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Chemical and mineralogical alteration in the Rutki-Ligota basalts: Tertiary Volcanic Formation, Lower Silesia

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The paper shows chemical alterations of the Rutki-Ligota basalt deposit of the Tertiary Volcanic Formation of Lower Silesia. The investigations indicate that the chemical alterations of basalts result from their textures and variations in mineral composition. The results of mineralogic studies of basalts suggest varied alteration processes: serpentinization, iddingsitization, uralitization and carbonatization. Some of products of these alterations (largely amphiboles and iron hydroxides) were identified using Mössbauer spectroscopy. The results of the studies indicate the usefulness of the Rutki-Ligota basalts not only in breakstone but also in mineral wool production.

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Key words: Lower Silesia, Tertiary, basalts, chemical composition, serpentinization, iddingsitization, uralitization, carbonatization.

INTRODUCTION

The Rutki-Ligota basalts in the vicinity of Niemodlin belong to the Tertiary Volcanic Formation of Lower Silesia. The first documented research this formation, including basalts from the Opole region, were carried out by Rode (1934). Information on the geological structure, mineral and chemical composition and physical-mechanical properties of the Rutki-Ligota basalts are given in Kamieński (1946), Kamieński and Skalmowski (1947), Smulikowski (1960), Jerzmański and Maciejewski (1968), Birkenmajer (1974), Birkenmajer and Siemiątkowski (1977), Kapuściński and Pozzi (1980, 1984, 1985).

Our studies of the Rutki-Ligota basalts were aimed at elucidating the origin of the geochemical and mineralogical alteration of diversity these basalts. The Rutki-Ligota basalts are currently used as a breakstone. We also discuss its usefulness in mineral wool production.

The petrographic studies included traditional microscopic, chemical and X-ray diffraction analyses as well as Mössbauer spectroscopy, permitting characterization of their phase and chemical composition. The Rutki-Ligota basalts are compared with nearby basalts in the Opole region, e.g. at Święta Anna Mt. and Gracze (Chodyniecka, 1967, 1969, 1971).

GENERAL CHARACTERISTICS OF THE RUTKI-LIGOTA BASALT

The Rutki-Ligota basalt belongs, together with the neighbouring basalt occurrences (Święta Anna Mt. and Gracze), to the Tertiary basalt formation which comprises the eastern boundary of the Central European Volcanic Province (Smulikowski, 1960; Jerzmański and Maciejewski, 1968; Birkenmajer, 1974; Białowolska, 1980). This region is composed of Cretaceous, Tertiary and Quaternary deposits (Figs. 1 and 2) overlying older rocks.

The oldest rocks are Cretaceous (Upper Cenomanian) cross-bedded, fine-grained sands of continental origin. These deposits are locally absent due to a breaks in sedimentation, and here the older basement is overlain by sandy glauconitic marls followed by light grey platy and tabular marls with pyrite concretions. The marls have yielded Lower Turonian bivalves (*Inoceramus labiatus*) (Aleksandrowicz and Birkenmajer, 1973). Upper Turonian deposits of the Opole Trough are composed of white marls, locally limestones, with abundant microfauna. The Coniacian and Santonian deposits are marly claystones containing fragments of ammonites and bivalves as well as numerous foraminifers — *Globotruncana marginata,*

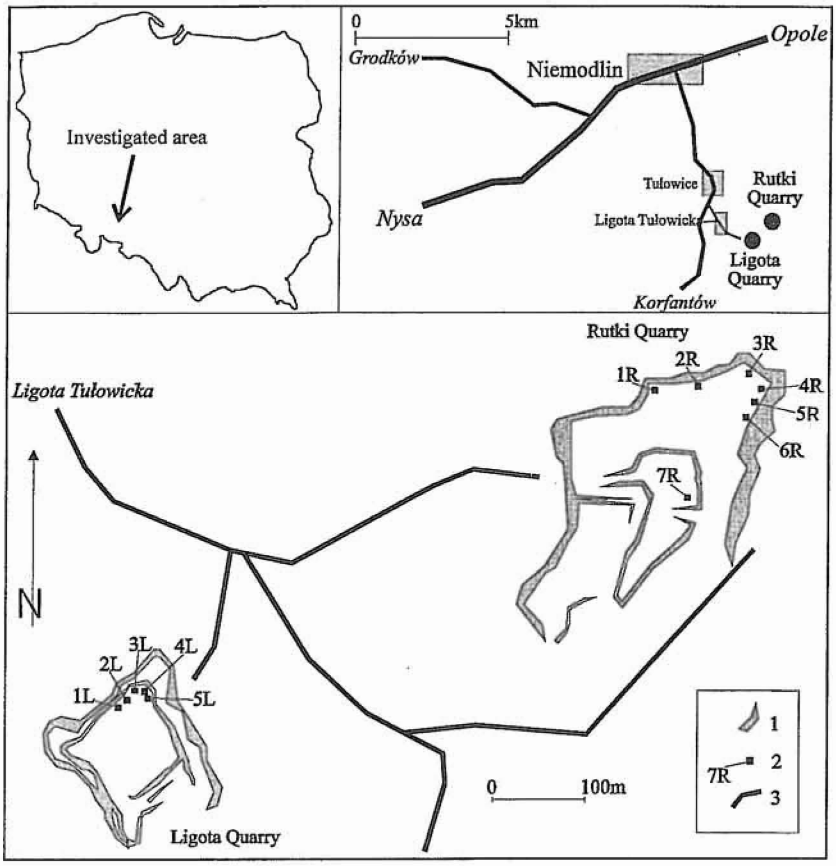

Fig. 1. Location map of the Rutki-Ligota basalts

1 — quarry wall, 2 — sampling site with sample number, 3 — routes

G. laparenti, G. ventricosa (Aleksandrowicz and Birkenmajer, 1973).

Tertiary deposits are represented by basalts, tuffs and volcanic breccias.

Quaternary deposits consist of fluvial muds and sands and glacial deposits (sands and fine-grained gravel) containing pebbles transported from the north by ice. Basaltic debris occurs at the base of the Quaternary deposits.

The basaltic plug is an irregular body with a variable thickness ranging from 0.7 to over 37 m. Drilling has not encountered the source of magma. The eruption was linear, determined as a part of the plug and coulée (Birkenmajer, 1974).

The basalt occurs as regular columns (most common), rock monoliths and local accumulations of volcanic bombs. These rocks are variably weathered. Intercolumnar fractures and fissures are abundantly filled with white and yellow clay minerals which probably represent a mixture of weathered basalt components and the overlying soil. The rock monolith is fractured into irregular blocks. Volcanic bombs, up to several tens of centimetres in diameter, are distributed irregularly. The basalt is weathered wherever it occurs, brittle and friable, and contaminated with residual clay and scales.

The total resources of the Rutki-Ligota deposit are about 30 mln tons. The main production takes place at Rutki, and no production is currently run at Ligota. Annual production of grit, breakstone, key aggregate, fine aggregate and road mix is around 267 thousand tons (Bolewski and Ney, 1966).

SAMPLING AND RESEARCH METHODS

12 samples were collected from the Rutki-Ligota basalt for mineralogical and chemical analyses (Fig. 1, Tab. 1):

— 5 samples from the northern wall of Ligota quarry,

— 2 samples from the central part of the northern wall of Rutki quarry,

— 4 samples from the northeastern and eastern walls of Rutki quarry,

— 1 sample from the central part of Rutki quarry.

Microscopic analyses using transmitted and reflected light enabled selection of samples with the most diverse petrographic structure (1L, 4L, 3R, 7R) for further investigation. These samples were subjected to chemical analyses (including trace element content) and X-ray diffraction. Using Mössbauer spectroscopy, the major minerals containing iron were identified, and its atomic percentage content was determined for each mineral. A transmission technique at room temperature was employed for Mössbauer analyses, utilizing the ^{57}Co:Cr isotope, approximately 50 mCi, as a gamma ray source. The spectrometer was calibrated using α-Fe absorbent, sodium nitroprussiate.

RESULTS

Macro-scale observations allowed distinction between fresh basalt (mainly rock monolith) and variably altered basalt (mostly volcanic bombs). Rock colour varied from grey to dark grey, with local yellow coatings. The rock is compact and shows unoriented and porphyritic texture. Pracrystals are represented by pyroxene and olivine. Altered basalts often had orange weathering rinds. The volcanic bombs varyied from grey brown with violet tones to black in colour, indicating the presence of „Sonnenbrand" (Ryka and Maliszewska, 1991). The bombs frequently show red and yellow coatings and aphanitic texture.

The rock shows microporphyritic texture in thin section. Its mineral composition includes augite, olivine, plagioclases, magnetite, nepheline and biotite. There are also secondary mineral constituents, such as iddingsite, serpentine, calcite, chalcedony, iron hydroxides and zeolites.

Augite occurs as pracrystals and as one of the major components of the groundmass. Thus, it forms two generations of crystals, idiomorphic in both cases.

Augite pracrystals of the first generation are 0.40–1.50 mm in size. They form short columns showing perfect cleavage parallel to the walls. In planes nearly parallel to the *z* axis they show cleavage (110) and (1$\bar{1}$0) and poorly marked (although common in ordinary augites) parting (100) resulting from the chemical heterogeneity of the augite. This heterogeneity is seen as zonal or hourglass structure in the pracrystals. The nucleus of the zonal variety is usually colourless, $z/\gamma = 38$–$43°$ that points to diopside augite, while the rims show weak violet pleochroism and $z/\gamma = 48$–$51°$, indicating titanian augite. Hourglass and zonal-hourglass grains involve a combination of these two augites. Augite pracrystals with simple twinning on (100) were sporadically found in Rutki quarry. Lenticular concentrations of radially arranged augite grains have also been recorded. They are 0.4–1.0 mm in size and are typically composed of several augite grains. The augite grains, forming radial concentrations, are 0.25–0.40 mm in size. Their optical properties point to titanian augite.

Second-generation augites are represented by groundmass grains, not exceeding 0.20 mm in size. These grains optically resemble titanian augite with an hourglass and hourglass-zonal structure. Spaces between the augite crystals are sporadically filled with greenish volcanic glass. The intermediate size of the augite grains in the concentrations, and their characteristic radial arrangement, suggests that this is a generation formed under intermediate conditions between those favouring the formation of pracrystals and those promoting the formation of augite crystals in the groundmass. Uralitization and chloritization affected only some of the augite pracrystals. Groundmass augites are preserved fresh without any signs of alteration. Both these processes started from the outer parts of the pracrystals and along cleavage planes, later advancing inwards. Near the pracrystals affected by uralitization, fine biotite flakes were observed.

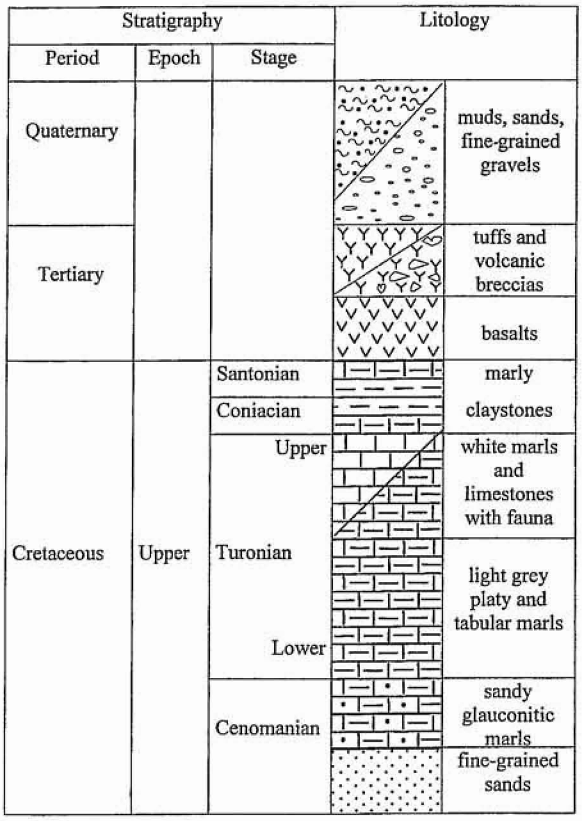

Fig. 2. Lithological-stratigraphical log of the Rutki-Ligota basalts

Olivine, like augite, occurs as both isolated pracrystals and lenticular concentrations of crystals. Olivine is not present in the groundmass. Olivine pracrystals are generally altered. Idiomorphic olivine pracrystals do not exceed 0.20 mm in size. Embayments, characteristic of magmatic corrosion, were frequently observed. Samples containing fresh olivine crystals show weak cleavage along (010) and (100) as well as frequent irregular fractures transverse to the cleavage usually deflected towards (010). Olivine crystals are characterized by simple extinction. Olivine pracrystals showing pale-yellow pleochroism in their outer parts were sporadically observed, and indicates the chemical heterogeneity of these crystals. Lenticular concentrations of olivine crystals, approximately 2.00 mm (up to 4.00 mm) across, are composed of a few (up to twenty) intergrowing crystals. Some of these, like the pracrystals, show evidence of magmatic corrosion. The olivine pracrystals and lenticular concentrations are variably affected by iddingsitization and serpentinization. Iddingsitization affects all the olivine grains irrespective of their mode of occurrence. In lithologies containing magnetite grains, even large olivine pracrystals are wholly affected by iddingsitization (Ligota volcanic bombs). Locally, near the iddingsitized olivine pracrystals, poorly developed biotite flakes were observed. Serpentinization also proceeded variably. Chrysotile and

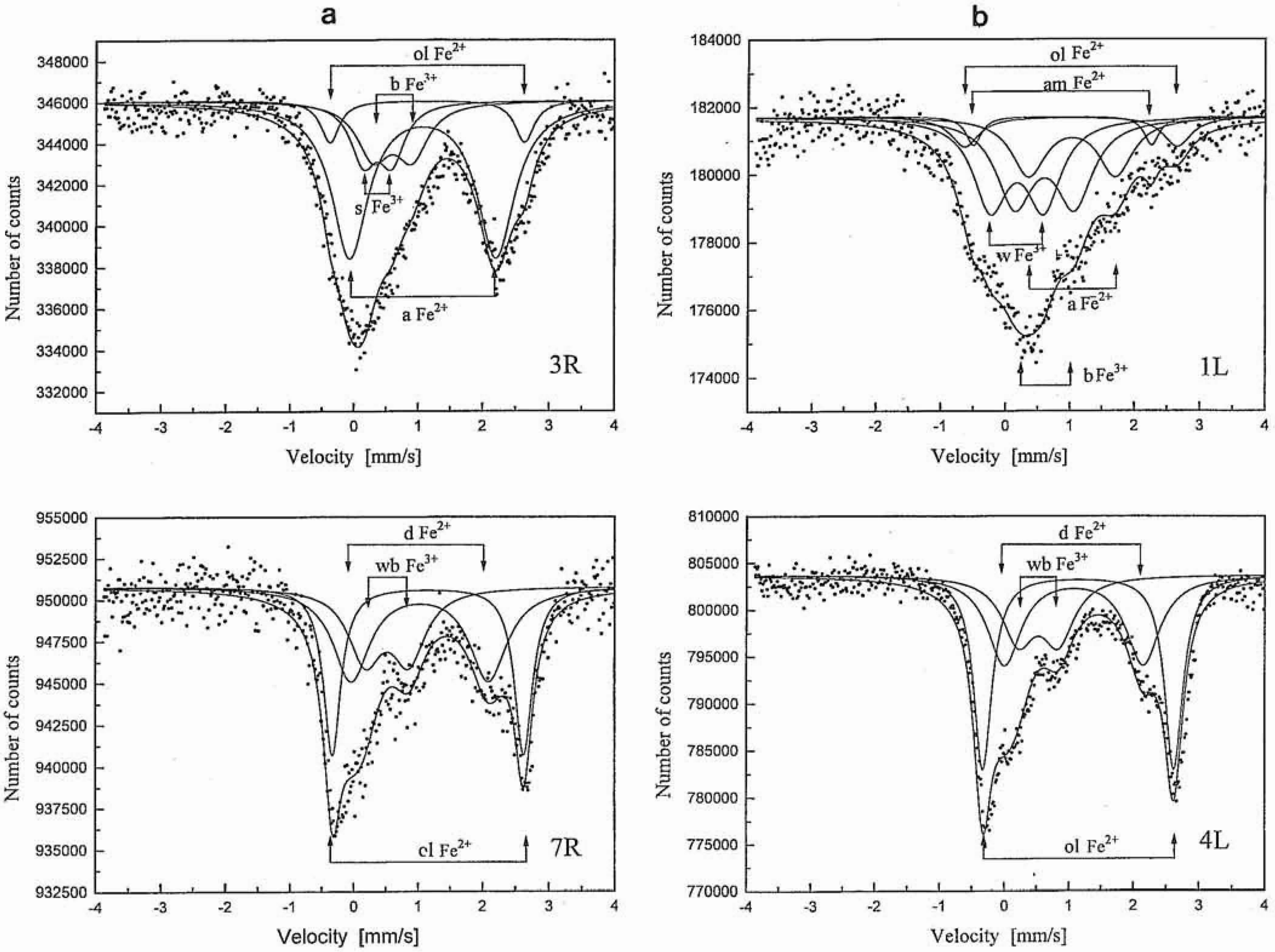

Fig. 3. Mössbauer spectra of a volcanic bomb (3R) and fresh basalt (7R) from Rutki (a) and of a volcanic bomb (1L) and fresh basalt (4L) from Ligota (b)

a — augite, b — biotite, d — diopside, ol — olivine, s — serpentine, w — iron hydroxide

antigorite pseudomorphs after olivine were observed. Some olivine pracrystals from the Ligota basalt show both iddingsitization along the grain margins and serpentinization (inside grains along fractures). These chemical changes reflect the chemical heterogeneity of the olivine. Serpentinization took place in relatively magnesium-rich olivine inside pracrystals, whereas the grain margins, showing iddingsitization, seem more iron-rich. The alteration histories of olivine from Ligota and Rutki are similar. Alteration is more intense in volcanic bombs than in the rock monolith, though even fresh basalts show signs of alteration of olivine. However, olivine grains in samples containing magnetite grains in the groundmass, giving a darker colour to the rock under the microscope, tend to be more strongly altered. Basalt samples containing fresh olivine are characterized by a trace content of magnetite.

Plagioclases, together with second-generation titanian augite, are the major components of the groundmass. They occur as laths twinned according to the albite law, and their optical properties are typical of labrador-bytownite.

Spaces between plagioclase and augite grains in the groundmass are filled with xenomorphic nepheline showing neutral relief in relation to Canada balsam, indistinct cleavage and weak anisotropy. Nepheline also occurs as veinlets crossing large olivine pracrystals, or as lenticular concentrations, being probably void-fill. Lenticular concentrations of nepheline often contain apatite inclusions showing rodded and columnar habit, as well as occasional rodded and tabular zeolites, difficult to identify under the microscope. They were observed both in the nepheline veinlets and as lenticular concentrations.

Pyroxene and olivine pracrystals are crossed by very irregular secondary calcite veins. There are also sporadical fine opaque grains, identified in reflected light as magnetite and ilmenite intergrowths. These grains are equally dispersed within the groundmass, only locally forming larger concentrations.

The altered Rutki basalts contain occasional concentrations of epidote minerals and biotite flakes, not previously recorded in these rocks (Kapuściński and Pozzi, 1980, 1984, 1985). The Mg^{2+}-rich variety of biotite — meroxene — was reported from

Table 1

Samples from the Rutki-Ligota basalts

Quarry	Sample number	Sample symbol	Location
Ligota	1L	volcanic bomb	northern wall
	2L	volcanic bomb	
	3L	altered cloddish basalt	
	4L	fresh basalt	
	5L	fresh basalt	
Rutki	1R	fresh basalt	northern wall
	2R	weathered basalt	
	3R	volcanic bomb	northeastern and eastern walls
	4R	volcanic bomb	
	5R	altered basalt	
	6R	weakly altered basalt	
	7R	fresh basalt	
Total	12		

Table 2

Chemical analyses of the Rutki-Ligota basalts

Component	1L volcanic bomb [wt.%]	4L fresh basalt [wt.%]	3R volcanic bomb [wt.%]	7R fresh basalt [wt.%]	Min. Max. Arithm. mean	Min. Max. Arithm. mean (after Żołnierczyk, 1981; Kapuściński and Pozzi, 1984)	Lower Silesian basalts average (after Szpila, 1959)	Gracze dolerite (after Chodyniecka, 1971)
SiO_2	42.39	41.92	40.07	41.60	40.07 42.39 41.49	41.78 42.80 42.29	42.76	44.45
Al_2O_3	18.08	12.57	14.56	11.79	11.79 18.09 14.25	11.20 12.05 11.63	12.51	15.80
TiO_2	0.27	0.19	0.09	0.49	0.09 0.49 0.26	2.47 2.50 2.49	2.85	2.41
Fe_2O_3	*11.02	*15.11	*13.04	*11.79	*11.02 15.11 12.74	6.50 8.20 7.35	6.14	11.82
CaO	13.03	14.54	13.39	15.44	13.03 15.44 14.10	12.04 12.50 12.27	11.77	8.41
MgO	8.58	12.66	11.15	15.49	8.58 15.49 11.97	10.03 11.00 10.51	10.21	3.41
Na_2O	2.11	1.90	2.51	1.93	1.90 2.51 2.11	3.02 4.00 3.51	3.10	3.35
K_2O	0.70	0.44	0.42	0.75	0.42 0.75 0.58	1.02 1.02 1.02	1.38	1.40
H_2O^-	0.85	0.04	0.98	0.19	0.04 0.98 0.51	0.64 3.58 2.11	–	1.44
Ignition loss	3.58	0.76	3.47	1.05	0.76 3.58 2.21	–	–	4.05
Total	100.62	100.13	99.55	100.52	–	–	–	–
M_k	2.80	2.00	2.23	1.73	–	–	–	–

M_k — acidity coefficient, * — total iron content

Table 3

Viscosity values calculated using the Bottinga-Weill method (in Pas)

Sample number	Temperature [°C]												
	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800
1L	6.76	5.86	5.25	4.37	3.69	3.07	2.66	2.02	1.83	1.41	1.17	0.98	0.88
4L	5.63	4.70	4.43	3.67	3.06	2.58	2.28	1.85	1.78	1.25	1.05	0.94	0.92
3R	5.92	4.91	4.08	3.81	3.15	2.62	2.28	1.75	1.61	1.16	0.96	0.82	0.76
7R	5.07	4.01	3.88	3.24	2.54	2.14	1.82	1.43	1.36	0.85	0.72	0.62	0.60

gabbros and norites and their effusive and vein-rock equivalents (Bolewski and Manecki, 1993). Biotite flakes have also been reported from other basalt occurrences (Jerzmański and Maciejewski, 1968; Duźniak *et al.*, 1976; Jaworski, 1983; Smulikowski and Kozłowska-Koch, 1984; Adamczyk, 1998).

Interiors of pyroxene pracrystals from sample 5L (Ligota basalt) are highly altered and filled with minute anisotropic concentrations of serpentine minerals. Rocks composing volcanic bombs are most strongly altered: pyroxenes have undergone uratilization, whereas olivines have been iddingsitized and serpentinized. Volcanic bombs from both Rutki and Ligota contain chalcedony and opal as alteration products. Pyroxenes from sample 3R (Rutki basalt) have been dolomitized. Volcanic bombs from Ligota contain iron hydroxides concentrated around altered pyroxenes and olivines.

These basalts can be classified as nepheline basalts.

Their chemical composition is typical of basalts from this area (Tab. 2). Silica, calcium and magnesium contents are similar to those reported by Szpila (1959) and Kapuściński and Pozzi (1984). The residual clay content resembles that from the Gracze dolerite (Chodyniecka, 1969). Sodium, potassium and titanium contents in the Rutki-Ligota basalts are smaller compared with the values reported by earlier authors.

The chemical analyses allowed calculation of the acidity coefficient (Tab. 2) which is the weight ratio of the total sum of acid oxides ($SiO_2 + Al_2O_3$) and basic oxides ($CaO + MgO$):

$$M_k = \frac{SiO_2 + Al_2O_3}{CaO + MgO}$$

This coefficient defines approximate rock casting properties of silicate materials. The coefficient values vary from 1.73 to 2.80 and point to favourable rock casting properties of the samples studied. Lower values are characteristic of fresh basalt.

Viscosity, calculated from the chemical composition using the Bottinga-Weill method (Bottinga and Weill, 1972), shows the highest values in volcanic bombs. This results from proportions of the components SiO_2, Al_2O_3, MgO and CaO (Tab. 3). Optimum defibering during mineral wool production occurs at viscosity values of a silicate liquid ~10 Pas and temperature 1250°C (Żołnierczyk, 1981). The Rutki-Ligota basalts can be used in mineral wool production, and defibering can proceed at a temperature even below 1200°C.

Trace element contents (Tab. 4) are similar in both the Rutki and Ligota basalts. Increased contents of only Cd, Co and Ni are observed at Rudki. It seems that alteration processes in basalts, which affected in particular volcanic bombs (samples 1L and 3R), have not caused any variability in the content of the elements identified. It may result from their sorption by products liberated during alteration (mainly iron oxides, serpentines, iddingsite). Sample 7R from Rutki contains slightly higher amounts of Cd, Co, Cu and Ni than the other samples, probably reflecting a higher content of pyroxenes and olivine.

Contents of Co and Cu in the samples are similar to with average contents of these elements reported by Szpila (1959) from the Lower Silesian basalts. Cr and Ni contents are considerably lower. Co, Cr, Cu and Ni contents in the Rutki-Ligota basalt are lower than those reported from Gracze and Święta Anna Mt. (Chodyniecka, 1967, 1969).

X-ray diffraction confirmed that the samples 1L, 4L, 3R and 7R contain major minerals such as pyroxenes (augite, diopside), olivine and plagioclases (Tab. 5).

Table 4

Trace element contents in the Rutki-Ligota basalts (in ppm)

Element	1L volcanic bomb	4L fresh basalt	3R volcanic bomb	7R fresh basalt	Lower Silesian basalts average (after Szpila, 1959)	Gracze basalts (after Chodyniecka, 1969)	Święta Anna Mt. (after Chodyniecka, 1967)
Cd	0.44	0.23	0.72	1.06	–	–	–
Co	25	24	27	29	25	50	300
Cr	194	150	172	190	330	700	610
Cu	84	61	65	118	80	1400	1250
Mn	541	561	730	557	–	–	–
Ni	100	88	103	122	280	1150	560
Pb	26	53	23	26	–	–	–
Zn	112	79	93	107	–	–	–

Table 5

X-ray diffraction results from the Rutki-Ligota basalts

1L volcanic bomb		4L fresh basalt		3R volcanic bomb		7R fresh basalt		Mineral
d_{hkl}	I	d_{hkl}	I	d_{hkl}	I	d_{hkl}	I	
4.07	2	4.07	3	4.07	2	4.06	1	anortite
3.91	1	3.91	1	3.91	1	3.91	1	anortite, olivine
3.66	1	–	–	–	–	–	–	anortite
–	–	3.35	–	–	–	3.35	–	diopside
3.24	7	3.24	7	3.24	6	3.24	7	anortite, augite
–	–	3.23	–	–	–	–	–	diopside
3.22	10	3.21	10	3.22	10	3.21	10	anortite
3.20	5	3.19	5	3.19	4	3.20	5	anortite
2.99	8	2.99	8	2.99	7	2.99	8	augite, diopside
2.96	–	–	–	2.96	–	–	–	augite
2.95	2	2.95	3	2.95	2	2.94	4	diopside, augite
–	–	2.89	2	–	–	–	–	diopside
2.80	1	2.79	1	2.79	1	2.80	1	anortite
2.77	3	2.76	4	2.77	3	2.77	3	olivine
–	–	2.57	3	–	–	2.58	2	diopside
2.56	6	–	–	2.56	5	–	–	augite
2.53	2	2.53	5	2.54	1	2.53	4	diopside, olivine
2.52	1	2.52	3	2.52	1	2.52	3	diopside, augite
2.51	5	2.51	1	2.51	6	2.50	1	augite
2.48	3	2.48	2	2.48	2	2.48	3	olivine
2.30	1	–	–	2.30	1	–	–	augite
2.27	1	2.27	1	2.27	1	2.27	1	anortite, olivine
2.16	3	2.15	2	2.15	2	2.16	1	anortite, augite
2.11	2	2.10	2	2.11	1	2.11	3	anortite, augite
1836	2	–	–	1.836	2	–	–	augite
1.753	4	–	–	1.753	3	–	–	augite
1.749	3	1.749	3	1.749	3	1.748	3	anortite
–	–	1.676	2	–	–	1.675	2	diopside

Mössbauer spectroscopy was used in a detailed identification of iron minerals which are difficult to detect by other methods. The Mössbauer analysis yields a γ-ray absorption graph of the ^{57}Fe line, dependent on relative velocity of the γ-ray source and the absorbent — a sample. The graph is called the measuring spectrum. Further numerical processing of the spectrum allows separation of subspectra of individual iron-bearing minerals together with a relative Fe-content. The Fe^{3+}/Fe^{2+} ratio, very important for studies of alterations in rocks (Smulikowski and Kozłowska-Koch, 1984; Bakun-Czubarow *et al.*, 1993; Komraus *et al.*, 1996), was also calculated. Identification of these minerals using other methods is difficult. Mössbauer spectra of samples 1L, 4L, 3R and 7R (Tab. 6, Fig. 3) resemble spectra of basalts from the Kaczawa Mountains in the Sudetes (Komraus *et al.*, 1996). Olivine, diopside, biotite and iron hydroxides have been identified in fresh basalts (samples 4L and 7R). Iron is the dominant element in olivine and diopside. Volcanic bombs are composed of olivine, augite, iron hydroxides (sample 1L), serpentine (sample 3R) and biotite. Sample 3R contains small amounts of olivine, whereas sample 1L contains amphibole. The total amount of iron in olivine is much smaller in volcanic bombs than in fresh basalts. Most iron in sample 3R comes from augite, less from biotite and serpentine. The majority of iron in sample 1L is concentrated in iron hydroxides, augite and biotite. Small amounts of iron are present in olivine and amphibole (Barb *et al.*, 1979).

The Fe^{3+}/Fe^{2+} ratio values range from 0.31 to 1.86, being higher in volcanic bombs than in fresh basalts. The Fe^{3+}/Fe^{2+} ratio value calculated for sample 1L is much greater than in other samples, indicating that this basalt is more intensely weathered. It is also legible from the shapes of Mössbauer spectra. The spectrum of sample 1L (Fig. 3b) is clearly dominated by subspectra originating from Fe^{3+}. Subspectra generated by Fe^{2+} predominate in the spectra from the other samples (Fig. 3). The scatter of measuring points in the Mössbauer spectra of the 1L and 7R samples, containing smaller amounts of iron, is greater compared with that of samples 4L and 3R that contain more iron (Fig. 3; Tab. 2).

No subspectra characteristic of magnetite and ilmenite were observed in the Mössbauer spectra, although these minerals were seen in the samples; this indicates a low content of these minerals in the rock. Different pyroxenes occur in fresh rock (monolith) and highly altered basalt (volcanic bombs). The former is dominated by diopside, the latter by augite. This variability may be related to the rapidity of basaltic lava crystallization (faster coagulation of volcanic bombs than lava) and might influence alterations.

SUMMARY AND CONCLUSIONS

The investigations permitted identification of fresh basalts and variably altered basalts (due to hydrothermal and hypergene weathering processes) in the Rutki-Ligota basalt. The nature of the alteration was identified using Mössbauer analysis together with mineralogical studies, allowing the detection of iron minerals that can easily be affected by chemical changes.

Table 6

Mössbauer subspectra parameters of iron compounds from the Rutki-Ligota basalts, with relative contents of iron from these compounds (in atomic %) and Fe^{3+}/Fe^{2+} values

Sample number	IS [mm/s]	QS [mm/s]	Mineral	Content [%]	Fe^{3+}/Fe^{2+}
1L volcanic bomb	1.01 0.88 1.03 0.17 0.60	3.29 2.76 1.35 0.81 0.92	olivine Fe^{2+} amphibole Fe^{2+} augite Fe^{2+} iron hydroxides Fe^{3+} biotite Fe^{3+}	9.1 4.7 21.1 31.7 33.4	1.86
4L fresh basalt	1.14 1.07 0.52	2.95 2.15 0.62	olivine Fe^{2+} diopside Fe^{2+} biotite+iron hydroxides Fe^{3+}	41.0 35.1 23.9	0.31
3R volcanic bomb	1.13 1.07 0.37 0.60	3.01 2.27 0.44 0.60	olivine Fe^{2+} augite Fe^{2+} serpentine Fe^{3+} biotite Fe^{3+}	8.2 59.0 14.9 17.9	0.49
7R fresh basalt	1.15 1.03 0.52	2.96 2.13 0.67	olivine Fe^{2+} diopside Fe^{2+} biotite+iron hydroxides Fe^{3+}	33.4 39.4 27.2	0.37

The Rutki-Ligota basalt is composed of diopside, augite, olivine, plagioclases, nepheline, zeolites, biotite, magnetite and ilmenite.

Superimposed alteration processes comprise:

- serpentinization and iddingsitization of olivine,
- uralitization of pyroxenes,
- carbonatization of the groundmass and pracrystals.

These produced serpentines, chalcedony, epidote, calcite, amphibole and iron hydroxides.

Biotite, occurring in volcanic bombs and fresh basalts, might have been formed during final crystallization of the magma. The formation of biotite by alteration of pyroxenes cannot be definitely precluded; amphiboles, formed in this way, may have been altered to biotite causing the appearance of calcite and silica minerals (chalcedony) together with biotite and epidote.

It seems that both the speed of basaltic lava crystallization (faster coagulation of volcanic bombs than lava) and deuteric or autometamorphic recrystallization proceeding during the final phase of lava coagulation exert a strong influence on the basalt alteration. These processes hamper the crystallization of diopside or augite, biotite and feldspathoids, that can influence the mode of weathering of basalts. Volcanic bombs are more strongly weathered than monolithic basalts, as seen in higher Fe^{3+}/Fe^{2+} values, due to their pyroclastic character and the diversity of pyroxene types. The pyroclastic character of volcanic bombs favours alteration. Pyroxenes from volcanic bombs are dominated by augite, whereas those from monolithic basalts are dominated by diopside.

Acidity coefficients of the basalts indicate favourable rock casting properties. Viscosity calculated for a temperature of 1250°C is 4–6 Pas, making them useful in mineral wool production.

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