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Sources of white- and light-firing ball clays for the production of *gres porcellanato* tiles in Poland

Key words

Gres porcellanato, ceramic tiles, ball clays, raw materials imports

Abstract

The paper reviews current and future demand for raw materials for *gres porcellanato* tiles production in Poland. Among the main raw materials necessary for their production, shortages of domestic supply of white- and light-firing ball clays occur. The paper presents domestic sources of white- and light-firing clays, as well as the quality of these raw materials. In detail, the analysis of foreign sources of white-firing ball clays for the Polish ceramic industry, especially for *gres porcellanato* tiles production, has been carried out. Ukrainian, German and Czech producers of ball clays are presented, together with quality characteristics of raw materials delivered by them. Finally, perspectives of future supplies of white- and light-firing ball clays to Polish *gres porcellanato* tiles industry (both domestic and imported) are discussed.

Introduction

Polish ceramic industry belongs to the most dynamically developing industries in Poland in recent years. It is especially well reported in the case of ceramic tiles produc-

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tion. The production of ceramic tiles in Poland has risen six times since 1990 up to ca. 70 million m^2 in 2003, following continuous growth of domestic demand for this type of ceramic products. Manufacture of *gres porcellanato* tiles, introduced in the late 1990s, was especially quickly developed. Capacities of their production achieved the level of ca. 35 million m^2py in 2003 (2 million m^2py in 1998), while production — ca. 25 million m^2 in the same year. Three quarters of this production is concentrated in central Poland, in the Tomaszów Mazowiecki-Opoczno-Końskie region, where over dozen ceramic tiles plants are located, including eight plants of two leading producers: "Opoczno" S.A. and "Paradyż" Group (Lewicka, Galos 2004).

Quick development of *gres porcellanato* tiles production in Poland should be correlated with adequate supplies of raw materials which are necessary for their production. Regarding main components of raw materials input, domestic supplies satisfy all or majority of needs. White- and light-firing clays are the only exception. Deficit of their domestic production results in continuously increasing imports of such raw materials, especially from some neighboring countries.

1. Demand of domestic *gres porcellanato* tiles industry for raw materials

The basic raw materials for ceramic tiles production are: clayey raw materials (kaolin, ball clays[1]), feldspar raw materials (feldspar, feldspar-quartz and nepheline syenite raw materials), and pure quartz sand. Intensive increase of ceramic tiles production in Poland resulted — among others — also in growth of demand for raw materials necessary for their production. Moreover, introduction of new technologies, e.g. development of *gres porcellanato* tiles, were the reasons of improvement of quality requirements regarding raw materials for their production. Increase of *gres porcellanato* tiles production was parallel with growth of demand for raw materials having low content of colouring oxides (Fe_2O_3, TiO_2). i.e. washed kaolin and white firing ball clays, as well as feldspar and quartz raw materials of adequate quality.

Despite of high quality of manufactured *gres porcellanato* tiles, their producers — due to economic reasons — tend to use relatively cheap raw materials, possessing stable quality parameters (Galos et al. 2001). The following raw materials are commonly used as the main components for preparation of ceramic bodies for *gres porcellanato* tiles production (Manfredini 2000; Partyka, Łukasik, 2002):

— white- and light-firing kaolinite or kaolinite-illite plastic clays, i.e. ball clays (25—30%),
— washed kaolin (15—20%),
— feldspar or feldspar-quartz raw materials (40—50%), and

[1] Ball clays — this term refers to fine-grained, white- or light-firing, highly plastic clay of sedimentary origin, consisting mainly of kaolinite with minor amount of quartz, illite and other minerals, possessing high bending strength.

— pure quartz sand (0—10%).

It is estimated, that current consumption of these basic raw materials for *gres porcellanato* tiles production in Poland amounts to ca. 500,000—600,000 tpy, including 150,000—180,000 tpy of ball clays, 75,000—90,000 tpy of washed kaolin, 225,000——270,000 tpy of feldspar-quartz raw materials, and 50,000—60,000 tpy of quartz sand. From among them, the following raw materials come from domestic mines:

— all quartz sand — primarily from sand mines near Tomaszów Mazowiecki,
— almost all washed kaolin — mainly from "Surmin-Kaolin" Co. as well as from "Biała Góra" Ltd. and "Grudzeń-Las" Ltd. (by-product of glass sand washing),
— over 70% of feldspar-quartz raw materials with low content of colouring oxides, primarily from Strzeblowskie Mineral Mines Ltd.,
— 20—30% of white- and light-firing plastic clays — from Żarnów, Zapniów and Jaroszów mines as well as from washing plants of "Surmin-Kaolin" Co. and "Ekoceramika" Ltd. (see below).

A few percent of washed kaolin for *gres porcellanato* tiles production is imported (Ukraine, the Czech Republic, Germany). Up to 30% of feldspar-quartz raw materials comes from Czech producers (Halamky, Krasno, recently also mines in Hrušovany region near Brno), and — since 2002 — also from Turkey. However, probably as much as over 70% of demand for white- and light-firing plastic clays is met by imports, as their domestic sources are very limited. The main sources of these imports are Ukraine and Germany, with minor quantities coming from the Czech Republic, the United Kingdom and others.

2. Domestic sources of white- and light-firing clays

Domestic sources of white-firing clays, containing up to 1,5% Fe_2O_3+TiO_2, are very limited. The only suppliers of such clays are: "Ekoceramika" Ltd. and "Surmin-Kaolin" S.A., both located in Nowogrodziec. Total domestic supplies of these clays were under 20,000 tpy in recent years.

For years, "Ekoceramika" Ltd. has been delivering small amounts (a few thousand tpy) of white-firing clays on the basis of the output from Bolko mine, as well as Magnat clay obtained from processing of Zebrzydowa clay. Since 2003, a consecutive product, i.e. Janina clay — obtained in new processing plant in Suszki — has been offered by this company. In 2003, its production amounted 11,800 t, but in the coming years it can rise even up to 100,000 tpy (Lewicka, Galos 2004). Janina clay has low content of colouring oxides (under 1.3% Fe_2O_3+TiO_2), good bending strength and moderate water absorption after firing (Tab. 1).

White-firing clays are irregularly extracted in Turów lignite mine. They occur in inter-coal complex B. Since 1993, some amounts of this material have been processed by "Surmin-Kaolin" together with its own kaolin. Small quantities (2,000—4,000 tpy) of white-firing granulate are obtained. These are mainly represented by TC1/W and TC1/WB

TABLE 1

Quality parameters of the main white- and light-firing ball clays in Poland

TABELA 1

Parametry jakościowe ważniejszych gatunków iłów plastycznych biało i jasno wypalających się w Polsce

Parameter	White-firing clays		Light-firing clays				
	Surmin-Kaolin TC1/WB	Ekoceramika Janina JB1W	Ekoceramika Zebrzydowa Standard II	Glinkop Żarnów light grey	Jopex Zapniów G3S	Jaro Jaroszów G-1/C	Jaro Jaroszów G-3/C
Chemical composition (wt.%):							
SiO_2	56.4	58.2	60—64	64.3	56.58	54—56	59—63
Al_2O_3	29.9	29.35	21—25	20.3	28.45	37—39	29—35
Fe_2O_3	0.74	0.61	2.19	1.3	1.26	1.8—2.5	1.8—2.5
TiO_2	0.81	0.65	1.41	1.06	1.30	<1.0	<1.7
CaO	0.08	0.06	0.20	0.28	0.00	<0.4	<0.5
MgO	0.20	0.40	0.50	0.62	0.93	<0.6	<0.6
K_2O	0.81	1.14	1.27	1.65	1.56	1.5—2.1	1.6—2.2
Na_2O	0.06	0.01	0.04	1.07	0.10		
LOI	10.7	9.7	5.5—9.5	9.72	9.74	<13.0	<13.0
Mineralogical composition [%]:							
Kaolinite	65	60	35		14	72	70
Illite	13	20	29		62	23	24
Quartz	20	19	34		24	3	13
Others	2	1	2		<1	2	3
Sieve residue 63 μm [%]	3.9	2—6	<17	10.1		<2.0	<8.0
Ceramic properties:							
Bending strength [MPa]	2.0	3.0	3.4—3.8	2.64	>2.5	2.5	
Drying shrinkage [%]	2.5 (110°C)	3—5	3—5	5.5	5.3	5.8	
Firing shrinkage [%]	7.3 (1230°C)	5—9 (1250°C)	6—10 (1200°C)	11.6 (1250°C)	8.8	12.1 (1200°C)	
Water absorption after firing [%]	8 (1230°C)	6—10 (1250°C)	8—12 (1200°C)	6.0 (1250°C)		1.9 (1200°C)	
Whiteness [%] or color after firing	77 (1230°C)	75 (1250°C)		light grey		light grey	light grey

Source: Producers' catalogues, Wyszomirski 1999, Wyszomirski et al. 2000

grades, characterized by high whiteness, moderate bending strength and water absorption after firing (Tab. 1). Moreover, the purest variety of Turów clay extracted in intercoal complex B can be used without processing for the production of *gres porcellanato* tiles (Wyszomirski et al. 2003). For this purpose some Lower Silesian non-exploited — up till now — kaolin deposits with large resouces (e.g. Kalno deposit with reserves of 19.9 million t) should be taken into consideration.

In contrast to white-firing clays, there is a wealth of deposits of well sintering (stoneware) plastic clays in Poland. Some of them are interesting sources of light-firing clays (up to 3.0% Fe_2O_3+TiO_2). The most important examples are: 1. kaolinite-illite well sintering clays of Jurassic age in Opoczno region (Żarnów, Zapniów), 2. kaolinite well sintering clays of Miocene age from Jaroszów deposit, 3. kaolinite-illite well sintering clays of Miopliocene age from Zebrzydowa deposit (Tab. 1).

In the both deposits in Opoczno region — Żarnów and Zapniów — two varieties of well sintering clays occur — light grey and dark grey. The light grey variety is characterized by moderate Fe_2O_3+TiO_2 content (up to 2.6%) and good plasticity, being used for *gres porcellanato* production (Wyszomirski 1999). Production of Żarnów clay commonly amounts to 30,000—40,000 tpy, while output of Zapniów clay — 25,000—35,000 tpy (Lewicka, Galos 2004). Jaroszów clays were used mainly for refractories until late 1990s. In the last few years, their use in ceramic tiles is still increasing, up to 40,000 tpy (Minerals Yearbook..., 2003). They are characterized by high plasticity and bending strength, what is a result of presence of disordered variety of kaolinite (kaolinite D). The best grades show moderate Fe_2O_3+TiO_2 content (2.7—3.5%). Zebrzydowa clay is traditionally used for the production of sintered ceramic tiles. It possesses high plasticity and elevated content of colouring oxides (usually over 3%) (Tab. 1).

3. Foreign sources of white-firing ball clays for Polish ceramic tiles industry

Due to increasing demand of domestic tiles industry for white-firing ball clays and very limited possibilities of their domestic production, imports of such raw materials to Poland are continuously increasing in recent years. The information on the quantity of these imports is not precise, as they are classified under various items of Combined Nomenclature, used for external trade statistics (Tab. 2). However, it is estimated, that total imports of white-firing ball clays to Poland have risen from ca. 30,000 t in 1998 to ca. 90,000 t in 2000 and over 300,000 t in 2003 (excluding kaolinite clays imported for domestic refractory industry). Minimum three quarters of these imported clays find application in the ceramic tiles industry, especially for *gres porcellanato* manufacture. White-firing ball clays are imported to Poland primarily from Ukraine (270,000 t in 2003), Germany (66,400 t in 2003), with minor quantities coming from the United Kingdom, the Czech Republic and others (Tab. 2).

TABLE 2

Ceramic clays imports to Poland[1] ['000 t]

TABELA 2

Import iłów ceramicznych do Polski[1] [tys. t]

	1998	1999	2000	2001	2002	2003
Total imports	46.5	77.6	118.1	242.6	269.4	347.9
Ukraine[2]	21.8	46.1	88.7	186.2	201.6	270.0
Germany[3]	15.1	20.9	22.2	48.3	58.3	66.4
United Kingdom[4]	1.6	3.2	4.4	5.6	5.8	6.0
Czech Republic[4]	6.1	5.7	2.0	1.7	2.6	1.8
Others	2.0	1.7	0.8	0.8	1.1	3.7

[1] Total imports reported in CN items: 250700800 "Kaolinite clays (except of kaolin)", 250830000 "Refractory clays", 250840000 "Other ceramic clays".

[2] Imports reported mainly in CN item 250830000 "Refractory clays", some amounts are consumed by the refractory industry (up to 40,000 tpy).

[3] Imports reported mainly in CN item 250840000 "Other ceramic clays".

[4] Imports reported mainly in CN item 250700800 "Kaolinite clays (except of kaolin)".

Source: The Central Statistical Office

Deposits of ceramic clays in Ukraine belong to the largest in the world. They are classified as deposits of refractory and ball clays. The majority of deposits is concentrated in Donetsk region (eastern Ukraine). Regarding plasticity, bending strength, whiteness and organic matter content, they belong to the most appreciated grades on the European market, though stability of quality parameters of commercial grades is often problematic (Stentiford 2003). On the other hand, these unique Tertiary deposits have unfavourable mining conditions: thick overburden — even up to 40—45 m, and relatively thin thickness of clay bed — 2—4 m (Winkler 1996). Total reserves of 20 recognized refractory clays deposits amount to over 500 million t, while reserves of over 20 ball clays deposits — ca. 100 million t. Currently, ca. 20 deposits of kaolinite clays, possessing ca. 360 million t of reserves, are extracted (Geoinform). Total production achieves level of ca. 2.0 million tpy, but 80% of production is delivered by two main producers — "Vesco" JSC and "Donbas Clays" JSC (Tab. 3).

"Vesco" JSC is a joint stock company established in 1994 by "Veselovsky" Combine and Italian company "Mineraria Sassolese" srl. The company extracts Veselovskoye and Novoandreyevskoye deposits near Druzhkovka in Donetsk region. Reserves of these deposits approach 60 million t. Mining output is carried on selectively in five open pits. Clays extracted in various open pits are then appropriately blended to obtain various commercial grades. Annual production amounts to ca. 1.0 million t, while capacity of commercial grades stocks — 600,000 t. Clays from "Vesco" are transported by sea to Italy, Spain, Turkey,

TABLE 3

The main producers of white-firing ball clays in Ukraine

TABELA 3

Główni producenci biało wypalających się iłów plastycznych na Ukrainie

Company	Deposits	Region	Main commercial grades
Vesco JSC	Novoandreyevskoye, Veselovskoye	Donetsk	Vesco extra, prima, granitic, ceramic ($0.9—1.2\%$ Fe_2O_3, $23—34\%$ Al_2O_3)
Donbas Clays JSC	Yuzhnooktabrskoye, Kutscherov-Yarskoye, Novostepanovskoye, Novoschweitsarskoye	Donetsk	DBY, DBM ($0.8—1.5\%$ Fe_2O_3, $27—29\%$ Al_2O_3)
Keramet JSC (Druzhkovskoye RU)	Novorayskoye, Oktabrskoye, Zapadodonskoye	Donetsk	DN-0, DN-1, DN-2, DN-3 ($1.0—1.1\%$ Fe_2O_3, $30—33\%$ Al_2O_3) OKT-1, OKT-2, OKT-4 ($1.3—1.4\%$ Fe_2O_3, $24—30\%$ Al_2O_3) ZD-1, ZD-2 ($1.4—2.0\%$ Fe_2O_3, $27—29\%$ Al_2O_3)
Czasov-yarsky OK JSC	Czasov-Yarskoye	Donetsk	CH-2, CH-3 ($1.0—1.6\%$ Fe_2O_3, $27—31\%$ Al_2O_3)
Donkerampromsyryo	Toretskoye	Donieck	
Mineral JSC	Pology	Zaporozhe	PLG-1, PLG-2, PLG-3 ($1.6—2.0\%$ Fe_2O_3, $30—37\%$ Al_2O_3)

Greece and United Arab Emirates, while by rail to Russia, Poland, Belarus, Slovakia and Hungary. Company offers six various grades. Three of them — *Vesco extra*, *Vesco prima* and *Vesco granitic* — are suitable for *gres porcellanato* tiles production (Tab. 4).

"Donbas Clays" JSC, established in 1995 by Ukrainian combine "YUG" and British company "WBB Minerals", is the second leading producer of white-firing ball clays in Ukraine. Company extracts four deposits near Slavyansk in Donetsk region, possessing reserves of ca. 11 million t (Tab. 3). In Mertsalovo processing plant, three main grades of plastic clays are obtained: *DBX* (the highest quality), as well as *DBY* and *DBM* (Tab. 4). Annual production currently amounts to ca. 650,000 t, while capacity of commercial grades stocks — 100,000 t. Clays from this company are traded by WBB in over 20 countries, mostly in Europe.

"Druzhkovskoye Rudoupravleniye" (DR), being a part of Ukrainian "Keramet" JSC company, is the another important supplier of white-firing ball clays (Tab. 3). It currently extracts three deposits near Druzhkovka, including Novorayskoye deposit possessing clays of the highest quality (e.g. *DN-0*, Tab. 4). The company delivers clays mainly for Ukrainian and Russian markets, though there are trials to sell them also to other European countries.

However, stability of quality parameters of clays produced by this company, especially in comparison with clays from "Vesco" and "Donbas Clays", is still the main problem. Other minor producers ("Czasov-yarsky" OK, "Mineral" JSC and others) offer lower quality clays.

Germany is the second important supplier of white-firing clays to Poland. Production of refractory and ball clays in Germany is very substantial and varies between 4.5—5.5 million tpy (Bundesrepublik Deutschland Rohstoffsituation 2002). Their production is traditionally

TABLE 4

Quality parameters of the main white-firing ball clays from Ukraine

TABELA 4

Parametry jakościowe ważniejszych ukraińskich gatunków iłów plastycznych biało wypalających się

Parameter	Vesco extra	Vesco granitic	Donbas Clays DBY	Donbas Clays DBM	Keramet DN-0
Chemical composition (wt.%):					
SiO_2	60.0	65.0	56—58	56—57	51.4
Al_2O_3	34.0	28.0	27—29	28—29	32.7
Fe_2O_3	0.9	1.0	0.8—1.0	1.0—2.0	1.0
TiO_2	1.6	1.5	1.5	1.1—1.4	0.7
CaO	0.5	0.5	0.4	0.4	0.8
MgO	0.6	0.6	0.6	0.6	0.7
K_2O	2.1	2.1	2.6—2.8	2.8—2.9	2.1
Na_2O	0.6	0.5	0.5—0.6	0.5	
LOI	<11	8.5	7.4—7.6	7.5—7.6	9.9
Mineralogical composition [%]:					
Kaolinite	55	40	55	55	
Illite	28	28	30	30	
Quartz	17	22	15	15	
Others	—	10	—	—	
Sieve residue 63 μm [%]	<0.8	<3.0	0.2	2	
Ceramic properties:					
Bending strength [MPa]	6.5	6.0	12	12	
Firing shrinkage [%]	13.4 (1200°C)	11.5 (1200°C)	6.5 (1220°C)	6.0 (1220°C)	
Water absorption after firing [%]	0.5 (1200°C)	2.5 (1200°C)	0.0 (1220°C)	0.0 (1220°C)	
Whiteness [%]	83.5 (1200°C)	78.5 (1200°C)	80 (1220°C)	70 (1220°C)	

concentrated in the Westerwald region, north of Koblenz (Rheinland), where a lot of varieties of plastic clays occur: from white-firing to dark-firing ones. These are primarily illite-kaolinite clays containing 15—45% of illite, 20—35% of kaolinite (disordered type: kaolinite D), 30—35% of quartz and small quantities of smectites. Meißen-Lausitz region in Saxony is the second important area of ball clays production in Germany. These are commonly kaolinite-illite clays containing 34—48% of kaolinite, 20—30% of illite and 20—40% of quartz. Kaolinite is represented mainly by well ordered variety — kaolinite Tc, so these clays possess — in comparison to Westerwald clays — lower bending strength, worse sintering properties, but higher whiteness (Wilson 1998).

"WBB Fuchs" (former Fuchs'sche Gruben), currently being a part of "WBB Minerals" concern, is the most important German producer of plastic clays (ca. 2.0 million tpy, i.e. 40% of their production in Germany). "Stephan Schmidt" group is the second most important producing group delivering such clays in Germany (ca. 1.6 million tpy, i.e. over 30%). Both capital groups have the most important mines of plastic clays in the Westerwald region, but they possess also some mines in Saxony near German/Polish border. "WBB Fuchs" is the

TABLE 5

Quality parameters of the typical white-firing ball clays from WBB Fuchs

TABELA 5

Parametry jakościowe typowych gatunków iłów plastycznych biało wypalających się firmy WBB Fuchs

Parameter	FT-A	FT-S	FT-BW	L204/5	SL-J
Chemical composition (wt.%):					
SiO_2	62.7	65.4	66.4	55.1	68.5
Al_2O_3	24.9	23.0	22.0	30.3	20.3
Fe_2O_3	1.0	1.0	0.8	1.1	0.4
TiO_2	1.4	1.4	1.3	1.3	0.2
CaO	0.2	0.2	0.2	0.2	0.1
MgO	0.1	0.1	0.3	0.3	0.1
K_2O	2.2	2.2	1.9	1.9	5.6
Na_2O	0.2	0.1	0.1	0.2	0.1
LOI	7.3	6.6	6.4	9.6	4.7
Sieve residue 63 μm [%]	1.7	2.0	2.5	1.0	58.9
Ceramic properties:					
Bending strength [MPa]	6.4	5.7	4.9	8.2	1.9
Firing shrinkage [%]	11.0 (1220°C)	10.5 (1220°C)	9.0 (1220°C)	12.0 (1220°C)	13.0 (1220°C)
Water absorption after firing [%]	0.0 (1220°C)	0.0 (1220°C)	0.5 (1220°C)	0.5 (1220°C)	13.0 (1220°C)

TABLE 6

Quality parameters of the selected white-firing ball clays from Stephan Schmidt group

TABELA 6

Parametry jakościowe wybranych gatunków iłów plastycznych biało wypalających się firmy Stephan Schmidt

Parameter	Stephan Schmidt Meißen 12128	Stephan Schmidt Meißen 12090	Stephan Schmidt Meißen 14329	Stephan Schmidt KG 1303	Mittelhessische Tonbergbau GmbH T 20	Marx Bergbau GmbH LRV 18
Chemical composition (wt.%):						
SiO_2	61.8	65.7	70.2	68.3	70.2	71.0
Al_2O_3	25.6	23.9	23.9	19.8	18.8	17.7
Fe_2O_3	1.2	1.0	1.3	1.0	1.4	0.9
TiO_2	1.5	1.0	1.0	1.6	1.2	1.4
CaO	0.3	0.2	0.1	0.2	0.2	0.2
MgO	0.3	0.3	0.6	0.4	0.4	0.3
K_2O	1.5	2.1	2.7	1.9	2.1	1.8
Na_2O	0.2	0.2	0.2	0.2	0.2	0.2
LOI	8.4	6.0	6.0	5.8	4.5	5.2
Mineralogical composition [%]:						
Kaolinite	45	35	34	35	20	20
Illite[1]	30	30	26	15	40	40
Quartz	25	35	40	45	35	35
Others	—	—	—	5	5	5
Sieve residue 63 μm [%]	0.3	0.8	9.6	4.0	4.3	8.0
Ceramic properties:						
Bending strength [MPa]	3.6	2.8	2.0	4.5	5.8	4.3
Firing shrinkage [%]	9.6 (1200°C)	4.8 (1200°C)	12.6 (1230°C)	8.1 (1250°C)	8.4 (1250°C)	8.2 (1250°C)
Water absorption after firing [%]	5.3 (1200°C)	6.7 (1200°C)	0.1 (1230°C)	0.7 (1250°C)	1.6 (1250°C)	3.1 (1250°C)
Whiteness [%]	84 (1170°C)	84 (1170°C)	84 (1170°C)	83 (1150°C)	84 (1150°C)	85 (1150°C)

[1] Together with montmorillonite

owner of almost 20 mines in the Westerwald and Pfalz regions in Rheinland (Willis 2002), delivering the majority of plastic clays from these areas. Company has also small daughter company "Kaolin und Tonwerke Seilitz-Löthain" in Käbschütz (Saxony), which produce ca. 100,000 tpy of white-firing ball clay, e.g. SL-J grade (Pieczarowski 2000).

"Stephan Schmidt" group consists of five companies with over 15 mines in the Westerwald region and Gießen region (Hessen). These are: "Stephan Schmidt" KG, "TGA Tonbergbau Grube Anton", "Müllenbach & Thewald" GmbH, "Mittelhessische Tonbergbau" GmbH and "Marx Bergbau" GmbH. In Saxony, the group is the owner of "Stephan Schmidt Meißen" company, which has Kamenz-Wiesa clay open-pits with capacities of ca. 250,000 tpy (Plüschke, Kleinsorge 2002). Plants of "Stephan Schmidt" group offer a wide range of various white- and light-firing clays. Quality parameters of selected grades are presented in Table 6.

The Czech Republic is one of the most important and traditional producers of ball and refractory clays in Europe. However, their production of such clays has decreased from the level of almost 2.0 million tpy to only ca. 600,000 tpy in recent years (Kavina 2003). White- and light-firing clays probably are less than 1/4 of all extracted clays. Ceramic and refractory clays are currently mined in the Czech Republic in 26 deposits, but white- and light-firing clays occur only in a few of them. The most important are so-called vildštejn clays from Cheb and Sokolov region. They are currently extracted in Cheb area in Nova Ves and Karel mines by "Kemat Skalna" Ltd., a part of Lasselsberger group (Marciniak 2003). A few varieties of clays occur there: 1. white-firing kaolinite-vermiculite coarse-grained clays (rich in coal) containing 1.1—1.5% Fe_2O_3 (e.g. IB, BD, NF grade, Table 7), 2. well sintering kaolinite--illite grey 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), and 4. refractory kaolinite clays possessing poor sintering properties, which contain 1.3—1.6% Fe_2O_3. The production of white-firing clays in this region amounts to over 100,000 tpy (Pieczarowski 2000, Wilson 1998).

"Keramost" Co. is the minor Czech producer of white-firing clays. It delivers some amounts of such clays from Brnik mine, e.g. IBB grade (Tab. 7). 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. Ca. 160,000—190,000 tpy of ceramic and refractory clays are exported from the Czech Republic (Kavina 2003), but export of ball clays is decreasing (down from 74,000 t in 1998 to 35,800 t in 2003). These clays are sold primarily to Germany, Slovakia and Austria, as well as to Poland to a lesser extent.

4. Prospects of white-firing ball clays supplies for the domestic production of ceramic tiles

Demand of the domestic ceramic tiles sector for white- and light-firing ball clays, used especially in *gres porcellanato* manufacture, is continuously increasing. In the coming years,

TABLE 7

Quality parameters of the selected white-firing ball clays from the Czech Republic

TABELA 7

Parametry jakościowe wybranych gatunków iłów plastycznych biało wypalających się z firm czeskich

Parameter	Kemat Skalna B3/S	Kemat Skalna BD	Kemat Skalna NF	Kemat Skalna CH	Kemat Skalna U	Keramost a.s. IBB
Chemical composition (wt.%):						
SiO_2	60.4	48.1	42.8	52.3	63.7	65—75
Al_2O_3	25.6	34.5	29.4	31.8	23.2	22—30
Fe_2O_3	1.7	1.4	1.6	1.3	1.8	0.8—1.4
TiO_2	1.0	0.9	0.6	0.8	1.2	1.3—1.7
CaO	0.2	0.2	0.4	0.1	0.1	0.2
MgO	0.3	0.3	0.2	0.3	0.4	0.2
K_2O	2.3	2.8	2.1	2.8	3.2	0.6
Na_2O	0.1	0.2	0.1	2.8	0.3	0.1
LOI	8.2	11.5	22.7	10.4	5.9	8—11
Mineralogical composition [%]:						
Kaolinite						60
Illite						—
Quartz						30
Others						10
Sieve residue 63 μm [%]	16.3	2.1	2.5	8.9	10.9	13—19
Ceramic properties:						
Bending strength [MPa]	2.6	1.8	1.3	1.5	1.6	1.5
Firing shrinkage [%]	7.4 (1250°C)	6.4 (1250°C)	14.6 (1250°C)	4.6 (1250°C)	6.7 (1250°C)	10 (1250°C)
Water absorption after firing [%]	3.4 (1250°C)	11.3 (1250°C)	14.5 (1250°C)	13.5 (1250°C)	5.4 (1250°C)	13 (1250°C)

further growth of this demand is expected, even by 30—50%. Unfortunately, share of domestic grades of such clays in total consumption will probably not exceed 20—30%, though development of Janina clay production is expected. It is a result of limited reserves of white-firing clays deposits, as well as of low or medium quality of domestic clays, in comparison to imported grades.

White-firing ball clays of highest quality for the production of *gres porcellanato* tiles should represent the following features:

1) appropriate quality parameters:
   a) low content of colouring oxides — less than 1% Fe_2O_3 and less than 1% TiO_2,
   b) high whiteness after firing — over 80%,
   c) high plasticity and dry bending strength — over 2 MPa,
   d) low water absorption after firing — less than 2%;
2) stability of quality parameters in particular deliveries;
3) assured punctuality of supplies at necessary level;
4) low or moderate price.

None of domestic clays fulfills all these conditions. It is hard to achieve both high whiteness and high plasticity. Polish white-firing clays (e.g. TC1/WB and Janina) are characterized by quite good whiteness, but their bending strength commonly do not exceed 2 MPa. Light-grey varieties of Żarnów, Zapniów and Zebrzydowa clays show better plasticity, but water absorption is still high, while content of colouring oxides is much higher than 2%. Jaroszów clays represent good plasticity, relatively low water absorption after firing, but higher colouring oxides content — above 3%.

It is expected that — due to deficiency of adequate domestic sources — the majority of white-firing ball clays for the Polish ceramic industry will originate from imports. These imports will probably come, as previously, from neighbouring countries, as — except of quality — price of such clay at the gate of customer (loco price and 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 Italian, Spanish and North American mines. Ukraine, Germany and the Czech Republic will remain the main sources of white-firing ball clays in Poland. However, various clays originating from these countries significantly differ in quality parameters.

Regarding quality, some varieties of plastic clays from Donetsk region (Ukraine) and Westerwald region (Germany) are the most interesting. Ball clays from Donetsk region represent very high bending strength, very low water absorption after firing, as well as low iron content and high whiteness (ca. 80%). 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 problematic (maybe except of Vesco and Donbas Clays, where Western European companies are shareholders). Nevertheless, Ukrainian deposits will probably remain the most important source of white-firing ball clays for Polish ceramic industry. After improvement of technology and

logistics other Ukrainian suppliers, like Keramet or Czasov-yarsky plant, can develop their deliveries to Poland.

Clays from Westerwald region in Germany have high bending strength and very low water absorption after firing. The content of colouring oxides is very variable: 1.0—1.4% TiO_2 and 0.9—2.5% Fe_2O_3, but sometimes the latter reaches even up to 8%. White-firing varieties are commonly expensive. Moreover, costs of transportation to Opoczno region in central Poland (over 1000 km), where the majority of tiles factories is located, are very high.

White-firing ball clays from Saxony and western part of the Czech Republic have different quality characteristics compared to Westerwald clays. They 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 are characterized by higher bending strength (even up to 3 MPa), while in the case of vildštejn clays from Cheb area in the Czech Republic it varies between 1,3—1,8 MPa.

The paper reveals that further development of demand for white-firing ball clays for *gres porcellanato* tiles production, will be mostly met by import. The majority of this import will come from Donetsk region in Ukraine as well as from some Saxonian producers in Germany. Supplementary import can be derived from Westerwald region in Germany, Cheb region in the Czech Republic, and — exceptionally — from English producers.

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KRZYSZTOF GALOS, PIOTR WYSZOMIRSKI

ŹRÓDŁA BIAŁO I JASNO WYPALAJĄCYCH SIĘ IŁÓW CERAMICZNYCH DO PRODUKCJI PŁYTEK *GRES PORCELLANATO* W POLSCE

Słowa kluczowe

Gres porcellanato, płytki ceramiczne, iły ceramiczne, import surowców

Streszczenie

Artykuł ocenia obecne i przyszłe zapotrzebowanie na surowce do produkcji płytek *gres porcellanato* w Polsce. Wśród głównych surowców niezbędnych do ich produkcji, znaczący deficyt krajowych źródeł występuje w przypadku iłów biało i jasno wypalających się. Artykuł przedstawia obecne krajowe źródła iłów tego typu, a także ich parametry jakościowe. Szczegółowo przeprowadzona została analiza zagranicznych źródeł iłów biało i jasno wypalających się do produkcji płytek *gres porcellanato*. Zaprezentowano producentów takich iłów z Ukrainy, Niemiec i Czech, dokonując charakterystyki jakościowej dostarczanych przez nich surowców. W końcowej części artykułu przedstawiono perspektywy przyszłych dostaw iłów biało i jasno wypalających się dla polskiego przemysłu płytek *gres porcellanato* zarówno ze źródeł krajowych, jak i zagranicznych.