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Polish Feldspar Raw Materials for the Domestic Ceramic Tile Industry – Current State and Prospects

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Abstract

The development of the Polish ceramic tile industry, observed since the mid-1990s, resulted in the increased demand for raw materials, especially feldspar and/or feldspar-quartz ones, which constitute 50-60 % of the *gres porcellanato* tile body composition. In 2007 the consumption of feldspar raw materials in Poland approached ca. 900,000 tpy, more than 80 % of which accounted for the tile industry [1]. Their domestic production, ranging from 400,000 to 600,000 tpy in recent years, has been supplemented by importation, predominantly from the Czech Republic and Turkey.

The Strzeblów Mineral Mines of Sobótka (Lower Silesia) is the oldest and the largest Polish feldspar producer. The company offers basically feldspar-quartz grits with min. 7.5 % K_2O+Na_2O, $K_2O/Na_2O \geq 1$, and ca. 0.5 % Fe_2O_3, which are mainly used in the ceramic tile manufacturing. The viscosities of the melt calculated from chemical analyses are as follows: $24.04 \cdot 10^3$ Pa·s at softening temperature (*i.e.*, 1260ºC) and $5.64 \cdot 10^3$ Pa·s at melting temperature (1360ºC).

The growth of the Polish tile industry resulted in increasing interest in alternative sources of feldspar raw materials. The examples of them are weakly weathered pegmatites and granitoids occurring in the marble quarry of Sławniowice near Nysa (Lower Silesia), containing ca. 6.5 wt.% K_2O with Na_2O. The essential constituents of these rocks are feldspars and quartz, with a subordinate amount of mafic and clay minerals. Their suitability, after simple processing (crushing, milling, blending), for the production of *gres porcellanato* tiles has been checked in the course of industrial-scale examinations. This has been also confirmed by proper viscosities of the molten raw material studied, *i.e.*, $21.31 \cdot 10^3$ Pa·s at softening temperature (1250ºC) and $4.22 \cdot 10^3$ Pa·s at melting temperature (1350ºC).

Keywords: Polish feldspar-quartz, Strzeblów Mineral Mines, Tile industry, Sławniowice deposit, Lower Silesia

POLSKIE SUROWCE SKALENIOWE DLA KRAJOWEGO PRZEMYSŁU PŁYTEK CERAMICZNYCH – STAN OBECNY I PERSPEKTYWY

W wyniku rozwoju polskiego przemysłu płytek ceramicznych, obserwowanego od połowy lat 90-tych ubiegłego wieku, zwiększyło się zapotrzebowanie na surowce naturalne, a szczególnie na skaleń i/lub surowce skaleniowo-kwarcowe, które stanowią 50-60 % składu materiału płytki *gres porcellanato*. W 2007 zużycie surowców skaleniowych w Polsce osiągnęło ok. 900 000 t na rok, z czego ponad 80 % przypadło na przemysł płytek [1]. Krajowa produkcja tych surowców, mieszcząca się w zakresie od 400 000 do 600 000 t na rok, została uzupełniona przez import, głównie z Czech i Turcji.

Kopalnia surowców mineralnych Sobótka w Strzeblowie (Dolny Śląsk) jest najstarszym i największym polskim producentem skalenia. Firma oferuje w zasadzie grys skaleniowo-kwarcowy zawierający min. 7,5 % K_2O+Na_2O ($K_2O/Na_2O \geq 1$) i ok. 0,5 % Fe_2O_3, który jest głównie wykorzystywany do wytwarzania płytek ceramicznych. Lepkości stopu obliczone na podstawie analizy chemicznej są następujące: $24,04 \cdot 10^3$ Pa·s w temperaturze mięknięcia (tj. 1260ºC) i $5,64 \cdot 10^3$ Pa·s w temperaturze topnienia (1360ºC).

Rozwój polskiego przemysłu płytek wywołał zwiększające się zainteresowanie alternatywnymi źródłami surowców skaleniowych. Przykładem takich materiałów są słabo zwietrzałe pegmatyty i granitoidy, występujące w kamieniołomie marmuru w Sławnowicach pod Nysą (Dolny Śląsk), które zawierają ok. 6,5 % mas. K_2O+Na_2O. Zasadniczymi składnikami tych skał są skaleń i kwarc przy podrzędnej zawartości minerałów maficznych i ilastych. Przydatność tych materiałów po prostym przetwarzaniu (kruszenie, mielenie, mieszanie) do produkcji płytek *gres porcellanato* została sprawdzona w trakcie badań na skalę przemysłową. Potwierdzają ją również odpowiednie wartości lepkości stopionych surowców, tzn. $21,31 \cdot 10^3$ Pa·s w temperaturze mięknięcia (1250ºC) i $4,22 \cdot 10^3$ Pa·s w temperaturze topnienia (1350ºC).

Słowa kluczowe: polski surowiec skaleniowo-kwarcowy, Strzeblów kopalnie surowców mineralnych, przemysł płytek, złoże Sławniowice, Dolny Śląsk

1. Ceramic tile industry development

The ceramic tile industry has been one of the fastest developing sectors in Poland over the past several years, owing to the nationwide housing construction and repairs boom experienced from the late 1990s [2]. The increase of the total domestic tile production was spectacular: since 1992 it has grown fifteen-fold, while in the years 1998-2007 by more than 500 %, *i.e.*, from 360,000 t to 1.9 Mt per annum [3] (Fig. 1).

Large-scale investments in new production facilities and technologies resulted in the modernization and expansion of the industry's total capacity from ca. 60 million m^2py in the beginning of the XXI century to ca. 140 million m^2py in 2007 [4].

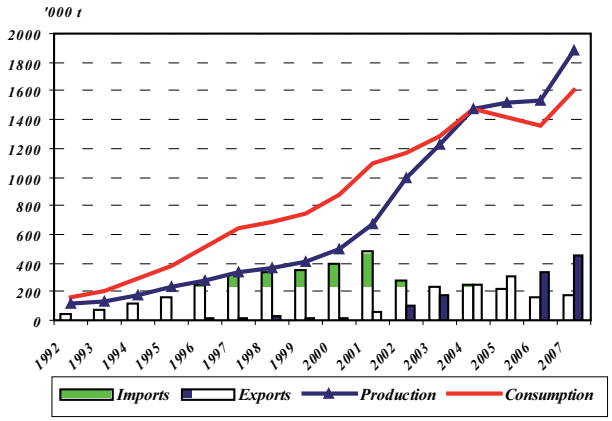

Fig. 1. Ceramic tile statistics in Poland, 1992-2007.

The investments included the installation of fast-firing technology lines (licensed by Italian company Sacmi Imola), the introduction of high-pressure presses, wet grinding in tube mills, spray-drying, *etc*. This resulted in a change in the tile supply structure, with a progressively increasing share of porcelainized stoneware (*gres porcellanato*), the production of which grew from 730,000 t in 2002 to 1.5 Mt in 2007, while their capacity approached 60 million m^2py (an increase from 30 million m^2py in 2002). As many Polish producers (*e.g.*, Cersanit, Paradyż Group, Końskie Group) have announced further capacity development, by 2010 the potential of the domestic tile industry is expected to exceed 150 million m^2py [1, 5].

Over 70 % of the total domestic tile production (ca. 90 million m^2) comes from central Poland, *i.e.*, the region of Tomaszów Mazowiecki – Opoczno – Końskie, which is the historical ceramic tile centre of the country and home of the largest producers, *i.e.*, the Paradyż Group and the Opoczno. Approximately 20 % of the domestic production originates from the Lower Silesia in the SW part of the country, and the remaining 10 % from the Upper Silesia [6]. Taking into account the European tile production, Poland is the third largest producer (or fourth, when Turkey is considered), after Italy and Spain.

There are around 30 tile manufacturers (including clinker ones), among which the biggest are the following: the Paradyż Group with 32 million m^2py production capacity in 5 facilities located in the region of Tomaszów Mazowiecki and Opoczno the Opoczno (the oldest domestic producer) with 28 million m^2py in four plants, and the Cersanit III of Wałbrzych in the Lower Silesia which is a part of the Cersanit Group (ca. 20 million m^2py). In 2006, the latter company became a dominant shareholder of the Opoczno.

The increase in the domestic tile production and the improvement in their quality resulted in an intense competition between domestic and foreign tile suppliers. In recent years Polish producers have managed to capture a larger percentage of the domestic market as compared to foreign suppliers, despite an inflow of cheap tiles from China. They also successfully entered international markets. The number of Polish tiles recipients increased from 20 in 2000 to almost 50 in 2006-2007, including countries of the Central and Eastern Europe, *i.e.*, Ukraine, Russia, Lithuania, Belarus, Estonia, Latvia, being the largest importers, as well as the Czech Republic, Slovakia, Germany, Romania, and Hungary [3]. Most recently, due to the global financial crisis and the deterioration of eastern markets, especially of the Ukrainian one, the tile sales to this region diminished.

2. Feldspar raw materials supply/demand in Poland

Alkali-rich raw materials (feldspar, feldspar-quartz, nepheline syenite) are among the principal commodities utilized in the production of ceramic goods. Polish feldspar producers have had to keep pace with the domestic rapidly growing ceramic sector, especially of tiles and sanitaryware, and its demand for the raw materials. Moreover, the change in the technology of ceramic tile manufacturing, *i.e.*, introduction of single-firing process and expansion of porcelainized stoneware (gres porcellanato), exert pressure upon raw material suppliers to modify their products. This also resulted in increased supply of feldspar grits at the cost of flours. Feldspar-quartz rock has been extracted primarily by the Strzeblów Mineral Mines – SKSM, Sobótka/Lower Silesia, from the following leucogranite deposits: Pagorki Wschodnie, Pagórki Zachodnie, and Strzeblów I. In the last couple of years the company's production of feldspar-quartz grits and flours ranged from 350,000 to 420,000 tpy, *i.e.*, from 75 to 87 % of the total domestic supplies [1]. Up to now, the products have been obtained in course of simple processing (crushing, grinding, and blending). Their relatively high content of Fe_2O_3 (averaging ca. 0.5 %, Table 1) is to be lowered

Table 1. Chemical composition of feldspar-quartz raw materials from selected sources in Poland.

Chemical composition	SKSM	WKSM Graniczna	Pol-Skal Karpniki	Slawniowice
[%]	grit 0-5 mm	fraction 0-2 mm	grit 0-8 mm	average sample
SiO_2	74.0-78.0	71.5	71.4	72.0
Al_2O_3	13.0-15.0	13.6	15.6	15.1
K_2O	min. 4.0	4.21	5.10	2.94
Na_2O	min. 3.5	3.49	3.16	3.52
Fe_2O_3	average 0.5	3.28	0.5-0.9	0.47
TiO_2	max. 0.05	0.30	not determined	0.08
K_2O/Na_2O	ca. 1.1	1.2	1.6	0.8

by magnetic separation, which is currently introduced into the technological process.

Another producer, the Wrocław Mineral Mines – WKSM (a division of the Tarmac Group), specialized in the production of crushed aggregates, offers feldspar-quartz fine-grained fractions generated in course of granite crushing at its own Graniczna quarry (36,000-84,000 tpy). Despite their high content of Fe_2O_3 (ca. 3 %, Table 1), these alkali-rich products are successfully utilized in some branches of the ceramic tile industry.

In 2005, a new producer of feldspar raw materials entered the domestic market: Pol-Skal Ltd., Kraków. The company has restarted the Karpniki mine located also in the Lower Silesia, which was halted in 1999 due to problems with sales of the poor quality material. In the years 2005-2007 its output increased from 20,000 to 94,000 tpy (and is expected to approach 150,000 tpy in the nearest future).

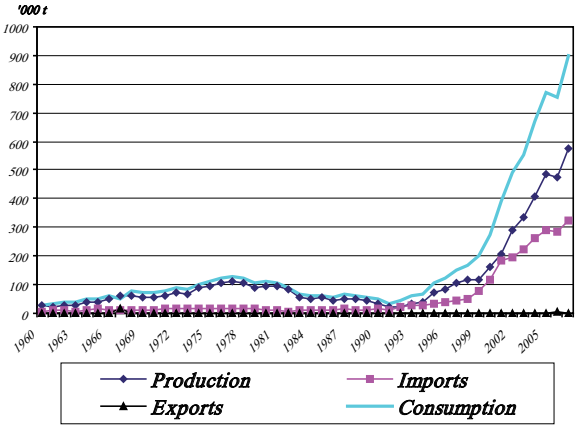

Fig. 2. Feldspar raw materials statistics in Poland, 1960-2007.

Small amounts (5,000-10,000 tpy) of the feldspar-quartz material, appropriated basically for the glass-making industry, have been also offered by the Jelenia Góra Mineral Mines, Szklarska Poręba/Lower Silesia. The total production of feldspar-quartz assortments from domestic sources in Poland has been constantly growing, up to 580,000 t in 2007 (Fig. 2).

The consumption of feldspar and feldspar-quartz commodities corresponds to the demand of the ceramic and glass-making industries, which reflects the building industry condition and general state of the national economy. The development of the ceramic tile industry in Poland and soaring production of *gres porcellanato* tiles has resulted in a significant increase of the demand for feldspar and feldspar-quartz raw materials, which accelerated in the 2000s, up to ca. 900,000 t in 2007 (Fig. 2). The tile sector has accounted for over 80 % of the total domestic feldspar consumption in recent years (Fig. 3). The remaining percentage went to the glass producers (ca. 10 %), the sanitaryware manufacturers (around 4 %), and others (ca. 3 %).

Despite the large domestic feldspar production capacity in Poland, there has been a deficit of feldspar commodities of the highest purity for the porcelain and sanitaryware industries, and for the glass production. Therefore these materials have to be imported, mainly from Norway and Finland. However, in recent years the large amounts of feldspar commodities have been also brought from abroad by the ceramic tile industry (over 60 % of the total imports) to supplement domestic supplies, which were insufficient to keep pace with the expansion of this sector demand. The principal deliveries of tile grades, characterized by the low content of colouring oxides, came from the Czech Republic [7] and Turkey [8] (0.2-0.6 and 0.05-0.15 % Fe_2O_3, respectively). The total importation of feldspar commodities to Poland has been increasing, approaching 330,000 tpy in 2007, *i.e.*, almost 40 % of the total consumption (Fig. 2). This value has included 25-30 % per annum of nepheline syenite, which has been purchased for the needs of the glass and sanitaryware industries predominantly from Norway.

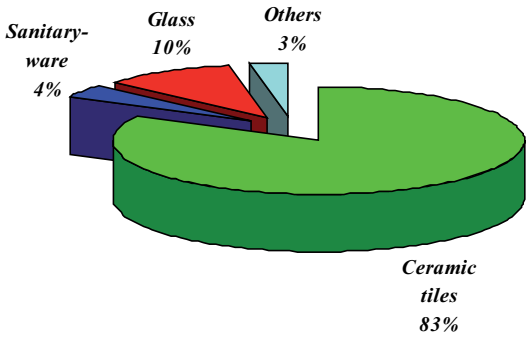

Fig. 3. The use of feldspar commodities in Poland, 2007.

3. A potential new domestic source of feldspar-quartz raw material for ceramics

High demand of the ceramic industry in Poland for raw materials, especially for feldspar, has resulted in growing interest in such sources, which have not been taken into consideration so far [9]. The examples of them are weakly weathered rocks, representing pegmatites and granitoids, which occur in the marble quarry in Sławniowice near Nysa, Lower Silesia. The main mineral constituents of the raw material are: potassium feldspar (microcline, microperthite; Fig. 4), plagioclases (albite-oligoclase), quartz and micas (strongly weathered biotite). Other minor components are: chlorite, smectite, and mixed layered minerals of chlorite-smectite type.

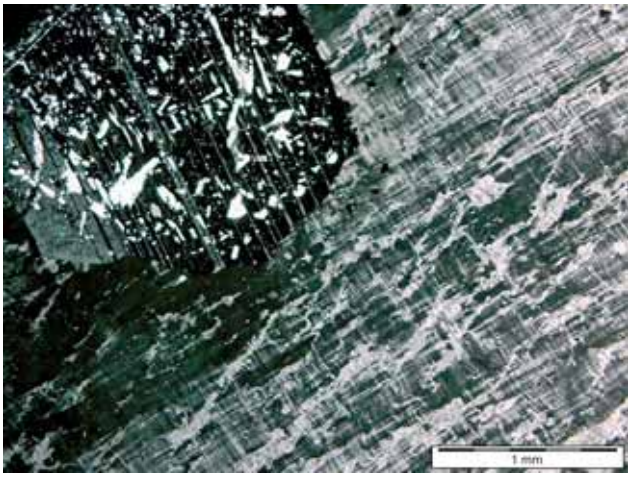

Fig. 4. Perthite (microcline with Na-feldspar exsolutions) and strongly sericitized plagioclase (left upper corner) in the feldspar-quartz rock from Sławniowice.

Despite the common quality (around 6.5 % of alkalis, 0.55 % of colouring oxides Fe_2O_3+TiO_2) the industrial-scale examinations, *i.e.*, single-firing of ceramic tiles with the use of the raw material in question, confirmed its suitability for the production of *gres porcellanato* tiles [10]. There were also such important parameters assessed as viscosity of the melt during heating and colour of the body after firing. The viscosities were calculated on the ground of the chemical composition using Priven's method [11]. The changes of viscosity in the case of the examined rock are similar to these of SKSM's sample (Fig. 5). A slight difference between both computed curves results from a prevelance of sodium oxide over potassium one in the chemical composition of the raw material from Sławniowice (Table 1). The viscosities of the molten rock were as follows: $21.31 \cdot 10^3$ Pa·s at softening temperature (1250ºC) and $4.22 \cdot 10^3$ Pa·s at melting temperature (1350ºC), while the viscosities of the melt of the SKSM's grit were negligibly higher, *i.e.*, $24.04 \cdot 10^3$ Pa·s at softening temperature (1260ºC), and $5.64 \cdot 10^3$ Pa·s at melting temperature (1360ºC).

The colour of a sample of feldspar-quartz from Sławniowice after firing at 1230ºC was light-grey which could be also acceptable from the point of view of glazed ceramic goods manufacturing.

However, further investigations revealed that the content of colouring oxides in the examined rock could be an obstacle for its utilization in the production of other ceramic goods (*e.g.*, sanitaryware). Iron minerals were observed in the transmission and scanning microscopes, such as intergrowths in the grains of other minerals, *e.g.*, quartz, feldspar [12].

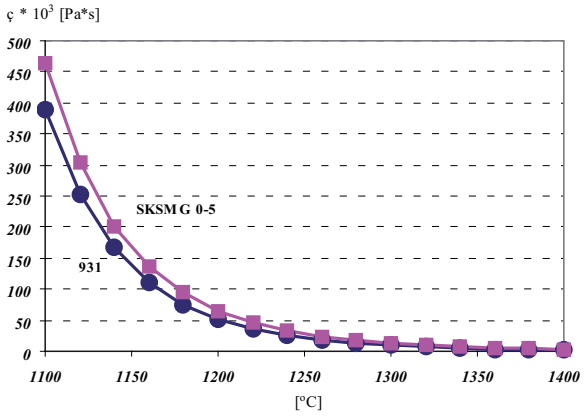

Fig. 5. The dependence of viscosity on temperature: Sławniowice (average sample 931) and Strzeblów Mineral Mines (SKSM; grit G 0-5 mm).

The study carried out by the Mössbauer spectroscopy method exhibited that iron not only occurs in its own minerals (goethite, hematite, lepidocrocite) but also forms isomorphous substitutions in the structure of feldspar and clay minerals [12]. This makes the diminishing of the content of colouring oxides practically impossible.

Nevertheless, the rock in question should be taken into consideration as a potential source of raw material for the production of ceramic tiles.

4. Conclusions

Feldspar and feldspar-quartz will continue to be the key raw materials for the ceramic industry in Poland, especially in view of huge ceramic tile production. The Strzeblów Mineral Mines is the most important domestic supplier of these commodities, which mainly offers feldspar-quartz grits. Apart from other producers (Wrocław Mineral Mines, Pol-Skal, Jelenia Góra Mineral Mines), there is a new potential source of raw material for the ceramic industry, *i.e.*, feldspar-quartz rock accompanying marble in the quarry of Sławniowice. Its suitability for the production of ceramic tiles (even *gres porcellanato*) has been confirmed in the course of industrial-scale examinations.

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