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ALKALI FELDSPARS IN THE LOWER PERMIAN RHYOLITE FROM WIELISŁAWKA HILL NEAR ŚWIERZAWA (WEST SUDETES)

Skalenie alkaliczne w ryolicie ze wzgórza Wielisławka koło Świerzawy (Sudety Zachodnie)

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CONTENTS

ABSTRACT: Permian potassium rhyolite from Wielisławka Hill has been recognized as a part of the lava surface extrusion. The rhyolite bears sanidine and albite phenocrysts. Albite has been investigated by the optic methods. On the basis of the orientation of the relic pericline composition plane (relic rhombic section) in albite it has been found that this mineral formed pseudomorphs after primary plagioclase of the oligoclase-andesine composition. This feldspar locally was submitted to autohydrothermal adularization during its subsequent evolution. Sanidine phenocrysts bear about 67 mole percent orthoclase molecule. This mineral has distorted unit cell parameters what probably results from the sodic and potassic phase exsolution. The ordering degree of the sanidine structure is relatively high and equals $2t_1 = 0.6$. On this basis the author has concluded that the cooling time of the rhyolite was probably relatively long.

INTRODUCTION

Results of the petrographical studies of the Rotliegendes rhyolites forming Wielisławka Hill are presented in this paper, with a special attention paid to the feldspar phenocryst analysis. The studies have been mainly made by means of the microscope methods. In lesser degree there have been applied the results of the analyses performed with use of the X-ray diffractometry, infrared absorption, whole rock wet chemical analyses and electron microprobe analyses of feldspars.

The hill occurs northerly of Świerzawa in Kaczawa Mts and it is an eastern slope of the Kaczawa River valley. This hill with a large abandoned quarry is an extraordinary sightseeing object. Geographically this region belongs to the Sudetes Mts. From the geological point of view this area is a part of the Świerzawa horst within the north-sudetic trough (Fig. 1).

The Wielisławka rhyolite has been the object of interest for scientists since over 200 years. The older works had mostly a cartographic, stratigraphic or general geological character (e.g. Jerzmański 1956). The publication by Kozłowski and Parachoniak (1967), discussing also petrographic problems, has been the most complete one. According to Zimmermann (1920), generally two types of the acid volcanic bodies can be distinguished in Kaczawa Mts and Wałbrzych Mts, i.e.:

1) surface extrusions (subaerial lava flows),
2) volcanic vents.

Smaller vein forms are subordinate.

The Wielisławka rhyolite is most probably a part of a surface volcanic body (Zimmermann 1936). This may be inferred from the following observations: 1) occurrence of numerous and approximately horizontal fluidal structures in the

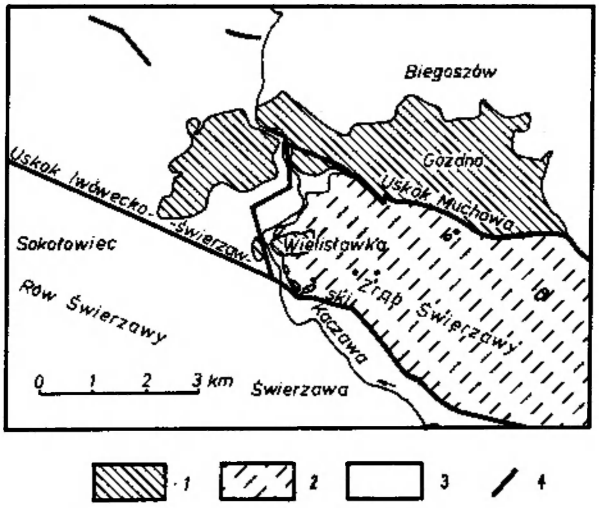

Fig. 1. Sketch map of the Permian rhyolite extrusive bodies occurrence in the region of Wielisławka Hill (after Kozłowski and Parachoniak 1967). *1* – rhyolites (Rotliegendes); *2* – metamorphic schists older than Rotliegendes; *3* – other Rotliegendes and younger beds; *4* – faults

Mapa poglądowa występowania permskich ryolitowych ciał ekstruzywnych w regionie wzgórza Wielisławka (według Kozłowskiego i Parachoniaka 1967). *1* – ryolity (czerwony spągowiec); *2* – łupki metamorficzne starsze niż czerwony spągowiec; *3* – inne skały z czerwonego spągowca i młodsze osady; *4* – uskoki

rhyolite, sometimes of an undulating or zigzag habit (Pl. I, *3*, *4*), 2) absence of visible uplift signs, 3) thermic joint pattern in shape of the reverse fan (Pl. I, *2*), suggesting that the heat outflow from the solidifying lava mass filling a morphological trough occurred through the underlying rocks.

GENERAL PETROGRAPHICAL CHARACTERISTICS OF THE RHYOLITE

Macroscopically this rocks is compact and hard. Its colour on a fresh fracture surface is pink to dark and grayish pink with light and dark spots of phenocrysts. One finds also varieties of the bleached, pale gray, creamy or beige rock, frequently with leached vugs. The joint surfaces have darker, earthy to black colour, probably resulting from the lichen cover. The rock is usually strongly fractured. In addition to the characteristic prismatic thermic joint (Pl. I, *1*, *2*) there occurs the horizontal joint (sometimes hidden), causing an impression of the rock "bedding" (Pl. I, *4*). Thickness of the "beds" ranges from a few to several tens centimeters.

The texture of the rock is holocrystalline porphyritic, either unoriented or fluidal. A significant homogeneity is the striking feature of the studied rocks. Varieties with partly spherolitic or porous textures of the rock matrix have been found very rarely.

The phenocryst size ranges from 0.5 to 2 mm, only rarely there occur crystals reaching 5 mm. Sometimes one can find rock parts of the glomerophyric texture. Aggregates and concrescenses of albite and sanidine, usually larger than single phenocrysts of these minerals, occur in the main mass of the rock. Locally the process of the protoclasis may be observed in the rock, and the fissures resulting from it are filled by secondary silica.

The mineral composition of the rock has been determined by the microscope methods. The quantitative ratios of the main components have been estimated by the planimetric method in 14 thin sections (Table 1).

The essential rock matrix consists of a completely recrystallized glass now comprising mainly tiny grains of potassium feldspar and quartz and

Table 1. Mineral composition of rhyolite from the Wielisławka Hill in volume per cent

Skład mineralny ryolitu ze wzgórza Wielisławka w % objętościowych

Sample	Rock matrix	Phenocrysts			
		sanidine	albite	quartz	biotite
1	79.8	0.8	5.4	9.6	4.4
2	81.3	6.0	5.9	4.8	2.0
3	73.3	12.2	4.2	8.1	2.2
4	82.4	2.0	10.8	3.3	1.5
5	80.4	13.5	1.7	1.7	2.7
6	87.0	4.8	6.2	2.0	0.0
7	88.7	2.0	4.4	3.2	1.7
8	80.1	8.3	5.6	4.4	1.6
9	81.5	11.5	3.1	2.8	1.1
10	82.0	7.1	7.5	2.7	0.7
11	96.9	1.1	0.7	1.3	0.0
12	92.1	6.4	1.3	0.0	0.3
13	94.8	3.4	0.4	0.3	1.1
14	77.9	8.7	5.5	5.4	2.5
Average	84.1	6.3	4.5	3.5	1.6

forming a kind of the granophyric intergrowth. This feature may suggest their coeval crystallization. The portion of potassium feldspar in the essential rock matrix equals almost 40%, the balance is mainly quartz.

Among the phenocrysts, besides the quartz and sanidine ones, there occur also granophyric intergrowths of these minerals (Pl. II, *1*). Their origin is not clear, they may be e.g. either a product of the rhyolite magma crystallization or country rock xenoliths.

Quartz phenocrysts and in lesser degree also feldspar phenocrysts have typically deep reentrants. This may indicate a crystal lattice distortion yielding crystal defects during the phenocrysts growth (Kozłowski 1981).

Potassium feldspars similarly to quartz occur in two main generations: as phenocrysts and as components of the fine-crystalline rock matrix, and the latter ones are the second generation of the same mineral. Adularia is locally replacing the albite pseudomorphs after a primary more basic plagioclase (oral information of A. Nowakowski). Plagioclase occurs only as phenocrysts. Both, potassium feldspars and plagioclases are twinned. Biotite phenocrysts are much rarer than the feldspar and quartz phenocrysts. Their size ranges from a few millimeters to tiny flakes, mostly there occur, however, the crystals of 1 millimeter in length.

The rock chemical composition is presented in the Table 2 on the basis of the two analyses. The investigated rock, according to the TAS petrochemical classification (Le Maître 1984), is potassic rhyolite. The chemical data indicate, that the rock is the silica-richest member of the effusive rock sequence of the Carboniferous-Permian regional European volcanism (Eckhardt 1979).

Albitization with accompanying sericitization of the primary plagioclase is the main process among the autometasomatic alterations found in the studied rhyolites. At places the secondary albite subsequently underwent adularization. Besides of sericite, sometimes there occurs in the albite and a rarer in K-feldspar a fine-flaky mineral optically close to kaolinite (low birefringence). The intensity of the feldspar albitization is indicated by the corundum norm content in the CIPW normative composition of the rhyolite (Table 3).

Strong enrichment of the rock in quartz (veinlets or nests) and biotite decomposition frequently connected with the bleaching (baueritization?) and opacitization are other secondary processes appearing in certain rock parts.

Table 2. Chemical composition of rhyolite from the Wielisławka Hill in weight per cent. *1* — Kozłowski, Parachoniak (1967); *2* — analysed by A. Nowakowski (unpubl.)

Skład chemiczny ryolitu ze wzgórza Wielisławka w procentach wagowych. *1* — Kozłowski, Parachoniak (1967); *2* — analizowane przez A. Nowakowskiego (dane niepublikowane)

	1	*2*
SiO_2	75.31	75.58
Al_2O_3	11.80	12.31
Fe_2O_3	0.47	1.54
FeO	0.43	0.28
MgO	1.40	0.39
CaO	0.45	0.26
Na_2O	2.75	1.87
K_2O	4.00	6.28
H_2O^+	2.19	0.71
H_2O^-	0.99	0.62
TiO_2	0.25	0.07
P_2O_5	—	—
MnO	tr.	0.01
CO_2	—	—
S	0.06	0.04
Σ	100.10	99.96
K_2O/Na_2O	1.45	3.36
PI	0.75	0.80

PI — peralcaline index (TAS)
tr. — traces
$PI = (Na_2O + K_2O)/Al_2O_3$

Table 3. CIPW norm of rhyolite of Wielisławka Hill

Norma CIPW ryolitu ze wzgórza Wielisławka

Norms	*1*	*2*
Q	41.0	39.5
C	2.1	2.0
or	23.6	37.1
ab	23.3	15.8
an	2.2	1.3
hy	3.5	1.0
mt	0.4	0.6
il	0.5	0.1
hm	0.2	1.1
pr	0.1	0.1
Σ	96.9	98.6
H_2O	3.2	1.3
Σ	100.1	99.9

Numbers of analyses according to Tab. 2.

FELDSPAR PHENOCRYSTS

The rhyolite from Wielisławka Hill bears two essential kinds of feldspar, namely potassium feldspar – sanidine, and plagioclase – albite, with the quantitative prevalence of the first one (Tab. 1). The habit of the both feldspars is usually subhedral. The pinacoids: longitudal {010}, transverse {100} and basic {001}, are the main forms of feldspars. Frequently the secondary albite is surrounded by the regular sanidine mantle (Pl. I, *2*), what proves the earlier crystallization of the primary plagioclase with respect to sanidine. The common crystallographic orientations of the both feldspars indicates a model of the epitaxial growth of the potassium feldspar on the plagioclase.

ALBITE

Extinction angle measurements $X'/(010)$* in the sections perpendicular to (010) and to (001) indicate the composition of the pure sodium feldspar An_0 (Pl. II, *5*). The same plagioclase composition has been stated in these rhyolites by Nowakowski (1976) and he has proved the albite secondary origin at the expense of the primary oligoclase and andesine An_{23-38}. Such origin of the albite results from the presence of the primary oligoclase relics, preserved very rarely in the secondary albite phenocrysts (Pl. II, *3*). Also the orientation of the pericline composition plane in the albite is typical of oligoclase and andesine, what is the second very important proof of secondary origin of albite confirmed by Nowakowski (1976).

The above plagioclase composition, determined in the present paper and being pure albite An_0, with except of the rare relics, is not consistent with the earlier determinations published by Kozłowski and Parachoniak (1967). According to those authors, the rhyolite from Świerzawa bears phenocrysts of oligoclase. The mentioned differences result probably from an error in the sign of the extinction angle determination.

All the investigated rhyolite specimens displayed the presence of the plagioclase phenocrysts of the pure albite composition, and the present author did not find in these specimens any relic of the primary plagioclase, though Nowakowski (1976) has been able to achieve it. It was also apparent that these feldspar phenocrysts show certain optic anomalies, namely:

1. The extinction angle $X'/(010)$ in the section perpendicular to (010) and (001) is frequently larger than $-15°$, reaching $-20°$, whereas the ordered end-member albite should have the extinction angle $-15°$ (Burri *et al.* 1967, Table XI).

2. The extinction angle $X/(001)$ in the section perpendicular to Z equals only $+17°$, what would indicate the content of 9 mole per cent An. However, the ordered albite An_0 should display the extinction angle $+23°$ (Borkowska, Smulikowski 1973). It is also worth noting, that albite in such sections had refractive index n_x distinctly lower than the refractive index of Canada balsam and the n_z – slightly lower than that of the balsam, what confirms the composition of pure albite.

The axial angle $2V_x$ varies within the range from 84° to 91°, indicating a relatively high ordering state expressed by the intermediacy index I.I. of Slemmons and modified by Nowakowski (oral information) equal from about 60° to 70° (Slemmons accepted the $2V_x$ angle equal 104° for the maximum ordered albite An_0 with I.I. = 100, but Nowakowski used the $2V_x$ angle equal 109°).

The small angle s between the planes RS and (001) equal to 1.8°, 3.0°, 4.7°, 5.0° and 5.2° (compare Pl. II, *6* and Fig. 2) is typical of the examined pericline twinned albite phenocrysts in spite of the fact, that the I.I. index is high. In such albite the angle s about 30° should be expected. Its low value (1.8 to 5.2) may indicate that the pericline twins have a relic character and they are inherited from the oligoclase replaced by the albite. One should suppose, that the similar angle s value would be obtained from the calculation according to the equation: $\mathrm{ctg}\,(s) = \mathrm{ctg}\,[(001)/(010)]/\cos(\gamma)$ (Tunnel 1952), if the interaxial angles of α and γ of the secondary albite are known. The obtained in this way value of the s angle would be the one corresponding to the presently existing albite but not the s angle of the pericline composition plane being the function of the α and γ angles characterizing the already nonexisting oligoclase.

In the case of the absence of the primary plagioclase relics in the studied albite, the interpretation of the measured s angle should be ambiguous, i.e. either this angle results from the albite crystallization at high temperature or originally this feldspar has been the oligoclase. Evidently, in the first case the mineral would be the primary albite (analbite) with the subsequent or-

*Crystallographic and optic signature according to Tröger (1972).

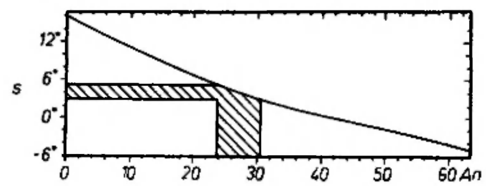

Fig. 2. Relation between the *s* angle being the inclination of the pericline composition plane to (001) and the anorthite content in plagioclase An based on the Nowakowski's (1976) plot. The shaded area indicates the approximate An-content of primary plagioclase resulting from the *s*-angle of relic pericline composition plane of secondary albite occurring in potassium rhyolite from Wielisławka Hill

Zależność między kątem *s* będącym nachyleniem płaszczyzny składu peryklinowego do (001) a zawartością anortytu w plagioklazie An oparta na wykresie Nowakowskiego (1976). Obszar zakreskowany pokazuje przybliżoną zawartość An plagioklazu pierwotnego wynikającą z kąta *s* nachylenia reliktowej płaszczyzny składu peryklinowego w albicie wtórnym pojawiającym się w ryolicie potasowym ze wzgórza Wielisławka

dering change, but in the second case the mineral would be the secondary albite forming the pseudomorph after oligoclase. In the discussed case there are no doubts, that the second interpretation is correct, because the primary plagioclase relics in the secondary albites have been ascertained in rhyolite from the Świerzawa environs. Nowakowski (1968, 1976) made similar observations in the volcanic rocks from the intra-Sudetic trough and from other locations of Europe and Asia. Thus the plagioclase in the rhyolite from Wielisławka Hill was oligoclase and anorthite-poor andesine (An_{24-31}) before its albitization (Fig. 2). It is approximately close to the composition of the primary plagioclase relics An_{35} (Pl II, *3*).

The polysynthetic albite twins are the most frequent twinning in the albite from the studied rhyolite; pericline twins occur rarer but commonly in combination with the Carlsbad and Ala-A twins. They are the growth twins in the primary plagioclase, next inherited by the secondary albite (Nowakowski 1968, 1976).

After the albitization process of the primary plagioclases there occurred sometimes adularization of the secondary albite. Similarly to the albitization, also in this case one may observe the sequence of the development stages of this process.

The adularia features distinguishing it from albite are as follows: lower birefringence, significantly lower refractive indices, small optical axes angle and sectorial pattern. As it appears from observations, certain cleavage planes and twin composition planes (e.g. in the Carlsbad twins) of albite and the adularia replacing the albite are common. It is characteristic, however, that the adularia did not inherit the albite twins.

SANIDINE

Sanidine phenocrysts belong to the best preserved rock components. Moreover, they seemingly have not undergone significant alterations. However, sometimes these phenocrysts were cut by a fine network of irregular veinlets filled by a mineral with the birefringence higher than that one of sanidine and coloured by a brown pigment. It is possible that the veinlets resulted either from the albite component exsolution or from a very weak albitization.

Sanidine cleavage chips are most frequently colourless and transparent, rarer milky or brownish. Unlike the albite cleavage chips, they have intensive luster on the cleavage surfaces.

In the thin sections the sanidine is frequently pale pink due to the hematite pigmentation. Kozłowski and Parachoniak (1967) have connected this with the presence of the radioactive potassium isotope ^{40}K. It appears from the optic studies, that the sanidine has the monoclinic symmetry and very small angle of the optical axes $2V_x \perp (010) = 10°$. The sanidine is rarely twinned. Mostly the sanidine twins are the simple Carlsbad twins (Fig. 3, Pl. II, *1*, *4*) and Ala-A twins, rarer the Ala-B twins, and even rarer the combined Ala-A and Baveno twins. The optic features of the sanidine are given in the Table 4.

Refractive indices have been determined by the immersion method for the cleavage chips, using the Jelley refractometer. The index n_y is so similar to the index n_z (the small $2V_x$ angle), that it is not possible to determine it precisely. This index could be calculated from the two remaining n_x, n_z and the $2V$ angle (Ziółkowska 1954), but the better measurement accuracy than the obtained one would be necessary.

The X-ray analysis has been applied for more precise determination of the degree of triclinicity, unit cell parameters, order-disorder degree and sanidine composition. The standard diffractograms (Fig. 4) have been performed from the powder preparation obtained from the transparent sanidine crystals handpicked under a binocular. The Cu_{K_α} radiation of the wavelength 1.5418 Å has been used in the angle range 2θ from 15° to 60°. The *hkl* indices of the individual reflections have been identified on the basis of the Wright and Stewart (1968) tables.

The UCIN computer program prepared by Z.

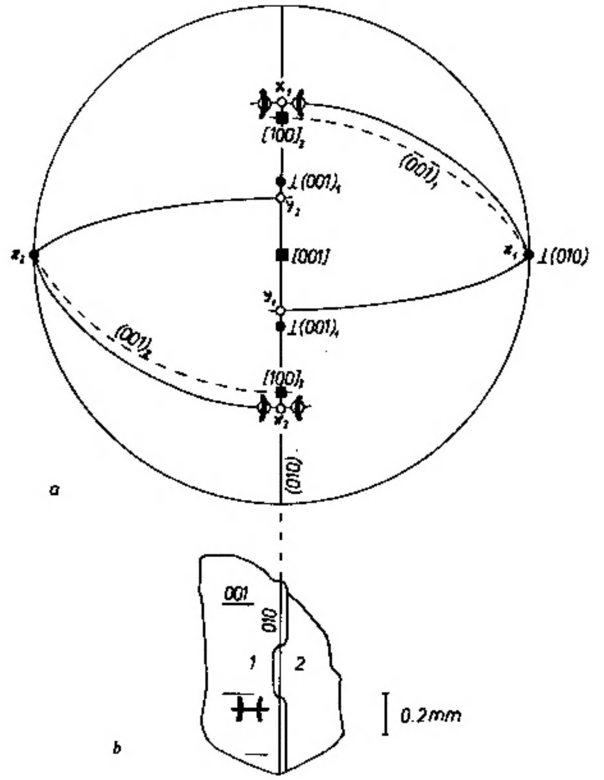

Fig. 3. Optic orientation of the sanidine Carlsbad twin in the stereographic projection (*a*) and its section drawn as seen in the microscope (*b*). The twin axis $c = [001]$ is the projection axis

Orientacja optyczna zbliźniaczeń karlsbadzkich sanidynu w projekcji stereograficznej (*a*) i przekrój przez nią naszkicowany tak, jak był widziany pod mikroskopem (*b*). Oś zbliźniaczenia $c = [001]$ jest osią projekcji

Table 4. Optical features of sanidine from the Wielisławka Hill

Właściwości optyczne sanidynu ze wzgórza Wielisławka

OAP	$\perp$ (010)
Optic orientation	$Z = b$, X & Y in (010)
$2V_x$	10°
n_x	1.5202
n_y	—
n_z	1.5264
Δ	0.0062
Extinction angles:	
$X/(001) \perp [010]$	5°
$X^1/(010) \perp a$	0° (parallel)

Weiss from the Scientific-Research Coal Institute in Ostrava has been used for the unit cell parameters calculations and for the accuracy determination of the d_{hkl}. The Table 5 presents the reflection list in °2θ for the studied sanidine and the calculated corrected d-values.

The feldspar triclinicity according to Goldsmith and Laves (1954) is expressed as a splitting of the reflections coming from the lattice planes (131) and (1$\bar{3}$1). Only one sharp reflection (131) occurs in the diffractogram of the studied sanidine, thus the triclinicity equals zero, confirming the monoclinic symmetry inferred also from the optic studies (Fig. 3).

The calculated parameters of the unit cell were

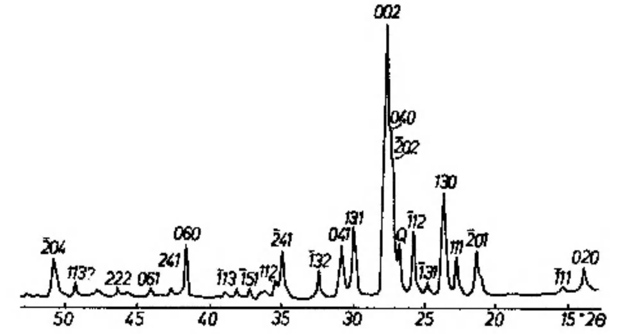

Fig. 4. Diffractogram of the Wielisławka sanidine (Cu_{K_α}). *Q* denotes the reflection caused by a quartz admixture

Dyfraktogram sanidynu z Wielisławki (Cu_{K_α}). *Q* oznacza odbicie spowodowane domieszką kwarcu

Table 5. Results of diffractometric investigations of sanidine from the Wielisławka Hill

Wyniki badań dyfraktometrycznych sanidynu ze wzgórza Wielisławka

$h \cdot k\ l$	2θ [°]	d-observed	d-calculated
0 2 0	13.68		
$\bar{1}$ 1 1	15.22		
$\bar{2}$ 0 1	21.30	4.17130	4.18419
1 1 1	22.72	3.91370	3.91592
1 3 0	23.61	3.76816	3.76654
$\bar{1}$ 3 1	24.64	3.61292	3.61228
$\bar{1}$ 1 2	25.80		
$\bar{2}$ 0 2	27.23	3.27487	3.27001
0 4 0	27.50		
0 0 2	27.70	3.22035	3.22041
1 3 1	29.94	2.98434	2.98074
0 4 1	30.81	2.90202	2.90149
$\bar{1}$ 3 2	32.41	2.76232	2.76294
$\bar{2}$ 4 1	34.98	2.56503	2.56665
1 1 2	35.40		
$\bar{1}$ 5 1	37.21	2.41627	2.41604
$\bar{1}$ 1 3	38.90	2.31510	2.31727
0 6 0	41.70	2.16590	2.16663
2 4 1	42.75	2.11510	2.11464
0 6 1	44.11		
2 2 2	46.38	1.95766	1.95795
1 1 3	49.41		
$\bar{2}$ 0 4	50.91	1.79360	1.79329

$a =$ 8.48559 $\pm$ 0.01026 Å
$b =$ 12.99972 $\pm$ 0.00659 Å
$c =$ 7.17454 $\pm$ 0.00295 Å
$\alpha =$ 90.0000°
$\beta =$ 116.1388 $\pm$ 0.0430°
$\gamma =$ 90.0000°
$V =$ 710.486 $\pm$ 0.850 Å^3

used for the determination of the mole content of Or in the sanidine. The value of the a parameter of the unit cell is a simple function of the chemical composition of the alkali feldspars of the normal lattice structure (Orville 1967). However, among cryptoperthites one may frequently find feldspars that do not follow this simple regularity. Stewart and Wright (1974, p. 362) call such feldspars "anomalous" or strained ones. The straining appears due to the exsolution of the sodic and potassic phases in the originally homogeneous alkali feldspar. It is connected with the significant difference between the sodium and potassium ions radii what influences appropriately the unit cell parameters, especially the a parameter (Kroll, Ribbe 1983). The difference between the a parameter observed and that one estimated from the b and c parameters or between the $2\theta(\bar{2}01)$ value observed and the $2\theta(\bar{2}01)$ estimated from the plot 2θ (060) versus 2θ $(\bar{2}04)$ (Wright, Stewart 1968; Stewart, Wright 1974), as presented in the Fig. 5, is the expression of the alkali feldspar unit cell straining. The investigated feldspar is characterized by the changed unit cell parameters. Nevertheless, the unit cell volume (V) can be used for the determination of the Or content in the alkali feldspar (Wright, Stewart 1968). The modified equation of Waldbaum and Thompson (Stewart, Wright 1974) has been used for this purpose:

$$\text{Or(mole \%)} = 0.2962-(0.953131-0.0013\,V)^{0.5}/0.0018062, \quad (1)$$

together with the Kroll's equation (Kroll, Ribbe 1983):

$$n_{Or} = -584.6683+2.58732V-3.83499\cdot10^{-3}V^2+1.90428\cdot10^{-6}V^3 \quad (2)$$

and with the Orville's plot (1967, p. 71). The results obtained were as follows, respectively: 68.9±1.8%, 68.4+1.8% and 67% Or. The obtained values have been compared with the feldspar composition calculated from the analysis made by the atomic absorption method at the Institute of Oil and Gas Prospecting at Wołomin:

$$Or_{0.6636},$$

and with the average of the seven electron microprobe analyses of sanidines from Wielisławka Hill (Kozłowski 1990):

$$Or_{0.6564}.$$

Taking into account the fact, that completely different methods have been employed to determine the Or content, the coincidence of the obtained results can be evaluated as completely satisfactory. Somewhat higher calculated values with respect to the measurement results is similar to the observations given by Stewart and Wright (1974). The results coincidence is also a good confirmation of the feldspar composition equations applicability as the function of the unit cell volume when one considers feldspars with the strained lattice parameters.

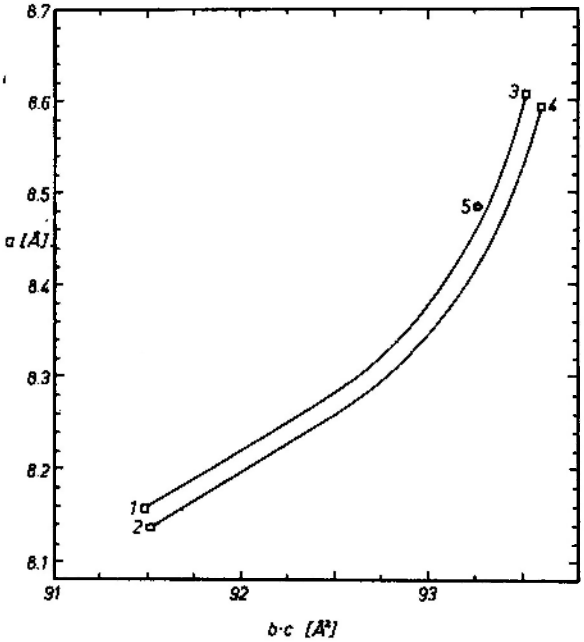

Fig. 5. The dependence of the a parameter on the $b \cdot c$ values of the alkali feldspars according to Bernotat (Kroll, Ribbe 1983). The feldspars with the strained lattice parameters have their projection points outside the area bordered by the lines *1–3* and *2–4*. *1* – analbite; *2* – low albite; *3* – high sanidine; *4* – low microcline; *5* – sanidine of Wielisławka Hill

Zależność parametru a od wartości $b \cdot c$ skaleni alkalicznych według Bernotata (Kroll, Ribbe 1983). Skalenie z odkształconymi parametrami komórki elementarnej mają punkty projekcyjne położone na zewnątrz pola ograniczonego liniami *1–3* i *2–4*. *1* – analbit; *2* – niska zawartość albitu; *3* – wysoka zawartość sanidynu; *4* – niska zawartość mikroklinu; *5* – sanidyn ze wzgórza Wielisławka

The comparing of the infrared absorption spectra is one of methods of the quantitative structure ordering determination of the feldspars. Minerals of the higher degree of order yield usually sharp and more symmetric absorption bands, and the disordering causes the bands diffusion and broadening (Laves, Hafner 1956). The absorption intensity of the ν_1 band (the symmetric stretching vibrations Si–O–Si and Si–O–Al near 700 cm $^{-1}$) increases during the transition from the disordered to the ordered structures (Kubisz, Żabiński 1979, p. 425).

The infrared absorption spectrum of the sanidine from Wielisławka Hill (Fig. 6) has been compared with that one of the sanidines from the Keiserstuhl massif (Laves, Hafner 1956), from Eifel, Siebengebirge (FRG), from Arizona (USA) and from Wakayama Puf in Japan (van der Marel, Beutelspacher 1976). It has been found that the spectrum of the sanidine from Wielisławka Hill indicated a higher ordering degree than almost all the above listed samples. The spectrum of the Wielisławka sanidine differs especially distinctly from the sanidine spectra from Eifel and Keiserstuhl. In the latter spectra, contrary to the Wielisławka sanidine, the absorption bands between 840 and 870 cm^{-1} are completely absent, the bands near 700 cm^{-1} have very low intensity and a very weak splitting of the two absorption peaks in this range. Also the symmetry of the individual absorption bands is lower than in the studied feldspar spectrum.

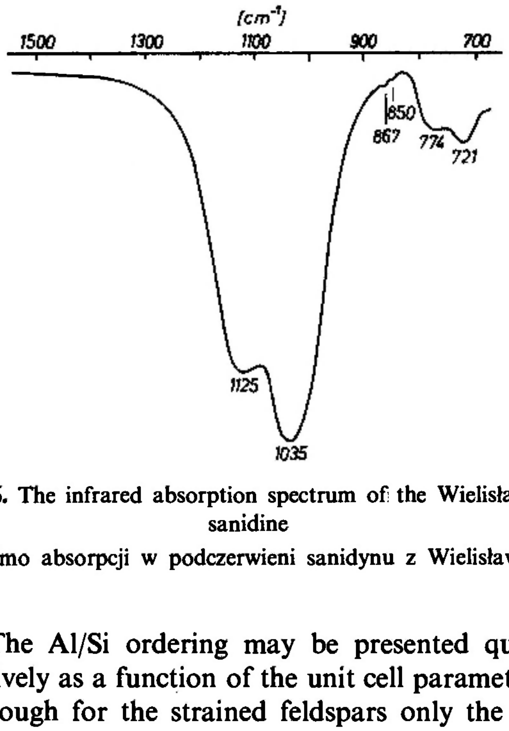

Fig. 6. The infrared absorption spectrum of the Wielisławka sanidine

Widmo absorpcji w podczerwieni sanidynu z Wielisławki

The Al/Si ordering may be presented quantitatively as a function of the unit cell parameters. Although for the strained feldspars only the apparent structure ordering can be determined (Wright 1968), the fact of the straining does not seem to influence the ordering in a significant degree (Kroll, Ribbe 1983). The structure ordering degree of the alkali feldspars is expressed by the presence of Al (Σt_1) at the tetrahedral sites T_1. The Σt_1 varies in the ranges from 1.0 for the completely ordered structure to 0.56 for the completely disordered feldspar structure (Kroll, Ribbe 1983). For the monoclinic sanidine the t_1o equals the t_1m, hence the value $\Sigma t_1 = 2t_1$ is the order/disorder degree index. It has been calculated from the equations, in which it is a function of the b and c parameters of the unit cell:

$$2t_1 = -7.590-2.3258b+5.3581c \qquad (3)$$

(Kroll, Ribbe 1983), and

$$t_1o+t_1m = (c-0.45132b-1.22032)/(1.6095-0.11252b) \qquad (4)$$

according to Luth (Stewart, Wright 1974). The obtained results are respectively equal 0.617 and 0.594, being relatively high ones if compared with the value of 0.56 typical of the high sanidine (Kroll, Ribbe 1983). The Fig. 7 is the graphical image of the equation (3).

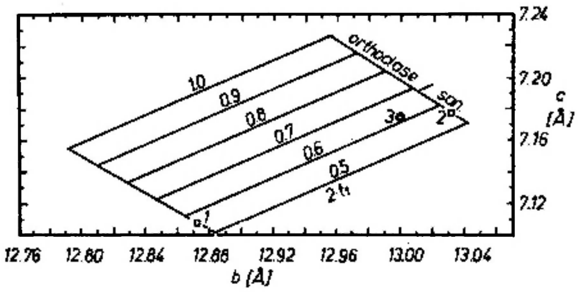

Fig. 7. The relation between the ordering degree expressed by the $2t_1$ value and the b and c parameters of the alkali feldspars, after Kroll and Ribbe (1983). *1* — analbite; *2* — high sanidine; *3* — sanidine from Wielisławka Hill

Zależność między stopniem uporządkowania wyrażonym przez wartość $2t_1$ a parametrami b i c skaleni alkalicznych według Krolla i Ribbego (1983). *1* — analbit; *2* — sanidyn wysokotemperaturowy; *3* — sanidyn ze wzgórza Wielisławka

The relatively high degree of order calculated for the sanidine from Wielisławka Hill may indicate a relatively durable rock cooling under undisturbed geological conditions and absence of latter thermal alterations.

CONCLUSIONS

The performed field and laboratory studies allowed to express the following most important conclusions:

1. The presence of the fluidal textures transversal with respect to the columnar joint and the columnar joint orientation in the shape of the reverse fan suggest, that the Wielisławka rhyolite is a part of a lava surface extrusion but not an intrusive form in this place, as it has been suggested by Kozłowski and Parachoniak (1967).

2. The rhyolite from Wielisławka Hill is the rock with the abundant phenocrysts of sanidine, albite and quartz, and with rarer phenocrysts of biotite. The main rock mass is a glass recrystallization product rich in sanidine and quartz. According to the TAS petrochemical classification this rock is potassium rhyolite. A high homogeneity is a striking feature of this rhyolite.

3. Plagioclase in the studied rhyolite is exclusively albite An_0, frequently twinned according to the Albite-Carlsbad and pericline law. The low value of the s angle ($1.8 \div 5.2°$), that means the angle between the traces of the (001) plane and the pericline composition plane (rhombic section RS) is the most essential feature of the albite, indicating the secondary origin of this feldspar, forming pseudomorphs after a primary Ca-richer plagioclase. The pericline twinning is a relic one, inherited after a primary plagioclase of the composition ranging from oligoclase to anorthite-poor andesine. The primary plagioclase alteration in albite was a process of the autometasomatic rearrangement of the plagioclase composition which occurred most probably in the final stage of the rhyolite lava consolidation.

4. The adularia origin at the expense of the earlier formed albite was locally a following stage of the plagioclase evolution. This process displayed a significantly less important role than albitization of the plagioclase. Thus, the general evolution trend for these processes was as follows: oligoclase → albite → adularia. These processes did not lead to an increase of the total feldspar content in the rock but only to the chemical composition rearrangement of the primary plagioclase with preservation of its morphology.

5. The potassium feldspar is sanidine fairly rarely twinned. Crystals twinned according to the laws: Carlsbad, Ala-A, rarely Ala-B (Esterel) and even rarer the combination Ala-A and Baveno, have been found. These twinning laws are typical of the magmatic feldspars (Gorai 1951). It has been determined that sanidine bears ca. 67 mole per cent Or. The unit cell parameters indicate a structure straining resulting probably from an exsolution in form of the cryptoperthite, though it has not been found in the diffractogram. The ordering of the structure is high as for sanidine ($2t_1$ equal ca. 0.6). It may indicate the absence of rapid thermic changes in the geological history of the studied area after the rhyolite origin, i.e. since the Rotliegendes time.

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SKALENIE ALKALICZNE W RYOLICIE ZE WZGÓRZA WIELISŁAWKA KOŁO ŚWIERZAWY (SUDETY ZACHODNIE)

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Streszczenie

Permski ryolit potasowy ze wzgórza Wielisławka uznano za fragment pokrywy wulkanicznej. Ryolit zawiera fenokryształy sanidynu i albitu. Albit zbadano metodami optycznymi. Na podstawie orientacji płaszczyzny reliktowego przekroju rombowego w albicie stwierdzono, że tworzy on pseudomorfozy po pierwotnym plagioklazie o składzie oligoklazu-andezynu. Skaleń ten w swej dalszej ewolucji autohydrotermalnej miejscami uległ adularyzacji. Fenokryształy sanidynu zawierają około 67% molekularnych cząsteczki Or. Minerał ten posiada odkształcone parametry komórki elementarnej, co jest prawdopodobnie efektem odmieszania fazy sodowej i potasowej. Stopień uporządkowania struktury sanidynu wynosi około $2t_1 = 0.6$ i jest stosunkowo wysoki. Na tej podstawie wyciągnięto wniosek o prawdopodobnym względnie długotrwałym stygnięciu ryolitu.

PLATES AND EXPLANATIONS

PLATE I – PLANSZA I

"The Wielisławka Organ" – the abandoned rhyolite quarry
Organy Wielisławskie – opuszczony kamieniołom ryolitu

1. Wielisławka Hill. A general view of the rhyolite quarry situated on the south-western slope
Wzgórze Wielisławka. Widok ogólny kamieniołomu ryolitu usytuowanego na południowo-zachodnim zboczu

2. Thermic joint of the rhyolite resembling by its shape a reverse fan
Szczeliny termiczne w ryolicie przypominające kształtem odwrócony wachlarz

3. The rhyolite fluidal texture visible as dark, sometimes undulated (the right side of the photo) stripes approximately perpendicular to the thermic joint direction
Ryolitowa tekstura fluidalna widoczna jako ciemne, czasem faliste pasma (prawa strona fotografii) w przybliżeniu prostopadłe do kierunku spękań termicznych

4. Two assemblages of the fractures in the rhyolite, approximately perpendicular one to the other: the columnar joint (parallel to the shorter photo side) and fluidal structures
Dwa zestawy spękań w ryolicie w przybliżeniu prostopadłe do siebie: spękania słupowe (równoległe do krótszej strony fotografii) i struktury fluidalne

2

4

1

3

Andrzej WILAMOWSKI – Alkali feldspars in the Lower Permian rhyolite from Wielisławka Hill near Świerzawa (West Sudetes)
Skalenie alkaliczne w ryolicie ze wzgórza Wielisławka koło Świerzawy (Sudety Zachodnie)

PLATE II – PLANSZA II

Feldspar phenocrysts from the rhyolite from Wielisławka Hill
Fenokryształy skaleni z ryolitu ze wzgórza Wielisławka

1. Granophyric intergrowth of sanidine (Carlsbad twin) and quartz. Nicols crossed, magn. ca. 110×
Granofirowe przerosty sanidynu (zbliźniaczenia karlsbadzkie) i kwarcu. Nikole skrzyżowane, pow. ok. 110×

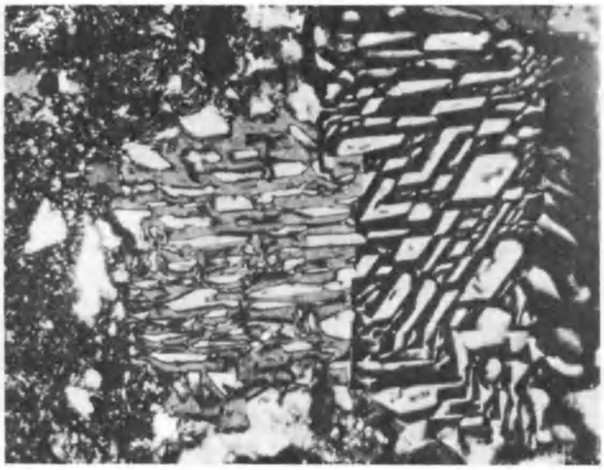
2. Two albite phenocrysts enveloped by sanidine. According to the longer photo side there are visible traces of the (001) cleavage planes of both feldspars. Nicols crossed, magn. ca. 120×
Dwa fenokryształy albitu otoczone sanidynem. Wzdłuż dłuższego boku fotografii są widoczne ślady płaszczyzn kliważu (001) obu skaleni. Nikole skrzyżowane, pow. ca. 120×

3. Relics of andesine An_{35} (light irregular spots) preserved in the secondary albite phenocrysts (dark); both feldspars cut $\perp$ *a*. The (010) and (001) cleavage traces of the both feldspars are approximately parallel to the longer and shorter photo sides. Photo taken from the sample of A. Nowakowski. Nicols crossed, magn. ca. 140×
Relikty andezynu An_{35} (jasne nieregularne plamki) zachowane we wtórnych fenokryształach albitu (ciemne); oba skalenie przecięte $\perp$ *a*. Ślady kliważu (010) i (001) w obu skaleniach są w przybliżeniu równoległe do dłuższego i krótszego boku fotografii. Sfotografowana próbka A. Nowakowskiego. Nikole skrzyżowane, pow. ok. 140×

4. Sanidine Carlsbad twin bearing an inclusion of the partly mechanically removed albite crystal. Nicols crossed, magn. ca. 100×
Zbliźniaczenie karlsbadzkie sanidynu zawierające wrostek kryształu albitu częściowo mechanicznie zniszczony. Nikole skrzyżowane, pow. ca. 100×

5. Albite- and pericline-twinned albite phenocryst (the twin stripes approximately parallel to the longer and shorter photo sides, respectively); the section $\perp$ *a*. Nicols crossed, magn. ca. 100×
Fenokryształ albitu zbliźniaczony albitowo i peryklinowo (pasma bliźniacze w przybliżeniu równoległe do dłuższego i krótszego boku fotografii); przekrój $\perp$ *a*. Nikole skrzyżowane, pow. ca. 100×

6. Relic pericline twinning (RS) in a phenocryst of the secondary albite replacing primary oligoclase. The angle *s* between the RS trace and the visible (001) cleavage equals 5°, what corresponds to composition An_{25} of primary plagioclase. Nicols crossed, magn. ca. 100×
Reliktowe zbliźniaczenie peryklinowe (RS) w fenokrysztale wtórnego albitu zastępującego pierwotny oligoklaz. Kąt *s* między śladem RS i widocznym kliważem (001) wynosi 5°, co odpowiada składowi An_{25} w pierwotnym plagioklazie. Nikole skrzyżowane, pow. ca. 100×



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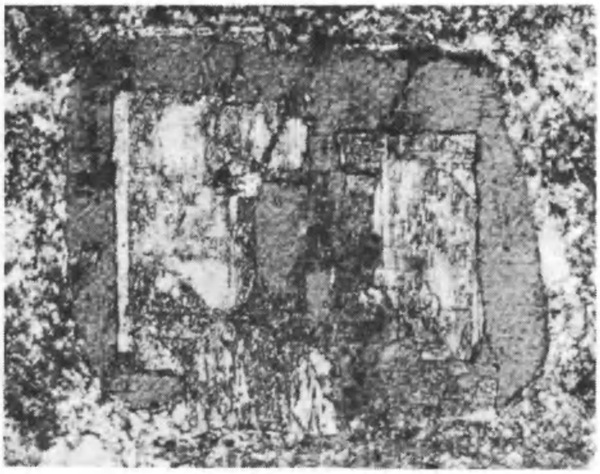

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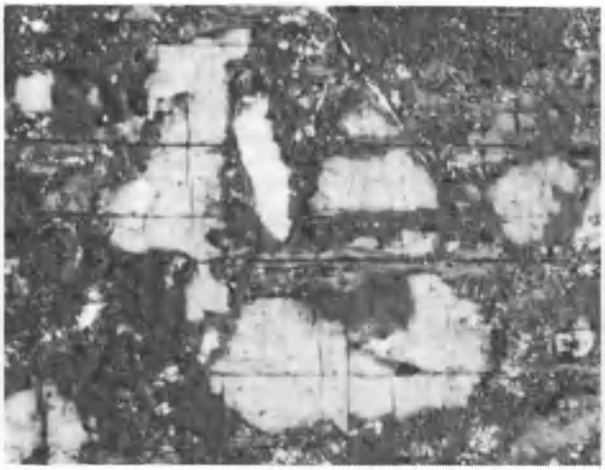

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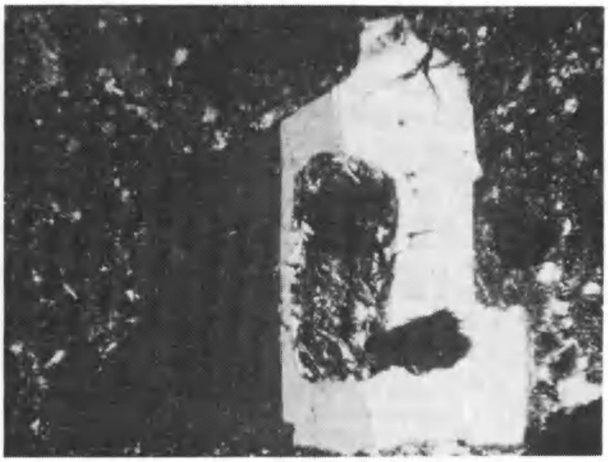

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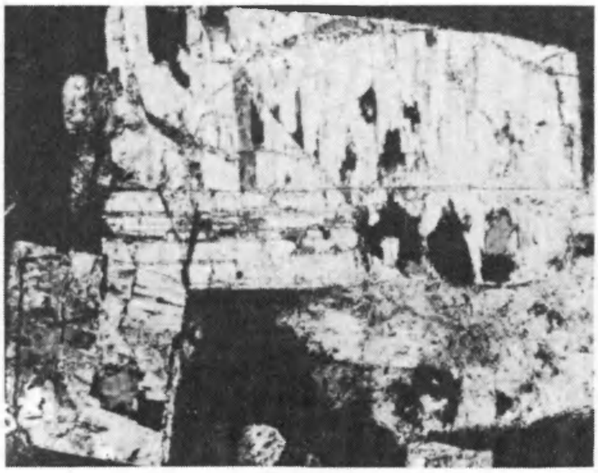

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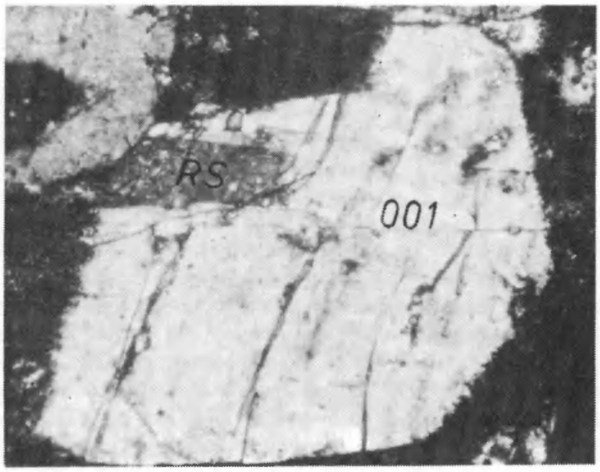

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Skalenie alkaliczne w ryolicie ze wzgórza Wielisławka koło Świerzawy (Sudety Zachodnie)