246	0,207	0,145	0,239	0,250	0,210	0,192	0,145	0,209	0,260	0,072	0,102	0,091	0,223	0,091	0,218
Fe^{2+}	0,004	0,090	0,000	0,000	0,049	0,000	0,000	0,015	0,004	0,096	0,000	0,018	0,068	0,047	0,073	0,011	0,299	0,007
Mn	0,010	0,013	0,008	0,010	0,007	0,005	0,005	0,011	0,010	0,014	0,011	0,012	0,011	0,011	0,014	0,009	0,012	0,013
Mg	0,659	0,671	0,638	0,670	0,685	0,664	0,622	0,659	0,659	0,697	0,643	0,594	0,789	0,722	0,756	0,642	0,554	0,626
Ca	0,928	0,935	0,926	0,963	0,939	0,960	0,967	0,942	0,928	0,933	0,955	0,891	0,823	0,833	0,877	0,946	0,941	0,979
Na	0,086	0,043	0,075	0,050	0,050	0,064	0,061	0,066	0,085	0,043	0,073	0,087	0,080	0,100	0,077	0,069	0,045	0,061
K	0,008	0,001	0,008	0,005	0,002	0,006	0,005	0,000	0,008	0,000	0,007	0,006	0,011	0,008	0,004	0,008	0,010	0,005
Wo	58,3	55,1	59,2	58,6	54,9	59,1	60,8	58,3	58,3	54,1	59,7	58,9	46,8	49,0	50,1	59,2	52,4	60,5
En	41,4	39,6	40,8	40,8	40,0	40,9	39,2	40,8	41,4	40,4	40,3	39,3	44,8	42,4	43,3	40,2	30,9	38,7
Fs	0,2	5,3	0,0	0,0	2,9	0,0	0,0	1,0	0,2	5,6	0,0	1,2	3,9	2,8	4,2	0,7	16,7	0,5
Jd	0,0	0,0	0,0	0,7	2,2	0,0	0,0	0,0	0,0	0,0	0,0	0,6	4,6	5,8	2,4	0,0	0,0	0,4

The compositional variation of clinopyroxene in basanites and tephrites is largely a function of ferrian diopside and ferrian fassaite variants. High fO_2 during crystallization is reflected in high Fe^{3+} in both octahedral and (tetrahedral) positions (calculated on the base of stoichiometry). This translates to a lower Fs-component and almost all clinopyroxenes are characterised by low Si-contents compensated by substitution of Al^{IV} and Fe^{IV}.

Amphibole is a minor phase in rhyolite and trachyte of Špičák Hill. Microphenocrysts are columnar, with strong pleochroism and typically rimmed by biotite. The alkali amphiboles are Mn-varieties (up to 6.1 wt.% MnO), manganoan magnesioriebeckite in rhyolite and manganoan winchite in trachyte using Leake's (1978) classification (Table 8). Magnesioarfvedsonite of similar composition is known from alkali trachyte in Siebengebirge (Vieten, 1965; Vieten et al., 1988) and fenites in the Čistá Massif (Ulrych, 1978).

Table 8. Representative chemical analyses of amphiboles

	magnesio riebeckite	winchite	kaersutite		kaersutite megacryst	kaersutite veinlet
Sample No.	202/1	180/1	251/11	251/10	P1/1R	P1/2M
Rock type	RY	TR	TA		BA	
SiO_2	54,07	53,72	39,34	39,09	39,00	39,15
TiO_2	0,27	0,52	5,09	5,44	5,03	5,10
Al_2O_3	0,77	1,45	12,38	12,64	13,56	13,55
$Fe_2O_{3\,tot}$	17,66	12,11				
Cr_2O_3						
FeO			11,18	12,06	8,54	9,52
MnO	6,06	4,43	0,14	0,13	0,32	0,34
MgO	8,43	15,05	13,01	11,83	13,85	13,09
CaO	2,98	7,26	12,09	12,12	12,69	12,57
Na_2O	7,39	3,63	2,67	2,81	2,50	1,95
K_2O	0,84	0,71	1,61	1,37	2,14	1,96
H_2O^+	2,07	2,12	2,00	2,00	1,98	1,98
Total	100,54	101,00	99,51	99,49	99,61	99,21
	Number of ions per 23 (O)					
Si^{IV}	7,849	7,608	5,889	5,872	5,788	5,836
Al^{IV}	0,132	0,242	2,111	2,128	2,212	2,164
Ti						
Fe^{IV}	0,019	0,150				
Al^{VI}			0,073	0,109	0,159	0,216
Ti	0,029	0,055	0,573	0,614	0,561	0,572
Cr						
Fe^{3+}	1,385	1,141				
Fe^{2+}	0,525	0,000	1,400	1,515	1,06	1,187
Mg	1,824	3,178	2,903	2,649	3,064	2,908
Mn	0,745	0,531	0,018	0,017	0,04	0,043
Ca	0,464	1,101	1,939	1,951	2,018	2,007
Na					0,097	0,066
Na	2,080	0,997	0,775	0,818	0,622	0,498
K	0,156	0,128	0,307	0,263	0,405	0,373

Strongly corroded, originally euhedral phenocrysts (up to 12 cm) of kaersutite rimmed by clinopyroxene and titanian magnetite occur in trachyandesite. Their chemical composition is close to that of amphibole megacrysts worldwide. They are also similar to polycrystalline aggregates (15 by 10 cm) of oxykaersutite in basanite and its tuff from the nearby Vlčí hora Hill at Černošín (Ulrych, 1986). The basanite includes also infrequent oxykaersutite veinlets as a result of re-equilibration (?) between melt and megacrysts (phenocrysts or cumulates)?

Biotite is found only in trachyte from Špičák Hill. It occurs in the form of (i) rare euhedral phenocrysts (up to 4 mm) and smaller inclusions in the alkali feldspar phenocrysts (Mg# = 0.61-0.62) and (ii) rims of amphibole microphenocrysts composed of subhedral dark brown flakes (Mg# = 0.58), locally opaque due to tiny inclusions of titanian magnetite. Micas are typically Fe-Mg biotite, exceptionally phlogopite (Table 9). A low content of micas and amphiboles in rocks of both series gives evidence of a relatively dry parental magma.

Table 9. Representative chemical analyses of biotite

Sample No.	180/ 1C	180/ 1R	180/ 2C	180/ 2R
Rock type	TR			
SiO_2	36,02	35,46	38,01	37,49
TiO_2	4,07	5,90	4,93	5,50
Al_2O_3	14,25	14,91	13,72	15,80
FeO	15,33	16,73	14,17	13,33
MnO	1,41	1,31	1,77	1,46
MgO	14,82	13,02	14,82	13,69
CaO				0,01
Na_2O	0,57	0,69	0,81	0,56
K_2O	9,35	8,46	9,31	9,33
Total	95,82	96,48	97,54	97,17
Number of ions per 22 (O)				
Si	5,675	5,558	5,833	5,730
Al^{IV}	2,325	2,442	2,167	2,270
Al^{VI}	0,319	0,310	0,313	0,574
Ti	0,482	0,696	0,569	0,632
Fe^{2+}	2,020	2,193	1,819	1,704
Mn	0,188	0,174	0,230	0,189
Mg	3,481	3,042	3,391	3,119
Ca				0,002
Na	0,174	0,210	0,241	0,166
K	1,879	1,692	1,823	1,819
Z	8,000	8,000	8,000	8,000
Y	6,490	6,415	6,322	6,218
X	2,053	1,902	2,064	1,987

Titanomagnetite in trachytes (manganoan titanian magnetite) is characterised by a high amount of Mn (up to 6.6 wt.% MnO, cf. Table 10). The higher contents of Ti (up to 19.9 wt.%), Al, Cr, Mg, and V are characteristic, especially for titanomagnetites from trachybasalts, basanites and olivine nephelinites. Concentric zoning is manifested mostly in an increase of Ti towards rims, accompanied by a decrease of Mn, Al and Mg.

Accessory minerals

Accessory minerals occur sporadically in the rocks. Euhedral, partly corroded *titanite* occurs in the entire range of rocks except for rhyolite. For its chemical composition see Table 11. Needle-like *apatite* is a rare accessory and is mainly concentrated in the more mafic and intermediate rocks of the WAS.

Table 10. Representative chemical analyses of titanian magnetites

Sample No.	180/1C	180/2R	186/3	186/4	251/8	251/9	256/12	256/13	255/17	255/18
Rock type	TR	TR	TR	TR	TA	TA	BTA	BTA	TB	TB
SiO_2	0,13	0,06	0,23	0,16	0,38	0,24			0,08	0,12
TiO_2	9,05	10,98	10,27	9,06	13,93	15,88	13,41	15,44	16,11	13,81
Al_2O_3	0,41	0,46	0,50	0,63	1,37	1,26	1,30	1,28	2,83	3,52
Cr_2O_3									0,12	0,13
Fe_2O_3	50,76	47,02	47,55	50,64	39,99	37,01	41,11	37,54	36,44	40,28
FeO	33,33	38,22	35,87	32,56	40,44	40,76	40,83	41,40	39,71	37,46
MnO	5,63	2,65	4,53	6,64	2,57	2,73	1,73	2,73	1,34	1,12
MgO	0,23	0,12	0,20	0,33	0,96	1,25	0,45	0,71	3,62	3,98
CaO	0,04	0,20	0,07	0,02	0,13	0,72	0,11	0,10	0,07	0,08
V_2O_5										
Total	99,10	99,71	99,28	100,04	99,77	99,85	99,94	99,20	100,32	100,50
Number of ions per 3 cation and 4 (O) positions										
Si	0,005	0,002	0,009	0,006	0,014	0,009			0,003	0,004
Ti	0,258	0,309	0,297	0,258	0,399	0,446	0,376	0,431	0,434	0,371
Al	0,018	0,020	0,022	0,027	0,059	0,054	0,057	0,056	0,119	0,147
Cr									0,003	0,004
Fe^{3+}	1,494	1,383	1,404	1,481	1,162	1,071	1,211	1,101	1,026	1,125
Fe^{2+}	1,038	1,189	1,120	1,007	1,242	1,248	1,272	1,284	1,183	1,107
Mn	0,178	0,084	0,143	0,208	0,080	0,085	0,055	0,086	0,040	0,034
Mg	0,014	0,015	0,014	0,019	0,058	0,096	0,029	0,043	0,195	0,213
Ca	0,002	0,008	0,003	0,001	0,005	0,028	0,004	0,004	0,003	0,003
cation	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
$MgAl_2O_4$	1,8	1,9	2,1	2,7	4,8	4,2	4,8	4,4	9,0	11,7
$MgMgTiO_4$	0,5	0,4	0,3	0,5	2,3	5,4	0,1	1,2	10,3	11,2
$MnMnTiO_4$	17,7	7,7	13,5	20,5	6,5	6,6	4,6	6,8	3,1	2,7
$FeFeTiO_4$	33,2	49,2	42,1	29,9	56,3	57,4	58,4	60,0	52,6	45,6
$MnCr2O_4$	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
$MgCr_2O_3$	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
$FeCrO_4$	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,3
Fe_3O_4	46,8	40,7	42,1	46,4	30,1	26,4	32,2	27,6	24,7	28,6

Table 10. continued

Sample No.	Z13/1c	Z13/2	P-1/1	P-1/2	Z15/1	Z15/2	Z14/1	Z14/2	Z17/1	Z17/2
Rock type	BA	BA	BA	BA	ON	ON	ON	ON	MON	MON
SiO_2	0,06	0,08	0,04	0,04	0,06	0,04	0,12	0,07	0,19	0,12
TiO_2	20,05	19,90	6,37	14,52	12,30	15,47	19,08	20,79	23,72	22,21
Al_2O_3	2,31	2,27	4,09	8,37	2,18	2,80	2,54	3,04	2,34	2,45
Cr_2O_3	0,15	0,17	0,23	0,15	0,74	0,70	0,71	0,32	0,44	0,37
Fe_2O_3	29,71	29,24	53,23	34,01	43,56	36,44	30,11	27,41	21,65	25,26
FeO	43,27	43,20	30,16	34,66	38,32	40,50	42,36	42,30	45,62	43,64
MnO	1,42	1,55	1,64	1,37	0,79	1,25	0,91	0,99	1,49	1,34
MgO	3,68	3,39	3,21	5,71	2,21	2,32	3,48	4,53	3,70	4,51
CaO			0,21	0,43	0,22	0,14	0,25	0,40	0,77	0,36
V_2O_5			0,77	0,79	0,46	0,60	0,53	0,33		
Total	100,65	99,80	99,95	100,06	100,84	100,26	100,10	100,18	99,92	100,26
Number of ions per 3 cation and 4 (O) positions										
Si	0,002	0,003	0,001	0,001	0,002	0,001	0,004	0,002	0,007	0,004
Ti	0,538	0,541	0,173	0,378	0,336	0,423	0,520	0,557	0,644	0,596
Al	0,097	0,096	0,173	0,340	0,093	0,119	0,108	0,127	0,098	0,102
Cr	0,004	0,005	0,007	0,004	0,021	0,020	0,020	0,009	0,012	0,010
Fe^{3+}	0,836	0,831	1,511	0,928	1,243	1,043	0,856	0,768	0,611	0,707
Fe^{2+}	1,287	1,299	0,906	1,000	1,156	1,226	1,273	1,254	1,362	1,292
Mn	0,043	0,047	0,050	0,040	0,024	0,038	0,028	0,030	0,045	0,040
Mg	0,195	0,182	0,180	0,310	0,127	0,131	0,196	0,255	0,226	0,252
Ca	0,000	0,000	0,008	0,016	0,009	0,005	0,010	0,015	0,029	0,014
cation	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
$MgAl_2O_4$	6,7	6,6	17,4	24,6	7,9	9,2	7,5	8,5	6,2	6,7
$MgMgTiO_4$	10,2	9,2	9,4	10,1	6,9	5,4	9,9	12,8	11,1	13,1
$MnMnTiO_4$	3,0	3,3	5,0	2,9	2,1	2,9	1,9	2,0	2,8	2,6
$FeFeTiO_4$	61,5	62,3	20,5	41,8	48,4	56,4	60,8	60,0	66,9	62,2
$MnCr2O_4$	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
$MgCr_2O_3$	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
$FeCrO_4$	0,3	0,3	0,7	0,3	1,8	1,5	1,4	0,6	0,8	0,7
Fe_3O_4	18,4	18,2	46,9	20,3	32,9	24,5	18,3	16,0	12,2	14,7

Subhedral isometric grains of *zircon* are a typical accessory of trachytes and rhyolite. Submicroscopic crystals (20-30 μm in size) of rare oxide *fersmanite* (Ca,TR) $(Nb,Ti)_2$ $(O,OH)_6$ occur in matrix of trachyte from Špičák. The tentative chemical analysis (in wt.%) of fersmanite is as follows: Nb_2O_5 (50.0), Ta_2O_5 (4.2), TiO_2 (13.0), ThO_2 (2.8), UO_2 (2.7), Ce_2O_3 (4.5), Fe_2O_3 (2.4), MnO (1.7), CaO (18.6).

Late magmatic and postmagmatic minerals

Carbonates and sulphates are commonly present in the rocks. The younger hydrothermal calcites occur both in basaltic trachyandesite and in trachybasalt, where also complex carbonate of the intermediate composition between *rhodochrosite* and *calcite* was found (Table 11). *Barite* grains were identified in the matrix of basaltic trachyandesite (Table 11).

Mn-oxyhydroxide is very characteristic mineral of the Špičák trachyte. It occurs as an irregular network of subvertical veins and small veinlets (from 1 mm to 10 cm wide), vugs fillings, pseudomorphs after feldspars and in irregular impregnations copying the fluidal structure of the rock. In the apparently (by the naked eye) homogeneous monomineral veins the Mn-mineral forms only up to 10 vol.%. It cements very fine crushed material (feldspars, quartz, clay mineral) of the host rocks. The Mn-mineral is probably a product of a younger hydrothermal precipitation in fissures. It represents a poorly crystalline, originally colloidal phase, most probably a mixture of Mn-oxyhydroxides. A chemical study (Table 11) of the oxidation state (Ulrych et al., 1997) shows that Mn is mainly present in tetravalent form (8.55 wt.% from the total content of manganese expressed as 12.35 wt.% of MnO); the minor part (3.79 wt.%) corresponds to the trivalent form of Mn.

Sulphur and organic matter were rarely found in the altered and cavernous part of the Špičák trachyte as a yellow powder coating vugs (Ulrych et al., 1997). The sulphur crystallised most probably as a result of decomposition of gaseous volcanic emanations (oxidation of H_2S or reduction of SO_2).

Nontronite occurs in numerous veinlets, vugs and concentrations around the feldspar glomerophyres (Melka et al., 2001) in the trachyte of Špičák Hill. It forms 50-100 μm sized flakes, yellow-green in colour, occurring mixed with finely fragmented feldspars and goethite, sometimes in association with Mn-oxyhydroxide.

Table 11. Representative chemical analyses of accessory and secondary minerals

Sample No.	180	186	180	256	256	255	255
Rock type		TR		BTA		TB	
Mineral	titanite		Mn-oxy hydroxide	barite	calcite	Mn-carbonate	calcite
SiO_2	29,63	31,82					
TiO_2	36,87	36,07	0,75				
Al_2O_3	1,44	1,56	2,61	0,01			
Fe_2O_3			15,00	0,46			
FeO	1,44	2,02			0,77	0,24	0,49
MnO	0,38	0,38	71.87*	0,22	0,16	31,87	0,04
MgO	0,33	0,02	0,37	0,78	0,03	0,32	0,18
CaO	26,92	26,93	1,68		55,48	25,04	55,20
BaO		0,12		63,22	0,21		0,02
Na_2O	0,07	0,25	0,56				
K_2O	0,08	0,03	2,24				
H_2O			4,92				
Total	97,16	99,18	100,00	64,69	56,65	57,47	55,93

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Chemical analyses of the basanites and their proposed differentiates (see below) are presented in Table 2A, while olivine nephelinites, tephrites and trachyandesites are given in Table 2B. Position of the rocks of both series is presented in the TAS diagram (Fig. 6) of Le Maitre ed. (1989).

In the TAS diagram (Le Maitre, 1989) the majority of the W Bohemian rocks plot in the basanite, tephrite, trachybasalt, basaltic trachyandesite, trachyandesite, trachyte, and rhyolite fields (Fig. 6). Three samples (Lysina, Polom, Číhaná) plot as alkali-basalts because they contain numerous microxenoliths of the surrounding granitic rocks. Their mineral composition indicates that their original bulk chemistry was more

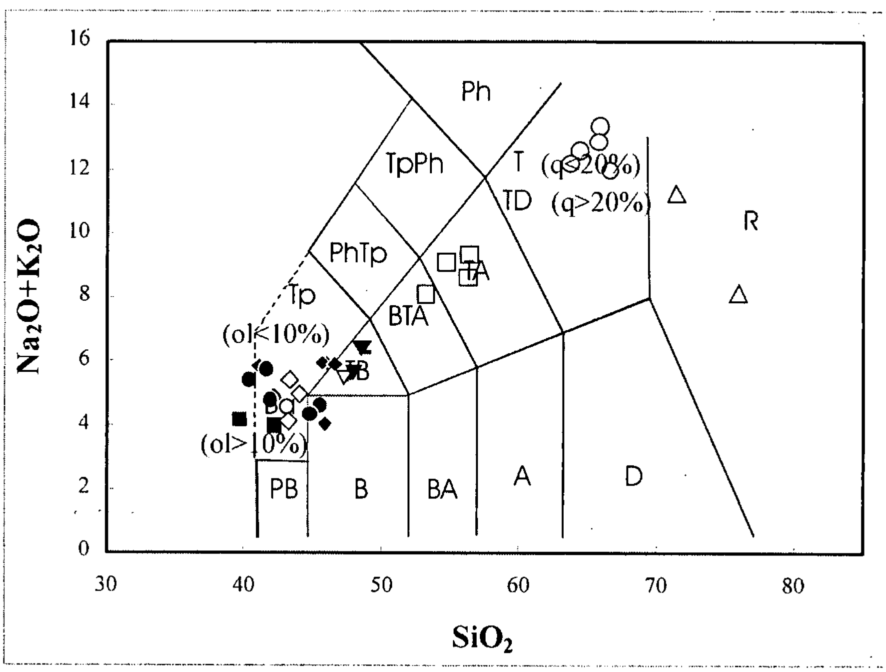

Fig. 6. Rocks of the weakly and strongly alkaline series associated with the Cheb-Domažlice Graben plotted in TAS diagram (Le Maitre ed. 1989). Symbols as in Fig. 1.

undersaturated in silica. Although most of the mafic rocks plot in the basanite field, they vary significantly in modal composition (see mineralogy section), which was used to distinguish olivine nephelinites and basanites.

In terms of Na_2O and K_2O most of the rocks belong to the potassic series: potassic trachybasalt - shoshonite - latite - trachyte - rhyolite (classification of Le Maitre, 1989); see Fig. 6. The rare rock samples represented only by hawaiite (flow at Zbraslavský vrch Hill) and latite (agglutinate in a feeding channel of Třebouňský vrch Hill) are members of sodic series in the same classification.

In comparison to Siebengebirge (Vieten et al., 1988) and Cantal, Massif Central (Wilson et al., 1995), the volcanic rocks of W Bohemia reveal a similar extent of fractionation, but at a lower level of alkalinity (cf. Fig. 2 in Pivec et al., in press). The rhyolite from the laccolith of Stěnský vrch Hill with a gneissic roof reveals some stoping features, suggesting contamination of the magma by the host rock (cf. Ulrych et al., 2000b).

According to TAS and Harker's diagrams, trachybasalts, trachyandesite and trachytes can be considered as representatives of the Weakly Alkaline Series (WAS) series. This series corresponds to that from the Cantal, Massif Central (Wilson et al., 1995). In Cantal, a Strongly Alkaline Series (SAS) has also been recognised. Initially, a similar series, composed of olivine nephelinite-tephrite-phonolite was thought to exist in W Bohemia, but the two large phonolite bodies considered to represent the felsic end of this series proved to belong to an older series (26-31 Ma) characteristic of Doupovske hory Mts. (Ulrych et al., in press a). However, strongly alkaline volcanism is definitely represented in W Bohemia by the (olivine) nephelinites. Thus, analogous to Cantal, both weakly and strongly alkaline rocks are present.

The WAS shows no evidence of commonly recognized crustal assimilation in trachytic and rhyolitic rocks (cf. Wilson et al., 1995). They have relatively stable ratios of incompatible elements (Ulrych et al., in press b) that have not been significantly affected by crustal assimilation.

Discussion and Conclusions

The volcanism in W Bohemia is genetically associated with the uplift of NE-flank of the CDG. Two contemporaneous series were recognised there:

WAS: basanite – trachybasalt – (basaltic) trachyandesite – trachyte – rhyolite,

SAS: (melilite-bearing) olivine nephelinite – tephrite.

The contemporaneous rock series represents products of the Middle to Late Miocene episode, which is part of the continuous Cenozoic volcanic activity in the Bohemian Massif (Ulrych et al., 1999). Despite the similar age of both series, their initial magmas differ in degree of partial melting of the mantle source. Initial nephelinitic magma was formed by a lower degree of partial melting than the basanitic magma.

The age of the volcanism associated with the CDG coincides with the Late Miocene intrusions in the České středohoří Mts. (13-9 Ma; Cajz et al., 1999), young volcanism in Germany (11-6 Ma; Lippolt, 1983) and with the time of the tectonic event (Downes, 1996) causing principal changes in chemical composition of volcanism in Carpathians.

Initial parent magmas (nephelinitic and basanitic) probably formed by different degrees of partial melting of metasomatised mantle lithosphere, with amphibole, olivine, garnet and clinopyroxene in residuum. Metasomatised mantle lithosphere has also been reported as a likely source of primitive alkaline magma from other parts of the Bohemian Cenozoic Volcanic Province (Svobodová and Ulrych, in press). The mantle source was enriched in incompatible elements compared to PM. Geochemical similarity of the rocks to OIB points to mantle metasomatism associated with plume-material.

The chemistry of the minerals characteristically reflects the differentiation development of the above rock series. Minerals of the differentiation series can be classified to:

1. The early magmatic crystallization

- Olivine phenocrysts (Fo_{66-76}), melilite, Ti-magnetite and (Ti,Fe^{3+})-diopside to fassaite in the mafic rocks,
- (Mn,Ti)-magnetite, diopside and high-temperature K-oligoclase (cores to anorthoclase phenocrysts) characterise the felsic rocks.

2. The continuous to late magmatic crystallization

- Kaersutite phenocrysts, nepheline at temperatures < 700°C (together with melilite in ijolite pegmatoidal segregations) and crystallization of labradorite-andesite series are characteristic of the mafic rocks,
- Andesine, sometimes with K-andesine to K-oligoclase rims and problematic olivine in tephritic rock (Fo_{49-52}) are typical of transitional types;
- Mn-magnesioriebeckite, Mn-winchite, Mg-biotites and anorthoclase perthite (occasionally with K-oligoclase cores and/or Na-sanidine rims) represent the felsic rocks; Na-sanidine and quartz in the matrix of the felsic rocks terminate the crystallization.

3. Late magmatic to postmagmatic crystallization

- Analcimes replacing plagioclases and nepheline, carbonates of calcite-rhodochrosite series and barite are products of the late magmatic stage in the mafic rocks,
- The presence of Mn-oxyhydroxide, nontronite, rare sulphur and organic matter in the felsic rocks reflects the postmagmatic stage.

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References

Balogh, K. (1985): K/Ar dating of Neogene volcanic activity in Hungary. Experimental technique, experiences and methods of chronologic studies, 277-278. ATOMKI Rep. D/1, Debrecen.

Barth, T. F.W. (1969): Feldspars. Wiley Interscience, New York.

Behr, H. (1992): Lineare Krustenstrukturen im Umfeld der KTB lokation. In: KTB Report, 92-3, 3-82. Hannover.

CAJZ, V. (1992): Volcanic history of Podhorní vrch Hill (Western Bohemia). Čas. Mineral. Geol., **37**, 63-64 (in Czech).

CAJZ, V., VOKURKA, K., BALOGH, K., LANG M., ULRYCH, J. (1999): The České středohoří Mts.: Volcanostratigraphy and geochemistry. Geolines, **9**, 21-28.

CARMICHAEL, I. S. E. (1963): The crystallization of feldspar in volcanic acid liquids. Quat. J. Royal Soc., **119**, 95-131.

DOLLASE, W. A., THOMAS, W. M. (1978): The crystal chemistry of silica rich alkali-deficient nepheline. Contrib. Mineral. Petrol., **66**, 311-318.

DONNAY, G., SCHAIRER, J.F., DONNAY, J. D. H. (1959): Nepheline solid solutions. Mineral. Mag., **32**, 93-109.

DOWNES, H. (1989): Magma mixing in undersaturated alkaline volcanics, Cantal, Massif Central, France. Mineral. Mag., **53**, 43-53.

DOWNES, H. (1996): Neogene magmatism and tectonics in the Carpatho-Pannonian region. Mitt. Gesell. Geol.-Bergbaustud. Österr., **41**, 104. In: Decker L. (ed.): Pancardi Workshop 1996, Wien.

FEDIUK, F. (1995): Volcanics of Zbraslavský vrch Hill between the towns Manětín and Toužim (W Bohemia). Zpr. geol. Výzk. 1994, 48-50 (in Czech).

FOLAND, K. A., LANDOLL, J. D., HENDERSON, C. M. B., JIANFENG, C. (1993): Formation of cogenetic quartz and nepheline syenites. Geochim. Cosmochim. Acta, **57**, 697-704.

HAMILTON, D. L. (1961): Nephelines as crystallization temperatures indicators. J. Geol., **69**, 321-329.

HOERNLE, K., ZHANG, Y., GRAHAM, D. (1995): Seismic and geochemical evidence for large-scale mantle upwelling beneath the Eastern Atlantic and Western and Central Europe. Nature, **374**, 34-39.

HUCKENHOLZ, H. G., BÜCHEL, G. (1988): Tertiärer Vulkanismus der Hocheifel. - Exkursionsführer 66 Jahrestagung der DMN in Bonn. Fortschr. Mineral, **66**, 43-82.

KACHLÍK, V., 1993: The evidence for Late Variscan nappe thrusting of the Mariánské Lázně Complex on the Saxothuringian terrane (W Bohemia). Čas. Mineral. Geol., **38**, 43-58.

KOPECKÝ, L. (1978): Neoidic taphrogenic evolution of young alkaline volcanism of the Bohemian Massif. Sbor. Geol. Věd., Ř. Geol., **30**, 91-107.

LE MAITRE, R.W. (ed.) (1989): A Classification of Igneous Rocks and Glossary of Terms. Blackwell Sci. Publ., Oxford.

LEAKE, B. E. (ed.) (1978): Nomenclature of amphiboles. Mineral. Mag., **42**, 533-565.

LIPPOLT, H. (1983): Distribution of volcanic activity in space and time. In Fuchs, K. (ed.): Plateau Uplift, 112-120. Springer, Berlin.

MELKA, K., ULRYCH, J., NOVÁK, J. K., LANGROVÁ, A. (2001): Nontronite from Špičák Hill near Teplá: product of the late magmatic alteration of trachyte. Abstract. Mid-European Clay Conference, Sept. 9-14, 2001, Stará Lesná, Slovakia.

MILANI, L., BECCALUVA, L., COLTORTI, M. (1999): Petrogenesis and evolution of the Euganean Magmatic Complex, Veneto Region, North-East Italy. Eur. J. Mineral., **11**, 379-399.

MORIMOTO, M. (ed.) (1988): Nomenclature of pyroxenes. Mineral Mag., **52**, 535-550.

NEKVASIL, H. (1990): Reaction relations in the granite system: implications for trachytic and syenitic magmas. Amer. Mineralogist, **75**, 560-571.

NEKVASIL, H. (1992): Ternary feldspar crystallization in high temperature felsic magmas. Amer. Mineralogist, **77**, 592-604.

ODIN, G. S. et 35 collaborators (1982): Interlaboratory standards for dating purposes. In: Odin G. S. (ed.): Numerical Dating in Stratigraphy, 123-150. Wiley and Sons, Chichester.

PECERILLO, A., TAYLOR, S. R. (1976): Geochemistry of Eocene calc-alkaline volcanic rocks from the Kastomonu area, northern Turkey. Contrib. Mineral. Petrol., **58**, 68-81.

PIVEC, E., ULRYCH, J., HÖHNDORF, A., RUTŠEK, J. (1998): Melilitic rocks from northern Bohemia: Geochemistry and mineralogy. N. Jb. Mineral., Abh., 312-339.

PIVEC, E., ULRYCH, J., ÁRVA-SÓS, E., NEKOVAŘÍK, Č. (in press): Weakly alkaline trachybasalt-rhyolite series from the Teplá Highland, Western Bohemia: geochemical constraints. Geologica Bavarica, 25 pp.

SCHREIBER, U., ANDERS, D., KOPPEN, J. (1999): Mixing and chemical interdiffusion of trachytic and latitic magma in a subvolcanic complex of the Tertiary Westerwald (Germany). Lithos, **46**, 695-714.

SHRBENÝ, O. (1979): Geochemistry of the West Bohemian neovolcanites. Čas. Mineral. Geol., **24**, 9-21.

SVOBODOVÁ, J., ULRYCH, J. (in press): Alkaline rocks with carbonatite affinity in the Bohemian Massif, Czech Republic. – Proc. Symp. Carbonatite Assoc. Rocks, 12-18 February 2001, Chennai, India, 25 pp.

ULRYCH, J., KAŠPAR, P. (1977): Relation of microhardness to the structure of monoclinic pyroxenes and amphiboles. Acta Univ Carol., Geol., Kratochvíl Vol., 13-19.

ULRYCH, J. (1978): Magnesioarfvedsonite from fenites near Hůrky in the Čistá Massif (West Bohemia). Čas. Mineral. Geol., **23**, 67-70.

ULRYCH, J. (1986): Oxykaersutite from Vlčí hora Hill in western Bohemia in comparison with kaersutites of the Bohemian Massif. Sbor. Západočes. Muz., Odd. Přír., 1-46 (in Czech).

ULRYCH, J., KOPECKÝ, L., KROPÁČEK, V. (eds.) (1991): Guide to post-symposium excursion: Neoidic volcanism of the Bohemian Massif. SCEAVR Meeting, 1991, Prague.

ULRYCH, J., PIVEC, E., POVONDRA, P. (1997): Sulphur and Mn-oxyhydroxides from trachyte of Špičák Hill near Teplá. Bull. min. petr. odd. Nár. Mus. v Praze, **4-5**, 210-212 (in Czech).

ULRYCH, J., PIVEC, E., LANG, M., BALOGH, K., KROPÁČEK, V. (1999): Cenozoic intraplate volcanic rock series of the Bohemian Massif: a review. Geolines, **9**, 123-129.

ULRYCH, J., CAJZ, V., PIVEC, E., NOVÁK, J. K. ULRYCH J., NEKOVAŘÍK, Č. (2000a): Cenozoic intraplate alkaline volcanism of western Bohemia. Stud. geoph. geod., **44**, 346-351.

ULRYCH, J., PIVEC, E., HÖHNDORF, A., BALOGH, K., BENDL, J., RUTŠEK, J. (2000b): Rhyolites from the Roztoky Intrusive Centre, České středohoří Mts.: xenoliths or dyke differentiates? Chem. Erde, **60**, 327-352.

ULRYCH, J., PIVEC, E., LANG, M., LLOYD, F. E. (2000c): Ijolitic segregations in melilite nephelinite of Podhorní vrch volcano, Western Bohemia. N. Jb. Mineral., Abh., **175**, 317-348.

ULRYCH, J., BALOGH, K., CAJZ, V., NOVÁK, J. K., FRÁNA, J. (in press a): Cenozoic alkaline volcanic series in W Bohemia: age relations and geochemical constraints. Acta Montana, Ser. A Geodynamics, 20 pp.

ULRYCH, J., ŠTĚPÁNKOVÁ, J., LLOYD, F. E.' BALOGH, K. (in press b): Coexisting Miocene alkaline volcanic series associated with the Cheb-Domažlice Graben, W Bohemia: geochemical characteristics. Geologica Carpathica, 25 pp.

VIETEN, K. (1965): Mangan-reicher Fluortaramit aus dem Alkalitrachyt der Hohenburg bei Berkum (Siebengebirge). N. Jb. Mineral., Mh., 166-171.

VIETEN, K. (1979): The minerals of the volcanic rocks association of the Siebengebirge I. Clinopropyroxenes. 1. Variation of chemical composition of Ca-rich clinopyroxenes (salites) in dependence of the degree of magma differentiation. N. Jb. Miner., Abh., **135**, 270-286.

VIETEN, K. (1980): The minerals of volcanic rocks association of the Siebengebirge. I. Clinopyroxenes. 2. Variation of chemical compositions of Ca-rich clinopyroxenes (salites) in the course of crystallization. N. Jb. Miner., Abh., **140**, 54-88.

VIETEN, K., HAMM, M., GRIMMEISEN, W. (1988): Tertiärer Vulkanismus des Siebengebirges Exkursionsführer 66. Jahrestagung der DMN in Bonn. Fortschr. Mineral., **66**, 1-42.

VRÁNA, S. (2000): New occurrences of trachyte near Teplá in western Bohemia. Zpr. geol. Výzk. v roce 1999, 84-85 (in Czech).

WAGNER, G. A., GÖGEN, K., JONCKHEERE, R., KÄMPF, H., WAGNER, I., WODA, C. (1998): The age of Quaternatry volcanoes Železná hůrka and Komorní hůrka (Western Eger Rift), Czech Republic: alpha-recoil track, TL, ESR and fission track chronometry. In: Magma and Rift Basin Evolution Excursion Guide, Abstracts, Czech Rep., Liblice, Sept. 7-11, 1998, 95-96, Czech Geol. Survey, Prague.

WILKINSON, J. F. G., HENSEL, H. D. (1994): Nephelines and analcimes in some alkaline igneous rocks. Contrib. Mineral. Petrol., **118**, 79-91.

WILSON, M., DOWNES, H., CEBRIA, J. M. (1995): Contrasting fractionation trends in coexisting continental alkaline magma series, Cantal, Massif Central, France. J. Petrology, **36**, 1729-1750.

WILSON, M., ROSENBAUM, J. M., ULRYCH, J. (1994): Cenozoic magmatism of the Ohře Rift, Czech Republic: geochemical signatures and mantle dynamics. Abstracts IAVCEI, Ankara.

WIMMENAUER, W. (1974): The alkaline province of Central Europe and France. In: Sørensen H. (ed.): The Alkaline Rocks, 286-291. Wiley and Sons, London.

WOHNIG, K. (1904): Trachytische und andesitische Ergussgesteine vom Tepler Hochland. Arch. naturwiss. Landesdurchforsch. Böhmen, **13**, 1, 1-43.

YODER, H. S. JR., 1973: Melilite stability and paragenesis. – Fortschr. Mineral., **50**, 140-173.

ZARTNER, W. R. (1939): Tonvorkommen am Fuße des Wolfsberges westlich von Tschernoschin (Sudetengau). Firgenwald, **12**, 20-23.

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