GOSPODARKA SUROWCAMI MINERALNYMI

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KRZYSZTOF GALOS*

Ball clays for the production of porcelain tiles in Poland

Introduction

Ball clays are defined as fine-grained sedimentary plastic clays, consisting mainly of disordered variety of kaolinite, which exhibit light or white colour after firing to ca. 1200°C under oxidising conditions. Ball clays contain varying proportions of kaolinite (20–80%), illite and muscovite (10–25%), and fine-grained quartz (5–65%), with small amounts of organic matter and accessory minerals (smectites, anatase and various iron minerals). The wide variation of mineral composition and variable size of the clay particles, result in various characteristics of individual ball clays grades from different deposits and even from individual parts of clay seams. In general, ball clays are not deeply processed after excavation, but blending of various grades is common (Wilson 1998).

Ball clays are one of the basic mineral commodities for numerous ceramic products manufacture. Significant development of some sectors of the Polish ceramic industry, especially of porcelain tile production, would not be possible without assurance of deliveries of raw materials. Supplies of appropriate clayey raw materials, which exhibit the largest variability of quality, seem to be the most important. For porcelain tiles, kaolin and ball clays (white- or light-firing clays) are the most important clayey components. In the last ten years, intense development of demand for such clays for porcelain tiles production was reported in Poland. There were also significant changes in the set of ball clays used by this industry. Due to limited sources of such clays in Poland, their domestic producers satisfy industry's needs only in a small extent, while over 80% of demand is met by imports (Lewicka, Galos 2004; Galos 2010a).

** Ph.D. Eng., Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, Kraków, Poland; AGH University of Science and Technology, Kraków, Poland; e-mail: kgalos@min-pan.krakow.pl

1. Domestic supply of white-firing and light-firing clays

Sources of white-firing clays in Poland are very limited. They are related almost entirely to Upper Cretaceous clayey and sandy-clayey sediments in Bolesławiec basin (SW Poland). On the contrary, there is a wealth of well sintering plastic clays in Poland, which find use in the ceramic industry. In some mines, extraction of light-firing varieties is possible. It is especially the case of Lower Jurassic clays in the northern border of the Holy Cross Mts. (central Poland), as well as some Tertiary clays in Lower Silesia (SW Poland).

1.1. Production of white-firing clayey raw materials from Upper Cretaceous sediments in Bolesławiec area

1.1.1. Reserve base

In Upper Cretaceous sediments of Bolesławiec basin, sandy-clayey and clayey series of total thickness ca. 200 m occurs. It is composed mainly of clay-bonded sandstones, with seams and lenses of kaolinitic white-firing clays, stoneware clays and refractory clays located mainly in the lower part of the series (Milewicz 1974). The sediments have inclination from a few degrees to twelve degrees in the both wings of the Bolesławiec basin and are often faulted. Lenses and seams of clays have variable thickness: 0.2–3.0 m, mostly 0.5–1.5 m. In the past they were documented as separate “seams” (total number 5 to 15), constituting ca. 25% of the whole series. However, besides extraction of white-firing clays from the above mentioned seams and lenses, it is also possible to obtain white-firing clayey raw material from the whole sandy-clayey series, by washing of such material, if content of clay minerals of good quality amounts to over 20% (Nieć, Ratajczak 2004a).

Deposits of white-firing and stoneware clays are recognized mainly in the southern wing of Bolesławiec basin, in the vicinity of Węgliniec and Nowogrodziec, as well as between Bolesławiec and Lwówek Śląski. They were extracted since the Middle Ages in open-pits, while in the 20th century also in underground mines, being known as so-called *Bolesławiec clays*. They exhibit differentiated mineralogical composition. Share of coarse fraction >0.063 mm sometimes exceeds 50%. The main components are well-ordered kaolinite, illite and muscovite (Fig. 1), while share of quartz is very variable: from 15% up to even 80% (Stoch 1962). Due to their large lithological and mineralogical variability, a lot of varieties was distinguished, according to values of bending strength after drying, content of >0.063 mm grains, water absorption and whiteness after firing (Nieć, Ratajczak 2004a). The best variety – A1 – exhibited bending strength after drying >3 MPa, less than 1.5% of >0.063 mm grains, water absorption after firing at 1200°C under 6%, whiteness after firing at 1200°C over 70%. Difficult geological and mining conditions, especially large water inflow, resulted in closure of underground mines of Bolesławiec clays (Lewicka, Galos 2004).

Recently, selective extraction of Bolesławiec clays seams and lenses was abandoned. In newly opened Janina and Czerwona Woda mining and processing plants, the whole

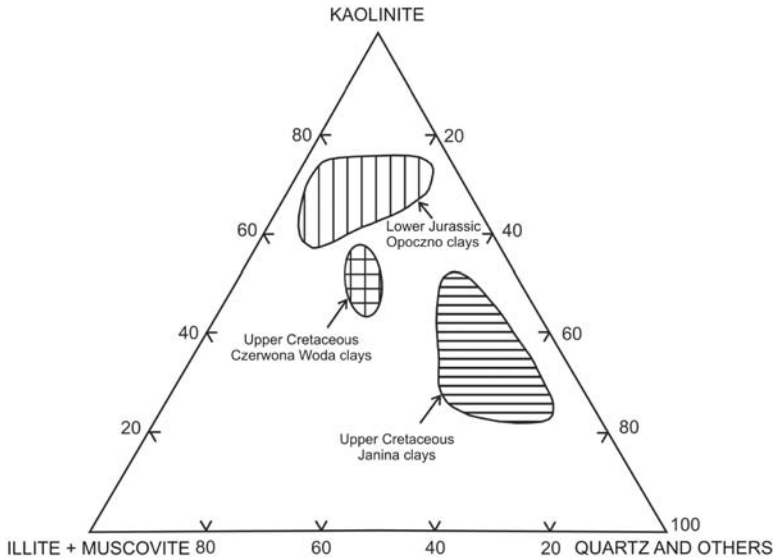

Fig. 1. Variability of the mineral composition of white-firing clays from Janina and Czerwona Woda deposits (Milewicz 1974) and of light-firing clays from Opoczno area (Kozydra 1968)

Rys. 1. Zmienność składu mineralnego iłów biało wypalających się ze złóż Janina i Czerwona Woda (wg Milewicza 1974) oraz iłów jasno wypalających się z rejonu Opoczna (wg Kozydry 1968)

sandy-clayey series – clay-bonded sandstones and clays – are extracted, while after washing one homogenized clay product is obtained. The undeveloped deposits available for such activity are: Nowe Jaroszowice and Janina-Zachód (Nieć, Ratajczak 2004a; Galos 2010a).

Resources of white-firing clays are currently recognized in six deposits in Bolesławiec basin. Three of them are abandoned (Bolko II, Janina, Janina-Zachód), two deposits are undeveloped (Nowe Jaroszowice and Ocice), and one deposit is currently extracted – Janina I (Table 1). Their total resources amount to ca. 59.7 million t, but resources of pure clays in seams and lenses are recognized at the total level of ca. 1.1 million t in the three abandoned deposits. In the other three deposits – Janina I, Nowe Jaroszowice i Ocice – resources of sandy-clayey raw material for the production of white-firing clay after washing, are recognized at the total level of ca. 58.6 milion t, what enables production of ca. 17.2 million t of white-firing clayey raw material. Moreover, in the two nearby undeveloped stoneware clays deposits – Anna-Włodzice Małe i Ocice II – with total resources ca. 11.5 million t, some amounts of white-firing varieties of clays also occur (Bilans Zasobów... 2009). Czerwona Woda sandy-clayey deposit, recognized previously as natural foundry sand deposit, recently also started to be the source for the manufacture of white-firing clayey raw material. Available resources of this deposit amount to ca. 5.0 million t (Bilans Zasobów... 2009). Perspective areas, not yet recognized as deposits, which occur primarily between Bolesławiec, Jaroszowice, and Nowogrodziec, have total estimated perspective resources ca. 132 million t of sandy-clayey raw material (Table 1), what could enable production of ca. 40 million t of white-firing clayey raw material (Galos 2010b).

TABLE 1

The most important deposits and perspective areas of Upper Cretaceous white-firing clays and sandy-clayey raw materials in the Bolesławiec basin

TABELA 1

Najważniejsze złoża i obszary prognostyczne górnokredowych biało wypalających się iłów i kopalin piaszczysto-ilastych w niecce bolesławieckiej

Deposit/Area	Reserves/Resources in million t (including estimated amount of clayey fraction)[1]	Status
Deposits of sandy-clayey raw material for washing:		
Czerwona Woda	5.0 (1.5)	extracted deposit
Janina I	2.7 (0.8)	extracted deposit
Nowe Jaroszowice	41.2 (12.0)	undeveloped deposit
Ocice	14.7 (4.4)	undeveloped deposit
Perspective areas of sandy-clayey raw material for washing:		
Ustronie-Jaroszowice	62.0 (18.6)	perspective area
Bolesławiec-Jaroszowice	20.0 (6.0)	perspective area
Nowogrodziec-Skała	45.2 (13.6)	perspective area
Parowa	5.2 (1.6)	perspective area
Deposits of stoneware and white-firing clays[2]:		
Anna-Włodzice Małe	7.5	undeveloped deposit
Ocice II	4.0	undeveloped deposit

[1] Assumed average share of grain fraction <0.01 mm ca. 30%.

[2] Recognized reserves of clays in seams and lenses among sandstones, documented for underground extraction.

Source: Bilans Zasobów... 2009; Galos 2010b

1.1.2. Producers

White-firing ball clays are extracted from deposits of Upper Cretaceous clayey and sandy-clayey sediments of Bolesławiec basin for centuries. The highest production – ca. 80,000 tpy – was reported in 1970, when three underground mines were active: Janina, Bolko, and Anna-Włodzice. Due to difficult mining conditions, these mines were consecutively abandoned: Anna in 1970, Janina in 1980, and finally Bolko in 1997. Since the 1980s, small additional production of white-firing clayey raw materials has been carried on by Surmin-Kaolin S.A. in Nowogrodziec (mainly TC1/WB granulated raw material). Total production of white-firing clayey raw materials in the beginning of the 21st century, after closure of Bolko mine, went down to only ca. 4,000 t in 2002 (Lewicka, Galos 2004).

In 2003, Ekoceramika Ltd. of Suszki commenced a new Janina mine and processing plant, while in 2006 – Bolesławieckie Zakłady Materiałów Ogniotrwałych Ltd. of Bolesławiec opened a new processing plant near existing Czerwona Woda mine. This is why total production of white-firing clayey raw materials rose to almost 60,000 tpy in recent years. However, it still secured only less than 20% of demand of the Polish ceramic industry. It is worth mentioning that currently all white-firing clayey raw materials are produced in Poland by washing of sandy-clayey rocks of Cretaceous age (Minerals Yearbook... 2010). These raw materials exhibit moderate plasticity (bending strength after drying under 2 MPa) and weak sintering properties (water absorption after firing above 10%), but high whiteness after firing (ca. 80%) and commonly good rheological properties (Galos, Pietrzyk 2008). There are some possibilities of further development of production, but no more than to 120,000–140,000 tpy.

For years, Ekoceramika Ltd. has been delivering small amounts (a few thousand tpy) of white-firing clays, primarily on the basis of the output from Bolko underground mine (closed in 1997). After 1997, small production of such raw materials was maintained on the basis of some extracted materials stockpiled on the dumps, but in 2002 it decreased to only 1,000 t (Galos, Wyszomirski, 2006a). In 2003, the company opened new Janina open-pit and processing plant (Fig. 2). Total thickness of clay-sandstone series amounts to ca. 110 m, with total thickness of clay seams 20 m. Sandstone/clay series is extracted as a whole, and then it is washed, classified in hydrocyclone and dewatered in press. One grade of clayey raw

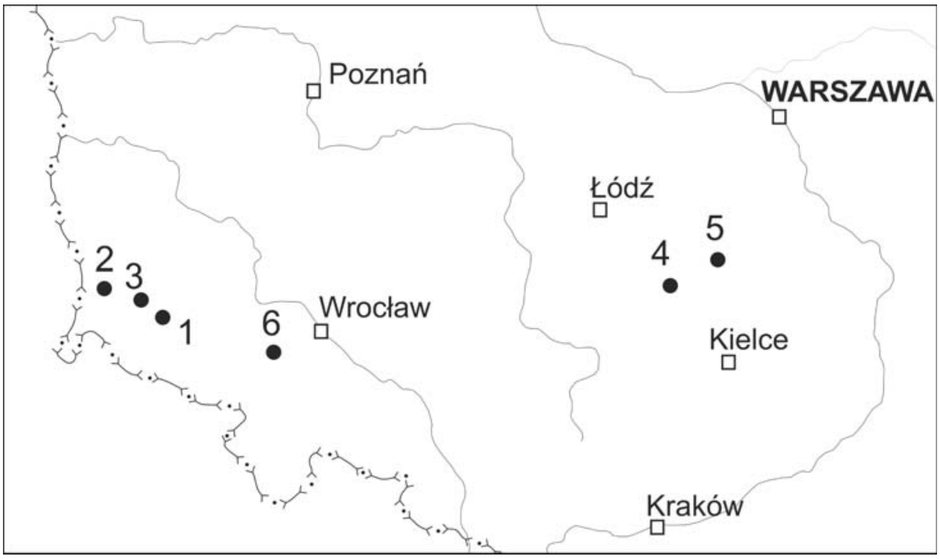

Fig. 2. Location of the Polish producers of white-firing and light-firing clays
1 – Janina, 2 – Czerwona Woda, 3 – Surmin-Kaolin, 4 – Żarnów, 5 – Zapniów, 6 – Rusko-Jaroszów

Rys. 2. Lokalizacja polskich producentów iłów biało i jasno wypalających się
1 – Janina, 2 – Czerwona Woda, 3 – Surmin-Kaolin, 4 – Żarnów, 5 – Zapniów, 6 – Rusko-Jaroszów

TABLE 2

Producers of white-firing and light-firing clays in Poland

TABELA 2

Producenci iłów biało i jasno wypalających się w Polsce

Company	Deposit/Mine	Level of production (ktpy)	Clay grades
White-firing clays:			
Ekoceramika Ltd.	Janina I/Janina	40–45	JB1W
Bolesławieckie Zakłady Materiałów Ogniotrwałych Ltd.	Czerwona Woda	12–14	CWW
KSM Surmin-Kaolin S.A.	Nowogrodziec	2–4	TC1/WB
Light-firing clays:			
Glinkop Ltd.	Paszkowice/Żarnów II	30–70	Żarnów
Kopalnia Zapniów Ltd.	Kryzmanówka/Zapniów	20–30	Zapniów G3S, G3
Jaro S.A.	Rusko-Jaroszów/Stanisław	40–50	G1/C, G2/C, G3/C

Source: Minerals Yearbook... 2009; Galos 2010a

material – Janina JB1W – is offered (Galos, Pietrzyk 2008). Production recently rose to over 40,000 tpy (Table 2).

Since 2006, Bolesławieckie Zakłady Materiałów Ogniotrwałych Ltd. in Bolesławiec started to be the another white-firing clayey raw material producer. Nearby the active clayey sand Czerwona Woda mine, a new modern processing plant was constructed. Sandy-clayey raw material from the mine is homogenized on the stockpile, and then loaded into the washing drum. Later on, the suspension is classified in the hydrocyclone battery, with purifying classification on the Derrick sieves, and finally dewatering in press filters (Galos, Pietrzyk 2008). The plant's production recently amounted to 12,000–14,000 tpy, while capacities were estimated at ca. 20,000 tpy (Minerals Yearbook... 2010).

For over 20 years, production of white-firing clayey raw material (TC1/WB granulate) is carried on by KSM Surmin-Kaolin S.A. of Nowogrodziec. This product is obtained by blending of tertiary white-firing clays from Turów lignite mine and kaolin semiproducts from Surmin-Kaolin plant in Nowogrodziec. The last one originates from the processing of Upper Cretaceous kaolinite-bonded sandstone coming from Maria III deposit. TC1/WB granulate is characterized by high whiteness after firing, good rheological properties, moderate bending strength after drying and water absorption after firing. Its production do not exceed 4,000 tpy (Minerals Yearbook... 2010).

1.2. Production of light-firing clays from Lower Jurassic sediments in Opoczno and Przysucha areas

1.2.1. Reserve base

Refractory clays and stoneware clays in Lower Jurassic sediments occur in so-called northern periphery of the Holy Cross Mts., in the area of Przysucha, Opoczno and Żarnów, and are known as *Opoczno clays*. Light-firing varieties of clays were formed in the top part of series as a result of decrease of iron content in the clays due to weathering (Kozydra 1968). Such clays occur in two, sometimes three seams, in between of sandstone series. Seams have inclination from three to fifteen degrees and are often faulted. The main components of these clays are: medium-ordered kaolinite (commonly 50–60%), illite and muscovite (20–30%) and quartz (Brański 2008; Kozydra 1968). Due to the depth of seams and faulting, Lower Jurassic clays were extracted mainly by underground method.

Opoczno clays have been extracted in Opoczno, Żarnów and Przysucha vicinity from the middle of the 19th century, initially in open-pits, but in the last few decades only in underground mines. From among numerous deposits being extracted, currently mining is maintained only in two of them: Paszkowice in Żarnów (available resources under 4.0 million t) and Kryzmanówka in Zapniów (ca. 0.8 mln t). A few deposits are abandoned, e.g. Rozwady-Mroczków, Jakubów, Żarnów. Recognized, undeveloped deposits – Borkowice-Radestów, Zawada i Rusinów – occur in Przysucha vicinity (Table 3). There is also

TABLE 3

The most important deposits and perspective areas of Lower Jurassic light-firing clays in Opoczno-Przysucha region

TABELA 3

Najważniejsze złoża i obszary prognostyczne dolnojurajskich iłów jasno wypalających się w rejonie Opoczna-Przysuchy

Deposit/Area	Reserves/Resources in million t	Status
Deposits:		
Paszkowice (Żarnów)	4.0	extracted deposit
Kryzmanówka (Zapniów)	0.8	extracted deposit
Borkowice-Radestów	5.2	undeveloped deposit
Zawada	2.1	undeveloped deposit
Rusinów	0.3	undeveloped deposit
Perspective areas:		
Mroczków-Barwinek	5.3	perspective area

Source: Bilans Zasobów... 2009; Galos 2010b one perspective area, initially recognized, between Mroczków and Barwinek. Its perspective resources are estimated at ca. 5.3 million t (Galos 2010b).

1.2.2. Producers

Lower Jurassic clays were extracted in Opoczno-Przysucha region for decades, being used primarily as refractory clays. Until the early 1990s, production was carried on by Opoczno Refractory Works, e.g. in Jakubów, Rozwady-Mroczków, Żarnów, Żarnów II (Paszkowice) and Zapniów mines. Three first mines were abandoned before 1990, while Żarnów/Paszkowice and Zapniów mines were bought by other ceramic materials producers. Their total production in the last years varied between 50,000–90,000 tpy (Lewicka, Galos 2004; Minerals Yearbook... 2010).

Paszkowice deposit is currently mined in the Żarnów II underground mine by Glinkop Ltd. Though total resources approach 4 million, available reserves of good quality light--firing clays will be exhausted in the next few years. Deposit is recognized to the depth 90 m, but extraction is carried on to max. 70 m. Two varieties of clays with good sintering properties can be distinguished there: plastic light-firing clays (containing ca. 1.5% Fe_2O_3) and medium-plastic dark-firing clays (up to 4% Fe_2O_3). Low-ordered kaolinite (commonly 50–60%), illite and muscovite (ca. 25%) and quartz (ca. 15%) are the main mineral components of these clays (Wyszomirski et al. 2000). Currently, Żarnów II mine does not extract these varieties separately. Żarnów clay is used for the production of porcelain tiles and other ceramic tiles. Recently, production of Żarnów mine varied between 30,000 and 45,000 tpy, with significant increase to almost 70,000 t in 2008 (Minerals Yearbook... 2010).

Clays from Kryzmanówka deposit were recently mined by Kopalnia Zapniów Ltd. (Fig. 2), a subsidiary of F. Jopek Ceramika Ltd. of Zabrze, in Zapniów underground mine (closed in 2009). Zapniów clays were similar to Żarnów clays. They were used primarily for ceramic tiles and sanitaryware manufacture. However, available reserves of good quality clays were recently exhausted. Two varieties were produced thanks to selective extraction: Zapniów G3S light-firing clay (ca. 1.3% Fe_2O_3) and Zapniów G3 clay exhibiting lower whiteness after firing (Wyszomirski 1999). Both varieties were shredded and homogenized in the mine. Zapniów mine production varied between 20,000 and 30,000 tpy in recent years (Table 2). G3S grade constituted ca. 80% of total production (Galos 2010a).

1.3. Production of other light-firing clays

Kaolinite light-firing clays, recognized as refractory or stoneware clays, are also known in some Tertiary sediments, especially in Miocene sediments of Strzegom area, and – as accompanying raw materials – in Turów and Bełchatów lignite deposits.

Miocene refractory clays, occurring in Rusko-Jaroszów and Lusina-Udanin basins near Strzegom, are one of the most important ceramic clays in Poland. Currently, only Rusko--Jaroszów deposit is extracted. Two seams of *Jaroszów clays* occur there: upper (main) seam ca. 14 m thick, and lower seam ca. 10 m thick. Lignite occurs between clay seams and over upper seam. Clays' quality is very variable. These are mainly high and medium quality refractory clays (G1-G4 grades), in a part – light-firing varieties, with minor amounts of light-firing stoneware clays (Szepietowska 1989). Jaroszów clays are very fine-grained, with presence of – commonly – over 70% of very low-ordered kaolinite. This is why they are very plastic, exhibiting bending strength after drying over 2.5 MPa, but also possess good sintering properties, as water absorption after firing at 1200–1300°C does not exceed 2% (Wyszomirski 1999).

Jaroszów clays are extracted for almost 150 years. Resources of Rusko-Jaroszów deposit are now very limited due to long-term extraction, amounting to ca. 1.9 million t (Table 4). Total resources of undeveloped satellite deposits – Lusina-Udanin and Różana – exceed 42 million t. Udanin perspective area, with perspective resources of refractory clays estimated at almost 57 million t (Table 4), can be the another source of Jaroszów clays (Galos 2010b).

TABLE 4

The most important deposits and perspective areas of Miocene refractory clays in the Strzegom area

TABELA 4

Najważniejsze złoża i obszary prognostyczne mioceńskich iłów ogniotrwałych w rejonie Strzegomia

Deposits/Area	Reserves/resources in million t	Status
Deposits:		
Rusko-Jaroszów	2.0	extracted deposit
Lusina-Udanin p. S	29.0	undeveloped deposit
Lusina-Udanin p. N	6.1	undeveloped deposit
Różana	7.0	undeveloped deposit
Perspective areas:		
Udanin	56.9	perspective area

Source: Bilans Zasobów… 2009; Galos 2010b

Jaroszów refractory clays until the 1990s were used almost entirely for the manufacture of aluminosilicate refractories. Their total output in Stanisław mine in Jaroszów was reduced in the 1990s by a few times, but recently it stabilized at 130,000–150,000 tpy. Jaro S.A. extracts Jaroszów clays very selectively. Thanks to that, four basic varieties G1-G4 are obtained. They are homogenized at their stockpiles and to a small extent – blended to obtain special grades. Since the mid-1990s, company offers also clays for ceramic tiles and sanitaryware – G1/C, G2/C, G3/C grades – at the total level of 40,000–50,000 tpy (Minerals Yearbook... 2010). Nevertheless, Fe_2O_3 content in these grades is commonly 2.0–2.8%, while TiO_2 content: 1.0–1.4%.

Some varieties of white-firing clays, stoneware clays and refractory clays were recognized as accompanying raw materials in Turów lignite deposit, especially in the so-called seam B between upper and lower lignite bed. Mineral and grain composition of these clays was very variable, but varieties with low content of sand form only discontinuous, irregular lenses, a few meters thick. Reserves of high quality white-firing clays were very limited. Almost all of them were removed during extraction of Turów lignite deposit. Now, only a small part of them is stockpiled (Nieć et al., 2004). The best varieties of white-firing clays from Turów deposit exhibited Al_2O_3 content at 27–29%, 1.3–1.6% Fe_2O_3 and 1.0–1.5% TiO_2. They were very plastic, with bending strength after drying at 2.8–2.9 MPa (Wyszomirski et al., 2003). Small amounts of Turów white-firing clays, currently from the stockpile, are still delivered to KSM Surmin-Kaolin S.A. in Nowogrodziec, where they are blended with kaolin semiproducts from Surmin-Kaolin plant to obtain TC1/WB granulate (see above).

In the Bełchatów lignite mine, various varieties of clays occur in lignite overburden. The most interesting of them are extracted and stockpiled selectively. These are mainly stoneware clays, but some varieties are light-firing ones. There were trials to use them for ceramic tiles production, but it was difficult due to large variability of their mineral and chemical composition, as well as unstable content of coloring oxides (Wyszomirski 1999).

Other sources of white-firing clays in Poland have only historic importance. These are for example: Lower Jurassic clays from Grójec and Mirów in Krzeszowice vicinity (*Grójec clays*), Jurassic and Triassic light-firing clays near Siewierz and Zawiercie in NE periphery of the Upper Silesian Coal Basin, Triassic light-firing varieties of *Baranów clays* in Suchedniów vicinity in the northern periphery of the Holy Cross Mts. (Nieć, Ratajczak 2004b; Wyrwicki, Szamałek 1986).

2. Review of foreign white-firing ball clays for the Polish porcelain tiles industry

The world leading ball clays producers are Ukraine and Germany, but production in the US and the UK is also very important. The total world production of such clays is difficult to estimate, but it surely exceeds 20 million tpy (Stentiford 2003). Spectrum of producers is very wide – from single small mines to large international corporations (e.g. Imerys, WBB/Sibelco), which offer even a few dozens of commercial grades thanks to careful processing, homogenisation and blending. Deposits of high quality white-firing ball clays are rare, so they are often traded internationally and transported on long distances, sometimes even exceeding 1,000 km (Fiederling-Kapteinat 2008).

2.1. Donetsk region (eastern Ukraine)

Deposits of ceramic clays in Ukraine belong to the largest in the world. The majority of deposits is concentrated in Donetsk region (eastern Ukraine), with some single deposits also in other Ukrainian regions (e.g. Zaporozhye, Kirovograd). Total resources of ca. 40 recognized refractory and ball clays deposits in Ukraine amount to over 600 million t. Currently, ca. 20 deposits of kaolinite clays, possessing ca. 360 million t of resources, are extracted (Galos 2007a).

Regarding plasticity, bending strength after drying, whiteness after firing and organic matter content, ball clays of Donetsk region belong to the most appreciated grades on the European market, where they entered in 1992 (King 2006; Fiederling-Kapteinat 2004). However, stability of quality parameters of commercial grades is still sometimes questionable (Stentiford 2003).

Two genetic types of kaolinitic clays are distinguished there:

1. Triassic clays in the Druzhkovka area, NW of Donetsk (without economic importance),
2. Miocene clays in the Druzhkovka-Artemovsk area (being extracted).

Miocene clays are recognized also in the southwestern part of Donetsk region, near Volnovakha (e.g. Zateshanskoye and Peredovoye deposits), but they are not of economic importance due to lower quality and thick overburden, exceeding even 50 meters (Galos 2010a).

Miocene clays deposits in the Druzhkovka-Artemovsk area have unfavourable mining conditions. Sandy and clayey Quaternary overburden is typically 18–24 m thick, and upper Tertiary sand horizon – 5–6 m thick. Clays horizon consist of the upper clay seam (main seam – 1.5–4.0 m thick), quartz sand interlayer, and lower clay seam (typically under 1 m thick, usually not extracted). Clays contain 20–50% of kaolinite, 20–80% of illite and illite/smectite mixed-layered mineral, and only up to 10% of quartz. In each deposit, 4–14 different varieties of clay can be distinguished and commonly extracted selectively (Galos 2010a).

There are over 20 recognized deposits of Miocene kaolinitic clays in the Druzhkovka--Artemovsk area with total resources of ca. 200 million t. They are divided into two groups of deposits: 1. Druzhkovka-Oktyabrskoye group; 2. Chasov-Yar group (Fig. 3). Druzhkovka--Oktyabrskoye group of deposits is located to the west of Druzhkovka, 50–70 km north-west of Donetsk. These deposits possess ca. 70% of total Miocene kaolinitic clays resources in Druzhkovka-Artemovsk area. The thickness of the main clay seam is typically 3–4 meters, up to 6 meters, with overburden commonly ca. 30 m. Quality of clays is – in general – more variable in comparisonto clays near Chasov-Yar. Chasov-Yar group of deposits is located to the east of Druzhkovka, ca. 50 km north of Donetsk (Fig. 3). These deposits possess the remaining 30% of clays resources. The thickness of the clay seam is even up to 10 m, with similar thickness of overburden (ca. 30 m). Quality of clays is more stable, but varieties with higher content of organic matter occur also here (Fiederling-Kapteinat 2005; Galos, Wyszomirski 2006b).

Total mining output of Miocene kaolinitic clays of the Druzhkovka-Artemovsk area, after some decrease in the early 1990s to less than 2 million tpy, since the mid-1990s had stable increasing tendency due to development of a few new deposits (Fiederling-Kapteinat 2008). There is a lack of exact data, but estimated production of mines in the Druzhkovka-

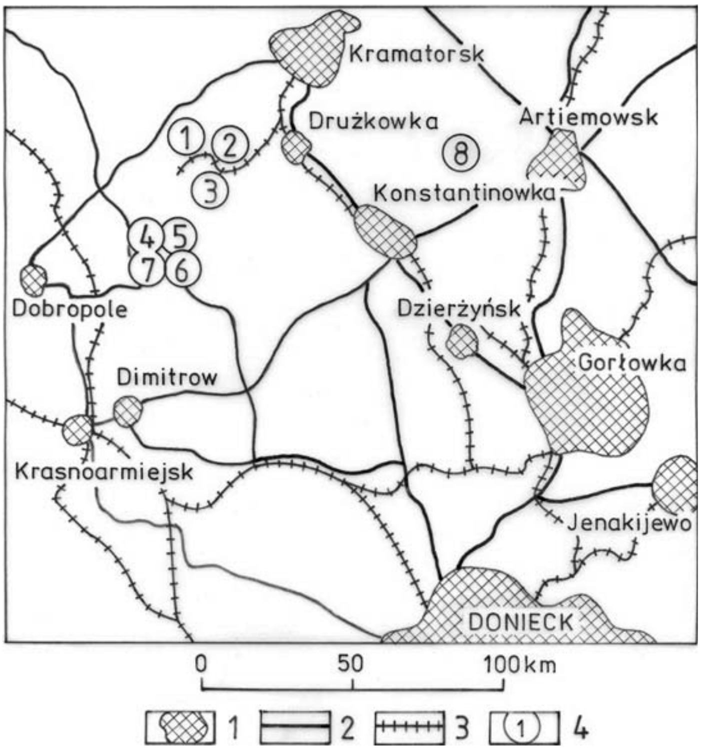

Fig. 3. Location of ball clay deposits in Donetsk region (Ukraine)
1 – towns, 2 – main roads, 3 – railways, 4 – clay deposits
Names of deposits: 1 – Novoandreyevskoye, 2 – Novorayskoye, 3 – Zapadodonskoye, 4 – Kutcherovyarskoye, 5 – Toretskoye, 6 – Oktyabrskoye, 7 – Yuzhnooktyabrskoye, 8 – Chasovyarskoye

Rys. 3. Lokalizacja złóż iłów biało wypalających się w rejonie Doniecka (Ukraina)
1 – miasta, 2 – główne drogi, 3 – linie kolejowe, 4 – złoża iłów
Nazwy złóż: 1 – Nowoandriejewskoje, 2 – Noworajskoje, 3 – Zapadodonskoje, 4 – Kuczerowjarskoje, 5 – Toreckoje, 6 – Oktiabrskoje, 7 – Jużnooktiabrskoje, 8 – Czasowjarskoje

-Oktyabrskoye group of deposits amounted to ca. 4 million tpy in recent years (Table 5), while in the Chasov-Yar area – only ca. 0.5 million tpy (one producer).

Ball clays from Donetsk region are highly suitable for porcelain tiles production. They exhibit: commonly low content of organic matter, moderate content of kaolinite (low--ordered variety), and high content of illite and illite/smectite mixed-layered mineral, with low amount of iron in the structure of these minerals (Romanenko 2002; Galos 2010a). These features contribute to high plasticity of raw clay, but they also allow to obtain material exhibiting high whiteness and low water absorption after firing (King 2006).

Five main producers of plastic ball clays in Donetsk region have diverse technological sets of extraction and processing of clays, what influences the quantity of offered grades and stability of quality parameters. In all mines, only upper clay seam is extracted, but its thickness varies in Druzhkovka-Oktyabrskoye area between 1.5 m and 4.0 m, while in

TABLE 5

Producers of ball clays in the Donetsk region (Ukraine)

TABELA 5

Producenci iłów biało wypalających się w regionie donieckim (Ukraina)

Company	Deposits	Level of mining output (million tpy)	Main grades
Vesco JSC (AO Vesko)	Novoandreyevskoye	1.5	Extra, Prima, Granitic
Donbas Clays JSC (ZAO Glini Donbasu)	Yuzhnooktiabrskoye, Kutcherovyarskoye, Novostepanovskoye, Novoshveytsarskoye	1.0	DB-X, DB-Y, DB-M
Oreadministration of Druzhkovka JSC (OAO Druzhkovskoye Rudoupravlyenye)	Novorayskoye, Oktyabrskoye, Zapadodonskoye	0.8	DN-0,-1,-2,-3 OKT-1,-2,-3 ZD-1,-2
Donkerampromsyryo Ltd. (OOO Donkerampromsyryo)	Toretskoye	0.6	DKPS-A,-B,-C,-D K-28, K-26
Chasov-Yar Refractory Works JSC (OAO Chasovyarskiy Ogneuporniy Kombinat)	Chasov-Yar	0.5	CH-0, CH-1, CH-2, CH-3, CH-PK

Source: Galos 2010a

Chasov-Yar area – commonly 4–6 m, sometimes even up to 10 m. Overburden thickness in the first area varies between 25–40 m, only in Andreyevskoye deposit less than 10 m. In Chasov-Yar deposits, typical overburden thickness is commonly lower: 18–30 m.

Extraction faces have width from only ca. 40 m in Novorayskoye mine and ca. 70 m in Novoandreyevskoye mine, to 200–400 m in the mines of Donbas Clays and Chasov-Yar Refractory Works and almost 1,300 m in Toretskoye mine. Wider faces allow to extract clays more selectively. Selective extraction in vertical profile is carried on in all mines, except of Oreadministration of Druzhkovka mines. Quantity of varieties extracted selectively in vertical profile can vary from 2 to 8, while minimal thickness of separate extraction may amount 0.5 m or even less. It is possible due to use of appropriate hydraulic excavators. Only in Oreadministration of Druzhkovka and Chasov-Yar Refractory Works mines, bucket wheel excavators are used (Galos 2010a).

Total quantity of clay varieties in a single mine varies from 3–5 in Oreadministration of Druzhkovka and Chasov-Yar Refractory Works mines, to 11 in Novoandreyevskoye mine of Vesco, and even 15 in Toretskoye mine of Donkerampromsyryo (Romanenko 2002; Galos 2010a). Two leading producers – Vesco and Donbas Clays – have systems of clays stock-piling with homogenisation, as well as clays shredding and blending. It allows to obtain high stability of commercial grades. It is especially well seen in case of Mertsalovo processing plant of Donbas Clays, where production of grades strictly meeting each customer demand, is possible. In the plants of Donkerampromsyryo and Oreadministration of Druzhkovka, only some clay shredding is carried on, while in case of Chasov-Yar Refractory Works extracted clay is not processed (Galos 2010a; Fiederling-Kapteinat 2005).

In case of each producer, a significant part of its production is directed to Maryupol port, and then by sea to customers in Italy, Spain, but also in Turkey, Egypt, the United Arab Emirates etc. Smaller part of production is delivered by rail, primarily to Ukrainian and Russian ceramic plants, but recently also to the Central Europe countries, especially to Poland. Up till now, Vesco and Donbas Clays were the main suppliers of ball clays to Poland, with some trial deliveries made by Oreadministration of Druzhkovka and Chasov-Yar Refractory Works. Donkerampromsyryo concentrated on Mediterranean markets (Galos 2010a; Fiederling-Kapteinat 2005).

2.2. Saxony (eastern Germany)

Germany is the second important producer of refractory and ball clays in Europe. Its production is very substantial, varying between 4.5–5.5 million tpy. Two companies are the most important: WBB Fuchs (a part of WBB Minerals, 25 mines, total production ca. 2 million tpy) and Stephan Schmidt group (ca. 20 mines, total production ca. 1.6 million tpy). Refractory and ball clays extraction in Germany is traditionally concentrated in three regions: Westerwald region in Rheinland and Hessen, Meißen-Lausitz region in Saxony, and – having minor importance – eastern Bavaria (Fig. 4).

Fig. 4. Deposits of kaolinite clays in Central Europe (acc. to Störr 1975, modified)

Rys. 4. Złoża iłów kaolinitowych w Europie Środkowej (wg Störra 1975, zmodyfikowane)

The largest production is concentrated in the Westerwald region, north of Koblenz, where a lot of varieties of plastic clays occur: from white-firing to dark-firing ones. These are commonly illite-kaolinite clays containing 15–45% of illite, 20–35% of highly-disordered kaolinite, 30–35% of quartz, and small amounts of smectite minerals (Kromer 1980). The three largest companies operating there are: WBB Fuchs, Stephan Schmidt group and Goerg&Schneider Co. Clays from this region are – in general – not supplied to Polish customers due to high price and transportation costs. They are used mostly in German and Italian ceramic plants, similarly as Bavarian clays, extracted primarily by Goerg&Schneider Co. and Adolf Gottfried Tonwerke plants (King 2006).

Meißen-Lausitz region in Saxony is also important area of ball clays production in Germany. These are commonly kaolinite-illite clays containing 35–50% of kaolinite, 20–30% of illite and 20–40% of quartz. Kaolinite is represented mainly by well-ordered variety, so these clays possess – in comparison to Westerwald clays – lower bending strength after drying, worse sintering properties, but higher whiteness after firing (Wilson 1998). Both large German ball clays producers – Stephan Schmidt group and WBB Fuchs – possess some clay mines in this region. Stephan Schmidt group is the owner of Stephan Schmidt Meißen company, which operates Kamenz-Wiesa clay open-pits and processing plant and delivers up to 240,000 tpy of various grades of white- and light-firing clays. Selective extraction is made by hydraulic excavators. Different grades are transported to two sorting plants with crushers, where these materials are shredded and blended. Processing and storage of blended clays is carried on under roof. Clay products are sold to ceramic tiles and sanitaryware plants in Eastern Germany, but primarily (ca. 80%) exported to Italy and Poland. The second company – WBB Fuchs – has also small daughter companies in this area: Kaolin und Tonwerke Seilitz-Löthain in Käbschütz near Meißen and Grana-Ton in Grana near Leipzig. Plants, smaller than this of Stephan Schmidt in Kamenz, deliver ca. 100,000 tpy of white-firing ball clay for similar markets (Galos 2010a). Kaolin- und Tonwerke Salzmünde near Halle is the next smaller Saxonian producer of ball clays (Galos et al. 2007).

2.3. The Czech Republic

The Czech Republic is one of the most important and traditional producers of ball and refractory clays in Europe. However, Czech production of such clays has decreased from the level of almost 2.0 million tpy to only ca. 600,000 tpy in recent years. White- and light-firing clays, containing under 2% of Fe_2O_3, probably constitute less than 1/4 of all extracted ceramic clays. Small portion (ca. 40,000 tpy) of ball and refractory clays is exported from the Czech Republic. Germany, Slovakia and Austria are the main recipients. Negligible amounts are sold also to Poland (Stary et al. 2009).

In the Czech Republic, three types of ceramic clays are distinguished: white-firing clays (JP), refractory clays (JZ, JO) and well-sintering stoneware clays (JN). Ceramic clays of these groups are currently extracted in the Czech Republic in over 20 mines, but white-firing clays and light-firing refractory varieties occur only in a few of them (Stary et al. 2009).

The most important are the so-called *vildštejn clays* of Pliocene age from Cheb and Sokolov region, in the most-western part of the Czech Republic. They are currently extracted in Cheb area in Nova Ves, Karel and Vackov mines by LB Minerals Ltd. (previously: Kemat Skalna Ltd.). The lower part of Cheb basin is formed by lignite covered by green clays layer. The main clay seams are: Vonsov seam, Nero coal-clay series, Nova Ves seam. Useful clays occur in the form of seams or lenses up to 9 m thick, surrounded by sandy clay. In the deposit profile, located up of green clays, a few varieties of clays are distinguished and selectively extracted:

1) white-firing kaolinite-vermiculite coarse-grained clays, sometimes rich in organic matter, containing 1.1–1.5% Fe_2O_3 (e.g. IB, BD, NF grades);
2) well sintering kaolinite-illite stoneware clays containing 2.2–4.8% Fe_2O_3 (e.g. AGB, U);
3) fine-grained well sintering refractory kaolinite clays containing 1.5–3.3% Fe_2O_3 (e.g. B1, BS, BN, WiR);
4) refractory kaolinite clays possessing poor sintering properties, which contain 1.3–1.6% Fe_2O_3 (Kuzvart 1984).

The company currently offers ca. 35 various grades of ceramic clays, including: 11 grades of white-firing not-sintering refractory clays, 14 grades of well-sintering refractory clays with higher Fe_2O_3 content, and 10 grades of well-sintering stoneware clays. The production of white-firing ball clays (under 2% Fe_2O_3) in this area is probably under 100,000 tpy. White-firing grades are commonly non-sintering varieties, exhibiting water absorption after firing usually over 10%. Recently, more selective extraction of these deposits has been introduced, as well as mixing of varieties and continuous quality control. These activities have the aim to enlarge spectrum of customers, including Polish ones (King 2006; Galos 2010a).

Keramost Co. is the minor Czech producer of white-firing clays. It delivers some amounts of such clays (of Cretaceous age) from Brnik mine, located to the east of Prague, e.g. IBB grade with 22–30% Al_2O_3, 0.8–1.4% Fe_2O_3 and 1.3–1.7% TiO_2, containing ca. 60% of kaolinite and 30% of quartz. Other grades of ceramic clays produced in the Czech Republic show well sintering properties with high iron content, or they represent refractory clays containing commonly 1.5–3.0 % Fe_2O_3, so they can not be regarded as typical ball clays (Galos 2010a).

2.4. Other foreign sources of white-firing ball clays

The United Kingdom is the most traditional producer of ball clay in the world, with production dated back by over 300 years. Three large Tertiary basins with ball clays seams occur in SW England: Bovey in S part of Devon county, Petrockstowe in N part of Devon county, and Wareham in SE part of Dorset county (Murray 2007). Clays from Bovey basin are especially useful for sanitaryware production, while clays from the two other basins – for ceramic tiles manufacture. Production is carried on by two large corporations: Imerys – in Bovey and Wareham basins, WBB/Sibelco – in Petrockstowe and Bovey basins

(McCuistion, Wilson 2006). Production of ball clays of the highest quality is distinctly decreasing due to their high prices and competition of clays from other sources. However, it still exceeds 1 million tpy, and over 80% of production is exported (King 2006).

Minor, but important producers of ball clays in Europe are: France, Italy, Spain, Portugal and Turkey. Small production of such clayey raw materials is carried on e.g. in Austria, Croatia, Serbia, Bulgaria, Hungary and Slovakia (King 2006; Galos 2007a; Fiederling--Kapteinat 2008). However, from among the mentioned above countries, ball clays exports are reported only from France and Portugal to Italy and Spain (Fiederling-Kapteinat 2008).

Outside of Europe, the US are the main producer of white-firing ball clays. Their extraction is concentrated – for over 150 years – in Tennessee and Kentucky, with minor output in Mississippi, Texas, California i Maryland. The main producers are: Kentucky--Tennessee Clay Co., HC Spinks Clay Co., Old Hickory Clay Co. and United Clays Inc. Total production exceeds 1 million tpy, but they are used almost entirely on the Northern America market (McCuistion, Wilson 2006). In the Southern America, ball clays production is reported in Brazil, Argentina and Chile, while in Asia – mainly in the southern China, Malaysia, Thailand, Indonesia, Vietnam and India. Some ball clays production is also reported in Australia and the Republic of South Africa (King 2006; McCuistion, Wilson 2006).

3. Current and perspective supplies of white-firing ball clays for the Polish porcelain tiles industry

For years, the Polish ceramic tiles industry fulfilled its demand for clayey raw materials from domestic sources. Radical change of quality requirements, being a result of introduction of new production technologies (especially commencement of porcelain tiles manufacture), resulted in necessity of use of highly plastic, white-firing clays. Limited supply of such raw materials from domestic producers caused intensive development of imports – primarily from Ukraine and Germany (Table 6) – which started in the second half of the 1990s. These imports were continuously growing from under 30,000 t in 1998 to almost 440,000 t in 2005, with some stabilization in the next three years and drop to less than 300,000 t in 2009 (Table 6). It is estimated, that over 75% of imported white-firing kaolinite clays find use in the ceramic tiles industry, ca. 15% – in ceramic sanitaryware industry, while ca. 10% – in the refractory industry (Minerals Yearbook... 2010). As a result, over 80% of domestic demand for white-firing kaolinite clays is currently met by imports and there is no perspective to change this situation. Key suppliers are Ukraine and Germany, smaller amounts come from the Czech Republic and the UK, marginal from the US, Spain and a few other countries (Table 6). Due to the fact that raw materials for ceramic tiles manufacture should be relatively cheap, importance of more distant suppliers probably will still be negligible. Ukraine, Germany (mainly Saxony) and maybe the Czech Republic will remain the main sources of ball clays for the Polish ceramic tiles industry.

Increasing imports of ceramic clays from Ukraine resulted in decreasing unit values of such imports until 2005, when Ukrainian producers started to increase – step by step – prices of clays sold on the Polish market (Table 7). On the other side, prices of some German and – especially – English clays were visibly reduced, though they were still two-three times more expensive than Ukrainian grades. Nevertheless, this disproportion will be probably continuously diminishing in the coming years.

The ideal white-firing ball clays for porcelain tiles production should represent the following parameters:

1. Raw clay:
   — high plasticity with bending strength after drying min. 3 MPa;
   — BET specific surface area 20–50 m^2/g;
   — very good rheological properties;

TABLE 6

Imports of ceramic clays to Poland [kt]

TABELA 6

Import iłów ceramicznych do Polski [tys. t]

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total imports	46.5	77.6	118.1	242.6	269.4	347.9	349.4	439.0	376.9	413.3	430.5	293.5
Ukraine	21.8	46.1	88.7	186.2	201.6	270.0	250.4	337.9	281.7	317.1	306.9	209.3
Germany	15.1	20.9	22.2	48.3	58.3	66.4	87.1	85.4	78.9	76.7	103.0	64.0
UK	1.6	3.2	4.4	5.6	5.8	6.0	6.7	7.5	8.5	8.3	7.3	5.0
Czech Rep.	6.1	5.7	2.0	1.7	2.6	1.8	3.2	4.3	6.4	5.3	5.8	7.4
Others	1.9	1.7	0.8	0.8	1.1	3.7	2.0	3.9	1.4	5.9	7.5	7.8

Source: Galos 2007b; Minerals Yearbook... 2010

TABLE 7

Average unit values of ceramic clays imports to Poland* [PLN/t]

TABELA 7

Średnie wartości jednostkowe importu iłów ceramicznych do Polski [PLN/t]

Country	2000	2002	2004	2006	2008	2009
Ukraine	129.4	116.2	94.9	98.2	124.9	142.6
Germany	353.5	304.4	332.2	254.4	307.2	420.9
UK	792.3	555.6	507.1	347.9	390.7	387.3
Czech Rep.	292.5	352.4	450.1	220.7	315.8	211.5

* On terms franco Polish border.

Source: Galos 2007b; Minerals Yearbook... 2010

2. Clay after firing at 1200°C:
   - high whiteness after firing – min. 70% (sometimes even over 80%), what is associated with low content of coloring oxides – commonly under 2.5% Fe_2O_3 + TiO_2;
   - low water absorption after firing – under 6% (preferably under 2%);
   - bending strength after firing min. 25 MPa.

Moreover, stability of quality parameters, assured punctuality of supplies, as well as attractive price are also necessary (Galos 2010a).

No one of domestic clays fulfills all these conditions. It is hard to achieve both high whiteness and high plasticity. Polish white-firing clays (e.g. Janina, Czerwona Woda, TC1/WB) have good whiteness, but their bending strength after drying commonly do not exceed 2 MPa. Light-grey varieties of Żarnów and Zapniów clays exhibit better plasticity, but water absorption after firing is commonly exceeding 6% (except of Zapniów G3S grade), while content of coloring oxides is distinctly higher than 2%. Jaroszów clays have good plasticity, low water absorption after firing, but higher coloring oxides content – above 3%.

It is expected that – due to deficiency of adequate domestic sources – over 80% of white-firing ball clays for the Polish ceramic industry will still originate from imports, coming from neighboring countries, as – except of quality – price of such clay at the gate of customer (loco price + transport cost) will remain the decisive factor. So, it is hard to expect significant imports from such important regions of ball clays production as: Devon and Dorset county in southern England, Armorican and Aquitaine basins in France, or some Portuguese, Italian, Spanish and US mines. Ukraine, Germany and the Czech Republic will remain the main sources of white-firing ball clays in Poland, with marginal importance of supplies from the UK and – maybe – France and Spain (Galos 2010a).

Regarding quality, some varieties of plastic clays from Donetsk region (Ukraine) and Westerwald region (Germany) are the most interesting. Ball clays from Donetsk region show very high bending strength after drying, very low water absorption after firing (related primarily to presence of significant amounts of illite and illite/smectite mixed-layered mineral), as well as low iron and titanium content and – as a consequence – high whiteness after firing (ca. 80%). Still competitive price of these clays on Polish market, in spite of long distance to Polish border (ca. 1000 km), is their additional advantage. However, stability of quality parameters and punctuality of supplies are still sometimes problematic. Nevertheless, Ukrainian deposits will probably remain the most important source of white-firing ball clays for the Polish ceramic industry. After improvement of technology and logistics, other Ukrainian suppliers – Oreadministration of Druzhkovka, Chasov-Yar Refractory Works or Donkerampromsyryo – can also develop their deliveries to Poland.

Clays from Westerwald region in Germany have high bending strength after drying and very low water absorption after firing. The content of coloring oxides is very variable: 1.0–1.4% TiO_2 and commonly 0.9–2.5% Fe_2O_3, but sometimes even up to 8% Fe_2O_3. White-firing varieties are commonly expensive. Moreover, costs of transportation to Opoczno region (over 1000 km) are very high.

White-firing ball clays from Saxony and western part of the Czech Republic have different quality characteristics. They – in general – demonstrate higher whiteness after firing, being a result of higher kaolinite content. On the contrary, water absorption after firing commonly exceeds 5%, sometimes even 10%. Clays from Kamenz-Wiesa in Saxony have higher bending strength after drying (even up to 3 MPa), while for vildštejn clays from Cheb area in the Czech Republic value of this parameter varies between 1.3–2.2 MPa (Galos 2010a).

Conclusions

Domestic sources of raw materials for white-firing ball clays production are very scarce. They are limited to Upper Cretaceous sediments in Bolesławiec basin. However, white-firing clayey raw materials obtained there by washing of sandy-clayey output do not possess all features of optimal ball clays for porcelain tiles production. Their plasticity and sinterability is too weak. Other domestic sources of light-firing clays – Opoczno clays – exhibit moderate plasticity, sinterability, and whiteness after firing, while Jaroszów clays – good plasticity and sinterability, but too low whiteness after firing. All these raw materials can still play a role of supplementary clayey raw materials in the production of porcelain tiles.

Lack of suitable domestic clays leads to conclusion that possible further development of demand for white-firing ball clays for porcelain tiles production in Poland, will still be met mostly by imports. Two main directions of these imports – Donetsk region in Ukraine, and Saxony region in Germany – are expected to be maintained. Supplementary imports can originate from Westerwald region in Germany, Cheb region in the Czech Republic, and – exceptionally – from English, French or Portuguese producers.

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PLASTYCZNE IŁY BIAŁO WYPALAJĄCE SIĘ DO PRODUKCJI PŁYTEK GRESOWYCH W POLSCE

Słowa kluczowe

Iły biało wypalające się, płytki gresowe, złoża iłów, import iłów

Streszczenie

Plastyczne iły biało- lub jasno-wypalające się są jednymi z podstawowych surowców do produkcji licznych wyrobów ceramicznych. Znaczący rozwój polskiego przemysłu ceramicznego, a w szczególności produkcji płytek gresowych, nie byłby możliwy bez zapewnienia dostaw odpowiedniej jakości surowców ilastych. W przypadku produkcji płytek gresowych, kaoliny i iły biało wypalające się są najważniejszymi składnikami ilastymi. W ostatnich dziesięciu latach, równolegle do szybkiego wzrostu produkcji tych płytek w Polsce, notowany był intensywny rozwój zapotrzebowania na plastyczne iły biało wypalające się. Nastąpiły także istotne zmiany w rodzaju stosowanych przez tą branżę iłów biało wypalających się. Wobec ograniczonych źródeł takich iłów w Polsce, ich krajowi producenci zaspokajają jedynie niewielką część zapotrzebowania, a ponad 80% użytkowanych iłów biało wypalających się pochodzi z importu.

Krajowe zasoby kopalin odpowiednich do produkcji surowców ilastych biało wypalających się są bardzo ograniczone. Występują one praktycznie wyłącznie w górnokredowych utworach piaszczysto-ilastych w niecce bolesławieckiej. Uzyskiwane tam – w wyniku szlamowania kopaliny piaszczysto-ilastej – surowce ilaste biało wypalające się nie posiadają wszystkich cech optymalnego iłu biało wypalającego się do produkcji płytek gresowych, szczególnie w zakresie plastyczności i spiekalności. Inne krajowe surowce ilaste jasno wypalające się – iły opoczyńskie – wykazują przeciętną plastyczność i spiekalność, a także niezbyt wysoką białość po wypaleniu. Jeszcze inna odmiana iłów jasno wypalających się – iły jaroszowskie – są plastyczne i dobrze się spiekają, ale wykazują zbyt niską białość po wypaleniu. Wszystkie wymienione surowce ilaste mogą zatem grać rolę jedynie uzupełniającego surowca ilastego do produkcji płytek gresowych.

Brak odpowiednich krajowych iłów powoduje, że dalszy oczekiwany rozwój zapotrzebowania na plastyczne iły biało wypalające się ze strony polskiego przemysłu płytek gresowych będzie musiał być zaspokojony głównie ich importem. Dwa główne obecnie kierunki tego importu – z regionu donieckiego na Ukrainie oraz z Saksonii w Niemczech – będą zapewne utrzymane, a znaczenie dostaw iłów donieckich wciąż będzie kluczowe. Uzupełniający import plastycznych iłów biało wypalających się może pochodzić z regionu Westerwald w zachodnich Niemczech, z regionu Chebu w zachodnich Czechach oraz – w wyjątkowych przypadkach – od producentów angielskich, francuskich i portugalskich.

BALL CLAYS FOR THE PRODUCTION OF PORCELAIN TILES IN POLAND

Key words

Ball clays, porcelain tiles, clay deposits, clays imports

Abstract

Ball clays (plastic white- or light-firing clays) are one of the basic mineral commodities for numerous ceramic products manufacture. Significant development of some sectors of the Polish ceramic industry, especially of

porcelain tile production, would not be possible without assurance of deliveries of appropriate clayey raw materials. For porcelain tiles, kaolin and ball clays are the most important clayey components. In the last ten years, intense development of demand for such clays for porcelain tiles production was reported in Poland. There were also significant changes in the type of ball clays applied by this industry. Due to limited sources of such clays in Poland, their domestic producers satisfy only a small part of industry's needs, while over 80% of demand is met by imports.

Domestic sources of raw materials for white-firing ball clays production are very scarce. They are limited to Upper Cretaceous sediments in Bolesławiec basin. However, white-firing clayey raw materials obtained there by washing of sandy-clayey output do not exhibit all features of optimal ball clays for porcelain tiles production, because their plasticity and sinterability is too weak. Other domestic sources of light-firing clays – Opoczno clays – show moderate plasticity, sinterability, and whiteness after firing, while Jaroszów clays – good plasticity and sinterability, but too low whiteness after firing. All these raw materials can only play a role of supplementary clayey raw materials in the production of porcelain tiles.

Lack of suitable domestic clays leads to conclusion that possible further development of demand for white-firing ball clays for porcelain tiles production in Poland, will still be met mostly by imports. Two main directions of these imports – Donetsk region in Ukraine, and Saxony region in Germany – are expected to be maintained, with crucial importance of Donetsk ball clays. Supplementary imports can originate from Westerwald region in Germany, Cheb region in the Czech Republic, and – exceptionally – from English, French or Portuguese producers.