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(Sr,Ba) PHILLIPSITE-Ca AND CHABASITE FROM "JÓZEF" BASALT DEPOSIT IN ZAREBA (LOWER SILESIA)

Abstract. Two minerals of the zeolite group, (Sr,Ba) phillipsite-Ca and chabasite, have been discovered in the "Józef" basalt quarry in Zaręba near Lubań Śląski. Both occur as secondary minerals, filling vesicles in olivine basalt. The dominant zeolite mineral is euhedral (Sr,Ba) phillipsite-Ca of the first generation, almost always surrounded by spherolitic aggregates of (Sr,Ba) phillipsite-Ca of the second generation. In places, the phillipsite of the first generation is intergrown with single, pseudoregular crystals of chabasite.

Formal chemical formulae of (Sr,Ba) phillipsite-Ca, based on results of microprobe analyses and normalized to 32 oxygen atoms, are as follows:
$(K_{1.09}Na_{0.38}Ca_{1.27}Sr_{0.34}Ba_{0.15}Mg_{0.06}\square_{1.71})[Al_{4.97}Fe_{0.01}Si_{10.98}O_{32}]\cdot nH_2O$ — (first-generation crystals),
$(K_{1.15}Na_{0.27}Ca_{1.26}Sr_{0.35}Ba_{0.16}Mg_{0.08}\square_{1.73})[Al_{4.77}Fe_{0.01}Si_{11.13}O_{32}]\cdot nH_2O$ — (second-generation crystals).

The unit cell parameters and refractive indices of euhedral (Sr,Ba) phillipsite-Ca of the first generation are: a = 9.989(5), b = 14.192(5), c = 8.678(7), β = 124,63°, n_α = 1.500, n_β = 1.502, n_γ = 1.505, and refractive indices of chabasite n_α = 1.491, n_γ = 1.493.

Key-words: "wellsite", (Sr,Ba) phillipsite-Ca, phillipsite, chabasite, harmotome, Zaręba, Poland

INTRODUCTION

Wellsite, a monoclinic intermediate member of the phillipsite-harmotome series of zeolites, was being distinguished till last years. This mineral was first described by Pratt and Foote (1897) from Clay Co. Buck Creek in North Carolina, and its status in the group exhaustively presented by Černý et al. (1977). According to the updated nomenclature of zeolites (Coombs et al. 1998) the name "wellsite" was discredited and replaced by "Ba phillipsite-Ca". Respecting the general rules of nomenclature, one of the zeolites analysed here has been described as (Sr,Ba) phillipsite-Ca, because of its relatively high content of strontium in comparison to other minerals of the series. Moreover, most of the physical features of this mineral are closer to "wellsite" and phillipsite than to harmotome.

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No occurrence of typical "wellsite" in Poland has been documented. Harmotome has been reported very rarely: the only undoubtful occurrence of this mineral is the old Friederike Juliane mine in Miedzianka-Ciechanowice near Janowice Wielkie in Lower Silesia (*vide* Lis, Sylwestrzak 1986) and the second is in Biała Woda in the Pieniny Mts (Wieser 1985). Phillipsite has been described much more frequently. Its occurrences are connected with basaltic rocks and known, e.g., from Jałowiec near Lubań Śląski, Koźlice and Gazdanin near Zgorzelec, Mały Śnieżny Kocioł near Szklarska Poręba (*vide* Lis, Sylwestrzak 1986), environs of Złotoryja and Jawor (August, Przybylski 1994). The second zeolite mentioned here, chabasite, is also common in Poland. Its occurrences in basalts from Lower Silesia are well documented in Koźlice near Zgorzelec, Żerków near Lubań Śląski, Lipa near Wojcieszów, Gilów near Niemcza (*vide* Lis, Sylwestrzak 1986), environs of Złotoryja and Jawor (August, Przybylski 1994).

GEOLOGICAL SETTING

The Lower Silesian basalt formation is the easternmost part of the Central-European Tertiary volcanic province (Smulikowski 1960). This volcanism reached peak of its activity between late Oligocene and late Pliocene. Petrographically, the formation is represented by nephelinites and olivine basalts, accompanied by volcaniclastic rocks. The basaltoids occur as lava flows (of the aa type, more rarely of the block type), necks, and dykes (Kozłowski, Parachoniak 1960; Smulikowski 1960; Dyjor, Kościuszko 1986), whereas volcaniclastic rocks intercalate basalt sheets and fill the necks (Jerzmański, Śliwa 1979).

The rock cropping out in the "Józef" basalt quarry in Zaręba near Lubań Śląski is the olivine basalt. Its primary minerals are represented by phenocrysts of pyroxene and olivine in the fine-grained plagioclase-opaque groundmass. The pyroxenes are Ti-rich augites with characteristic hourglass light absorption, whereas the olivines are to a large extent altered into iddingsite. Around vesicles filled with minerals of hydrothermal origin, distinct structural and compositional changes can be observed. Immediately next to such amygdales the rock is enriched in opaque minerals and plagioclase tablets of larger dimensions than in the unchanged groundmass.

Minerals filling cavities in other basalts from the same region are represented by calcium phosphates (apatite?), heulandite (Szpila 1966), Fe,Mg-smectite, zeolites (natrolite, tetranatrolite, phillipsite, chabasite) and carbonates (calcite, dolomite and aragonite) (August, Awdankiewicz 1993; August, Przybylski 1994). The similar mineral association has been observed in the quarry of olivine basalt in Zaręba. It is represented by Fe,Mg-smectites, zeolites [(Sr,Ba) phillipsite-Ca, chabasite], and carbonates (calcite, dolomite).

MODE OF OCCURRENCE

Crystals of (Sr,Ba) phillipsite-Ca from Zaręba represent two subsequent generations, both formed in primarily empty vesicles of basalts. First generation crystals are euhedral (Phot. 1, 2), with a maximum length of up to 2 mm, but usually 0.2—0.3 mm (Phot. 3, 4). They are colourless, with strong vitreous lustre, nearly always cross-twinned along (100), and grow either directly on the basalt or on smectite that lines the cavities.

(Sr,Ba) phillipsites-Ca of the second generation occur as microcrystalline varnish covering the euhedral crystals of the first generation (Phot. 5). Microliths are of fibrous and needle-shaped habits, and their bigger accumulations usually form spherolitic aggregates (Phot. 6) up to around 20—30 μm (Phot. 7). Very often these aggregates are surrounded with a goethite rim.

Crystals of chabasite are nearly always mutually intergrown with (Sr,Ba) phillipsite-Ca of the first generation and only rarely grow directly on basalt (Phot. 8). They are developed as colourless, crystals of characteristic, nearly isometric habit (result of triclinic or monoclinic twining) and show very strong glassy lustre. Euhedral grains of chabasite are up to 0.6 mm in size. Very often the quasi-isometric crystals approximate cubes so much that they can be described as pseudocubic (Phot. 8).

CHEMICAL COMPOSITION

Chemical composition of phillipsites of hydrothermal origin exhibits a considerable variability. The contents of main exchangeable cations in the unit cell of these mineral (apfu) are as follows: K 0.7—3.5, Na 0.1—4.2, Ca 0—2.1, Mg up to 0.25, while Ba can reach 1.57 apfu in wellsites (Gottardi, Galli 1985).

Chemical composition of phillipsites of both generations was analysed in the Institute of Nonferrous Metals in Gliwice with a SEMQuant JEOL 733 scanning microscope. The following standards were used: SiKα (SiO_2), AlKα (Al_2O_3), KKα ($K[AlSi_3O_8]$), NaKα ($Na[AlSi_3O_8]$), CaKα (Ca_2SiO_4), FeKα, SrKα (SrF_2), BaKα (BaF_2), MgKα (MgO), while counting time was 50 s and accelerating current 20 kV.

The unit cell compositions (apfu) of the analysed phillipsites (both generations) are relatively uniform, within the limits of variability typical of this mineral: K 1.09—1.05, Na 0.27—0.38, Ca 1.26—1.27, Mg 0.06—0.08, Ba 0.15—0.16 and Sr 0.34—0.35. The dominant cation is Ca, so the analysed minerals are described as phillipsite-Ca (Coombs et al. 1998). In the K–(Ba+Sr)–(Ca+Mg+Na) triangle used for classification of zeolites of the phillipsite-harmotome series (Černý et al. 1977), the minerals (samples 4 and 5; Table 1 and Fig. 1) fall into the field of wellsite — mineral currently named barium phillipsite. As the chemical analyses have shown a relatively high content of Sr in comparison to the

TABLE 1

Chemical analyses of the phillipsite-harmotome series minerals; formulae on the basis of 32 oxygens

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
SiO_2	41.42	41.53	54.97	48.65	50.73	43.86	49.40	46.89	50.81	40.30	49.30	49.97	44.4	44.1	42.5	50.3	46.67	46.3	47.22
Al_2O_3	23.82	24.33	16.24	18.71	18.44	24.97	19.14	21.45	17.30	22.81	18.97	15.15	18.6	19.2	18.3	17.9	16.35	16.4	16.52
Fe_2O_3	0.07	0.08	0.17	0.07	0.07	—	0.12	—	—	0.24	0.11	3.15	n.d.	n.d.	n.d.	n.d.	—	n.d.	—
BaO	0.09	0.08	1.24	1.71	1.90	5.07	4.84	4.95	4.90	4.57	4.36	8.75	7.9	7.2.	5.9	8.1	20.35	18.8	16.44
SrO	0.28	0.03	0.12	2.63	2.76	1.15	0.61	0.76	0.85	n.d.	0.10	0.10	n.d.	n.d.	n.d.	n.d.	—	n.d.	—
CaO	8.50	2.10	6.41	5.26	5.36	5.80	5.67	6.15	7.00	8.15	6.70	0.64	4.4	4.4	4.9	4.4	1.78	0.1	0.70
MgO	0.03	0.05	0.10	0.18	0.24	0.62	—	—	—	1.80	0.04	1.52	0.4	0.5	0.5	0.2	—	0.5	—
K_2O	6.50	13.00	2.49	3.82	4.12	3.40	3.50	3.72	2.45	4.70	2.50	2.24	2.2	2.5	3.2	2.8	0.23	0.2	0.77
Na_2O	0.65	3.16	0.50	0.86	0.63	1.80	0.12	0.45	0.20	1.32	0.31	3.33	0.2	0.2	0.3	0.5	—	1.9	2.22
H_2O	17.57	15.06	17.88	n.d.	n.d.	13.35	16.78	15.47	16.49	16.62	17.40	14.88	22.0	22.0	24.4	15.8	14.66	15.8	15.52
Total	99.23	99.42	100.12	81.89	84.25	100.01	100.18	99.84	100.00	100.51	99.79	99.73	100.1	100.0	100.0	100.0	100.00	100.0	99.39
Si	9.51	9.50	11.85	10.98	11.13	9.64	11.02	10.46	11.30	9.29	11.02	11.31	10.79	10.67	10.62	11.28	11.26	11.25	11.31
Al	6.45	6.56	4.13	4.97	4.77	6.47	5.03	5.64	4.53	6.19	5.00	4.04	5.32	5.47	5.39	4.73	4.65	4.69	4.66
Fe^{3+}	0.01	0.01	0.03	0.01	0.01	—	0.02	—	—	0.04	0.02	0.54	—	—	—	—	—	—	—
Ba	0.01	0.01	0.10	0.15	0.16	0.44	0.42	0.43	0.43	0.41	0.38	0.78	0.75	0.68	0.57	0.71	1.92	1.79	1.54
Sr	0.04	—	0.01	0.34	0.35	0.15	0.08	0.10	0.11	—	0.01	0.01	—	—	—	—	—	—	—
Ca	2.09	0.51	1.48	1.27	1.26	1.37	1.36	1.47	1.67	2.01	1.60	0.16	1.14	1.14	1.31	1.05	0.46	0.01	0.18
Mg	0.01	0.02	0.03	0.06	0.01	0.20	—	—	—	0.61	0.13	0.51	0.14	0.18	0.18	0.06	—	0.18	—
K	1.99	3.79	0.68	1.09	1.15	0.95	1.00	1.06	0.69	1.38	0.71	0.65	0.68	0.77	1.02	0.80	0.07	0.06	0.23
Na	0.29	1.40	0.27	0.38	0.27	0.77	0.05	0.19	0.09	0.58	0.13	1.46	0.09	0.09	0.14	0.21	—	0.89	1.03

1 — phillipsite — Cosal Brunori (Galli, Ghittoni1972); 2 — phillipsite — San Venanzo (Galli, Ghittoni 1972); 3 — phillipsite — Montegalda (Gottardi, Galli 1985); 4 — (Sr,Ba) phillipsite-Ca — Zaręba — (this study); 5 — (Sr,Ba) phillipsite-Ca (spherolite) — Zaręba — (this study); 6 — wellsite — Buck Creek (Pratt, Foote 1897); 7 — wellsite — Kurtsy (Fersman 1952); 8 — wellsite — Kurtsy (Shkabara 1950); 9 — wellsite — Vežna (Černý et al. 1977); 10 — wellsite — Inuyama City (Černý et al. 1977); 11 — wellsite — M. Calvarina (Galli 1972); 12 — "sodic harmotome" — Wikieup (Černý et al. 1977); 13 — wellsite — Vežna (Černý et al. 1977); 14 — wellsite — Vežna (Černý et al. 1977); 15 — wellsite — Buck Creek (Černý et al. 1977); 16 — wellsite — kurtsy (Černý et al. 1977); 17 — harmotome — Andreasberg (Rinaldi et al. 1974); 18 — harmotome — Korsnäs (Černý et al. 1977); 19 — harmotome — Hrubšice (Černý and Povondra 1965).

typical "wellsites" (Table 1), the prefix "strontium" has been added to the name. The formal chemical formulae of the investigated (Sr,Ba) phillipsites-Ca normalized to 32 oxygen ions are as follows:

— first generation:

$(K_{1.09}Na_{0.38}Ca_{1.27}Sr_{0.34}Ba_{0.15}Mg_{0.06}\square_{1.71})[Al_{4.97}Fe_{0.01}Si_{10.98}O_{32}]\cdot nH_2O$;

— second generation:

$(K_{1.15}Na_{0.27}Ca_{1.26}Sr_{0.35}Ba_{0.16}Mg_{0.08}\square_{1.73})[Al_{4.77}Fe_{0.01}Si_{11.13}O_{32}]\cdot nH_2O$;

and the chemical spectrum of the first generation (Sr,Ba) phillipsite-Ca is presented in Figure 2.

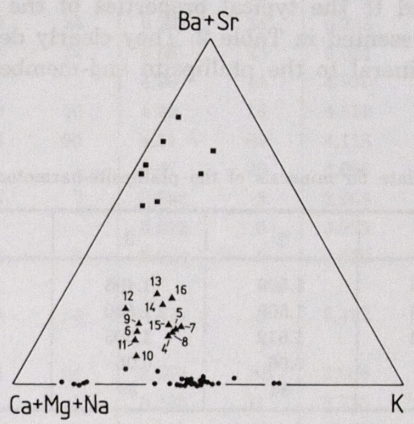

Fig. 1. Phillipsite (dots), wellsite (triangles), and harmotome (squares) in the K–(Ca+Mg+Na)–(Ba+Sr) plot. Numbers of wellsite analyses like in Table 1

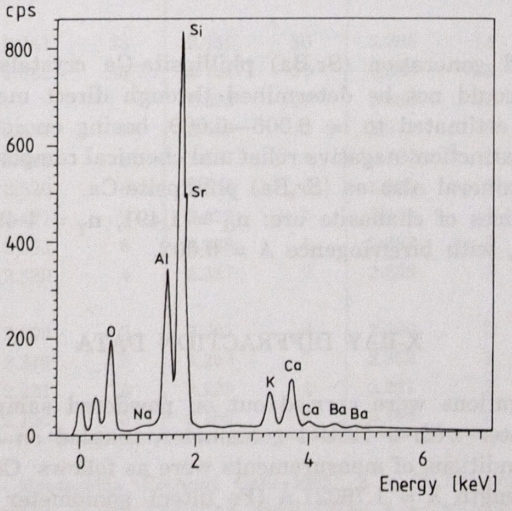

Fig. 2. Chemical composition of Zaręba (Sr,Ba) phillipsite-Ca (first generation)

OPTICAL DATA

Principal optical parameters were measured on untwinned crystals. Minimum and maximum indices of refraction were determined in a mixture of triacetine and cinnamon aldehyde, while the intermediate index n was calculated from the optical axes angle $2V_\alpha$.

Refractive indices of the first generation (Sr,Ba) phillipsite-Ca crystals are significantly higher than typical ones of harmotome, being close to those of wellsite and phillipsite. Optical parameters of the first generation (Sr,Ba) phillipsite-Ca compared to the typical properties of the harmotome-phillipsite series minerals are presented in Table 2. They clearly demonstrate similarities of the investigated mineral to the phillipsite end-member.

TABLE 2

Optical data for minerals of the phillipsite-harmotome series

	1	2	3	4	5
n_α	1.506	1.506	1.498	1.500	1.490
n_β	1.509	1.509	1.500	1.502	1.493
n_γ	1.514	1.512	1.503	1.505	1.498
Δ	0.08	0.06	0.05	0.05	0.08
$2V_\alpha$	80	84	39	84	60—80

1 — harmotome — Korsnäs (Sahama, Lehtinen 1967); 2 — harmotome — Biała Woda (Wieser 1985); 3 — wellsite — Buck Creek (Pratt, Foote 1897); 4 — (Sr,Ba) phillipsite-Ca — Zaręba (this study); 5 — phillipsite — Mt. Calvarina (Galli, Ghittoni 1972).

As the second generation (Sr,Ba) phillipsite-Ca crystals are small, their optical features could not be determined through direct measurements. Birefringence Δ was estimated to be 0.006—0.009, basing on interference colours. Almost straight extinction, negative relief and chemical composition have enabled to classify this mineral also as (Sr,Ba) phillipsite-Ca.

Refractive indices of chabasite are: $n_\alpha = 1.491$, $n_\gamma = 1.493$; the mineral is optically positive, with birefringence $\Delta = 0.002$.

X-RAY DIFFRACTION DATA

X-ray investigations were carried out on powdered samples using a TUR M-62 diffractometer with a HZG-4 goniometer, coupled *on line* with an IBM PC computer. Conditions of measurements were as follows: CoK_α radiation with the mean wavelength $\lambda = 1.79021$ Å (Fe filter), goniometer speed 2°(2θ)/min., scanning step 0.02°, time constant 5. X-ray patterns were recorded in a 2θ

TABLE 3

X-ray data for minerals of the phillipsite-harmotome series

1		2		3		4		5	
d_{hkl}	I	d_{hkl}	I	d_{hkl}	I	d_{hkl}	I	d_{hkl}	I
8.15	5	8.151	8	8.15	19	8.130	7	8.12	60
7.14	74	7.121	57	7.13	100	7.143	46	7.16	65
								7.05	19
6.39	4	6.377	9	6.41	19	6.410	7	6.39	95
5.36	24	5.353	25	5.36	24	5.348	9		
5.04	15	4.995	22	5.05	23	5.051	9	5.03	32
4.95	15			4.96	19	4.950	7		
4.29	5	4.289	10	4.30	16	4.310	7	4.31	35
4.11	32	4.100	55	4.11	65	4.115	41	4.11	56
4.07	9			4.07	26	4.065	11	4.07	67
3.950	6	3.944	7	3.962	5	3.968	3	4.05	59
				3.922	5	3.922	2	3.859	32
3.675	7	3.672	5	3.684	3	3.960	2	3.667	10
								3.573	5
3.466	3	3.460	4	3.474	5	3.472	2	3.466	18
								3.410	5
3.260	26	3.255	24	3.263	38	3.268	16	3.241	62
3.215	20			3.220	31	3.215	14	3.195	28
3.191	100	3.182	100	3.189	100	3.196	46	3.169	70
3.139	21	3.134	16	3.138	58	3.135	25	3.126	100
3.088	3	3.082	3	3.093	7	3.096	3	3.075	31
2.931	13	2.931	24	2.934	23	2.933	9	2.918	29
								2.847	10
2.744	17	2.741	23	2.752	30	2.755	14	2.747	54
2.687	25	2.682	35	2.702	37	2.688	28	2.697	61
2.665	13			2.669	47	2.688	21	2.678	54
2.561	4	2.559	5	2.569	7	2.571	3	2.561	9
2.535	2	2.523	6	2.537	6	2.538	3	2.529	33
2.521	3	2.520	6	2.528	9	2.525	4	2.515	20
		2.477	2	2.479	3	2.481	1	2.470	11
2.384	3	2.383	6	2.388	5	2.387	2	2.369	18
2.328	2	2.330	4	2.337	7	2.336	3	2.343	15
								2.320	23
2.306	2	2.306	2	2.301	4	2.309	2	2.299	17
2.245	3	2.245	5	2.250	7	2.252	3	2.261	10
2.225	6	2.221	3	2.228	4	2.227	2	2.241	15
2.159	2	2.156	3	2.159	5	2.160	2	2.151	18

1 — phillipsite — Montegalda (Gottardi, Galli 1985); 2 — (Sr,Ba) phillipsite-Ca — Zaręba (this study); 3 — wellsite — Mt. Calvarina (Galli 1972); 4 — wellsite — JCPDS 39-1396; 5 — harmotome — Andreasberg (Gottardi, Galli 1985).

range of 4—60°. Diffraction peaks were interpreted using the XRAYAN computer program and JCPDS standards.

Variability of chemical composition of minerals of the phillipsite-harmotome series is also reflected in X-ray patterns. Substitution of potassium cations by much heavier barium and strontium results in a decrease of the intensity of reflexes (Černý et al. 1977). It is particularly distinctive in the case of intensity of the first peak (8.15—8.12 Å). Phases closer to harmotome exhibit much higher intensity, sometimes reaching 100 (Wieser 1985), while the intensity of the same peak in typical phillipsite and wellsite very rarely exceeds 20. Basic X-ray data and the above discussed relationships are presented in Table 3.

The increased content of heavy cations (Ba, Sr) also results in lowering of *a* and *b* parameters of the unit cell (Černý et al. 1977). This relationship was confirmed for the first generation of the investigated (Sr,Ba) phillipsite-Ca as well. Parameters of its unit cell are: a = 9.989(5), b = 14.192(5), c = 8.678(7), β = 124,63°.

INFRARED SPECTROSCOPIC DATA

Infrared spectra were recorded in the range 400—3800 cm^{-1} using a FTS BIO-RAD Model 165 spectrometer. Samples were prepared as pressed tablets, composed of 1 mg sample and 300 mg KBr. Infrared data of (Sr,Ba) phillipsite-Ca were compared (Fig. 3) with standard spectra of phillipsite and harmotome (Moenke 1962), and also with those of Pechar and Rykl (1985).

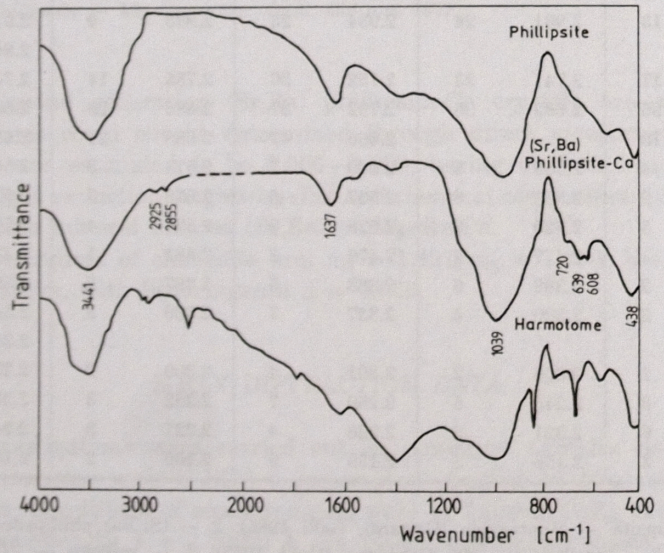

Fig. 3. Infrared absorption spectrum of Zaręba (Sr,Ba) phillipsite-Ca (first generation)

A strong and broad band of stretching vibrations of (Si,Al)–O tetrahedra between 1130 and 880 cm^{-1} is characteristic of individual zeolites. The position of its maximum enables to determine the Al content in relation to Si in the unit cell of the zeolite analysed. The lack of distinct split of a this band into two maxima from Si–O and Al–O groups confirms an almost complete disordered distribution of SiO_4 and AlO_4 tetrahedra in the structure of zeolites (Pechar, Rykl 1985). They attributed two weak bands in the range 2925—2855 cm^{-1} (not present in typical phillipsite) as resulting from the overlapping of H–O–H bending vibrations with vibrations of the alumino-silicate framework.

The positions of the remaining bands are less characteristic of the whole zeolite group, so they are less suitable for distinguishing of individual minerals phases. Relatively strong, smooth and broad stretching bands between 3610 and 3420 cm^{-1} as well as the band between 1650 and 1630 cm^{-1} are related to H_2O.

Two bands about 720 and 1400 cm^{-1} belong to the minerals of the carbonate group. The same bands were mistakenly interpreted by Pechar and Rykl (1985) as the "bands of external $(Si,Al)O_4$ vibration" of zeolites.

CONCLUSIONS

On the basis of the investigations carried out, the following sequence of crystallization of minerals in gas vesicles of the basalt from the "Józef" quarry has been established: smectite → a phosphate (apatite?) → I st generation of phillipsite + chabasite → II nd generation of phillipsite → calcite/dolomite. It is probable that the temperatures of precipitation of the minerals studied here were similar to those determined by August and Przybylski (1994) for the same type of mineralization in the area of Jawor and Złotoryja, i.e. 270—85°C.

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Wojciech FRANUS

(Sr,Ba) PHILLIPSYT-Ca I CHABASYT Z ŁOMU BAZALTU „JÓZEF" W ZARĘBIE (DOLNY ŚLĄSK)

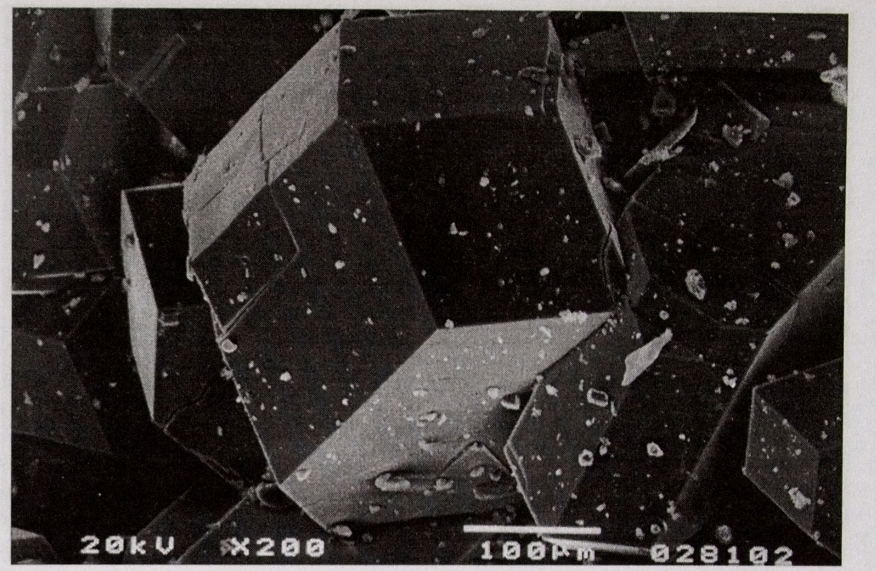
Streszczenie

W łomie bazaltu „Józef" w Zarębie stwierdzono obecność dwóch generacji (Sr,Ba) phillipsytów-Ca oraz chabasytu, minerałów z grupy zeolitów. Oba minerały występują w pogazowych pustkach w bazalcie oliwinowym. Zeolitem dominującym jest euhedralny (Sr,Ba) phillipsyt-Ca (I generacji), który otaczają sferolityczne skupienia (Sr,Ba) phillipsytu-Ca (II generacji). W I generacji kryształów spotykane są pojedyncze pseudoregularne kryształy chabasytu.

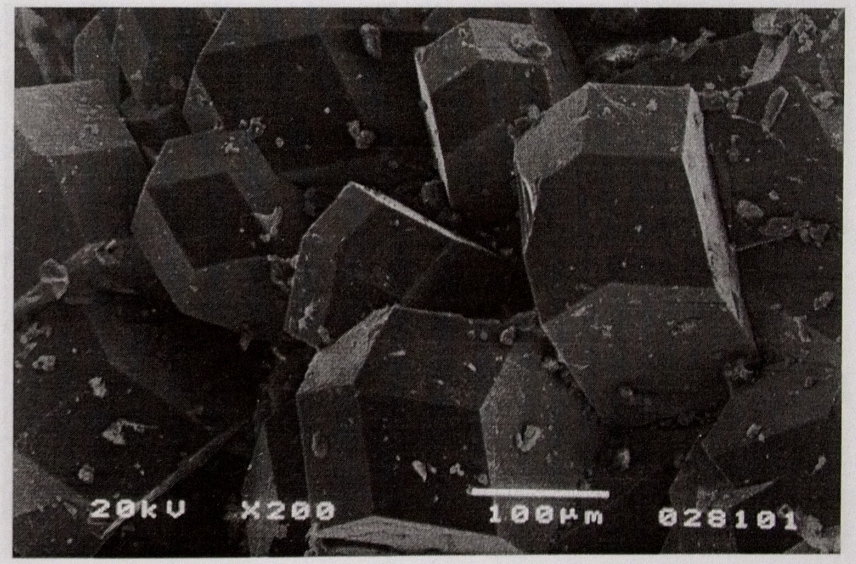
Wzory jednostek formalnych (Sr,Ba) phillipsytu-Ca w przeliczeniu na 32 atomy tlenu w oparciu o analizy mikrosondowe przedstawiają się następująco:
$(K_{1,09}Na_{0,38}Ca_{1,27}Sr_{0,34}Ba_{0,15}Mg_{0,06}\square_{1,71})[Al_{4,97}Fe_{0,01}Si_{10,98}O_{32}]\cdot nH_2O$ — (I generacja),
$(K_{1,15}Na_{0,27}Ca_{1,26}Sr_{0,35}Ba_{0,16}Mg_{0,08}\square_{1,73})[Al_{4,77}Fe_{0,01}Si_{11,13}O_{32}]\cdot nH_2O$ — (II generacja).

Parametry komórki elementarnej i współczynniki załamania światła euhedralnych (Sr,Ba) phillipsytów-Ca wynoszą: a = 9.989(5), b = 14.192(5), c = 8,678(7), β = 124,63°, n_α = 1,500, n_β = 1,502, n_γ = 1,505, a dla chabasytu n_α = 1,491, n_γ = 1,493.

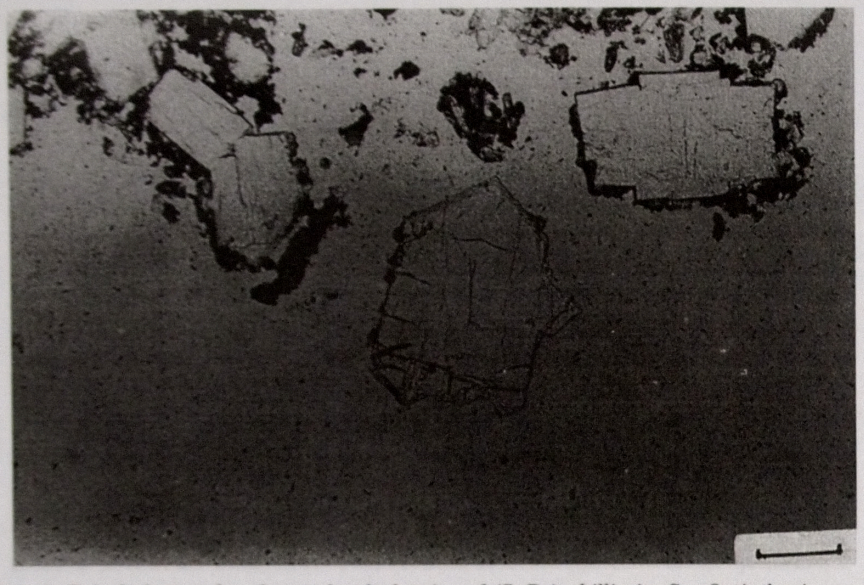
Powstanie obu generacji (Sr,Ba) phillipsytów-Ca oraz chabasytu należy wiązać z dwustopniowym (wyżej- i niżejtemperaturowym) oddziaływaniem roztworów hydrotermalnych w pustkach pogazowych w bazalcie.



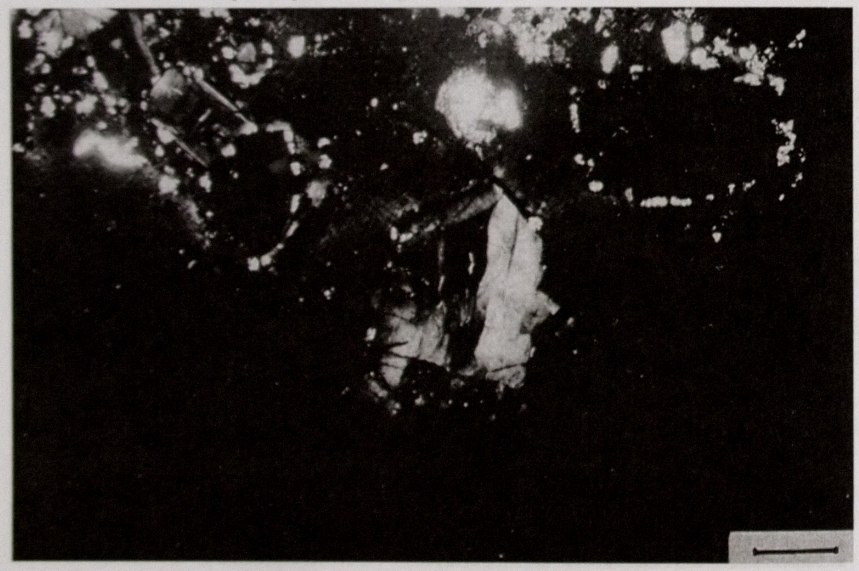
Phot. 1. Euhedral crystal of (Sr,Ba) phillipsite-Ca. Scanning microscope, scale bar 100 µm



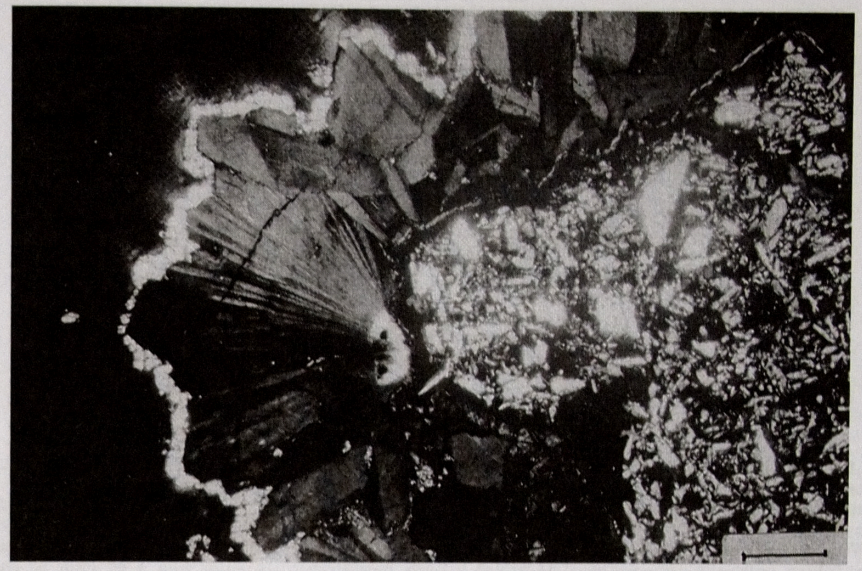
Phot. 2. Aggregate of euhedral crystals of (Sr,Ba) phillipsite-Ca. Scanning microscope, scale bar 100 µm



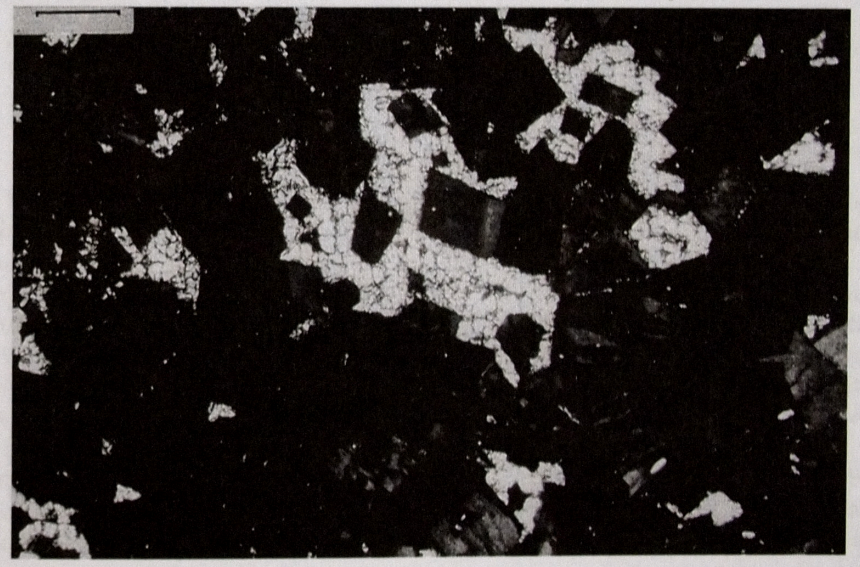
Phot. 3. Euhedral crystal and cross-hatched twins of (Sr,Ba) phillipsite-Ca. Optical microscope, plane polarized light, scale bar 0.125 mm



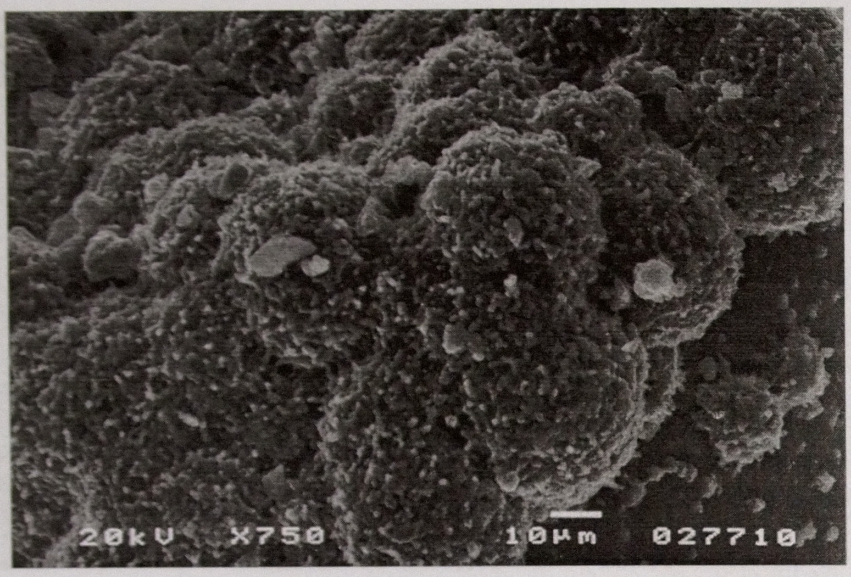
Phot. 4. Euhedral crystal and cross-hatched twins of (Sr,Ba) phillipsite-Ca. Optical microscope, crossed polars, scale bar 0.125 mm



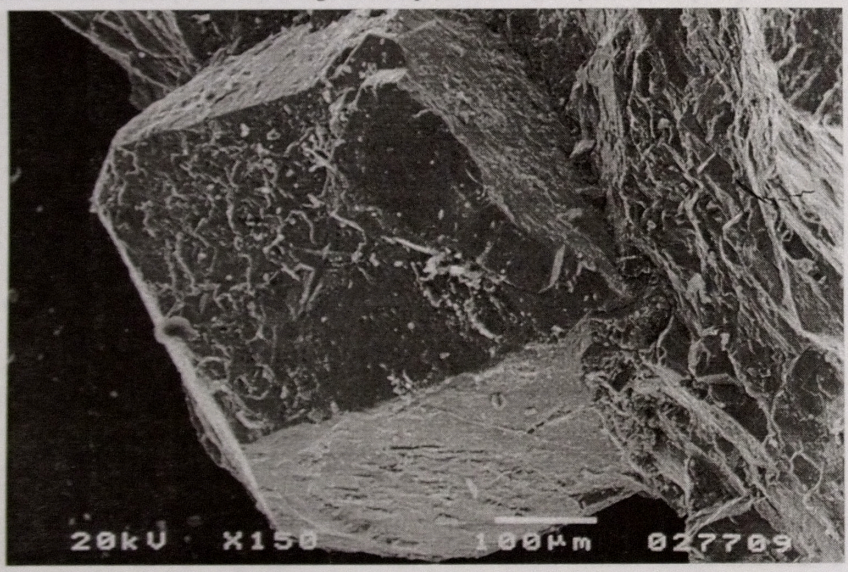
Phot. 5. Rosette aggregates of crystals of (Sr,Ba) phillipsite-Ca (first generation) with spherolitic microliths of (Sr,Ba)phillipsite-Ca (second generation). Optical microscope, crossed polars, scale bar 0.5 mm



Phot. 6. Cavity in basalt filled with crystals of both generations of (Sr,Ba) phillipsite-Ca. Optical microscope, crossed polars, scale bar 0.5 mm



Phot. 7. Spheroidal aggregate of microliths of (Sr,Ba) phillipsite-Ca (second generation), Scanning microscope, scale bar 10 μm



Phot. 8. Euhedral crystal of chabasite, Zaręba. Scanning microscope, scale bar 100 μm