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JARMILA KUDĚLÁSKOVÁ*

PETROLOGY AND GEOCHEMISTRY OF SELECTED ROCK TYPES OF TESCHENITE ASSOCIATION, OUTER WESTERN CARPATHIANS

(Figs. 18, Tabs. 9)

Abstract: Picrites, monchiquites, fourchites, ouachitites, teschenites s.s. and teschenite clinopyroxenites are the representatives of major effusive and hypabyssal rock types of teschenite association of Silesian unit of the Western Carpathians flysch belt. They belong to basic even ultrabasic unsaturated rocks of alkaline series. We presented their petrological, mineralogical (giving the compositions of olivine, clinopyroxene, amphibole and K-feldspar) as well as geochemical (distribution of trace elements, transition metals and REE) characteristic. Chemical trend of the rocks suggests fractional crystallization of original magma of mantle genesis and assimilation of continental crust material.

Резюме: Пикриты, мончикиты, фурчиты, уачититы, тешениты в узком смысле слова и тешенитовые клинопироксениты представляют главные типы эффузивных и гипабисальных пород тешенитовой асоциации силезийской единицы флишевой зоны Западных Карпат. Они относятся к основным и ультраосновным ненасыщенным породам щелочной серии. Они характеризованы петрологически, минералогически, приводя химические составы оливина, клинопироксена, роговой обманки и К-полевого шпата, а также геохимически (распределение редких элементов, переходных металлов и р.з.э.). Химическая тенденция пород намечает процессы фракционной кристаллизации первоначальной магмы мантийного происхождения и ассимиляцию материала континентальной коры.

Introduction

Igneous rocks of teschenite association occur in the sub-Beskydes region of NE Moravia. They form two major arched belts with SW-NE orientation passing from Hranice na Moravě through Český Těšín to Bialsko in Poland.

They are distributed in the Těšín-Hradiště formation (Valanginian—Lower Aptian) Cretaceous sediments of Silesian unit of the Western Carpathians flysch belt (Fig. 1) where they form a complex of hypabyssal bedded veins, effusives-pillow lavas, amygdaloidal and pyroclastic rocks. This is a typical region of the appearance of teschenite association rocks with locus typicus (Teschen = Těšín, Hohenneger, 1981; picrite — Tschermak, 1986).

Their study attracted the attention of a number of authors. From petrographical and mineralogical standpoints they were studied in detail by Klvaňa (1897), Pacák (1926), Smulikowski (1929, 1980), Šmíd (1961—1966, 1978) and Mandour (1981).

At present bodies of the rocks under study can be found separated from their root zones. Their geochemical character may also contribute to the explanation of some so far unknown evolutional relations of their petrogenetic cycle. Our paper thus brings besides petrographical characteristics also new data on che-

* RNDr. J. Kudělásková, Department of Geology and Paleontology, Faculty of Natural Sciences, J. E. Purkyně University, Kotlářská 2, 611 37 Brno.

mical composition of major rock types of teschenite association — picrite, monchiquite, fourchite, ouachitite, teschenite s.s. and teschenite clinopyroxenite.

Rock forming minerals

Olivine

Most often in occurs in picrites (20—35 vol. %), less in monchiquite s.s. (5——10 vol. %), and fourchite, ouachitite, teschenite s.s. and teschenite clinopyroxenite miss it.

Olivine occurs in the form of yellow-green phenocrysts in 0.04—10 mm size which are altered along the margins and transverse fissures where minerals of chlorite, serpentine, antophyllite, and carbonate groups are generated. Their margins are formed by segregated fine grains of metallic mineral — most often magnetite. Often the alteration is so strong that pseudomorphs of olivines

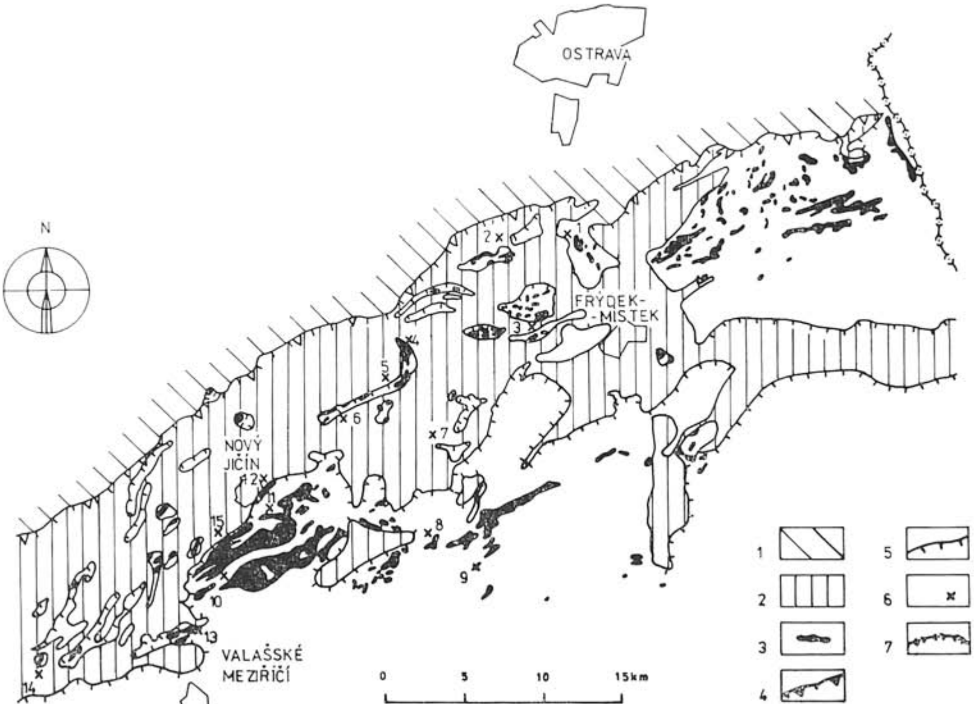

Fig. 1. Survey map of the outcrops of the rocks of teschenite association, adapted according to Matýsek (1984). Localization of the samples.

Notes: 1. Carpathian fore-deep; 2. Sub-Silesian nappe; 3. Silesian nappe with the bodies of the rocks of teschenite association; 4. Sub-Silesian front; 5. Silesian front; 6. localization. *Localities:* 1 — Paskov; 2 — Krmelín; 3 — Staříč; 4 — Hončova Hůrka 5 — Skotnice; 6 — Libhošť; 7 — Lubno, state border; 8 — Tichá; 9 — Frenštát p. Radh.; 10 — Stráník; 11 — Žilina u N. Jičína; 12 — Čertův Mlýn, 13 — Jasenice; 14 — Zámrsk; 15 — Kojetín u N. Jičína.

Table 1

Chemical composition of olivine

Sample	43	43	102	102
grain	1	1	1	1
point	1 rim	2 core	1 core	2 rim
SiO_2	40.31	40.45	40.02	40.42
TiO_2	—	—	—	—
Al_2O_3	0.10	0.15	0.12	0.15
FeO	12.45	12.32	12.30	12.95
MnO	0.22	0.23	0.20	0.26
MgO	45.94	45.83	46.20	45.85
CaO	0.18	0.27	0.15	0.18
Total	99.20	99.25	98.99	98,81
	ions calculated on 4 oxygens			
Si	1.007	1.009	1.002	1.006
Al	0.003	0.004	0.004	0.004
Fe	0.260	0.257	0.258	2.269
Mn	0.005	0.005	0.004	0.005
Mg	1.711	1.705	1.724	1.701
Ca	0.005	0.007	0.004	0.005
total	2.99	2.99	2.99	2.99
Mg	86.80	86.90	87.0	86.35
Fe^{2+}	13.20	13.10	13.0	13.65

Sample No. 43 – granular picrite, Hončova Hůrka; sample No. 102 – granular picrite, Žilina u N. Jičína.
Chemical analyses of silicate minerals (Tabs. 1—6) were performed by electron microprobe ARL-SEMQ in the laboratories of the Central Geological Institute, Prague.

are completely filled with a mixture of secondary materials. Along the margins phenocrysts are usually ragged and replaced by irregularly limited clinopyroxene grains.

Olivine chemical composition was investigated by electrone microprobe (spot analysis method) in picrite from the Hončova Hůrka and Žilina u N. Jičína localities. The analysis (Tab. 1) enables to characterize olivine as strongly magnesian with prevailing forsterite component (Mg = 86.35 — 87.00 atom. %). Olivine zonality is slight; Fe^{2+} content is a little elevated in grain rims.

Clinopyroxenes

They appear to be the most considerable group of mafic minerals in teschenite association rocks and are represented by diopside, titan-augite and aegirite. They occur in all studied types in varying amounts, the most (up to 60 vol. %) in teschenite clinopyroxenite.

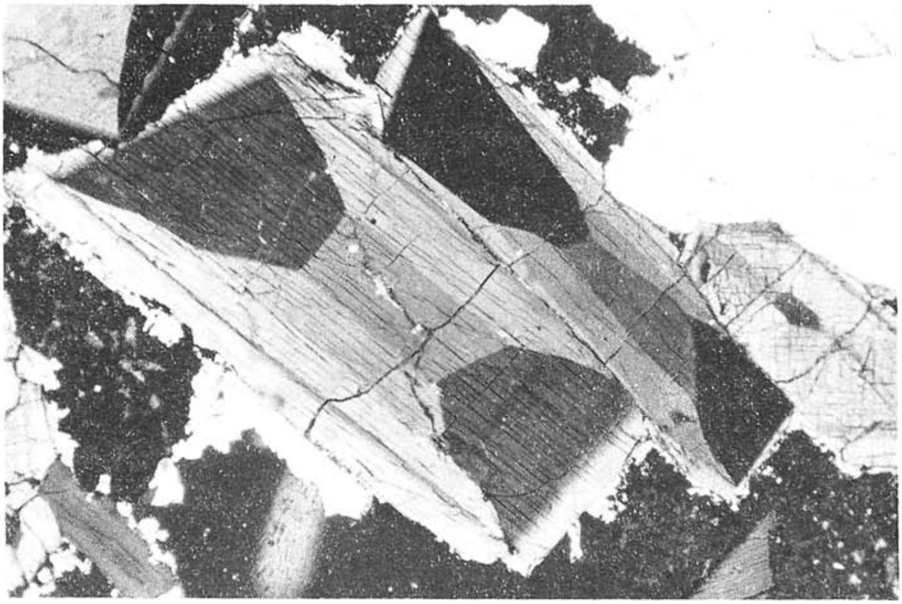

Fig. 2. Magnified 50 x with analyzer. Locality: Čertův Mlýn u N. Jičína; zonal structure and hourglass texture in titan-augites of teschenite clinopyroxenite.

Diopside is light yellow-green, non-pleochroic, $\gamma/z = 42°$, $2V = 62°$. It is euhedral in short prismatic sections. Some grains form twinned intercalated lamellae. Magmatic corrosion is apparent by rounding edges and forming lobate shapes. It is usually enclosed in the form of relics in titan-augite phenocrysts.

Titan-augite is present in two generations — euhedral even subhedral basaltiform phenocrysts (maximum size 10 mm) or fine prismatic shapes in matrix, from microlites up to 2 mm. Sections according to 001 can also be often seen. At a microscopical look it appears grey-pink to deep violet with slight pleochroism, $2V = 47—50°$, in zonal titan-augite rims 55° and cores 47°. The phenocrysts show zonality, hourglass structure is frequent (Fig. 2). Along the margins and fissures there are generated microcrystalline fibres and lamellae of chlorite.

Clinopyroxenes from aegirite — aegirite-augite series, greenyellow to deep green in thin section, show strong pleochroism, $\gamma/z = 4°$. In their matrix they occur in isolated thin basaltiform even spicular forms, however, mostly they form local hems on diopside, titan-augite and amphibole grains. They were less affected with chloritization than the other clinopyroxenes.

The results of spot analyses (Tab. 2) suggest varying chemical composition depending on varying magma composition. In sample No. 37 (teschenite clinopyroxenite) the analysis intercepts the core of a grain belonging to diopside and the rim corresponding to titan-augite. In sample No. 44 (monchiquite) as well varying chemical composition is obvious in the profile of a grain with aegirite-augite rim. Titan-augite zonality is in chemical composition suggested by decreasing SiO_2, MgO from core to rim and increasing Al_2O_3, TiO_2, FeO, MnO and Na_2O.

Amphibole

Amphibole represents the second group of mafic minerals as for the frequency of occurrence. It occurs in the forms of euhedral to subhedral phenocrysts (maximum size 6 mm) (Fig. 3) and fine columns even microlites in the groundmass. Also twinnings according to (100) can often be seen. In thin section it is red-brown, strongly pleochroic, $\gamma/z = 10—20°$. It is not as much altered as clinopyroxenes, and if altered, chlorite and titanite are evolved. It closes the relics of olivine, clinopyroxene, apatite and metallic minerals, overgrows clinopyroxene phenocrysts and often corrodes them.

Chemical composition of the analyzed amphiboles corresponds to that of kaersutite (Tab. 3), TiO_2 content reaches up to 6.70 wt. %. Chemical zonality can be seen in Mg and Fe contents; grain cores are richer in Mg and to rim Fe is increasing.

Biotites

Biotite occurs in varying contents. In picrites it is missing, or its content ranges below 3 vol. %, and the highest amounts of it can be found in ouachitite (up to 40 vol. %) for which it is the characteristic mineral. It forms leaves (0.2—3 mm) of red-brown colour having strong fissility and pleochroism. It also occurs in slab-like sections according to 001 which create clusters of several mm size. Being the youngest mafic mineral it was not affected too much by chloritization. Chloritized biotites have the shape of fibrous aggregates. Usually it closes grains of clinopyroxenes, amphibole, apatite and metallic material.

On the basis of chemical analyses (taken from the paper by Mandour, 1981) and their estimation titanic biotite (samples T_2, F_3) and siderophyllite which ion ratios of the sample S_7 structural formula correspond to. Compared to the other mafic silicates in teschenite association rocks the biotites under study show the highest Ti contents — up to 7.50 wt. %.

Feldspars

Plagioclases represent the highly metamorphosed minerals in the rocks under study. They occur only in small relics polysynthetically lamellated. High degree of analcimization, zeolitization, prehnitization and carbonatization made precise optical identification difficult. In teschenites from the Paskov locality, sample No. 13, basicity of An_{44} was measured using Fjodorov test.

K-feldspars are only slightly altered. They occur in slab-like and bar-like shapes with maximum size 5 mm. The bars are radially or fan-wise arranged (Fig. 9). Often Carlsbad coalesces can be found. The values $2V = 24—39°$ correspond to sanidine up to natrosanidine. They close the grains of clinopyroxene, amphibole and metallic minerals.

Table 2

Chemical composition of clinopyroxenes

Sample	43	43	43	43	37	37
grain	1	2	3	4	1	1
point	1	1	1	1	1 rim	2 core
mineral	diopside	diopside	diopside	diopside	Ti-augite	diopside
SiO_2	50.57	49.12	49.29	49.79	43.66	50.65
TiO_2	1.63	1.62	1.75	1.65	3.71	1.93
Al_2O_3	6.85	6.75	6.88	6.95	11.09	4.26
Cr_2O_3	—	0.10	—	—	0.04	0.08
FeO	5.59	5.43	5.30	5.43	6.59	5.35
MnO	0.07	0.13	0.16	0.12	0.11	0.06
MgO	12.86	13.12	13.01	12.88	11.60	14.80
CaO	23.20	21.26	21.50	21.82	21.80	23.20
Na_2O	0.22	0.67	0.55	0.09	0.30	0.27
Total	100.99	98.20	98.44	98.73	98.90	100.60
ions calculated on 6 oxygens						
Si	1.844	1.897	1.839	1.850	1.647	1.858
Al^{IV}	0.156	0.163	0.161	0.150	0.353	0.142
Al^{VI}	0.138	0.134	0.142	0.154	0.139	0.042
Cr	—	0.004	—	—	0.002	0.004
Ti	0.042	0.046	0.047	0.044	0.105	0.053
Fe	0.171	0.170	0.165	0.169	0.208	0.164
Mn	0.002	0.004	0.005	0.004	0.004	0.002
Mg	0.660	0.731	0.724	0.713	0.652	0.809
Ca	0.906	0.852	0.860	0.868	0.881	0.912
Na	0.015	0.048	0.040	0.007	0.022	0.020
Total	3.93	3.99	3.98	3.96	4.01	4.00
Fe	9.84	9.70	9.43	9.66	11.95	8.70
Mg	38.00	41.70	41.40	40.74	37.45	42.92
Ca	52.16	48.60	49.17	49.60	50.60	48.23

On the basis of spot analyses (Tab. 5) K-feldspar bars show chemical zoning. In the centre of bars albite content does not reach more than 1.98 mol. % and anortite is missing at all (very pure sanidine). The margins contain up to 30.39 mol. % of albite component, that of anortite represents 1.19 mol. % (natrosanidine). K-feldspar zoning documents rapid changing of magma chemical composition.

Continuation of Tab. 2

Sample	37	48	48	48	48	48
grain	1	3	3	3	3	5
point	rim 3	rim 1	core 4	rim 9	rim 10	rim. 2
mineral	Ti-aug.	Ti-aug.	Ti-aug.	Ti-aug.	aegiri-teaug.	aegiri-teaug.
SiO_2	46.15	41.34	44.46	43.56	49.78	49.58
TiO_2	3.62	4.11	4.12	4.59	0.88	0.84
Al_2O_3	7.27	11.20	8.02	9.26	10.51	11.40
Cr_2O_3	—	—	0.19	—	—	—
FeO	6.60	11.94	6.50	7.49	11.25	10.66
MnO	0.09	0.30	0.07	0.16	1.12	1.15
MgO	12.57	10.00	12.40	11.15	3.33	3.38
CaO	23.00	20.63	22.44	22.34	20.18	20.50
Na_2O	0.32	0.48	0.25	0.39	2.10	2.28
K_2O	—	—	—	—	0.26	0.25
Total	99.62	100.00	98.45	98.94	99.41	100.04

wt. % of the analysis calculated on 100 %

ions calculated on 6 oxygens

Si	1.734	1.589	1.694	1.660	1.884	1.861
Al^{IV}	0.266	0.411	0.306	0.340	0.116	0.139
Al^{VI}	0.056	0.096	0.054	0.076	0.353	0.365
Cr	—	—	0.006	—	—	—
Ti	0.097	0.113	0.110	0.125	0.025	0.024
Fe	0.208	0.384	0.207	0.239	0.356	0.335
Mn	0.003	0.010	0.002	0.005	0.036	0.037
Mg	0.740	0.573	0.704	0.634	0.187	0.189
Ca	0.926	0.850	0.916	0.912	0.818	0.824
Na	0.023	0.036	0.009	0.029	0.154	0.166
K	—	—	—	—	0.013	0.012
Total	4.05	4.06	4.01	4.02	3.94	3.96
Fe	11.10	21.25	11.33	13.39		
Mg	39.49	31.71	38.53	35.52		
Ca	49.68	47.04	50.14	51.09		

Sample No. 43 — granular picrite, Hončova Hůrka; sample No. 37 — teschenite clinopyroxenite, Čertův Mlýn u N. Jičína; sample No. 48 — monchiquite, Čertův Mlýn (Mandour, 1981).

Analcime

It occurs as a constituent of matrix as well as the product of K-feldspar alteration. In picrites with amygdaloidal structure together with carbonate, chlorite and zeolites it fills amygdales. In teschenite together with calcite it forms fissure fillings and has a typical system of crystallization.

Table 3

Chemical composition of amphibole

Sample	23	23	101	101	13A	13A
grain	1	1	1	2	1	1
point	1 rim	2 core	1 rim	1 core	1 core	2 rim
mineral	kaersut.	kaersut.	kaersut.	kaersut.	kaersut.	kaersut.
SiO_2	39.08	39.07	37.66	34.94	38.50	38.89
TiO_2	6.70	6.64	4.30	5.14	5.54	5.84
Al_2O_3	13.54	13.10	14.88	14.98	13.61	13.49
Cr_2O_3	—	—	0.09	0.08	—	—
FeO	9.85	9.52	15.99	15.78	13.55	14.38
MnO	0.18	0.10	0.37	0.19	0.25	0.26
MgO	12.74	13.51	9.25	9.98	10.37	9.54
CaO	12.26	12.44	12.89	13.98	12.04	11.44
Na_2O	2.52	2.45	1.75	1.80	2.54	2.64
K_2O	1.32	1.26	1.18	1.28	1.68	1.57
Total	98.12	98.09	98.36	98.15	98.08	98.05
	ions calculated on 24 oxygens					
Si	5.806	5.793	5.740	5.372	5.809	5.878
Al^{IV}	2.194	2.207	2.260	2.628	2.191	2.122
Al^{VI}	0.177	0.083	0.412	0.083	0.253	0.281
Cr	—	—	0.016	0.015	—	—
Ti	0.713	0.705	0.493	0.527	0.598	0.632
Fe	1.224	1.185	2.039	2.027	1.710	1.817
Mn	0.022	0.012	0.047	0.025	0.032	0.034
Mg	2.821	2.986	2.102	2.285	2.332	2.150
Ca	1.951	1.976	2.105	2.301	1.947	1.853
Na	0.727	0.704	0.516	0.535	0.743	0.774
K	0.250	0.239	0.230	0.250	0.323	0.303
theoret. (OH)	1.799	1.889	1.670	1.900	1.932	1.965
Total	18.59	17.78	17.63	18.01	17.87	17.81

Sample Nos. 23 — granular picrite, Staříč; 101 — porphyric picrite, Žilina u N. Jičína; 13 A — teschenite s.s., Paskov.

Optically it is pure or grey-dimmed without outer limitation, isotropic to slightly anisotropic. Often it is affected by carbonization. Its origin has been so far discussed. Obviously it belongs, together with calcite and zeolites, to the latest components of the mineral succession in teschenite association rocks.

Chemical analysis of crystalline analcime from Řepiště and the spot one of analcime from teschenite of the Bludovice locality are presented in Tab. 6.

Continuation of Tab. 3

Sample	32M	F5	44
grain	3	1	1
point	1	1	1
mineral	kaersut.	kaersut.	kaersut.
SiO_2	39.66	38.90	38.35
TiO_2	5.53	5.89	5.38
Al_2O_3	12.90	12.06	13.61
Cr_2O_3	—	0.05	0.04
FeO	13.05	11.97	10.84
MnO	0.22	0.25	0.18
MgO	10.95	14.64	13.48
CaO	12.17	10.05	11.67
Na_2O	2.39	2.69	2.81
K_2O	1.33	1.59	1.70
Total	98.20	98.09	98.06
	ions calculated on 24 oxygens		
Si	5.946	5.808	5.716
Al^{IV}	2.054	2.122	2.284
Al^{VI}	0.225	—	0.107
Cr	—	0.009	0.007
Ti	0.623	0.652	0.603
Fe	1.637	1.494	1.351
Mn	0.028	0.031	0.022
Mg	2.447	3.257	2.995
Ca	1.955	1.607	1.864
Na	0.695	0.779	0.811
K	0.254	0.303	0.322
theoret. (OH)	1.800	1.903	1.930
Total	17.66	17.96	18.01

Sample Nos. 32M — analcime teschenite, Horní Bludovice; F5 — fourchite, Frenštát p. Radh.; 44 — monchiquite, Čertův Mlýn u N. Jičína (analyses taken from the paper by M a n d o u r, 1981).

A p a t i t e

Most often it occurs in ouachitite (15—20 vol. %) and fourchite (7—10 vol. %) It appears in several forms, in short and long elongated euhedral columnar to spicular forms (0.05—3 mm) and in basal pseudohexagonal to isometric sections (Fig. 4). Optically it is pure, some grains have grey-dimmed cores. It closes numerous gas-liquid enclosures vertically elongated and metallic pigment.

Table 4

Chemical composition of biotites

Sample	T2	F3	S7
point	1	1	1
mineral	Ti-biotite	Ti-biotite	siderophyllite
SiO_2	36.70	34.70	33.96
TiO_2	7.50	7.40	3.91
Al_2O_3	15.02	14.80	14.90
FeO	12.80	11.90	30.97
MnO	0.10	0.15	0.61
MgO	16.98	18.82	3.84
CaO	0.44	0.71	—
Na_2O	0.70	1.05	0.43
K_2O	7.60	7.50	8.61
Total	97.84	97.03	97.23
	ions calculated on 24 oxygens		
Si	5.487	5.163	5.529
Al^{IV}	2.513	2.596	2.471
Ti	—	0.241	—
Al^{VI}	0.133	—	0.387
Ti	0.843	0.587	0.478
Fe	1.601	1.480	4.216
Mn	0.013	0.019	0.084
Mg	3.783	4.174	0.932
Ca	0.070	0.114	—
Na	0.203	0.302	0.135
K	1.450	1.423	1.788
theoret. (OH)	2.160	2.950	3.010
Total	18.25	19.05	19.03

Sample Nos. T2 — ouachitite, Tichá (Mandour, 1981); F3 — fourchite, Frenštát p. Radh. (Mandour, 1981); S7 — teschenite s.s., Staříč (Mandour, 1981).

Some grains were corroded and the evolved interstices were later filled with clinopyroxenes or amphibole.

Accessory minerals

Titanite occurs in rhomboidal or skeletal shapes, often also elongated grains clustered into chain lines. It is evolved also during alterations of titan-augite, amphibole and biotite where it is concentrated along the rims and in the cores of chloritized grains. Its amount is increasing with metamorphic degree of the rock.

Table 5

Chemical composition of K-feldspar

Sample	64	64	64	64	13b	13b
grain	1	1	1	1	1	1
point	1 rim	2 core	3 rim	4 rim	1 rim	2 rim
mineral	K-fsp	K-fsp	K-fsp	K-fsp	K-fsp	K-fsp
SiO_2	66.52	66.06	65.35	65.36	66.16	66.50
TiO_2	0.02	—	—	0.04	—	0.15
Al_2O_3	16.90	16.70	16.98	16.76	18.11	18.16
Fe_2O_3	—	0.14	—	—	0.16	0.14
CaO	—	—	—	—	0.21	0.23
Na_2O	0.16	0.11	0.14	0.18	3.35	3.41
K_2O	16.35	16.63	15.92	16.02	11.90	11.76
Total	99.95	99.54	98.35	98.36	99.89	100.35
			ions calculated on 32 oxygens			
Si	12.266	12.260	12.228	12.247	12.062	12.055
Ti	0.007	—	—	0.006	—	0.021
Al	3.673	3.643	3.745	3.698	3.886	3.878
Fe^{3+}	—	0.007	—	—	—	0.059
Ca	—	—	—	—	0.040	0.045
Na	0.058	0.040	0.051	0.064	1.182	1.198
K	3.848	3.938	3.801	3.831	2.764	2.719
Total	19.85	19.89	19.82	19.85	19.96	19.97
Or	98.52	98.99	98.32	98.36	69.35	68.63
Ab	1.48	1.01	1.32	1.64	29.65	30.24
An	—	—	—	—	1.00	1.13

Sample Nos. 64 — analcime teschenite, Horní Bludovice (Mandour, 1981); 13b — teschenite s.s., Paskov.

Opaque minerals are present in all studied types. Along the margins magnetite is altered to red-brown transparent hematite, in square or irregular sections, the other represented mineral is skeletal illmenite. During chloritization of mafic minerals fine metallic grains are concentrated on the margins and stress their original relief.

Secondary minerals

Prehnite arises from basal plagioclases. It forms fibrous shapes and rosette aggregates. Optically it was identified in teschenite s.s. and teschenite clinopyroxenite.

Chlorite group minerals occur as a constituent of matrix or the product of olivine, clinopyroxene, amphibole and biotite alterations. It was evolved in the

Continuation of Tab. 5

Sample	13A	13A	13A
grain	1	1	1
point	1 rim	3 core	3 rim
mineral	K-fsp	K-fsp	K-fsp
SiO_2	66.74	65.85	66.74
TiO_2	—	—	—
Al_2O_3	17.72	17.38	17.92
Fe_2O_3	0.05	0.11	0.08
CaO	0.24	—	0.22
Na_2O	2.40	0.21	3.40
K_2O	12.75	15.74	11.63
Total	99.90	99.29	99.99
	ions calculated on 32 oxygens		
Si	12.161	12.196	12.121
Al	3.810	3.792	3.835
Fe^{3+}	0.007	0.015	0.011
Ca	0.046	—	0.043
Na	0.847	0.075	1.196
K	2.967	3.721	2.696
Total	19.84	19.80	19.91
Or	76.87	98.02	68.52
Ab	21.94	1.98	30.39
An	1.19	—	1.09

form of microcrystalline fibers and lamellae, scarcely in euhedral slabs up to 0.2 mm size.

Serpentine group minerals were formed as a product of olivine alteration. Fissile and transverse olivine cracks are filled with fibrous serpentine perpendicular to their margins.

Antophyllite represents another secondary mineral, occurs in the form of fan-wise even chaotically arranged fibres or clusters of spicules arising at olivine alteration as well.

Carbonates together with zeolites take part in the filling of amygdales in picrites. They are originated also at plagioclase alterations.

Zeolites are represented by natrolite, harmotome, heulandite, ferrierite (identified by X-ray diffraction method).

Petrographical characteristic

The studied teschenite association rocks — picrites, monchiquites, fourchites, ouachitites, teschenites s.s. and teschenite clinopyroxenites represent a wide

Table 6

Analcime

Sample	54	32M	32M	32M
grain		1	1	1
point	—	1 core	2 rim	3 rim
SiO_2	56.19	50.66	51.57	51.94
TiO_2	—	—	—	—
Al_2O_3	22.05	26.77	25.85	26.07
Fe_2O_3	—	0.04	0.16	—
MnO	—	—	—	0.03
CaO	0.52	1.07	0.34	0.17
Na_2O	13.11	12.98	13.43	13.58
K_2O	0.15	—	—	—
H_2O^+	8.09	—	—	—
Total	100.11	91.52	91.35	91.81
ions calculated on 7 oxygens				
Si	2.052	1.860	1.886	1.907
Ti	—	—	—	—
Al	0.949	1.158	1.123	1.128
Fe^{3+}	—	0.001	0.004	—
Mn	—	—	—	0.001
Ca	0.021	0.042	0.014	0.007
Na	0.928	0.924	0.944	0.967
K	0.007	—	—	0.001
theoret. (OH)	1.971	2.072	2.102	2.006
Total	5.93	0.06	0.07	6.02

Sample No. 54 — fissure fillings in teschenite, Řepiště (Mandour, 1981), chemical analysis.

range of rocks with variable textures, structures and also quantitative mineral abundances. Total mineral paragenesis is similar in all types: ± ol, cpx, ± hbl, ± K-fsp, ± plg, ± analc., ± ap.

Following Tröger (1969) and Smulikowski (1980) on the basis of their modal composition they were included in the groups of picrite, monchiquite and teschenite. Among particular groups there is a number transitional types.

Picrite group

Picrites are melanocratic rocks characteristic for high olivine contents (20—30 vol. %) and lack of feldspar. According to variation of structures and textures the following types were distinguished:

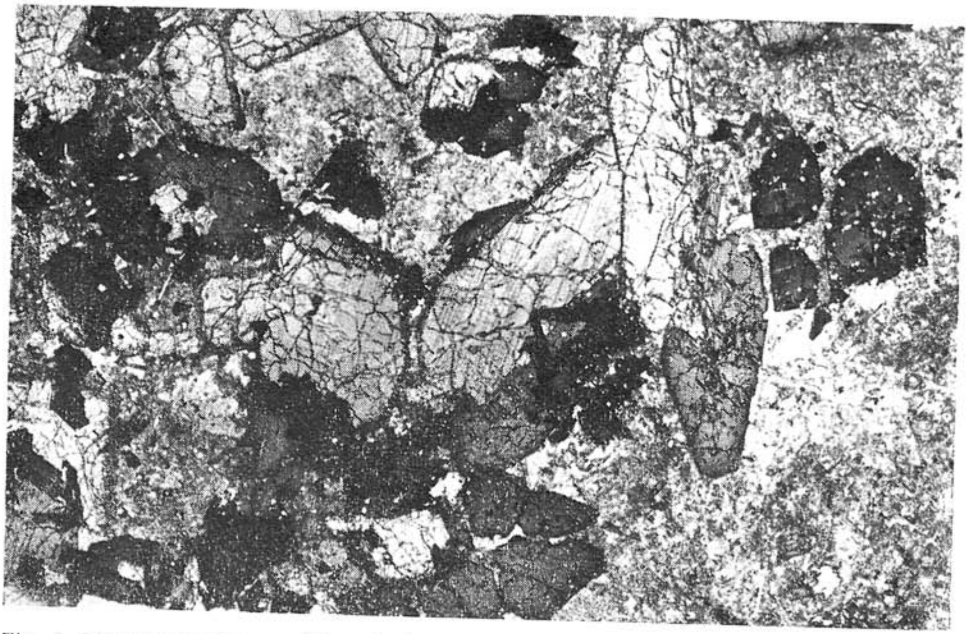

Fig. 3. Magnified 16.5 x with polarizer. Locality: Paskov; teschenite s.s. with clinopyroxene and amphibole phenocrysts.

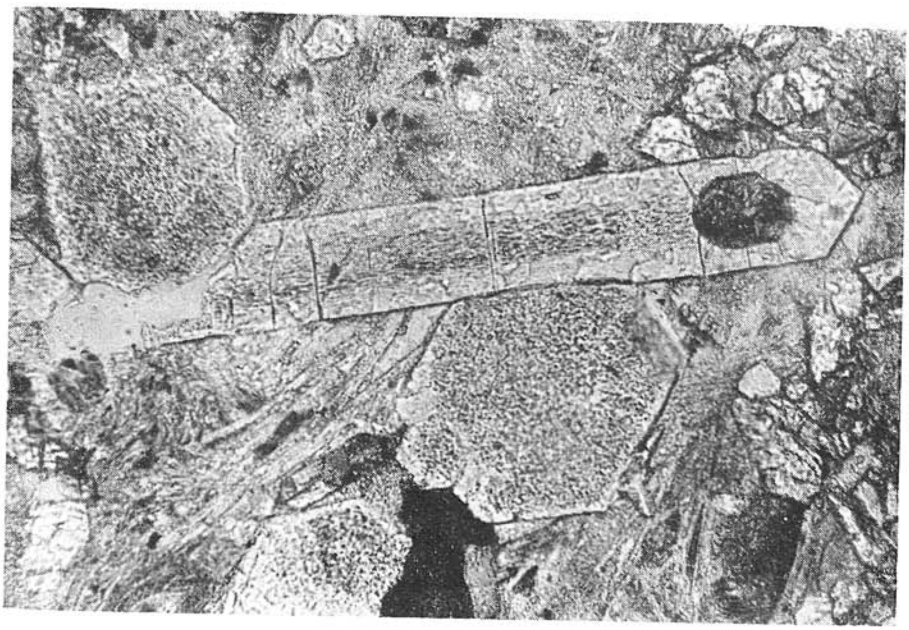

Fig. 4. Magnified 174 x with polarizer. Locality: Frenštát p. Radh.; sections of apatite with enclosures in fourchite.

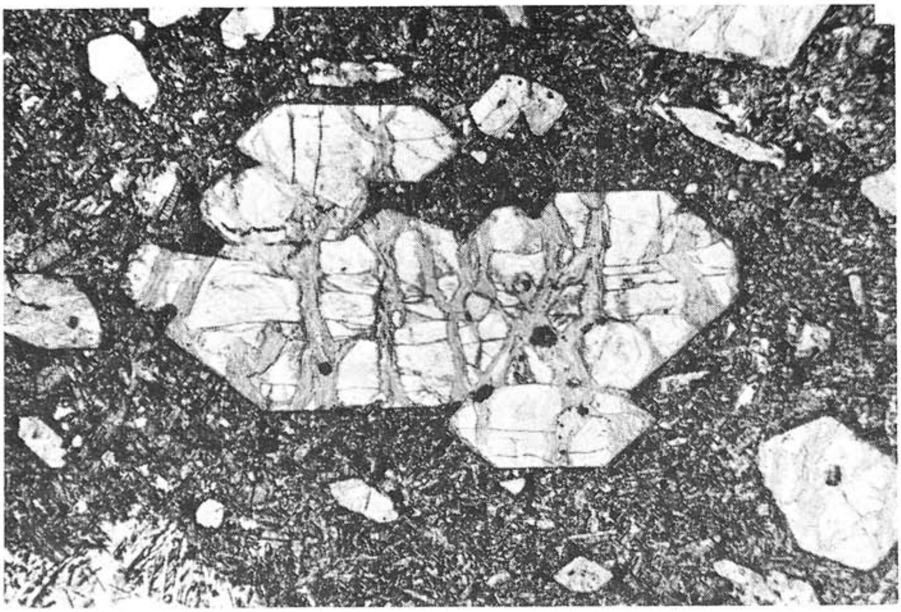

Fig. 5. Magnified 16.5 x with polarizer. Locality: Hončova Hůrka; porphyric picrite with serpentinized olivine phenocrysts.

— porphyric picrite is a compact, black-grey to green-grey rock with macroscopically visible phenocrysts of altered olivine. The texture is porphyric with hyalopilitic matrix (Fig. 5). Olivine phenocrysts with maximum size 10 mm are euhedral pseudomorphs filled with a mixture of minerals of serpentine, chlorite, carbonate and antophyllite groups. The phenocrysts contain also zonal titan-augite, slightly chloritized. The matrix is formed by little columns of titan-augite, diopside and spicular aegirite. Biotite and opaque minerals represent accessory constituents of the matrix.

In the sample from the Kojetín locality beside porphyric picrite there was founded fine-grained one with microporphyric texture. The boundary between both types is sharp without indications of gradual transition. It differs from the above mentioned type in lower olivine contents (maximum 26 vol. %) and high clinopyroxene ones in phenocrysts (up to 54 vol. %). For modal analysis see Tab. 7.

— picrite with amygdaloidal structure contains emygdales of mm rarely cm size with oval or lobate shapes. They are filled with carbonates and zeolites, in marginal parts with the minerals of chlorite and serpentine groups. They have porphyric texture with intersertal matrix. The phenocrysts consist of olivine pseudomorphs (0.5—6 mm) and clinopyroxenes (0.7—1 mm). In the matrix beside diopside, titan-augite there can be found biotite, amphibole and apatite, chlorite group minerals and volcanic glass in accessory amounts.

— granular picrite is a fine- to medium-grained rock with macroscopically visible grains of olivine clinopyroxene, amphibole and biotite lamellae. It differs from the other types of picrite group in the content of amphibole which is

Table 7
Modal analyses — a survey

Sample Nos.	44	34	47	43	23	2	27	1	4	5	45	30	7
olivine	35.72	35.00	25.55	27.40	34.10	12.50	12.40	9.60	—	—	—	—	—
cpx	43.30	43.90	54.40	12.60	26.70	44.50	35.50	42.70	18.20	25.30	15.16	20.00	57.13
amphibole	—	—	—	13.30	13.20	3.80	—	2.30	19.20	18.30	18.35	10.66	4.20
biotite	1.20	—	1.35	5.60	3.00	3.00	19.50	1.80	15.10	7.70	20.32	3.80	2.30
apatite	—	—	—	—	—	0.90	0.90	0.60	10.60	9.50	18.27	—	2.21
metallic mineral	3.80	5.80	4.73	6.45	1.00	2.80	10.20	3.20	11.00	10.00	11.80	3.83	3.63
matrix	15.48	15.30	12.00	34.67	22.00	32.50	21.50	39.80	30.90	25.60	16.30	61.71	30.53

Sample Nos. 44 — porphyric picrite, Hončova Hůrka; 34 — porphyric picrite, Staříč; 47 — microporphyric picrite, Krmelín; 43 — granular picrite, Hončova Hůrka; 23 — granular picrite, Staříč; 2, 1 — monchiquite s.s., Kojetín; 27 — monchiquite s.s., Zámrsky; 4, 5 — fourchite, Frenštát p. Radh.; 45 — ouachitite, Tichá; 30 — teschenite s.s., Paskov; 7 — teschenite clinopyroxenite, Staříč.

present in considerable amounts, up to 13 vol. %. Olivine grains (0.04—5.8 mm) with varying intensity of serpentinization are encircled by titan-augite clusters (0.02—1 mm). Bar-like to slab-like brown-red amphibole (0.2—3 mm) closes small grains of olivine and clinopyroxene. Biotite lamellae up to 5 mm size like amphibole closes small grains of the other mafic minerals. Rock texture is poikilitic (Fig. 6). For modal analysis see Tab. 7.

Monchiquite group

Following the classification by Smulikowski (1980) monchiquite group is represented by monchiquite s.s. (with olivine), fourchite (without olivine) and ouachitite (with a considerable amount of biotite, apatite and opaque mineral).

Monchiquite s.s. is a fine-grained even aphanitic rock of grey-black or green-grey colour. It differs from picrite in lower olivine content (9—12 vol. %) and the presence of feldspars in matrix.

The phenocrysts contain especially clinopyroxenes, less olivine pseudomorphs, amphibole and biotite. Green aegirite, locally overgrowing clinopyroxene grains, like amphibole is present in accessory amounts. Basic hollocrystalline mass consists of amphibole, biotite, aegirite as well as of bar-like polysynthetically lamellated plagioclases, desintegrated clinopyroxenes, minerals of chlorite, serpentine and zeolite groups. Opaque minerals are equally distributed in the whole rock. Their amounts range within 3—10 vol. %. The texture of the rock is lamprophyric, porphyric with euhedral granular hollocrystalline matrix. (Fig. 7). For modal analysis see Tab. 7.

Fourchite is a fine-grained rock of grey-black colour with macroscopically visible biotite lamellae. It differs from

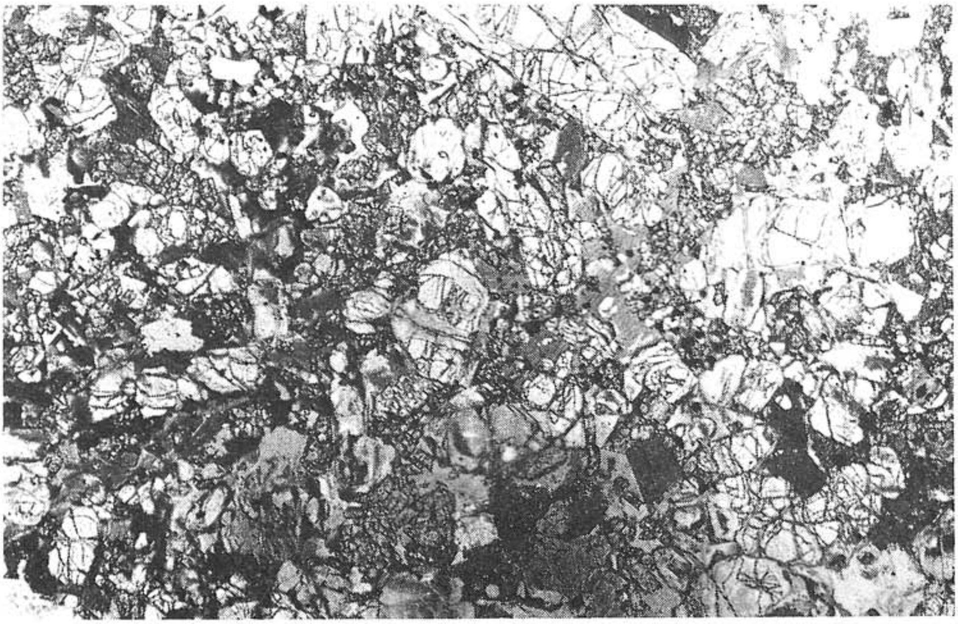

Fig. 6. Magnified 16.5 x with polarizer. Locality: Staříč — Kublův lom; granular picrite with poikilitic texture.

monchiquite in the lack of olivine and, on the contrary, higher biotite contents ·–15 vol. %).

The phenocrysts are represented by titan-augite (2 mm) which is altered to brown amphibole along the margins, then by columnar amphibole (up to 4 mm) and biotite in corroded slab-like shapes or lamellae (up to 5 mm) which like amphibole closes spicular or isometric apatite (0.02—4 mm), (Fig. 4), clinopyroxenes and opaque minerals. The phenocrysts are bound by slightly dimmed greenish matrix formed by isotropic analcime recrystallized by volcanic glass, feldspar relics, carbonate, zeolite spicules and chlorite lamellae. The texture of the rock is porphyric with hemicrystalline matrix. For modal analysis see Tab. 7.

Ouachitite is a medium-grained rock of grey-black colour, compact with macroscopically visible biotite lamellae. It is characteristic for higher apatite content (15—20 vol. %), (see Tab. 7).

The phenocrysts contain slab-like as well as columnar strongly pleochroic amphibole (maximum size 4 mm), strongly rimous, closing a considerable amount of apatite, pyroxene and analcime and metallic mineral. Brown-red biotite, partly chloritized, either forms isolated phenocrysts of intergrows with amphibole and similarly closes apatite, clinopyroxenes, analcime and metallic mineral. Clinopyroxenes in fine prismatic sections of pinkish colour, strongly chloritized are of considerable smaller sizes than the other mafites. Also aegirite of green colour is present in isolated columns or clinopyroxene hems. Apatite occurs in columnar hexagonal as well as isometric shapes (0.05—1 mm).

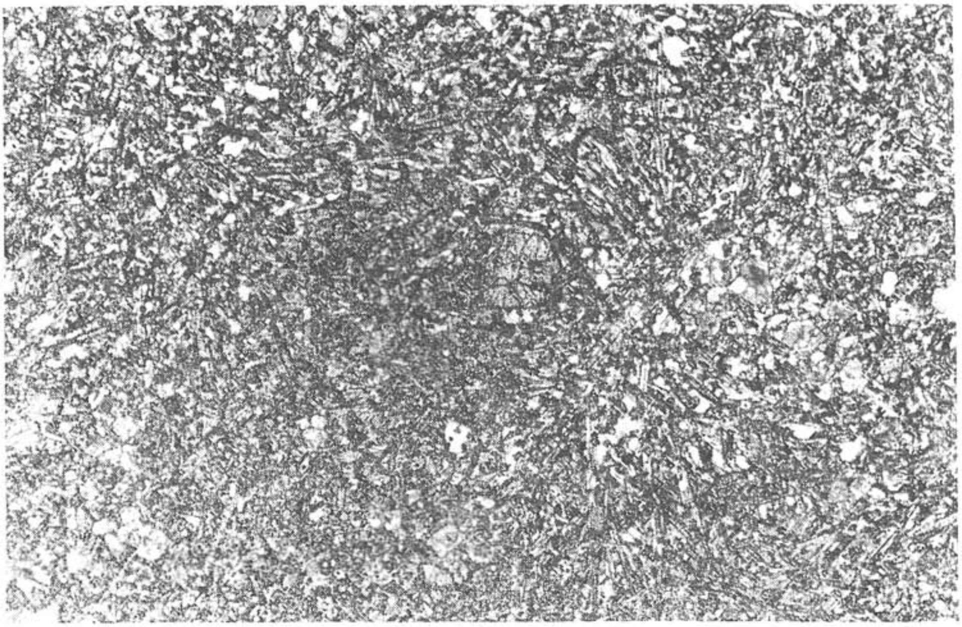

Fig. 7. Magnified 16.5 x with polarizer. Locality: Kojetín – Stráník; monchiquite, lamprophyric texture.

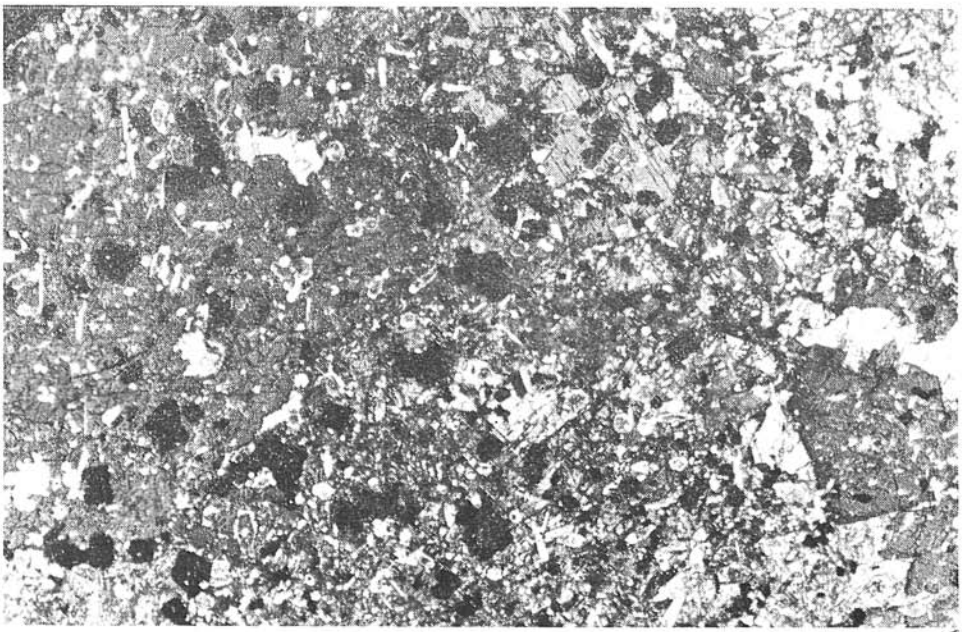

Fig. 8. Magnified 16.5 x with polarizer. Locality: Tichá; ouachitite, poikilitic texture.

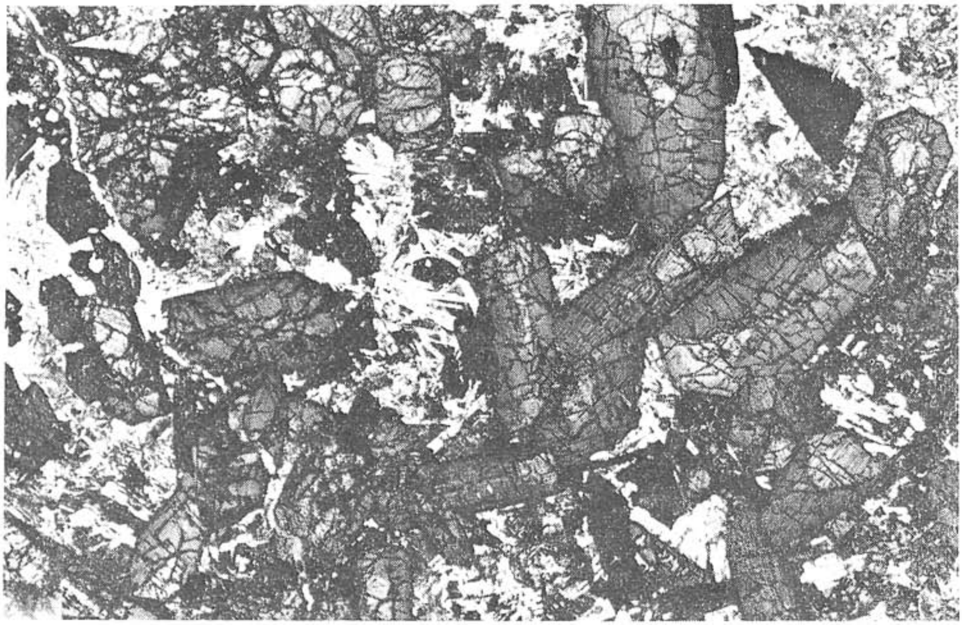

Fig. 9. Magnified 16.5 x with polarizer. Locality: Staříč – Kublův lom; teschenite clinopyroxenite with porphyric texture. Zonal titan-augite phenocrysts enclose diopside relics.

Colourless analcime together with desintegrated clinopyroxenes, carbonates metallic pigment, apatite and strongly desintegrated feldspars create a greenish matrix. The texture of the rock is porphyric, poikilitic (Fig. 8).

Teschenite group

This group is represented by medium- to coarse-grained rocks with colour index ranging from 30 to 65.

On the basis of the ratio of femic and mafic components the following types were classified: teschenite s.s. (with prevailing femic components) and teschenite clinopyroxenite (with prevailing mafic components) — following Smith (1979).

Teschenite s.s. is a medium to coarse-grained "feldspathic" rock with macroscopically visible elongated columns of clinopyroxenes, amphiboles and biotites emering from a light grey non-discernible mass.

The phenocrysts contain zonal titan-augite with hourglass structure encircling relics of diopside and euhedral, often twinned slightly zonal amphibole. Green aegirine-augite is present in accessory amounts and like amphibole it locally overgrows diopside, titan-augite and amphibole phenocrysts.

Femic minerals are intensively altered into a mixture of analcime, carbonate, zeolites and prehnite, scarcely it is possible to identify Carlsbad twins of sanidine bars appearing to have ophitic texture and plagioclase (An_{44}) relics polysynthetically lamellated. Apatite with spicular and isometric habit is present

Table 8

Chemical analyses of picrite, monchiquite, fourchite, ouachitite, teschenite s.s. and teschenite clinopyroxenite (in wt. %) with calculation on normative minerals of the system C. I. P. W. A

Sample	44	43	23	101	102	P1	P2	P3	2	3	9	10
SiO_2	37.10	37.60	39.12	40.20	40.32	39.38	40.79	39.78	39.30	39.50	41.20	38.00
TiO_2	2.15	2.10	1.60	2.10	1.40	1.73	—	2.39	2.95	2.30	2.60	3.50
Al_2O_3	11.60	13.00	11.99	8.71	8.71	7.64	10.41	8.41	13.50	14.60	13.60	13.10
Fe_2O_3	6.05	6.62	5.52	3.30	2.10	4.97	3.52	4.47	4.95	6.55	5.28	7.20
FeO	5.03	5.35	5.57	7.90	8.60	7.23	6.39	8.12	5.75	4.31	6.75	4.77
MnO	0.18	0.14	0.13	0.16	0.16	0.17	—	0.17	0.17	0.18	0.12	0.22
MgO	17.20	13.11	16.55	20.73	24.80	22.05	23.34	19.02	7.80	7.24	7.64	7.65
CaO	12.20	13.45	14.13	8.82	7.10	8.62	8.48	9.92	11.20	14.30	12.20	15.20
Na_2O	0.75	0.57	1.40	2.50	1.20	0.43	1.71	1.66	2.15	1.32	2.90	2.05
K_2O	0.55	0.39	0.80	0.80	0.40	1.12	0.71	0.74	2.05	2.18	0.75	0.65
P_2O_5	0.65	0.65	0.45	—	—	—	—	0.48	0.70	0.71	0.65	0.75
CO_2	4.28	3.00	0.50	—	—	0.44	—	—	7.00	4.48	3.50	2.04
H_2O	2.22	3.10	2.15	4.80	5.14	4.93	4.04	3.42	2.00	3.27	2.85	4.56
Σ	100.04	99.08	99.01	100.02	99.93	99.66	99.39	99.59	99.52	100.94	100.04	99.69
Qz									8.21			
Or	3.29	2.40							12.42	12.92	4.56	4.04
Ab	6.42	5.02							18.65	10.32	25.24	10.35
An	26.97	33.08	24.62						6.91	27.56	22.50	25.87
Ne			6.56							0.48		4.27
Di	6.25	9.56	24.45							15.95	10.02	26.98
Hy	11.90	18.36							14.21		5.15	
Ol	20.76	8.71	24.04							7.49	9.80	5.26
Mt	8.87	10.10	8.18						7.36	7.83	7.87	6.25
Hm										1.17		3.26
Il	4.13	4.15	3.11						5.74	4.38	5.08	6.98
Ap	1.56	1.60	1.09						1.70	1.69	1.58	1.87
C									8.48			
Cc	9.85	7.11	1.16						16.32	10.22	8.19	4.87

Notes to Tabs. 8 and 9: sample Nos. 44 – porphyric picrite, Hončova Hůrka; 43 – granular picrite, Hončova Hůrka; 23 – granular picrite, Staříč; 101 – porphyric picrite, Kamenná Hůrka; 102 – granular picrite, Žilina; P1 – picrite, Staříč, Pacák (1926); P2 – picrite, Hončova Hůrka, Pacák (1926); P3 – picrite, Kamenná Hůrka, Pacák (1926); 2 – monchiquite s.s., Kojetín; 3 – monchiquite s.s., Stráník; 9 – monchiquite s.s., Jasenice; 10 – monchiquite s.s., Libhošť; 4 – fourchite, Frenštát p. Radh.; 5 – fourchite, Frenštát p. Radh.; 8 – fourchite, Lubno; 45 – ouachitite, Tichá; 6 – teschenite s.s., Staříč; 30 – teschenite s.s., Paskov; 32 – teschenite s.s., Paskov; 12 – teschenite clinopyroxenite, Paskov; 7 – teschenite clinopyroxenite, Staříč; 24 – teschenite clinopyroxenite, Staříč; 46 – teschenite clinopyroxenite, Paskov.
Analyzed by L. Slanečka et al. in the laboratories of the Mining College Ostrava.

Continuation of Tab. 8

4	5	8	45	6	30	32	12	7	24	46
32.80	34.70	32.50	38.30	41.10	41.80	42.60	41.80	40.10	38.56	40.92
3.85	3.90	3.60	4.40	2.70	2.55	2.50	2.75	2.65	2.30	2.44
11.15	10.07	13.60	8.27	15.40	14.49	16.58	13.07	10.60	14.90	16.35
11.34	6.40	8.15	6.22	4.00	4.60	6.60	5.44	5.30	7.95	4.23
6.61	8.04	7.15	13.80	6.47	5.57	5.42	6.62	5.03	6.02	6.32
0.31	0.37	0.28	0.36	0.18	0.19	0.18	0.18	0.18	0.18	0.20
6.70	5.77	7.65	7.00	4.80	4.59	4.59	7.48	4.80	6.08	6.28
13.45	14.00	11.65	16.90	11.42	10.27	10.27	15.12	18.14	13.32	10.68
2.30	2.10	2.10	1.80	2.75	3.50	3.50	2.35	1.95	1.90	2.35
1.80	1.70	1.22	1.95	3.00	1.80	1.80	1.80	2.33	2.33	2.15
2.85	3.13	3.20	4.27	0.80	2.45	2.45	0.90	0.52	0.43	1.95
3.88	6.00	6.40	5.51	3.90	0.40	0.40	0.40	6.40	3.20	3.00
2.57	3.40	1.70	1.29	2.70	2.96	2.96	2.04	1.70	2.70	3.06
99.61	99.58	99.80	100.07	99.52	99.85	99.85	99.95	99.70	99.87	99.93
		3.30								
10.95	11.38	7.28	11.64	18.30	15.24	10.96	10.86	14.05	14.17	13.10
16.22	20.16	17.95	2.75	20.44	19.64	27.50	0.62	16.15	10.15	20.51
15.21			8.81	21.49	22.76	24.96	20.21	13.56	25.98	21.94
2.06	11.06		6.84	1.94		1.64	10.66	0.37	3.46	
7.04	13.49		10.27	4.94	3.88	6.62	37.86	26.27	14.35	
		21.34			11.12					15.05
9.74	2.34		19.26	10.49	3.42	6.64	3.30	0.53	7.00	4.06
11.48	10.10	11.94	9.11	5.99	6.88	9.86	8.05	7.84	11.86	6.32
3.75	1.37									
7.52	7.60	6.91	8.44	5.29	5.00	4.89	5.33	5.13	4.49	4.78
6.95	5.69	7.66	10.22	1.96	5.25	5.98	2.18	1.26	7.05	4.76
		8.92	1.00							2.43
9.08	13.65	14.70	12.66	9.16	6.80	0.94	0.93	14.85	7.49	7.04

in amounts up to 3 vol. %. Titanite in parallelogram and skeletal forms is a common accessory.

The texture of the rock is porphyric euhedrally grained and ophitic as well (Fig. 3). For modal analysis see Tab. 7. Teschenite clinopyroxenite is a medium to coarse grained rock with colour index ranging with 50—60. It differs from teschenite in higher clinopyroxene contents (up to 60 %) and, on the contrary, lower ones of amphibole, biotite and femic components. The texture and total composition are similar (Fig. 9). For modal analysis see Tab. 7.

Chemical composition

If possible petrogenetic models of the genesis of the rocks under study are to be estimated, a comparison of the above mentioned mineral variability and the corresponding chemical composition is necessary, and that is on the basis of major, minor and trace elements.

Within the study of chemical composition 23 analyses with calculations on normative minerals of the system C. I. P. W. were performed (Tab. 8). Variability in mineral composition can be clearly seen on the differences in the contents of major elements.

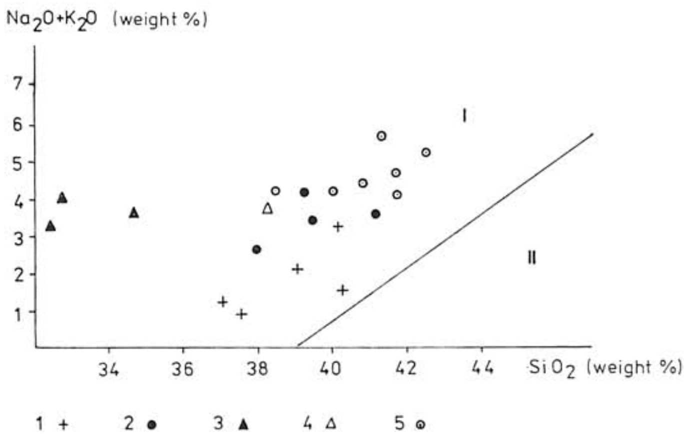

Fig. 10. $Na_2O + K_2O : SiO_2$ diagram.
Explanations: I — alkaline field, II — subalkaline (border line according to MacDonald—Katsura, 1964). 1 — picrites; 2 — monchiquites; 3 — fourchites; 4 — ouachitites; 5 — teschenites.

The results of analyses suggested also several other characteristic features such as rather elevated TiO_2 content, especially in fourchite (3.6—3.97 wt. %) and ouachitite (up to 4.4 wt. %) which is given by their mineral paragenesis; elevated alkaline contents in fourchite, teschenite s.s. and teschenite clinopyroxenite; varying CaO contents (relative to the intensity of carbonatization and others); elevated P_2O_5 contents especially in fourchite (up to 3.2 wt. %) and ouachitite (up to 5.01 wt. %) which is dependent on apatite (up to vol. %).

Al_2O_3 contents which are elevated in picrites (up to 13.9 wt. %) and monchiquites (up to 16.0 wt. %) are dependent on titan-augite and kaersutite abundances in these rocks, however, especially on the presence of analcime and minerals of zeolite group.

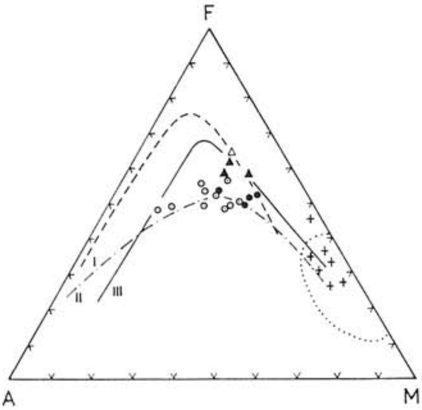

Fig. 11. AFM diagram on the basis of wt. %.
Explanations: Dotted — field of mafic and ultramafic cumulates according to Coleman (1977). I — trend line — Skaergaard intrusions, according to Carmichael et al. (1974); II — Hawaii alkaline trend; III — Hawaii tholeiite trend, according to MacDonald—Katsura (1964). For symbols see Fig. 2.

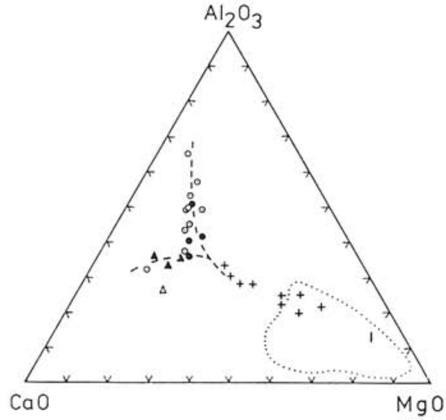

Fig. 12. Cao : Al_2O_3 : MgO diagram (in wt. %).
Explanations: I — field of ultramafic cumulates, according to Coleman (1977). For symbols see Fig. 2.

All studied rock types belong to unsaturated rocks of alkaline group (Fig. 10). Having low SiO_2 contents and those of alkaline metals elevated fourchites are clearly differed in the diagram $Na_2O + K_2O : SiO_2$ (due to higher amounts of kaersutite, biotite and apatite). Projection points in the ternary diagram AFM (Fig. 11) clearly show a separate field of picrites with rather low distribution compared to the other rock types which create a considerably large field between the curves of Hawaii alkaline and tholeiite trends. Similar situation is projected in the diagram $CaO : Al_2O_3 : MgO$ as well (Fig. 12) where again the field of projection points of picrites is clearly distinguished and is partly interfering with the field of ultramafite cumulates (following Coleman, 1977). There can be clearly seen gradual increase of CaO and Al_2O_3 at the expense of MgO from picrites to teschenites s.s. running in two directions (toward CaO, the more significant direction is toward Al_2O_3). The studied relationships suggest that the rocks of teschenite association underwent the stage of fractional crystallization and that of the assimilation of crust material. Then the plot of projection points suggests that these rocks do not represent a differentiation series such as the Skaergaard intrusion or Hawaii suite rocks.

The detected positive correlations between FeO^{tot}/MgO and TiO_2 (Fig. 13), and P_2O_5 and TiO_2 (Fig. 14) again suggest the effects of assimilation processes (increase of TiO_2 and P_2O_5 contents) on the original ultrabasic melt.

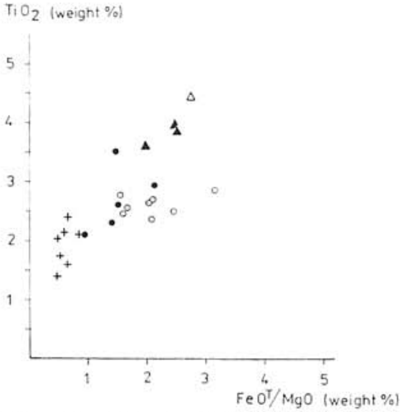

Fig. 13. TiO_2 : FeO^T/MgO diagram. For symbols see Fig. 2.

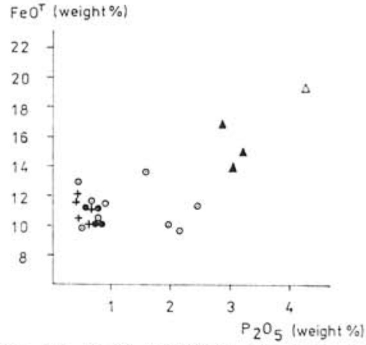

Fig. 14. P_2O_5 : FeO^{tot} diagram. For symbols see Fig. 2.

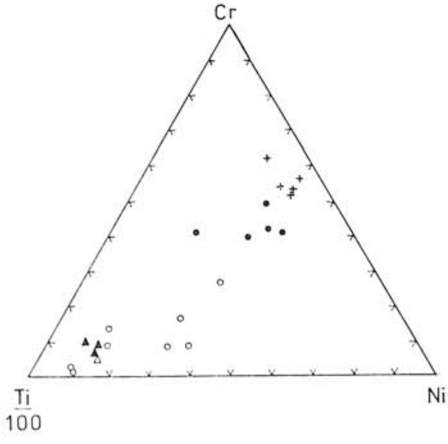

Fig. 15. Ti/100 : Cr : Ni ternary diagram (values in ppm). For symbols see Fig. 2.

A factor significantly contributing to the characterization of the rocks of teschenite association are the contents of transition metals (elements with low migration velocity). In the rocks under study there was followed the distribution of Ti, V, Cr, Co and Ni (Tab. 9). The study showed that their concentrations can be correlated to basicity of the rock and Mg content. In the ternary diagram of Ti (100 : Cr : Ni) (Fig. 15) and that of V : Co : Ni (Fig. 16) Ti- enrichment in teschenite s.s., ouachitite and fourchite and negative correlations between Ti and Cr or Ni can be clearly seen. Picrites and monchiquites have significantly lower contents of lithophile elements (Ti,V) and, on the contrary, Cr, Co, Ni ones are close to those in the upper mantle.

Transition metals distribution relative to Mg-index (Fig. 17) showed that the projection points of picrites and monchiquites s.s. fall within the field between ultramafite and tholeiite basalt points, those of fourchite, ouachitite and teschenite s.s. skirt points of mean values for continental crust and andesites.

Table 9

Contents of trace elements in the rocks of teschenite association (in ppm)

	44	43	23	2	3	9	10	1	4
Rb	—	—	—	85	—	—	—	—	—
Cs	—	<3	0.5	1.5	<1	<1	<1	<1	3.1
Ba	—	1770	2000	1350	3700	660	1730	540	700
Sr	—	<2000	—	950	<2000	<2000	<2000	1580	1250
Sc	—	28.1	58	18.7	28.0	23.2	28.7	21.1	11.8
Hf	—	—	—	7.5	4.9	5.5	4.8	2.0	8.9
Th	6.9	5.5	4.3	6.6	5.6	4.5	6.5	9.8	8.1
U	2.4	2.8	2.7	2.9	3.0	3.6	2.5	2.5	2.7
Ti %	1.26	1.26	0.96	1.77	1.38	1.56	2.10	1.67	2.31
V	80.0	22.0	28.0	25.0	25.0	25.0	26.0	28.0	75.0
Cr	752	800	12.90	193	387	326	330	303	29
Co	70	59	42	38	40	44	35	32	34
Ni	550	360	300	102	270	290	280	250	37
La	50	50	51	82	64	53	59	44	105
Ce	102	102	92	160	120	110	125	85	222
Nd	43	43	43	78	64	60	65	37	144
Sm	7.3	7.3	7.4	13	10	10	11	8.0	24
Eu	2.6	2.6	2.7	4.4	3.7	3.4	3.7	1.62	6.90
Tb	0.92	0.92	1.1	1.58	1.3	1.42	1.1	0.94	2.25
Ho	0.95	0.95	1.6	1.80	1.35	1.40	1.45	—	2.80
Tm	<1	<1	<3	<1	<1	0.53	<1	<1	<1
Yb	2.10	2.10	1.6	2.10	2.3	2.0	2.15	1.55	2.80
Lu	0.31	0.31	<1	0.35	0.29	0.44	0.45	0.29	0.30
Gd	—	12.0	9.68	10.6	8.3	8.1	7.7	5.00	15.5

	5	8	45	30	32	12	7	24	46
	—	—	—	—	—	—	99	—	—
	2.5	<1	—	—	—	—	—	1.1	—
	1330	590	—	—	—	—	760	800	—
	1020	—	—	—	—	—	—	—	—
	16.5	13.3	—	—	—	—	26	12.9	—
	—	10.0	—	—	—	—	—	—	—
	7.5	9.6	—	—	—	7.4	7.0	7.4	—
	2.7	4.5	—	—	—	2.5	2.8	2.4	—
	2.37	2.16	2.64	1.53	1.50	1.65	1.59	1.38	1.46
	68.0	85.0	75.0	90.0	104.0	80.0	75.0	65.0	75.0
	28	20	20	20	18	25	30	95	45
	23	29	34	28	20	30	25	32	33
	28	35	45	60	30	80	28	120	80
	98	—	—	—	—	—	50	53	—
	235	—	—	—	—	—	106	134	—
	135	—	—	—	—	—	50	60	—
	22	—	—	—	—	—	9.5	9.9	—
	7.2	—	—	—	—	—	2.9	3.7	—
	2.9	—	—	—	—	—	1.1	1.1	—
	2.8	—	—	—	—	—	1.4	1.4	—
	<1	—	—	—	—	—	<1	5.0	—
	3.8	—	—	—	—	—	2.20	2.1	—
	1.3	—	—	—	—	—	0.20	<1	—
	20.6	—	—	—	—	—	9.8	8.9	—

In major rock types of teschenite association there were determined the contents of 9 elements from rare earth elements group (further on REE). The values detected by analyses were normalized by those of REE in chondrites (following H a s k i n et al., 1968). REE distribution shows that all studied types appear to be more enriched in light REE than in heavy REE, the curves of mean values show descending tendencies (Fig. 18). Europium anomaly does not occur.

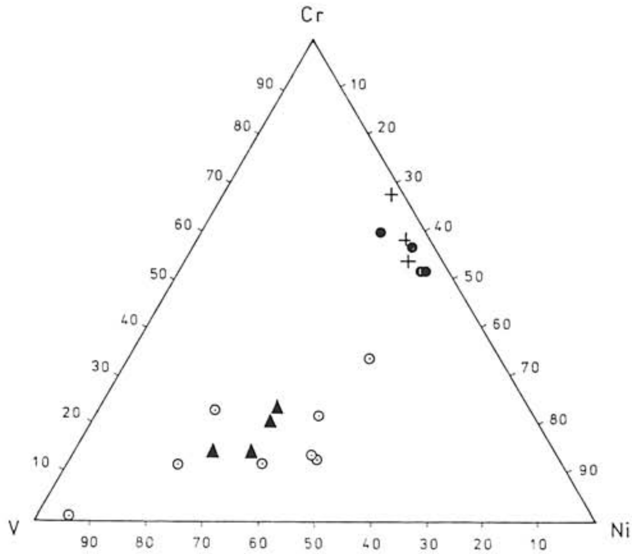

Fig. 16. V : Cr : Ni ternary diagram (values in ppm). For symbols see Fig. 2.

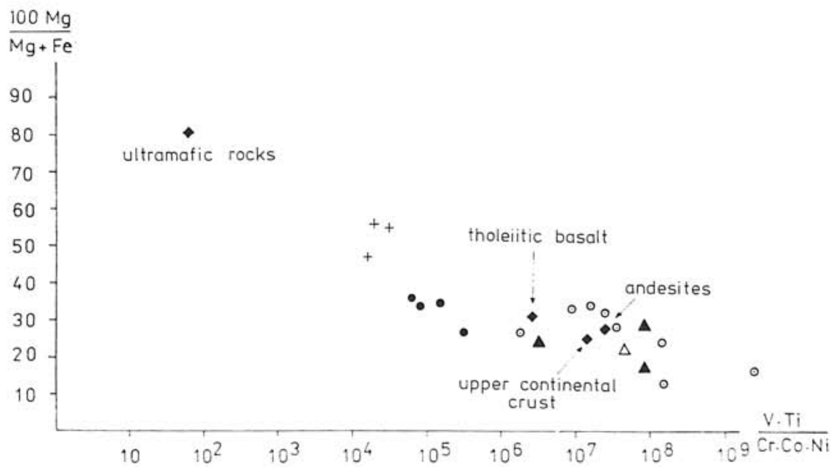

Fig. 17. Distribution of transition metals related to Mg-index in the rocks of teschenite association. Mean values of the given rock types taken from the paper by F i a l a et al. (1980). For symbols see Fig. 2.

The lowest REE contents are detected in picrites, the highest in fourchites where light REE show considerably higher values than those given for granitoides. Mean REE values of all studied types are comparable to those given for alkaline olivine basalt from Jefferson Co. (F r e y et al., 1968).

Rather elevated concentrations of other trace elements — Ba, Sr, Hf, Sc, Ta correspond with the contents given for alkaline rocks (W e d e p o h l, 1968).

U and Th contents are variable in particular types. Th/U ratios correspond with those in basic rocks, however, particular contents are higher than given values and they correspond rather to the concentrations in intermediary rocks.

K/Rb ratio considered to be measure of the rock differentiation degree varies within 160—200, it approaches to the values given for strongly differentiated rocks of crust origin (B o u š k a et al., 1980).

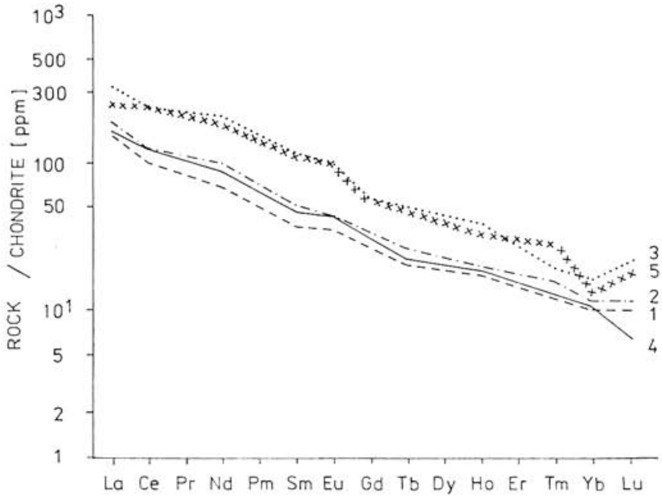

Fig. 18. Mean REE contents in the rocks of teschenite association, normalized REE contents in chondrites according to H a s k i n et al. (1968).
Explanations: 1 — picrite; 2 — monchiquite; 3 — fourchite; 4 — teschenite; 5 — alkaline olivine basalt from Jefferson Co.

Conclusion

Petrogenesis of the rocks of teschenite association has been discussed by now. In spite of the differing opinions of some details the dominating one is that at the origin and development of these rocks processes of intensive magmatic differentiation, metasomatism in magmatic as well as post-magmatic phases and metamorphism took place (P a c á k, 1926; S m u l i k o w s k i, 1929; Š m í d, 1978).

The study of mineralogy, petrography and chemical composition of selected rock types showed variability in the abundances of mineral components and particular chemical elements which suggests a considerable heterogeneity of original magma. The detected, rather elevated contents of Cr, Co, Ni in picrites may indicate their origin in the lower parts of Earth crust, and/or upper mantle while the elevated contents of Ti, V, Al, P, Fe, K in fourchites, ouachitites and teschenites s.s. suggest a complicated cycle of evolution of original magma manifested through fractional crystallization and pulsation which could result in gradual genesis of particular rock types and their gradual affecting by crust material.

The elevated contents of U, Th and other trace elements indicate their belonging to alkaline group. REE distribution appears to be the result of partial melting and assimilation of crust material.

Translated by M. Spišiaková

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