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Gabbro from Braszowice (Lower Silesia, Poland) as a potential raw material for production of rock wool

Key words

Gabbro, rock wool, mineral raw material

Abstract

A tendency to substitute basalts by gabbros for the production of rock wool is being currently observed. Gabbro studied of Braszowice deposit represents an olivine-free variety. Its main mineral components (plagioclases, clinopyroxenes and secondary amphiboles) occur in variable proportions. The investigations completed have shown that the glasses produced out of this rock, both unmodified and modified with addition of dolomite from Rędziny, are characterized by a relatively low crystallization ability. The glasses in question, annealed at temperatures up to 800—850°C do not recrystallize, which is a favourable feature for the production of rock wool.

Introduction

Procurement and management of mineral raw materials represent important problems for any national economy. They result — first of all — from requirements of modern technologies in manufacturing of numerous products. It is also true in the case of ceramic insulation materials, into which, among others, rock wool is included, either unprocessed or after processing in the form of mats, felts, panels, lagging and various shaped products. According to the Polish standard PN 89/B-04620, classification of these materials is based on their structure, shape, content of a binder and flammability.

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Insulation materials are manufactured in Poland in some plants such as: Cigacice, Trzemeszno, Gliwice, Niedzica and Małkinia. The volume of production of rock wool — one of the main such materials — approximates annually 60,000 t, and 75% of that comes from two biggest and most modern plants: "Rockwool Polska" in Cigacice and "Izopol" in Trzemeszno. Technology implemented by these two plants utilizes a new raw material — gabbro from Słupiec (Fig. 1), while that of the remaining plants is mostly based on basalts. It is almost exclusively basalts that were extensively studied and numerous experiments on their suitability in production of rock wool conducted (e.g. Stoch, Wyszomirski 1976; Kapuściński 1985; Dyczek et al. 1996).

Since insulating materials, and rock wool in particular, become more widely used, there is the tendency to utilize in their production wider range of mineral raw materials that must meet more stringent requirements. One of these criteria includes low natural radioactivity, expressed as coefficients f_1 and f_2. Gabbros reveal a low content of actinides and contain 0.8 ppm U and 3.8 ppm Th, even less than basalts (Polański 1988). Such low contents of radioactive elements are important ecologywise, particularly considering human health protection.

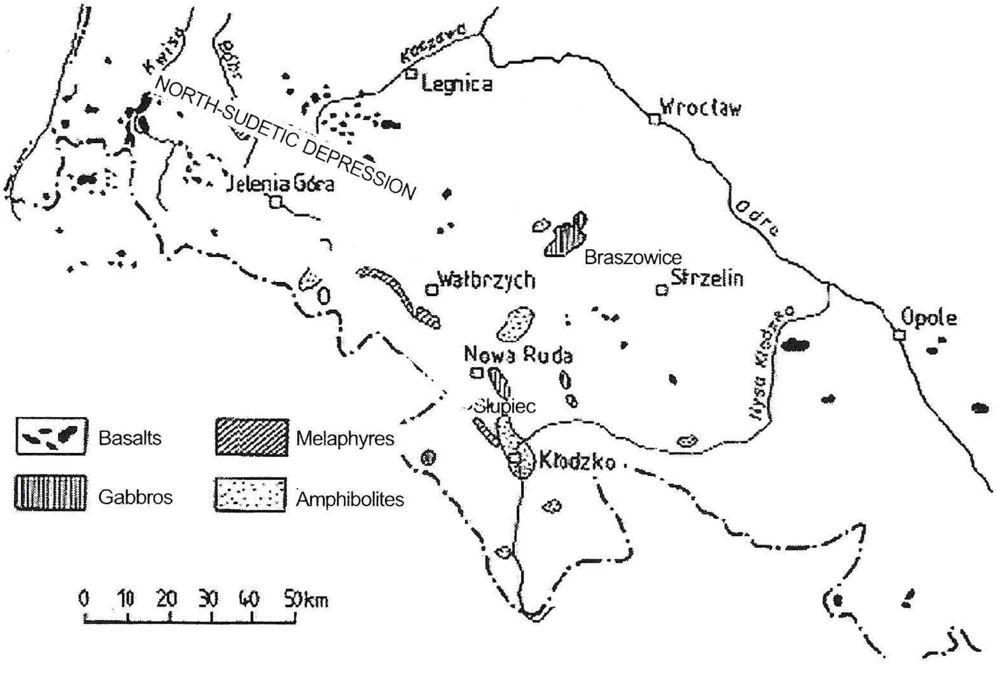


Fig. 1. Localization of Lower Silesian gabbros from Słupiec and Braszowice and some other traditional (basalts) and potential (melaphyres and amphibolites) mineral raw materials for production of rock wool

Rys. 1. Gabra dolnośląskie ze złóż Słupiec i Braszowice na tle innych, tradycyjnych (bazalty) i potencjalnych (melafiry, amfibolity) surowców do produkcji wełny mineralnej

The authors have characterized in the current paper technological properties of gabbro from the Bukowczyk hill in Braszowice near Ząbkowice Śląskie (Lower Silesia) as a new mineral raw material in production of insulating materials, and to do that have obtained two types of glass: from this rock itself and from the gabbro modified with a 10-wt.% admixture of dolomite from Rędziny. The deposits of gabbro in Braszowice and in Słupiec as well were not previously studied in this respect. The geological and industrial reserves of the former are substantial and reach 108,608,000 t, while the annual output is *ca* 173,000 t (Przeniosło 1999).

1. Petrographic characteristics of gabbro from Braszowice

Gabbro (*metagabbro*) from Braszowice was studied by Jamrozik (1975), Dziedzic (1988, 1989), Dziedzic and Kramer (1992). Supplementing mineralogical and petrographical investigations presented in this paper were carried out on samples collected in 1993 from the middle part of the exploitation wall on the lower level of the active quarry in Braszowice.

The results indicate that the rocks in question represent, as it is also in the case of gabbro from Słupiec, olivine-free gabbros. They are dark green to black-green, with coarse- or medium--crystalline, varigrained texture. The size of grains changes between 0.4 and 10.0 mm. The rocks reveal variable degree of dynamic and metasomatic alterations (mainly uralitization). Their mineral composition includes plagioclases, clinopyroxenes and amphiboles, occurring in variable proportions. The latter are secondary constituents, formed mainly at the expense of pyroxenes that are in places totally replaced. The list is completed by accessory, primary components: Fe and Ti oxides, apatite and titanite.

The plagioclases are represented mainly by labradorite ($An_{52\text{-}66}$ — Wierzchołowski 1989; $An_{63\text{-}70}$ — Dziedzic 1989). They form irregular grains and hipautomorphic tablets with sizes from 0.2 to *ca* 8.0 mm, usually medium altered. Minerals replacing them include amphiboles and epidotes *sensu lato* that are microcrystalline, which makes their microscopic identification impossible, and also subordinate albite-oligoclase feldspars, quartz and chlorites.

The clinopyroxenes are either diallags (Dziedzic 1989) or diopside augites (Wierzchołowski 1989), replaced to a different degree by amphiboles (uralitization). They form irregular grains with various sizes (0.8—10.0 mm).

The amphiboles, determined by Dziedzic (1989) as hornblende, are developed as prisms with diversified sizes, elongation and habits. They show weak pleochroic colours: α — pale yellowish, $\beta = \gamma$ — greenish, bluish-greenish, olive-green, that point to their low iron content; the angles of extinction range between 15 and 29°.

The chlorites have pale greenish colours without noticeable pleochroism and show livid-bluish, anomalous interference colours. These features indicate that they represent Fe-Mg variety of chlorites.

Amphiboles, chlorites, acid plagioclases, quartz and minerals of the epidote group compose additionally irregular microveins, formed by infilling of rock fractures. The network of small veins is locally dense, proving a strong tectonic involvement of the Braszowice rock prior to its alterations.

2. Investigations on melting of gabbro from Braszowice

The investigations were preceded by the chemical analysis of the gabbro (Table 1). Its results helped prepare composite, batch samples for melting, and also calculate viscosity of the glass obtained.

In production of rock wool, gabbros are better suited raw materials than widely used basalts, considering particularly a relatively high crystallization ability of the latter. This fact is highlighted by a position of the projection points of the Lower Silesian basalts in the A'B'C' diagram (Fig. 2) of Stoch and Wyszomirski (1976). The diagram visualizes for the raw material its content of three following groups of components, determined on the basis of the CIPW normative mineral composition:

A' — fast crystallizing (magnetite, ilmenite, titanite, pyroxene, olivine),

B' — slowly crystallizing (anorthite),

C' — very slowly crystallizing (albite, nepheline).

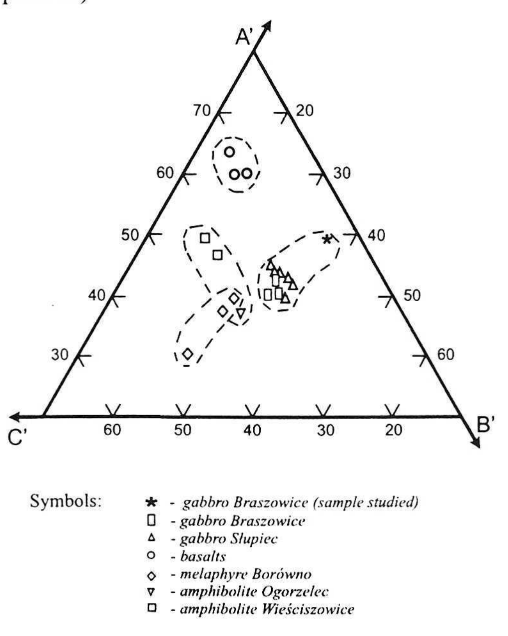


Fig. 2. The A'B'C' diagram with the projection point of the sample of the Braszowice gabbro studied against the background of other basic igneous and metamorphic rocks (after Dyczek et al. 1996; slightly modified)

Rys. 2. Diagram A'B'C' z naniesionym punktem projekcyjnym badanej próbki gabra z Braszowic na tle danych literaturowych (wg Dyczka et al. 1996; nieco zmodyfikowany)

TABLE 1

Chemical composition and normative mineral CIPW composition of gabbro from Braszowice

TABELA 1

Skład chemiczny i normatywny skład mineralny (CIPW) gabra z Braszowic

Component	Content [wt.%]
SiO_2	50.65
Al_2O_3	15.86
TiO_2	0.48
Fe_2O_3	6.56
CaO	13.84
MgO	9.70
K_2O	0.06
Na_2O	1.70
MnO	0.12
Loss on ignition	1.46
Total	100.43
Quartz, Q	0.91
Orthoclase, Or	0.35
Albite, Ab	14.39
Anorthite, An	35.47
Light components, total	51.12
Diopside, Di	26.42
Hyperstene, Hy	17.46
Magnetite, Mt	3.06
Ilmenite, Il	0.91
Mafic components, total	47.85
Total of light and mafic components	98.97

The relatively high ability of basaltic melts to recrystallize is strongly disadvantageous regarding the durability of mineral fibres produced. Considering this feature, more interesting seem to be other igneous (gabbros, melaphyres) and metamorphic (amphibolites) rocks, as it is indicated by positions of their projection points in the A'B'C' diagram. The projection of the sample of the Braszowice gabbro studied has also been shown in the diagram (Fig. 2).

Current experiments were carried out on two samples. Batch 1 was composed exclusively of the Braszowice gabbro, while batch 2 was a modified sample, composed in 90 wt.% of this gabbro and a 10-wt.% admixture of dolomite from Rędziny. The chemical composition of both samples is presented in Table 2. The crushed and mixed samples were placed in alundum crucibles and melted in an electric furnace at the temperature 1350°C, established on the basis of literature data (Stoch, Wyszomirski 1976; Dyczek et al. 1996). The melted samples were held at this temperature for two hours, then poured out onto a steel plate to quench them rapidly with the formation of glass.

Basing on the results of chemical analyses, the authors also determined other properties of the gabbroic glasses, important for their applicability in manufacturing of rock wool, namely viscosity and the modulus of acidity. Samples of the glasses obtained after melting as well as products of their recrystallization in a gradient furnace were studied applying thermal, X-ray and microscopic methods. All these experiments aimed at determination of applicability of the gabbroic glass for manufacturing of rock wool.

TABLE 2

Chemical composition of samples prepared on the basis of the Braszowice gabbro assigned for glass melting

TABELA 2

Skład chemiczny zestawów surowcowych na bazie gabra z Braszowic przeznaczonych do wytopu szkliwa

Component	Batch 1	Batch 2		
	100% gabbro	90% gabbro + 10% dolomite		
	wt.%	mol.%.	wt.%	mol.%
SiO_2	50.65	53.88	45.58	50.03
Al_2O_3	15.86	9.62	14.27	9.24
TiO_2	0.48	0.38	0.43	0.30
Fe_2O_3	6.56	2.58	5.86	2.44
CaO	13.84	16.06	15.50	18.28
MgO	9.70	15.39	10.92	17.89
K_2O	0.06	0.04	0.05	0.07
Na_2O	1.70	1.92	1.53	1.65
MnO	0.12	0.13	0.11	0.10
Loss on ignition	1.46	—	6.07	—
Total	100.43	100.0	100.32	100.0

One of the most important features of a melt prepared for manufacturing of such an amorphous product as rock wool is its viscosity. Viscosity η was calculated for both batch samples on the basis of their mineral composition, following the formula of Fulcher-Vogel--Tammann that has traditionally been used in glass industry since 1925 (Zięba 1987):

$$\log \eta = \frac{B}{T - T_0} - A$$

where:

T — temperature,

A, B, T_0 — experimental coefficients.

The results obtained are presented in Table 3. It can be concluded that the addition of dolomite lowers the viscosity of the melt at high temperatures. Figure 3 shows the dependence *log* η *vs temperature* for both samples. The values of viscosity were also calculated following the method of Bottinga and Weill (1972), applicable mainly to natural silicate glass. The method has been found to be of limited use in relation to technical, manufactured glass.

TABLE 3

Viscosity coefficient calculated on the basis of chemical composition following Fulcher — Vogel — Tammann (1925; *fide* Zięba 1987) formula and modulus of acidity of glasses obtained from batch samples of gabbro from Braszowice

TABELA 3

Współczynnik lepkości obliczony na podstawie składu chemicznego wg wzoru Fulchera — Vogela — Tammanna (1925; *fide* Zięba 1987) oraz moduł kwasowości szkliw otrzymanych na bazie gabbra z Braszowic

Viscosity coefficient log η [dPa·s] at a temperature of:	Experimental coefficients for:	
	batch 1: A = 2.2078, B = 6071.8198, T_0 = 255.8818	batch 2: A = 2.3068, B = 6026.8421, T_0 = 266.3796
700	11.46	11.59
800	8.95	8.99
900	7.22	7.20
1000	5.95	5.91
1100	4.98	4.92
1200	4.22	4.15
1300	3.61	3.52
1400	3.10	3.01
1500	2.67	2.58
1600	2.30	2.21
Modulus of acidity M_k	2.05	1.74

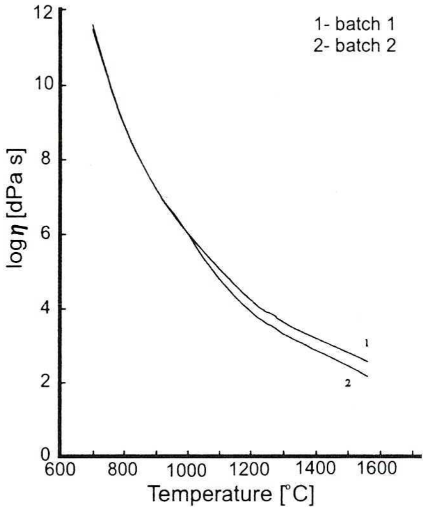


Fig. 3. log η (viscosity coefficient) *vs* temperature for unmodified and modified gabbroic melts, determined on the basis of Fulcher-Vogel-Tammann formula (1925; *fide* Zięba 1987)

Rys. 3. Zależność współczynnika lepkości log η od temperatury dla niemodyfikowanego i zmodyfikowanego stopu gabrowego, wyznaczona na podstawie wzoru Fulchera-Vogela-Tammanna (1925; *fide* Zięba 1987)

The modulus of acidity M_k describes the ability of a melt to form fibbers at its determined viscosity, and is expressed as the ratio of the total of silicon and aluminium oxides to the total of calcium and magnesium oxides:

$$M_k = (SiO_2 + Al_2O_3) / (CaO + MgO)$$

The modulus M_k should be > 1.2, and this figure is determined in most cases from technological condition of fibber-making and the physical and chemical parameters of the fibres produced. In production of rock wool the optimum range of the modulus of acidity is 1.5—2.1, the condition fulfilled by both batch samples studied (Table 3). It should be stressed that the addition of dolomite to batch 2 lowered significantly its modulus of acidity, and this should favourably influence manufacturing parameters as mineral fibres may be produced at lower temperatures.

The next stage of experimental investigations of the glasses obtained involved differential thermal analysis. The analyses were carried out using a Paulik-Paulik-Erdey derivatograph of Hungarian production, and their results (DTA curves) are presented in Figure 4. They were the basis to calculate characteristic temperatures and glass-forming ability of both batch samples, applying the following formula (Zięba 1987):

$$\Delta T = T_x — T_g$$

where:

T_x — temperature of the beginning of crystallization,

T_g — temperature of vitrification.

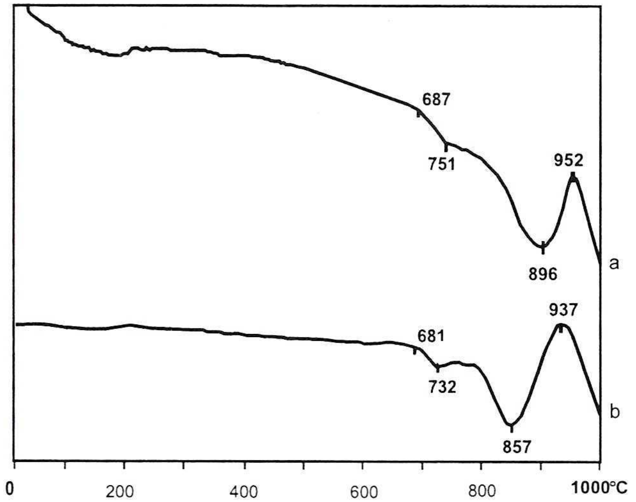


Fig. 4. DTA curves of the glasses obtained by melting at the temperature 1350°C for 2 hrs of: a — pure gabbro from Braszowice (batch 1), b — the mixture composed of 90 wt.% of gabbro from Braszowice and 10 wt.% of dolomite from Rędziny (batch 2)

Rys. 4. Krzywe DTA szkliwa otrzymanego ze stopienia w temperaturze 1350°C przez 2 godziny: a — gabra z Braszowic (zestaw 1), b — mieszaniny o składzie 90% wag. gabra z Braszowic i 10% wag. dolomitu z Rędzin (zestaw 2)

The results are shown in Table 4.

Comparing the temperatures of characteristic transformations taking place during annealing of the glasses produced and marked in their DTA curves it has been found that the admixture of dolomite in the batch 2 caused a substantial lowering of all temperatures, and in particular the temperatures of the beginning and maximum crystallization, which is unfavourable in rock wool making. But, on the other hand, the admixture of dolomite affects positively many other properties of gabbroic glass. It should be mentioned that in manufacturing of rock wool on the basis of gabbro from Słupiec, limestone is used as the modifying admixture, while some foreign

TABLE 4

Characteristic temperatures of the gabbroic glasses studied determined by means of DTA method

TABELA 4

Charakterystyczne temperatury badanych szkliw gabrowych określone metodą DTA

Temperature [°C] of:	Batch 1	Batch 2
Transformation	687	681
Dilatometric softening	751	732
Beginning of crystallization	896	857
Maximum of crystallization	952	937
ΔT	209	176

plants, e.g. in Nová Baňa (the Slovak Republic), use the mixture of dolomite and some per cents of blast furnace slag.

Crystallization ability of the gabbroic glasses produced was studied using X-ray and microscopic methods. Samples were annealed in a gradient furnace at various temperatures for different times. Their X-ray powder analyses were carried out using a DRON-3 (former USSR) and a RICH SEIFERT (Germany) diffractometers, applying CuK_{α} radiation.

The glass obtained from pure gabbro (batch 1) does not reveal any presence of crystalline phases after annealing it at 860°C for 1 hr (Fig. 5). Only prolonged annealing (24 hrs) does result in appearance of reflections corresponding to plagioclase (anorthite) against the background of a wide diffraction band, typical of an amorphous phase (Fig. 6). Full recrystallization of the glass

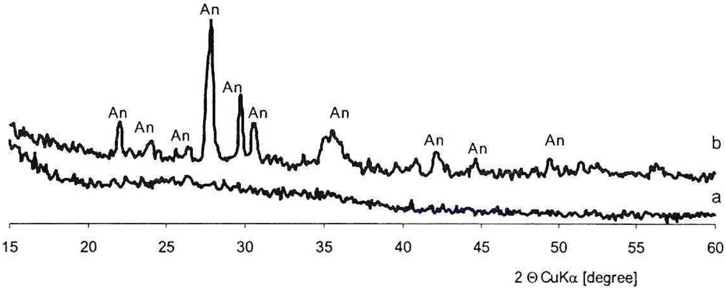


Fig. 5. XRD patterns of gabbroic glass annealed during 1 hr at the temperature: a — 860°C, b — 1120°C. Abbreviations: An — anorthite

Rys. 5. Dyfraktogramy rentgenowskie szkliwa gabrowego wygrzewanego przez 1 godz. w temperaturze: a — 860°C, b — 1120°C. Stosowane skróty: An — anortyt

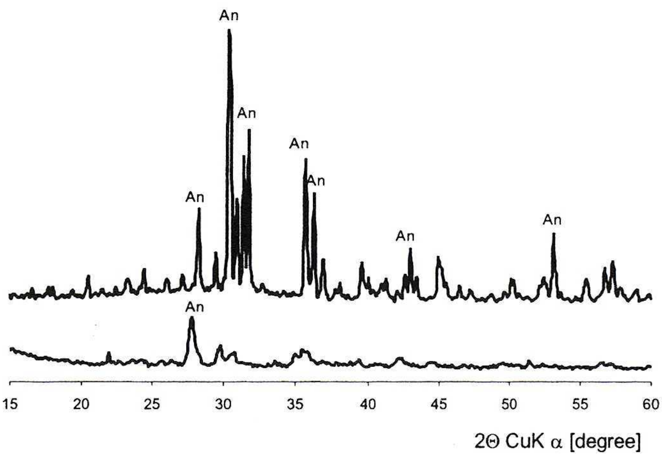


Fig. 6. XRD patterns of gabbroic glass annealed during 24 hrs at the temperature: a — 860°C, b — 1050°C. Abbreviations: An — anorthite

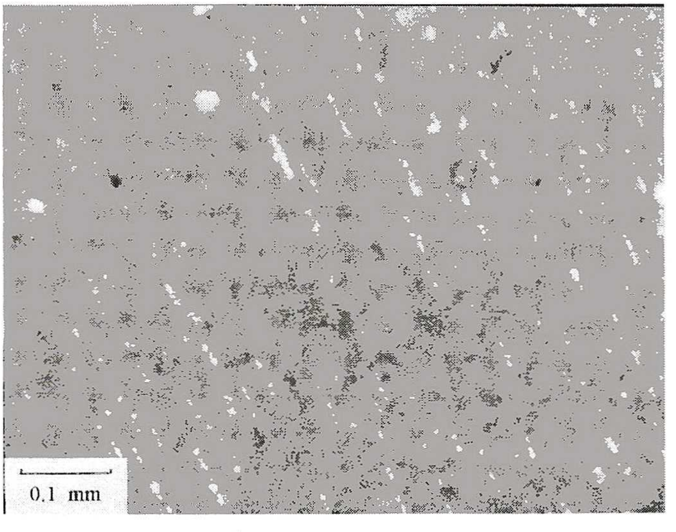
Rys. 6. Dyfraktogramy rentgenowskie szkliwa gabrowego wygrzewanego przez 24 godz. w temperaturze: a — 860°C, b — 1050°C. Stosowane skróty: An — anortyt in question took place after annealing at 1050°C for 24 hrs (Fig. 6), but at 1120°C already after 1 hr. In both cases newly formed crystalline phases gave reflections corresponding to plagioclase of the anorthite type (Figs. 5, 6). Characteristic fibrous and needle-like habit of these crystals — visible in microscopic observation — is typical of crystallization from over-cooled glasses (Lofgren 1974, Kirkpatrick 1975).

The gabbroic glass modified with a 10-% addition of dolomite (batch 2) contains only few fine needles of crystalline phases (Phot. 1) after annealing at 770°C for 2 hrs. Annealing at higher temperatures (860, 940, 980°C) increases the amount of these phases, while their habits and sizes are more diversified (Phot. 2). Full recrystallization was obtained at 1060°C (Phot. 3) and in higher temperatures (Phot. 4) during 2 hrs of annealing. Crystalline phases formed in this experiment include pyroxenes of the diopside type, åkermanite ($Ca_2MgSi_2O_7$), olivine of the forsterite type and — probably — traces of plagioclase (anorthite?) (Fig. 7). These phases are characterized by diversified development of their crystals.

Summarizing the results of phase investigations of two gabbroic glasses in question, the following observations have been made:

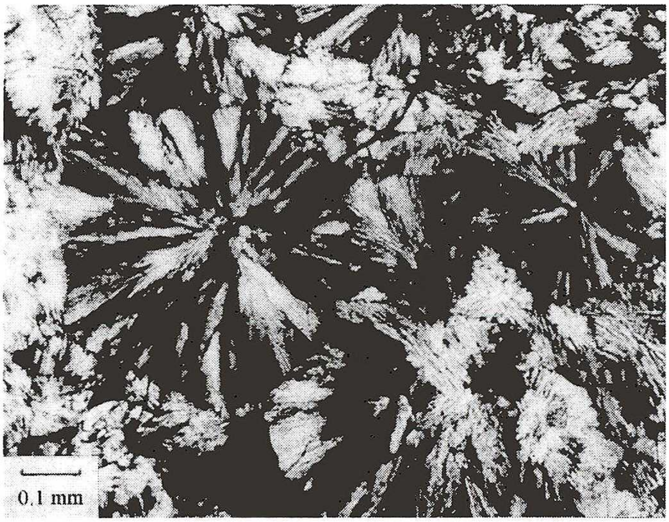
— recrystallization of the glasses during a short (1—2 hrs) annealing takes place at the temperatures above 850°C for the purely gabbroic glass and about 800°C for the variety modified with dolomite;

— full recrystallization of both glasses takes place at temperatures above 1000°C, particularly after longer annealing (24 hrs);



Phot. 1. Gabbroic glass modified with a 10-% addition of dolomite, partly recrystallized after annealing at 770°C for 2 hrs. Few needle-like crystals in amorphous glass can be seen.
Polarizing microscope, partly crossed polaroids

Fot. 1. Szkliwo gabrowe zmodyfikowane 10-procentowym dodatkiem dolomitu, częściowo przekrystalizowane w wyniku wygrzewania w temperaturze 770°C przez 2 godz.
Widoczne są nieliczne, drobnoigiełkowe kryształy w amorficznym szkliwie.
Mikroskop polaryzacyjny, polaroidy częściowo skrzyżowane

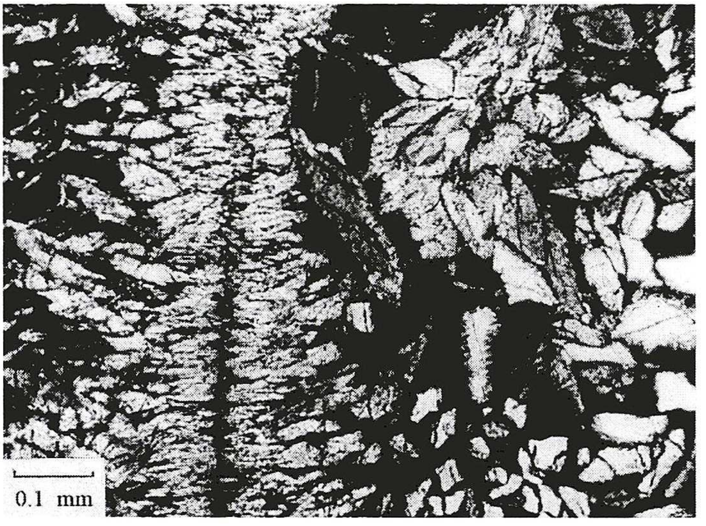


Phot. 2. Gabbroic glass modified with a 10-% addition of dolomite, partly recrystallized after annealing at 980°C for 2 hrs. Spherolitic aggregates of fibrous crystalline phases can be seen. Polarizing microscope, crossed polaroids.

Fot. 2. Szkliwo gabrowe zmodyfikowane 10-procentowym dodatkiem dolomitu, częściowo przekrystalizowane w wyniku wygrzewania w temperaturze 980°C przez 2 godz. Widoczne sferolitowe skupienia włókniście wykształconych faz krystalicznych. Mikroskop polaryzacyjny, polaroidy skrzyżowane

Phot. 3. Gabbroic glass modified with a 10-% addition of dolomite, totally recrystallized after annealing at 1060°C for 2 hrs. Anisometric, mostly fibrous and needle-like development of crystalline phases should be noted. Polarizing microscope, crossed polaroids

Fot. 3. Szkliwo gabrowe zmodyfikowane 10-procentowym dodatkiem dolomitu, całkowicie przekrystalizowane w wyniku wygrzewania w temperaturze 1060°C przez 2 godz. Zwraca uwagę anizometryczne, w przewadze włókniste i igiełkowe, wykształcenie faz krystalicznych. Mikroskop polaryzacyjny, polaroidy skrzyżowane



Phot. 4. Gabbroic glass modified with a 10-% addition of dolomite, totally recrystallized after annealing at 1100°C for 2 hrs. Anisometric development of crystalline phases can be seen
Polarizing microscope, crossed polaroids

Fot. 4. Szkliwo gabrowe zmodyfikowane 10-procentowym dodatkiem dolomitu, całkowicie przekrystalizowane w wyniku wygrzewania w temperaturze 1100°C przez 2 godz.
Widoczne anizometryczne wykształcenie powstałych faz krystalicznych.
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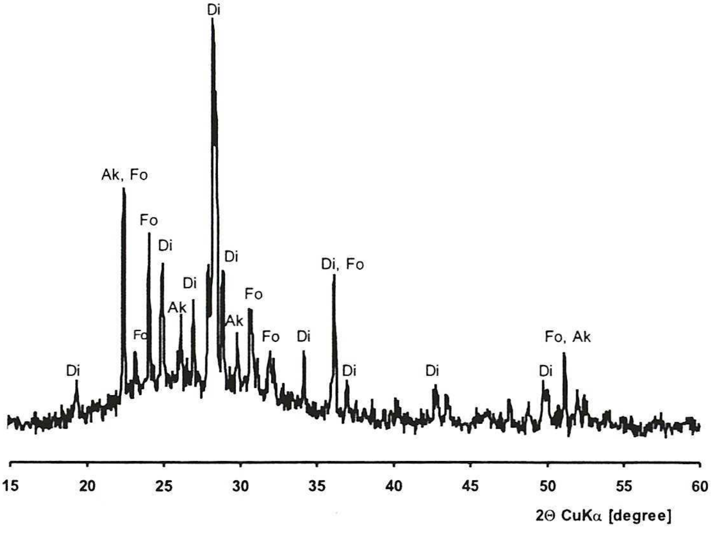

Fig. 7. XRD pattern of gabbroic glass modified with a 10-wt.% addition of dolomite, annealed at the temperature 1120°C during 2 hrs.
Abbreviations: Ak — åkermanite, Di — diopside, Fo — forsterite

Rys. 7. Dyfraktogram rentgenowski szkliwa gabrowego zmodyfikowanego 10-procentowym dodatkiem dolomitu, wygrzewanego w temperaturze 1120°C przez 2 godz.
Stosowane skróty: Ak — åkermanit, Di — diopsyd, Fo — forsteryt

— crystalline phases appearing in the recrystallized glass produced from pure gabbro are represented by plagioclases of the anorthite type, while in the glass modified with dolomite it is a mixture of pyroxene (diopside), åkermanite and olivine, with — probably — a smaller amount of plagioclase of the anorthite type;

— the crystalline phases are typically developed as fibrolitic and needle-like individuals;

— the gabbroic glasses, both modified and unmodified with dolomite, annealed at temperatures lower than 800—850°C do not recrystallize, which is a favourable feature for the production of rock wool.

Summary

Considering the fact that insulating materials are becoming more popular in Poland, new mineral raw materials that meet essential technological requirements should be introduced in their production. Gabbro from Braszowice represents one of such materials. The investigations completed have shown that the glass produced of it, both unmodified (batch 1) and modified with 10-wt.% of dolomite from Rędziny (batch 2) are characterized by a relatively low crystallization ability. This feature is highly advantageous in rock wool making. It is also of some importance that the rock wool produced from gabbro has not only better technological properties but reveals interesting aesthetic features. Its light green colour is more attractive in comparison with the brownish coloration of the rock wool produced of basalts. Thus, utilization of gabbro from Braszowice may extend domestic mineral resources for the industry of insulating materials.

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GABRO Z BRASZOWIC (DOLNY ŚLĄSK, POLSKA) JAKO POTENCJALNY SUROWIEC DO PRODUKCJI WEŁNY MINERALNEJ

Słowa kluczowe

Gabro, wełna mineralna, surowce mineralne

Streszczenie

Wełna mineralna do niedawna była wytwarzana w Polsce wyłącznie z bazaltów dolnośląskich. W ostatnich latach do jej produkcji zastosowano też gabro ze Słupca koło Nowej Rudy. W niniejszej pracy przedstawiono wyniki badań gabra z innego złoża dolnośląskiego, tj. z Braszowic koło Ząbkowic Śląskich. Skała ta reprezentuje odmianę bezoliwinową. Jej głównymi składnikami mineralnymi są: plagioklazy, pirokseny jednoskośne i wtórne amfibole, które występują w zmiennych proporcjach. Szkliwo uzyskane z tego surowca — zarówno o niezmodyfikowanym składzie, jak też po wprowadzeniu dodatku dolomitu — charakteryzuje się małą podatnością krystalizacyjną. Jego wygrzewanie do temperatur rzędu 800—850°C nie prowadzi do przekrystalizowania; pełną rekrystalizację obserwuje się dopiero w temperaturach powyżej 1000°C. W rekrystalizowanym szkliwie o niezmodyfikowanym składzie powstają plagioklazy o składzie zbliżonym do anortytu, natomiast modyfikacja jego składu sprzyja przede wszystkim krystalizacji piroksenów typu diopsydu, oliwinów zbliżonych do forsterytu oraz åkermanitu. Podatność krystalizacyjna szkliwa gabrowego jest mniejsza w porównaniu ze szkliwami bazaltowymi, co jest korzystne z punktu widzenia produkcji wełny mineralnej.