MINERAL RESOURCES OF POLAND

POLISH GEOLOGICAL INSTITUTE
NATIONAL RESEARCH INSTITUTE
WARSAW 2012

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Calculations and computer works were done
in the Department of Mineral Resources and Mining Areas Information of PGI-NRI
with using the System of Management and Protection of Mineral Resources in Poland MIDAS

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11th of December 2012

Financed by National Fund
for Environmental Protection
and Water Management

ISBN 978-83-7863-092-0
ISBN (CD) 978-83-7863-093-7

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Cover: Longwall shearer. Hard coal deposit Brzeziny (*phot. by M. Szuflicki*)

Circulation: 225 (book) + 1,000 (CD) copies
Printed by: Drukarnia Braci Grodzickich S.J., ul. Geodetów 47a, 05-500 Piaseczno

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FOREWORD

It gives me great pleasure to present you with our latest edition of "Mineral Resources of Poland". I sincerely hope that this book will help English speaking readers to become more familiar with issues related to Polish mineral resources, especially as they are presented in brief form, yet including all important information.

The 2012 edition of "Mineral Resources of Poland" is the fourth published by the Polish Geological Institute – National Research Institute (PGI-NRI) and a continuation of those published in 1996, 2000 and 2005. As before, it presents the basic information on domestic mineral resources, their development and scale of production as of December 31st, 2011, and the main trends which have appeared in that sector during the last seven years. Nevertheless, some important changes have been introduced.

It should be noted that this is the first time when the edition of "Mineral Resources of Poland", similarly as its forerunner and precursor "The balance of mineral resources deposits in Poland", was not compiled at the order of the Ministry of the Environment but the PGI-NRI as the task of the Polish Geological Survey. A special attention should be paid to changes in the form in which information is provided, especially care taken to present data on mineral resources in accordance with requirements of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009). That approach makes it possible to get clear information given in units comparable with those used in Europe and elsewhere, possible even for readers unfamiliar with specific features of practice in mineral resources assessments in Poland. Moreover, this is the first edition which also presents resources of curative, thermal water and brines, treated as mineral resources in accordance with the Polish Geological and Mining Law.

It is also worth to note changes in arrangement, aimed at making the 2012 edition more easily readable. These changes made the data presentation similar to that from "The balance of mineral resources deposits in Poland" that is based on subdivision of mineral resources into groups with reference to usability of a given mineral raw material. The range of information here is identical as in "The balance of mineral resources deposits in Poland", being confined to discovered and explored deposits, for which geological documentations have been completed and approved. Therefore, you will not find here information on reserves of mineral raw materials such as shale gas, which are still the subject of wide and extensive exploration through the area of Poland. The information on perspective resources of these raw materials may be found in a "Perspective resources of raw materials in Poland" but I sincerely hope to be able to present results of assessments of shale gas resources of Poland in the next edition of this publication.

Following the current practice, along with the book we also provide electronic version on CD. Moreover, that version has been placed on the PGI-NRI website. I sincerely hope that this will facilitate access to information on mineral resources of Poland for the English speaking readers interested in Polish mineral resources as an important component of the nation's wealth.

Prof. Jerzy NAWROCKI

Director
The Polish Geological Institute –
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1. INTRODUCTION

The Polish Geological Institute – National Research Institute fulfils the state geological survey according to the art. 163 of the Geological and Mining Law. One of the tasks performed by the state geological survey is carrying out the national balance of mineral resources. The data on all of the mineral raw material deposits and resources base and on the output and developing possibilities are collected in the System of Management and Protection of Mineral Resources in Poland MIDAS. The MIDAS System is carried out by the Department of Mineral Resources and Mining Areas Information of PGI-NRI. It has been systematically updated since 1988 and collects information on more than 12,400 mineral raw materials deposits in Poland (as of 31.12.2011). There are two main data sources for the MIDAS System – geological documentations collected in the Central Geological Archive (covering basic information on a deposit such as location, deposit structure, hydrogeological conditions, raw material types and parameters, deposit resources) and forms prepared by concession holders and sent once a year to the PGI-NRI (containing information on the yearly output and resources changes in a deposit). The MIDAS System is a base for preparing by the Department of Mineral Resources and Mining Areas Information the publication "The balance of mineral resources deposits in Poland" (in Polish: *Bilans zasobów złóż kopalin w Polsce*). This publication has been issued annually since 1953, is being accepted by the Department of Geology and Geological Concessions (at the Ministry of the Environment) and is financed by the National Fund for Environmental Protection and Water Management.

"The balance of mineral resources deposits in Poland" is in extended form in two versions (Polish and English) placed on the PGI-NRI website http://geoportal.pgi.gov.pl/surowce.

One of the outcomes of carrying out the MIDAS System and issuing "The balance of mineral resources deposits in Poland" is the publication "Mineral Resources of Poland". There were three editions of this paper issued in the past – 1996, 2000 and 2005.

The present publication "Mineral Resources of Poland" (2012 edition) contains the data on more than 12,400 deposits in Poland. Data are presented in form of chapters within four raw materials groups – energy, metallic, chemical and rock raw materials and others. These groups are selected on the basis of the raw material usability as a mineral commodity. The data within the groups are presented according to the administrative or – for hard coal, crude oil and natural gas – regional configuration. There is also a set of maps presenting occurrence of mineral raw materials deposits in Poland.

In almost every chapter there is a table presenting th magnitude of mineral raw material resources and state of their identification and management (for the whole country). For most of the mineral raw materials there is a graph showing the resource base and the output of particular mineral raw material in a representative period of time. There are also chapters connected with: export and import of mineral raw materials; brines, curative and thermal water and the glossary, where all definitions of the terms used in the publication can be found. Definitions given in the glossary are based on the word "resources" which means the quantities assessed on the basis of geological data as distinct from the word "reserves" understood as the quantities foreseen to be exploited considering losses and depletion (Nieć, 2010).

The present paper contains also the chapter which is devoted to the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources (UNFC-2009) and to adapting this international scheme to the classification used in Poland.

2. ENERGY RAW MATERIALS

2.1. BROWN COAL

In Poland, brown coal deposits occur in younger geological formations, mainly the Neogene. Older brown coal occurrences are known in the Cretaceous and Jurassic. Their characteristics and properties were markedly influenced by the type of parent plant material and environment in which they originated. The coals form extensive seams or lenses a few meters to several dozen meters in thickness. Thickness of overburden is usually quite small which makes possible opencast mining of the deposits. In Poland glacitectonic play important role in the model of deposits of brown coal. The methods of underground mining were lately used in Poland to mine coals in the Babina and Sieniawa deposits.

Brown coal resources are calculated to the maximum depth of 350 m, the minimum coal layer thickness in bed of 3 m and maximum overburden/deposit thickness ratio of 12:1. The minimum weighted-average calorific value in bed (with intercalations) should equal 6.5 MJ/kg, in practice lignite humidity of 50% and maximum medium sulfur content equal 2% (for brown coal bed with intercalations and at humidity of 50%). These are the basic balance criteria for energy coals which are common in Polish deposits.

Due to these criteria prognostic brown coal resources were calculated to be equal 27,540.71 million tonnes as of 31.12.2009 (Kasiński, 2011). These resources are more than 21% bigger than total anticipated economic resources calculated as of 31.12.2011. Prognostic resources occur in 90 prognostic deposits or prognostic areas near documented deposits within 7 coal-bearing regions: Bełchatowski, Koniński, Legnicki, Łódzki, Północno-zachodni, Wielkopolski i Zachodni (Plate 2). The most important are prognostic resources in satellite deposits for mine-power boards.

Anticipated economic resources were equal 22,663.08 million tonnes as of 31.12.2011 and increased by 2,844.21 million tonnes in comparison with the previous year, mostly due to amounts of resources documented in D and higher categories in 9 deposits (3,050.07 million tonnes of new resources) (tab. 1). Anticipated economic resources within exploited deposits amounted to 1,668.42 million tonnes (7% of total anticipated economic resources) but economic resources in place as of 31.12.2011 amounted to 1,287.03 million tonnes and decreased by 23.92 million tonnes.

Strip mining of brown coal of the Czempin, Krzywin and Gostyń deposits with total resources of 3,690 million tonnes is nowadays precluded on environmental grounds and in connection with high class and value of agricultural lands in area of the planned open strip mine.

Production amounted to 62,889 thousand tons in 2011 being 6,373 thousand tons higher than in the previous year. The most important is Bełchatów deposit (39.77% of domestic production from Bełchatów area and 21.56% of domestic production from Szczerców area). Almost the whole production of the largest brown coal strip mines (Bełchatów, Turów, Adamów and Konin) was used as energy coal in power plants.

The Figure 1 shows changes in resources and production of brown coal in Poland in the years 1989–2011.

In the years 2005–2011 anticipated economic resources of brown coal increased by 9,028.15 million tonnes, the most significant growth was noted in the years 2009–2011. That was due to the 16 new documented deposits with the total resources of 7,236.61 million tonnes: Gubin 1 (541.75 million tonnes), Gubin–Zasieki–Brody (2,018.97 million tonnes), Lubsko (340.68 million tonnes), Łęki Szlacheckie (82.96 million tonnes), Mosina (1,495.41 million tonnes), Nakło (245.34 million tonnes), Naramowice (296.32 million tonnes), Oczkowice

Table 1. Brown coal resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	90	22,663.08	5,015.58	17,647.50	3,551.21	1,287.03
Including resources of exploited deposits						
Total	12	1,668.42	1,651.31	17.11	101.10	1,287.03
1. Deposits of operating mines	11	1,666.56	1,649.46	17.11	97.78	1,286.27
2. Deposits exploited temporarily	1	1.86	1.86	–	3.32	0.76
Including resources of non-exploited deposits						
Total	73	20,985.39	3,355.63	17,629.75	3,445.84	–
1. Deposits covered by detailed exploration	31	4,044.60	3,355.63	688.96	797.36	–
2. Deposits covered by preliminary exploration*	42	16,940.79	0.00	16,940.79	2,648.48	–
Including abandoned deposits						
Total	5	9.28	8.64	0.64	4.27	–

* Including resources of deposits in area of the so-called Poznań Trough (3,690 million tonnes)

(143.05 million tonnes), Radomierzyce (349.09 million tonnes), Radziejów (43.04 million tonnes), Ruja (345.15 million tonnes), Sieniawa 2 (17.63 million tonnes), Szamotuły (746.33 million tonnes), Węglewice (49.98 million tonnes), Więcbork (509.11 million tonnes) and Władysławów II (11.8 million tonnes). The brown coal output in this period was quite stable – between 57.1 million tonnes in 2009 and 62.89 million tonnes in 2011 (with a little drop in 2010). In 2011 the output increased by 6.37 million tonnes in comparison with 2010.

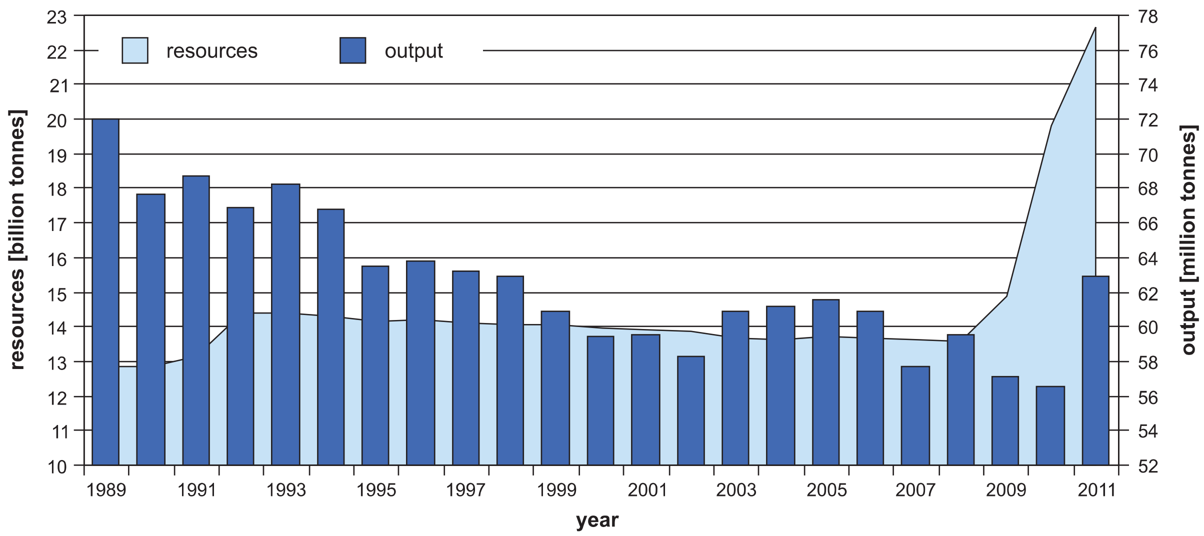

Fig. 1. Brown coal anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

2.2. COAL BED METHANE (CBM)

Coal bed methane (CBM) is natural gas trapped in coal and occurring in the form of gas particles adsorbed at coal grains. A drop in bed pressure along with mining activities is followed by an increase in coal bed methane desorption and its release from coal and surrounding rocks to work areas of a coal mine. The release of methane is a serious safety concern as it can create an explosive hazard. Therefore, much attention is paid to draining methane from coal beds before and in the course of coal mining. This is achieved by methane capture on advance of longwall coalfaces by boreholes drilled in front of the face and reduction of concentration of methane to acceptable level by ventilation of work areas.

The last decades witnessed development of a technology of draining methane from coal beds by multiple boreholes drilled from the surface. The technology of drainage involves hydrofracturing of coal beds and surrounding rock and filling up fissures with permeable medium (usually sand) to facilitate migration of CBM released by desorption. The next step is removal of water from coal beds to achieve a drop in bed pressure in the area of a given borehole, necessary for start of processes of desorption and emission and migration of CBM. Draining of CBM by production wells is treated as natural gas production from unconventional source.

CBM occurs in coal deposits of the Upper Silesian Coal Basin, especially those from its southern and western parts. CBM concentrations in coal deposits of the Lower Silesian Coal Basin appear to be much smaller than in the Upper Silesian Basin. Economic importance of CBM occurrences in the Lublin Coal Basin is still to be established. Concentration of natural gas in areas of planned exploitation of coal deposits appears to be of negligible economic value whereas CBM accumulations matching economic criteria are expected in the case of deeper-seated coal fields as for example in the Dorohucza syncline.

The prospecting made it possible to evaluate CBM resources and show the presence of important CBM resources in 55 exploited coal fields in area of the Upper Silesian Coal Basin. Recoverable resources of CBM, that is resources for which there are economic incentives for production, were estimated at 89.1 billion m^3. That amount comprises 34.3 billion m^3 of CBM in areas of exploited coal fields and 54.8 billion m^3 in hitherto undeveloped coal deposits of so-called reserve coal mine fields or in deposits situated at depths over 1,000 m. In 2011, CBM resources decreased by 0.86 billion m^3.

CBM output amounted to 244.8 million m^3 in 2011. This number covers the amount of CBM which is picked up by every hard coal mine in Poland. There is also CBM emitted from the mines airing systems. It amounted to 489.5 million m^3 in 2011.

Economic resources of CBM, established for 22 developed coal fields, are equal 5.601 billion m^3. Prognostic and prospective resources of coal bed methane in USCB amounted to 107 billion m^3 as of 31.12.2009 (Kwarciński, 2011). Prospective resources in LCB and LSCB are much lower and amounted to about 15 billion m^3 and 1.75 billion m^3, respectively.

2.3. CRUDE OIL

In 2011, eighty four crude oil deposits were proven in Poland: 29 situated in the Carpathian Mts., 11 in the Carpathian Foreland, 42 in the Polish Lowland and 2 in the Polish economic zone of the Baltic Sea (Plate 1). Oil deposits of the Carpathian Mts. and Carpathian Foreland have had a long history as this is the area of the world's first commercial production of crude oil. However, nowadays these deposits are almost exhausted. The Polish oil deposits of the largest economic importance are now situated in the Polish Lowland. In 2011, resources of the Polish Lowland accounted *ca*. 75% of total exploitable crude oil resources of Poland. Resources of the Polish economic zone of the Baltic Sea were the second largest, accounting for 20% of the total exploitable resources. Resources of the Carpathian Foreland and Carpathian Mts. accounted for 3.0 and 2.0%, respectively.

In the Polish Lowland, oil deposits are related to traps in the Permian, Carboniferous and Cambrian rocks. Polish Lowland oil is of the medium paraffin type, with paraffin content ranging from 4.3 to 7.4%, content of sulfur slightly above 1% and density ranging from 0.857 to 0.870 g/cm^3. The majority of them are of the massive type, with gas cap expansion drive and with passive role of water. The Barnówko–Mostno–Buszewo oil and gas deposit is the largest in Poland. Its resources of crude oil were found to be twice larger that the total domestic resources before its discovery. Other large oil deposits situated in this region include the Lubiatów, Grotów and Cychry.

In the Carpathian Mts., oil deposits occur in several tectonic units, mainly in the Silesian unit. The oil deposits are related to traps of the structural or sometimes structural-lithological type, mainly of the type of oil layer surrounded by water. Production is initially driven by the expansion of natural gas dissolved in oil and subsequently by gravity driven drainage. Carpathian crude oils represent the methane type and are considered "sweet" because of negligible content of sulfur. Their density ranges from 0.750 to 0.943 g/cm^3 and content of paraffin – from 3.5 to 7%. Resources of Carpathian oil deposits are generally small, depending on size and character of structures with which they are related. The resources are largely exhausted in result of many years of exploitation.

The Carpathian Foredeep oil deposits are related to traps in Mesozoic sedimentary rocks (Jurassic carbonate rocks and sometimes Cretaceous sandstone series) of the platform type and in Miocene sediments. Crude oil density ranges from 0.811 to 0.846 g/cm^3, content of paraffin from 2.32 to 9.37% and sulfur content from 0.45 to 0.85%.

Resources of exploited oil deposits account for 96.0% of total exploitable resources in 2011. Exploitable resources of crude oil and condensate totaled 25.99 million tonnes (Tab. 2).

Table 2. Crude oil resources in Poland [thousand tonnes]

	Number of deposits	Exploitable resources				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B	C		
1	2	3	4	5	6	7
TOTAL RESOURCES	84	25,577.98 * 24,107.57 ** 1,470.41 ***	10,416.32 10,392.61 23.71	15,161.66 13,714.96 1,446.70	411.45 411.45 –	16,475.39 16,410.76 64.63
Including resources of exploited deposits						
Total	67	24,943.22 23,616.81 1,326.41	10,265.95 10,261.24 4.71	14,677.27 13,355.57 1,321.70	29.56 29.56 –	16,475.01 16,410.38 64.63
Baltic Sea	2	5,103.57 5,103.57 –	464.20 464.20 –	4,639.37 4,639.37 –	– – –	5,103.57 5,103.57 –
Carpathians	29	562.32 560.69 1.63	451.27 451.14 0.13	111.05 109.55 1.50	19.47 19.47 –	110.42 110.42 –
Polish Lowland	30	19,046.59 17,726.39 1,320.20	9,121.72 9,121.72 –	9,924.87 8,604.67 1,320.20	10.09 10.09 –	11,179.84 11,115.21 64.63
Carpathian Foreland	6	230.74 226.16 4.58	228.76 224.18 4.58	1.98 1.98 –	– – –	81.18 81.18 –
Including resources of non-exploited deposits						
Total	9	490.99 346.99 144.00	108.29 89.29 19.00	382.70 257.70 125.00	329.53 329.53 –	– – –

Table 2 cont.

1	2	3	4	5	6	7
Polish Lowland	6	375.06 231.06 144.00	108.29 89.29 19.00	266.77 141.77 125.00	– – –	– – –
Carpathian Foreland	3	115.93 115.93 –	– – –	115.93 115.93 –	329.53 329.53 –	– – –
Including abandoned deposits						
Total	8	143.77 143.77 –	42.08 42.08 –	101.69 101.69 –	52.36 52.36 –	0.38 0.38 –
Polish Lowland	6	143.77 143.77 –	42.08 42.08 –	101.69 101.69 –	1.43 1.43 –	0.38 0.38 –
Carpathian Foreland	2	– – –	– – –	– – –	50.93 50.93 –	– – –

* total, ** oil, *** condensate

Domestic production of crude oil and condensate from onshore and offshore totaled 601.99 thousand tons in 2011.

Anticipated economic resources of crude oil increased in the years 2005–2011 from 21.631 million tonnes to 25.578 million tonnes (Fig. 2). The significant growths were noted in 2006 and 2009. The first one came from the increasing of BMB (Barnówko–Mostno–Buszewo) deposit resources by more than 2 million tonnes and the inclusion of Dzieduszyce deposit (0.5 million tonnes) to "The balance of mineral resources deposits in Poland". The second was a result of a more detailed exploration of the already documented deposits – the biggest growth in off-shore B 8 deposit by nearly 3 million tonnes.

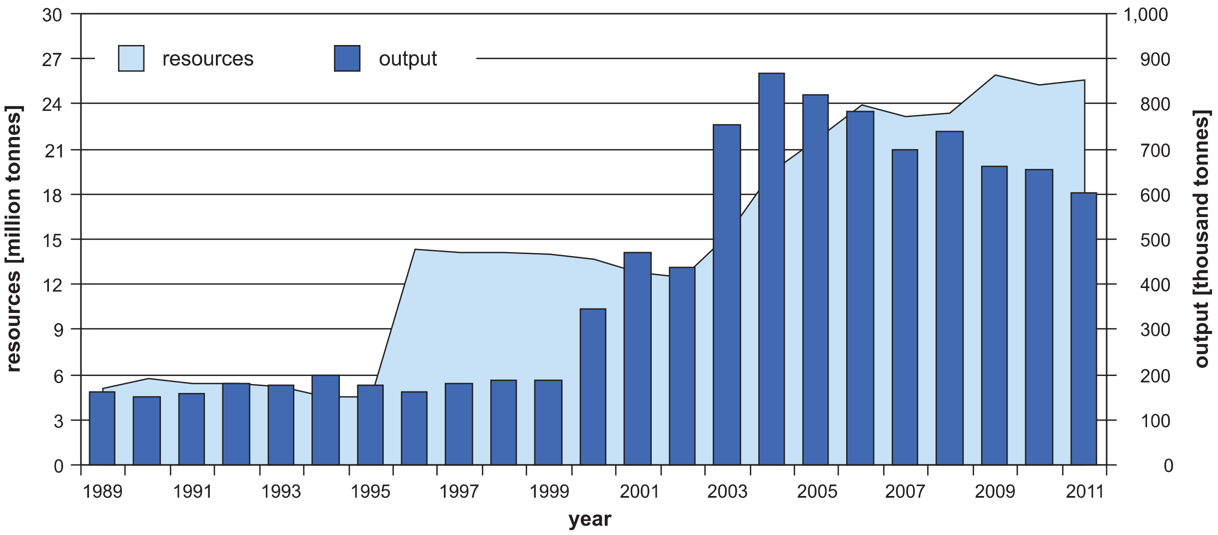

Fig. 2. Crude oil anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

In the years 2005–2011 the output of crude oil in Poland is characterized by upturn – from 818.7 to 601.99 thousand tonnes. The slight increase took place in 2008 due to growing output from B 8. More than 90% of exploited resources come from the Polish Lowland and the Polish economic zone of the Baltic Sea.

In the period prior to the years 2005–2011 resources of crude oil were quite stable till 1995 (4.5–5.6 million tonnes). In 1996 resources increased sharply (by 14.3 million tonnes) due to documentation of BMB (Barnówko–Mostno–Buszewo) deposit and till 2002 resources had been systematically decreasing. In the years 2003–2004 the resources base grew by 7 million tonnes as a result of Lubiatów deposit documentation and inclusion of the Polish economic zone of the Baltic Sea into "The balance…".

2.4. HARD COAL

Polish hard coal deposits belong to the Carboniferous Euro-American coal province. In Europe this province is represented by two belts of coal basins: a kind of paralic coal basins that originated near the sea in depressions along the front of the Variscan fold belt which was forming in these times, and that of limnic basins, with coals accumulating in closed basins and intermontane depressions with disconnected internal river systems. In Poland, coal deposits of the Carboniferous age occur in three basins (Plate 2): two basins of the paralic type – the Upper Silesian Coal Basin (USCB) and Lublin Coal Basin (LCB), and one of the limnic type – the Lower Silesian Coal Basin (LSCB). Exploitation of coal is being continued in the first two of these basins (USCB and LCB). The third, Lower Silesian Coal Basin (LSCB), is at present of historical value only.

The Upper Silesian Coal Basin (USCB) is the major coal basin in Poland. This is the area where all of the operating coal mines are situated except one large Bogdanka mine. The latter is a single mine operating in the Lublin Coal Basin (LCB). Mining operations were phased out in the Lower Silesian Coal Basin (LSCB) in 2000, along with closing works in the last active coal field (Słupiec) of the Nowa Ruda mine. Coal production ceased in LSCB due to difficult geological-mining conditions and resulting clearly excessive exploitation costs.

The area of Polish part of USCB is estimated at about 5,600 km^2. The currently exploited coal deposits occupy about 20% of that area, at present anticipated economic resources of USCB account for about 80.2% of hard coal domestic resources of Poland.

Coal resources of LCB remained at the early stages of development as prospecting and exploration works were not intensified in the last decades. This results in relatively poor geological knowledge of the Lublin basin, especially its boundaries. The available data make it possible to assume that the prospective coal resources are spread over an area of about 9,100 km^2. The Bogdanka mine, the first and the only mine operating in LCB, exploits a deposit occupying an area of about 77 km^2, which corresponds to 0.8% of total area of LCB. As shown by the latest data, the anticipated economic resources of LCB account for about 19.1% of anticipated economic resources of Poland.

The anticipated economic resources left in the abandoned mining fields of LSCB were reclassified as anticipated sub-economic and estimated at about 369 million tonnes. In 2011, in order of the Ministry of the Environment, there was the verification of the resources remained in abandoned deposits elaborated. The resources were recalculated according to the new criteria. Calculations applied also to seven LSCB deposits and new anticipated economic resources are now equal 360 million tonnes.

Polish coal mines have been subjected to restructuring and rationalization since the start of process of transformation of the national economy at the end of the 1980s. In consecutive years total anticipated economic resources of coals began to decrease steadily due to exploitation and associated mining losses and, on much larger scale, verification and reclassification of the resources in result of adjustments of the mining sector to requirements of free-market economy. These factors resulted also in decrease of coal production from over 150 to about 96 million tonnes in the years 1990–2003 and 67.6 million tonnes at the end of 2011.

Hard coal prognostic resources in Poland amounted to about 20,041 million tonnes and prospective resources to about 31,653 million tonnes as of 31.12.2010 (Jureczka *et al*., 2011). In USCB prognostic resources totaled 9,193.4 million tonnes (including 1,081.2 million tonnes of steam coal and 8,112.2 million tonnes of coking coal) and prospective resources totaled 25,533 million tonnes (19,156.8 million tonnes of steam coal and 6,376.2 million tonnes of coking coal). In LCB these resources amounted to 10,847.7 and 5,887.6 million tonnes respectively. LSCB prognostic resources equal 0.39 million tonnes (resources of Heddi deposits which were crossed out of the "The balance of mineral resources deposits in Poland") and prospective resources amounted to 232 million tonnes (Wałbrzych and Nowa Ruda area).

The anticipated economic resources as of 31.12.2011 totaled 48,541 million tonnes (Tab. 3). Steam coals represent almost $^{3}/_{4}$ of the resources and coking coal – about $^{1}/_{4}$ whereas the share of other types of coals remains negligible. Resources of the exploited coal deposits were equal 17,606 million tonnes, accounting for 36.3% of the total anticipated economic resources.

In 2011 anticipated economic resources increased significantly by 3,396.98 million tonnes in comparison with the previous year. That was mainly due to the verification (mentioned above) of the resources remained in abandoned deposits. There were new calculations made for 38 hard coal deposits from USCB and LSCB. Due to these calculations anticipated economic resources increased by 2,947.84 and 359.72 million tonnes, respectively. According to new "deposit criteria" anticipated sub-economic resources have been

Table 3. Hard coal resources in Poland [million tonnes]

	Number of deposits	Geological resources in place					Economic resources in place as part of anticipated economic resources
		anticipated economic				anticipated sub-economic	
		total	A+B	C_1	C_2+D		
1	2	3	4	5	6	7	8
TOTAL RESOURCES	145	48,540.84	5,795.09	13,819.37	28,926.38	17,494.87 * 2,598.77 **	4,178.45
steam coal		35,086.50	3,978.93	9,078.21	22,029.36	13,247.14 1,845.21	2,304.95
coking coal		12,666.74	1,808.62	4,689.56	6,168.56	4,211.18 753.56	1,873.50
other coals		787.60	7.54	51.61	728.45	36.56 –	–
Including resources of exploited deposits							
Total	49	17,606.03	4,326.64	7,613.73	5,665.66	5,921.29 2,158.88	4,178.45
steam coal		10,480.18	2,695.70	4,811.26	2,973.22	3,938.19 1,564.93	2,304.95
coking coal		7,123.60	1,630.94	2,802.32	2,690.34	1,983.10 593.95	1,873.50
other coals		2.25	–	0.15	2.11	–	–
1. Deposits of operating mines	46	16,441.87	4,246.36	7,111.74	5,083.77	5,550.87 2,158.88	3,952.39
steam coal		10,451.19	2,694.36	4,801.62	2,955.21	3,931.96 1,564.93	2,302.31
coking coal		5,990.54	1,552.00	2,309.98	2,128.56	1,618.91 593.95	1,650.08
other coals		0.15	–	0.15	–	–	–
2. Deposit exploited temporarily	1	28.04	1.34	9.37	17.33	5.99 –	2.64
steam coal		28.04	1.34	9.37	17.33	5.99 –	2.64

Table 3 cont.

1	2	3	4	5	6	7	8
3. Mines during preparation process	2	1,136.12	78.94	492.61	564.57	364.43 –	223.42
steam coal		0.95	–	0.26	0.69	0.24 –	–
coking coal		1,133.06	78.94	492.35	561.77	364.19 –	223.42
other coals		2.11	–	–	2.11	–	–
Including resources of non-exploited deposits							
Total	54	26,906.29	373.81	4,596.52	21,935.96	11,038.57 439.89	–
steam coal		21,683.04	369.63	3,006.96	18,306.45	9,049.96 280.28	–
coking coal		4,592.35	4.18	1,589.56	2,998.61	1,988.61 159.61	–
other coals		630.90	–	–	630.90	–	–
1. Deposits covered by detailed exploration	36	13,190.01	373.81	4,596.52	8,219.67	3,484.86 439.89	–
steam coal		10,007.56	369.63	3,006.96	6,630.96	2,590.12 280.28	–
coking coal		3,182.45	4.18	1,589.56	1,588.71	894.74 159.61	–
2. Deposits covered by preliminary exploration	18	13,716.28	–	–	13,716.28	7,553.71 –	–
steam coal		11,675.48	–	–	11,675.48	6,459.84 –	–
coking coal		1,409.90	–	–	1,409.90	1,093.88 –	–
other coals		630.90	–	–	630.90	– –	–
Including abandoned deposits							
Total	42	4,028.52	1,094.64	1,609.12	1,324.76	535.01 –	–
steam coal		2,923.28	913.59	1,259.98	749.70	258.99 –	–
coking coal		950.79	173.50	297.68	479.62	239.47 –	–
other coals		154.45	7.54	51.46	95.45	36.56 –	–

* group A, ** group B

included to anticipated economic resources. Anticipated economic resources increased also due to new documentation prepared for 4 new deposits: Barbara--Chorzów 1 (20.88 million tonnes), Jan Kanty 1 (49.60 million tonnes), Kazimierz-Juliusz 1 (61.18 million tonnes) and Żory–Warszowice (151.92 million tonnes).

In 2011, anticipated economic resources covered by detailed exploration (categories A, B and C_1 of the Polish classification of resources) totaled 19,614.46 million tonnes, accounting for 40.4% of total sum of anticipated economic resources. Economic resources in place of mined deposits as shown in the approved mine management plans (prefeasibility study) were equal

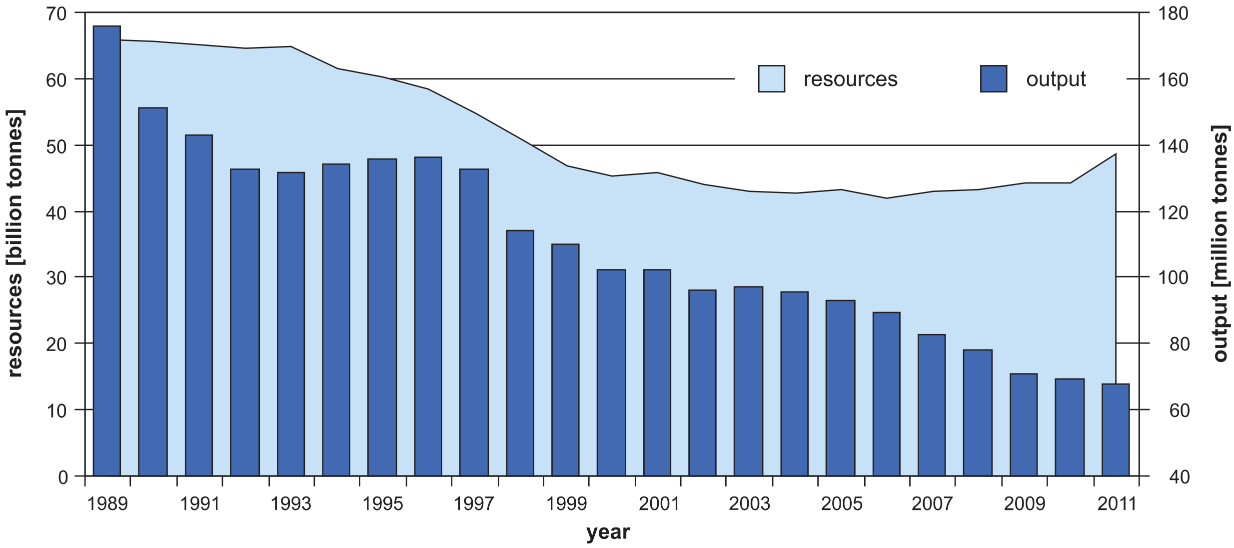

Fig. 3. Hard coal anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

4,178.45 million tonnes, decreasing by 85.77 million tonnes in relation to 2010.

According to the production data for the end of 2011 as supplied by operators of individual hard coal mines, total production equaled 67,637 thousand tonnes, decreasing by 1,552 thousand tonnes in relation to the previous year. The anticipated economic resources of coals decreased from over 65 to about 42 billion tonnes in the years 1989–2006 and then increased to 48 billion tonnes at the end of 2011– mainly because of the recalculating in 2011 (Fig. 3).

In USCB all technological types of hard coal occur. There is steam coal, coking coal and sometimes anthracite. Mean ash content varies from 11 to 17% and sulfur content from 0.59 to 2.3%. In LCB mainly steam coal and coking coal occur. A mean ash content amounts for 14.63% and sulfur content varies from 1.21 to 1.46%.

2.5. HELIUM

Helium is found in numerous natural gas deposits in the Polish Lowland. Its content is varying from 0.02 to 0.45%. Resources of that gas were demonstrated in sixteen natural gas deposits where its content is varying from 0.22 to 0.42% (Tab. 4). These gas deposits are situated in the Zielona Góra–Rawicz–Odolanów area (southern part of the Fore-Sudetic Monocline) and are related to the Rotliegend, Zechstein Limestone and Main Dolomite formations of the Permian. Helium is produced from gas deposits in which its content is above 0.27% at the average.

Table 4. Helium resources in Poland [million m^3]

	Number of deposits	Exploitable resources			
		anticipated economic			anticipated sub-economic
		total	A+B	C	
TOTAL RESOURCES	16	28.98	28.62	0.36	–
exploited	11	25.90	25.90	0.00	–
non-exploited	5	3.08	2.72	0.36	–

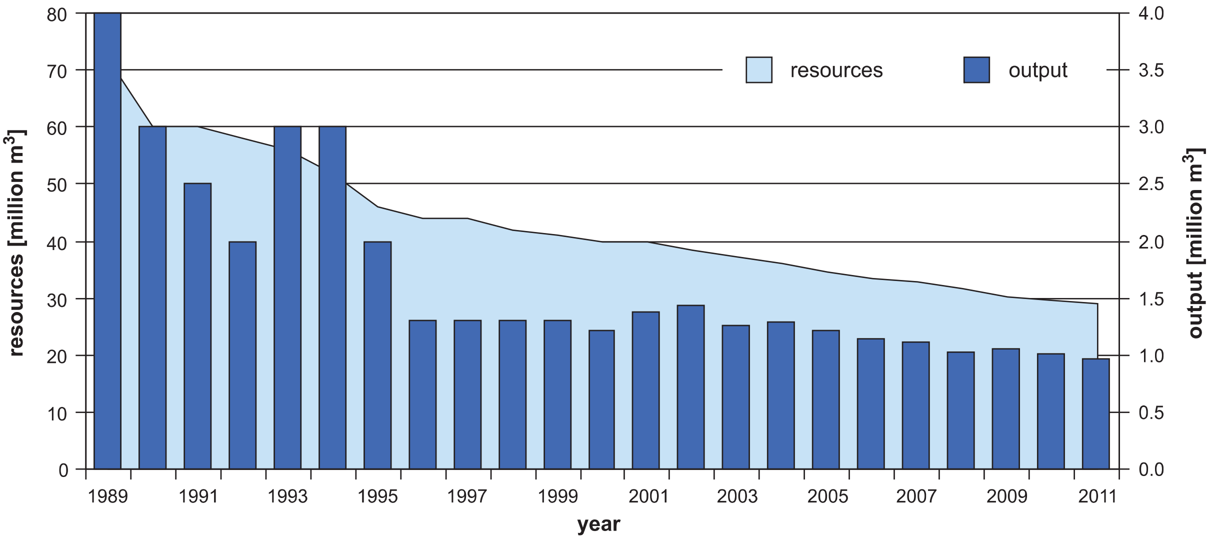

Fig. 4. Helium anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

In 2011, production of helium was equal 0.97 million m^3.

"The balance of mineral resources deposits in Poland" includes deposits with documented resources of helium. Data on helium output do not cover the quantity of helium recovered from gases with anticipated sub-economic concentrations of helium (Smakowski *et al*., 2009). The largest resources are documented in Bogdaj–Uciechów deposit. They constitute 42–53% of total resources. The resources of this deposit decreased from 37.28 million m^3 in 1989 to 13.56 million m^3 in 2011 due to output and reclassification of the resources in 1990 and the output in subsequent years. In the years 1990–2011 the output from the Bogdaj–Uciechów deposit totaled 14.51 million m^3 of helium which constitutes 47% of the total loss (Fig. 4).

2.6. HIGH NITROGENOUS NATURAL GAS

Up to the present, two high nitrogenous natural gas (HNNG) deposits have been discovered in Poland. These are Cychry and Sulęcin deposits, situated in the Polish Lowlands and characterized by nitrogen content over 90% (Plate 1). HNNG is good quality raw material for production of liquid nitrogen but it is more often used for correcting nitrogen content to specification of natural gas pipelines of the domestic distribution network. However, its utility for the latter purpose is smaller than that of gas from the deposits with lower nitrogen content but not smaller than 70%, which are not differentiated as a separate group of HNNG deposits.

At present, exploitation of HNNG is limited to the Cychry deposit only. The extracted gas is used for correcting nitrogen content to specification of natural gas pipelines. In 2011, HNNG production was about 4.94 million m^3.

2.7. NATURAL GAS

In Poland, major gas deposits were discovered in area of the Polish Lowland and also known from the Carpathian Foreland and smaller ones – from the Carpathian million tonness. and Polish economic zone of the Baltic Sea (Plate 1). About three quarters of the gas resources are related to plays involving Miocene and Rotliegend formations and the remaining resources – to plays in the Cambrian, Devonian, Carboniferous, Zechstein, Jurassic and Cretaceous formations.

In the Polish Lowland, gas deposits are related to the Permian in the Fore-Sudetic and Wielkopolska regions and the Carboniferous and Permian in the Western Pomerania. In these regions gas occurs in massive and block-type reservoirs with water or gas drive mechanism. In that area only four gas deposits contain high methane gas. The remaining are characterized by presence of nitrogen natural gas with content of methane ranging from about 30% up to over 80% that is nitrogen-methane or methane-nitrogen mixtures. Gas deposits containing natural gas with nitrogen content over 90%, called as "high nitrogenous natural gas" (HNNG), are discussed in a separate chapter.

In the Carpathian Foreland, natural gas deposits are related to plays involving the Jurassic, Cretaceous and Miocene formations. The deposits usually contain high methane natural gas with low content of nitrogen. The exceptions are few natural gas deposits containing high nitrogen concentrations. In this region gas occurs in structural-lithological multi-layer traps or, sometimes, massive-type reservoirs with gas drive mechanism.

In the Carpathians, natural gas occurs in gas and oil-gas and oil-gas-condensate deposits related to plays in the Cretaceous and Paleogene formations. These deposits are exploited using standard gas depletion drive mechanism. Produced gas is characterized by high content of methane (usually over 85%) whereas average content of nitrogen is a few percent at the average.

In the Polish economic zone of the Baltic Sea, there are two gas deposits (B 4 and B 6) and two oil-gas deposits (B 3 and B 8).

At present the Polish Lowland region accounts for 69% of proven domestic resources of natural gas and the Carpathian Foreland – for 26% of those resources. The resources of the Polish economic zone of the Baltic Sea and the Carpathians are subordinate, being equal 4.0 and 1.0% of the proven domestic resources, respectively.

The data given in the Table 5 refer to resources of natural gas actually present in the gas deposits and are not converted to those of high methane gas (high methane gas = extracted reserves × combustion heat of real

Table 5. Natural gas resources in Poland [million m^3]

	Number of deposits	Exploitable resources				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B	C		
1	2	3	4	5	6	7
TOTAL RESOURCES	283	**142,659.17***	**92,810.50**	**49,848.67**	**2,221.95**	**62,959.41**
		28,217.40**	11,307.05	16,910.35	655.71	13,637.20
		107,871.06***	74,932.74	32,938.32	1,566.24	48,728.69
		6,570.71****	6,570.71	–	–	593.52
Including resources of exploited deposits						
Total	198	119,570.55	86,886.19	32,684.36	666.78	58,623.71
		18,281.67	8,760.02	9,521.65	654.72	9,870.93
		94,718.17	71,555.46	23,162.71	12.06	48,159.26
		6,570.71	6,570.71	–	–	593.52
Baltic Sea	2	1,326.76	518.56	808.20	–	1,326.76
		1,326.76	518.56	808.20	–	1,326.76
		–	–	–	–	–
		–	–	–	–	–
Carpathians	30	1,131.92	635.10	496.82	15.10	407.15
		155.34	52.94	102.40	3.30	11.64
		855.08	460.66	394.42	11.80	274.01
		121.50	121.50	–	–	121.50
Polish Lowland	94	81,952.10	63,248.34	18,703.76	651.42	45,813.62
		14,951.85	6,363.14	8,588.71	651.42	7,347.15
		61,086.78	50,971.73	10,115.05	–	38,466.47
		5,913.47	5,913.47	–	–	–

Table 5 cont.

1	2	3	4	5	6	7
Carpathian Foreland	72	35,159.77 1,847.72 32,776.31 535.74	22,484.19 1,825.38 20,123.07 535.74	12,675.58 22.34 12,653.24 –	0.26 – 0.26 –	11,076.18 1,185.38 9,418.78 472.02
Including resources of non-exploited deposits						
Total	62	22,883.21 9,906.35 12,976.86 –	5,918.85 2,541.57 3,377.28 –	16,964.36 7,364.78 9,599.58 –	1,419.75 – 1,419.75 –	4,334.68 3,765.25 569.43 –
Baltic Sea	2	4,479.45 4,479.45 – –	– – – –	4,479.45 4,479.45 – –	– – – –	3,765.25 3,765.25 – –
Carpathians	2	240.00 – 240.00 –	240.00 – 240.00 –	– – – –	73.00 – 73.00 –	– – – –
Polish Lowland	38	15,525.55 5,426.90 10,098.65 –	5,388.85 2,541.57 2,847.28 –	10,136.70 2,885.33 7,251.37 –	1,346.75 – 1,346.75 –	– – – –
Carpathian Foreland	20	2,638.21 – 2,638.21 –	290.00 – 290.00 –	2,348.21 – 2,348.21 –	– – – –	569.43 – 569.43 –
Including abandoned deposits						
Total	23	205.41 29.38 176.03 –	5.46 5.46 – –	199.95 23.92 176.03 –	135.42 0.99 134.43 –	1.02 1.02 – –
Carpathians	3	– – – –	– – – –	– – – –	91.88 – 91.88 –	– – – –
Polish Lowland	15	205.41 29.38 176.03 –	5.46 5.46 – –	199.95 23.92 176.03 –	0.99 0.99 – –	1.02 1.02 – –
Carpathian Foreland	5	– – – –	– – – –	– – – –	42.55 – 42.55 –	– – – –

* total, ** from oil and condensate deposits, *** from gas deposits, **** from underground gas storage

gas/ combustion heat of high methane gas, that is about 34 MJ/m^3).

In 2011, exploitable resources of natural gas were found to be 144,881 million m^3 (anticipated economic and anticipated sub-economic resources).

The total domestic resources given above include those of gas deposits which are planned to be converted for use as underground natural gas storage facilities. Production from these gas deposits has been stopped in order to use the remaining gas as gas cushion (base gas) throughout the time of operation of the storage sites. The Brzeźnica (45.59 million m^3), Daszewo (27.72), Husów (372.88), Strachocina (121.5), Swarzów (28.80) and Wierzchowice (5,557.12) gas deposits were selected for conversion into underground storage facilities. In December 2010 Bonikowo Underground Natural Gas Storage Facility was officially opened. Total reserves of natural gas to be used as gas cushions are estimated at 6.48 billion m^3. Underground natural gas storage facilities are also built in salt (Mogilno II and Kosakowo facilities) and hard coal deposits (Nowa Ruda facility). The Mogilno II facility is the first of that type already in use for natural gas storage and the Kosakowo facility is under construction. In turn, the Góra facility is used for storage of liquid fuels. Up to now, 11 licenses for running underground natural gas and liquid fuel storage facilities were issued.

In the year 2011, domestic production of natural gas from exploitable gas resources was 5,646 million m^3 (Fig. 5).

In the years 2005–2011 anticipated economic resources of natural gas in Poland decreased by about 6%. The most significant drop in 2006–2007 was mainly due to increasing output and the verification of BMB (Barnówko–Mostno–Buszewo) gas deposit resources. The resources growth took place during the next two years as a result of a more detailed exploration of the already documented deposits and documentation of 16 new deposits with total resources of 3.1 billion m^3. The most significant growth was noted for Brońsko (by 8.9 billion m^3) and Paproć (by 3.3 billion m^3) gas deposits.

The natural gas output in the years 2005–2011 varied in the range of 5.305 billion m^3 in 2005 to 5.646 billion m^3 in 2011. The significant growth since 2009 was a result of increasing demand and therefore increasing output from the Polish Lowland gas deposits. More than 99% of exploited resources came from terrestrial deposits, less than 1% came from the Polish economic zone of the Baltic Sea.

Anticipated economic resources had been decreasing before 2005 with two periods of growth – in 1999 by 6.7 billion m^3 and in the years 2002–2004 by 15.7 billion m^3. The second one was due to documentations of 5 new deposits – Brońsko, Międzychód, Lubiatów, B 4 and B 6.

Shale gas accumulations are likely to occur in the Upper Ordovician–Lower Silurian formations in the Baltic and Lublin–Podlasie basins, as well as in the Łysogóry and Biłgoraj–Narol blocks. These forma-

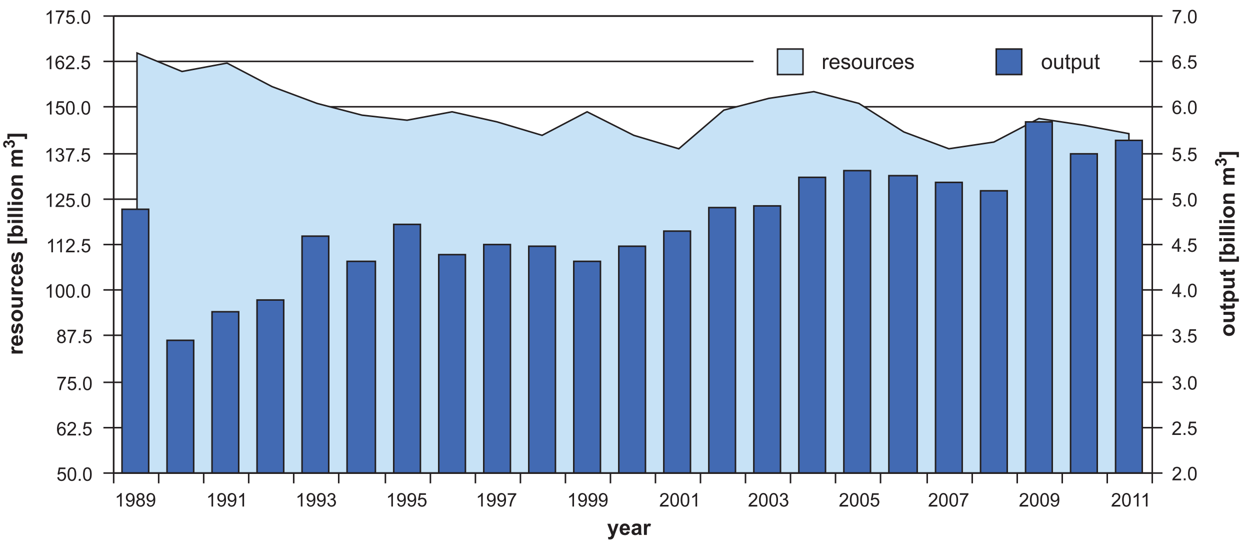

Fig. 5. Natural gas anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

tions are currently subject to industry exploration activity. Polish Geological Institute – National Research Institute in cooperation with U.S. Geological Survey on the basis of data from the period 1950–1990 estimated resources of gas and oil in the Upper Ordovician–Lower Silurian formations in the Baltic and Lublin–Podlasie Basins. Total exploitable resources of gas can be maximum 1,920 million m^3 and oil – 535 million tonnes. Taking into account all parameters of the evaluation, resources can be estimated with the highest probability in the range of 346–768 billion m^3 of gas and 215–268 million tonnes of oil (PGI-NRI, 2012).

Presence of tight gas accumulations is the most probable in the north-eastern rim of the Fore-Sudetic Monocline in the Rotliegend sediments developed in eolian facies. A few boreholes drilled in 2009–2011 east of Poznań confirmed presence of gas in Rotliegend tight sandstones in that region.

3. METALLIC RAW MATERIALS

3.1. ARSENIC

Arsenic ores occur mainly as arsenopyrite (FeAsS) in massive pyrite deposits or in vein form of basic metals ores, as accompanying elements of copper, zinc and lead ores, very rare as loellingite ($FeAs_2$). In Poland, the arsenic minerals reported from the major deposit situated at Złoty Stok (Plate 3) form numerous ore-bearing veins at Czarnów and Miedzianka near Kamienna Góra and other sites in the Sudetes. Arsenic ores were exploited at Złoty Stok in the period of XVI to XX century AD. Besides arsenic, gold was also extracted from rich ore with arsenic contents up to 40% being also a high grade gold ore, containing up to 40 ppm of gold. After the Second World War, the Złoty Stok deposit was exploited in the years 1954–1960 and then abandoned due to a very limited demand for As and high toxicity of arsenic ores during processing. According to mining records *ca*. 16 tonnes of gold was extracted from this deposit. The amount remaining after earlier extraction is estimated at 537,000 tonnes of As ores yielding 19,600 tonnes of arsenic and 1,500 kg of gold. The other abandoned arsenic deposit is that from Czarnów in the Sudetes. According to results of a general exploration from the year 1955, resources of that deposit are relatively small. Inferred resources were estimated at about 20,500 tonnes of arsenopyrite ore with mean content of arsenic equal about 10.15%. Sulphide ores are accompanied by gold mainly to a few grams per tone.

3.2. COPPER AND SILVER ORES

Copper ore deposits occur in several countries throughout the world and under various geological conditions. The most important are porphyry copper deposits as well as sediment-hosted stratiform and stratabound copper deposits and the volcanogenic-sedimentary ones (SEDEX and massive pyrite ores). Moreover, there are skarn and copper ores of hydrothermal vein association, generally characterized by smaller resources but locally of high economic value.

Polish copper ores belong to the sediment-hosted stratiform type. They are hosted by the Zechstein Kupferschiefer formation. The deposits are situated in areas of the Fore-Sudetic Monocline and North Sudetic Basin in the Lower Silesia (Plate 3). Ore minerals are mainly concentrated in the copper-bearing shales as well as underlying sandstones and overlying dolomites. Deposits of the largest economic importance occur in the Lubin district within the Fore-Sudetic Monocline.

The copper-bearing series comprises three separate lithological units: sandstones at the base, clay or dolomitic shales and dolomitic limestones in upper part. Copper mineralization is the richest in the black clay shales which, therefore, are named the Copper-bearing Shales (ger. Kupferschiefer). The major copper ore minerals include: chalcocite (Cu_2S), bornite (Cu_5FeS_4) and chalcopyrite ($CuFeS_2$). They are accompanied by numerous other minerals of copper, silver (including native silver), lead, zinc, cobalt and nickel.

The Lubin–Sieroszowice copper deposit area extends in a belt 60 km long and 20 km wide, from Lubin in the south-east to Bytom Odrzański in the north-west. The copper mineralization is fringed to the west by the Rote Fäule zone, which is represented by hematitized Au-Pt-Pd-bearing rocks (Oszczepalski, Rydzewski, 1997; Mikulski *et al.*, 2011b). Copper ores are currently exploited in the Lubin, Polkowice–Sieroszowice and Rudna underground mines.

In areas of the Fore-Sudetic Monocline, Żary Pericline and North Sudetic Basin estimated resources amount to 22.7 million tonnes of copper (5 regions with the area of 253 km^2, maximum depth of 2,000 m), prospective resources amount to 5.94 million tonnes of copper (7 regions with the area of 114 km^2, maximum depth of 2,000 m) and hypothetical resources to 229.1 million tonnes – including 42.7 million tonnes to the depth of 2,000 m and 186.4 million tonnes below 2,000 m depth (11 regions with the area of 1,830 km^2) (Oszczepalski, Speczik, 2011).

In 2011 anticipated economic resources of copper ore amounted to 1,810.44 million tonnes with copper amounted to 34.87 million tonnes and silver amounted to 107.37 thousand tonnes (Tab. 6). Anticipated economic resources of copper ore increased by 57.56 million tonnes in comparison with the previous year. Anticipated economic resources of copper ore in exploited deposits are 1,494.85 million tonnes (29.45 million tonnes of copper and 88.22 thousand tonnes of silver).

In 2011, copper mining gave 22,985 thousand tonnes of copper ore yielding 459 thousand tonnes of copper and 1,635 tonnes of silver. In comparison with 2010, production of copper ore and recovery of silver increased (by 2 and 33%, respectively).

Figures show resources and production of copper ores and changes in resources and output of copper in Poland in the years 1989–2011 (Fig. 6A, B). The anticipated economic resources of copper ore decreased in this period from 3.4 to 1.8 billion tonnes – mainly due to the changing criteria for evaluating of the anticipated economic resources. Copper ore resources occur-

Table 6. Copper ores resources in Poland

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	14	1,810.44* 34.87** 107.37***	1,749.43 33.88 103.14	61.01 0.99 4.23	830.98 13.33 42.18	1,251.81 24.73 74.87
Including resources of exploited deposits						
Total	6	1,494.85 29.45 88.22	1,494.85 29.45 88.22	– – –	2.98 0.03 0.08	1,251.81 24.73 74.87
1. Deposits of operating mines	5	1,488.38 29.32 88.04	1,488.38 29.32 88.04	– – –	2.13 0.02 0.07	1,245.33 24.60 74.69
2. Deposit exploited temporarily	1	6.48 0.13 0.18	6.48 0.13 0.18	– – –	0.85 0.01 0.01	6.48 0.13 0.18
Including resources of non-exploited deposits						
Deposits covered by detailed exploration	6	291.81 5.15 18.07	238.58 4.23 14.16	53.23 0.92 3.91	809.91 13.16 41.43	– – –
Including abandoned deposits						
Total	2	23.77 0.26 1.08	16.00 0.20 0.76	7.77 0.06 0.32	18.08 0.13 0.68	– – –

* ore [million tonnes], ** copper [million tonnes], *** silver [thousand tonnes]

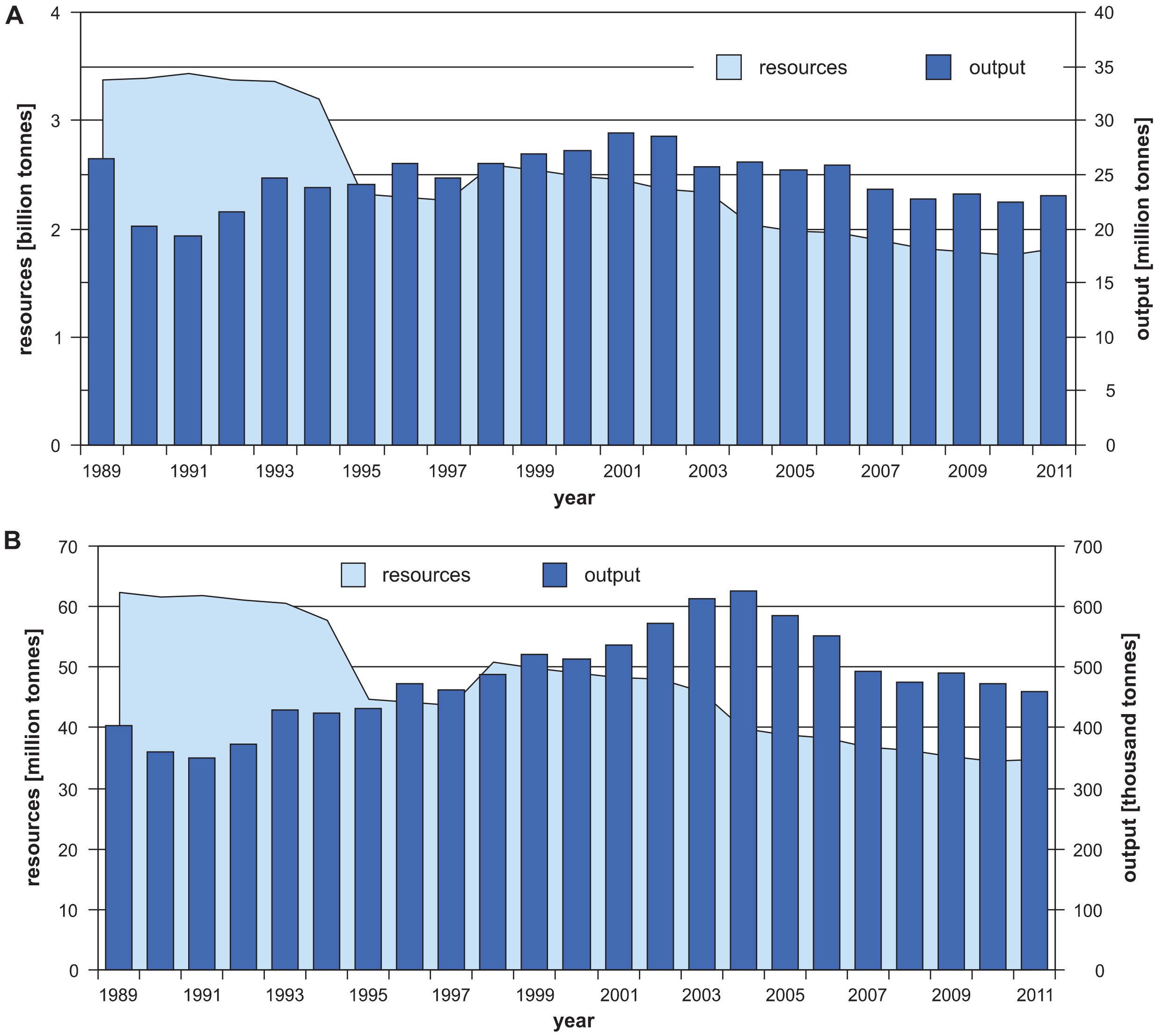

Fig. 6. Copper ores (A) and copper (B) anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

ring below the depth of 1,250 m were excluded from the Polish mineral resources balance in 1995. The resources drop took place also because of the exploitation and losses. The only one new copper ore deposit (named "Głogów Głęboki") was documented during this period – in 1998. Copper output has been decreasing since 2004 in connection with the decreasing copper content in the ore.

Other elements recovered from copper ores include Ag, Au, Ni, Pb, Pt-Pd, Se and Re. Recovery of silver is of the largest economic importance. According to the data provided by the KGHM Polish Copper S.A., in 2011 the copper processing was accompanied by recovery of 1,259.6 tonnes of silver, 510.1 kg of gold and 30.0 thousand tonnes of lead.

3.3. GOLD

Gold occurs in a few geological formations in Poland. The gold deposits were actively prospected and exploited at least since early Middle Ages. At present gold is extracted only from copper-silver deposits mined in area of the Fore-Sudetic Monocline. Gold occurs in sediments of the oxidized facies, mainly in rocks of the Weissliegendes Sandstone of the Rotliegende and lower parts of the Zechstein copper-bearing shales. Gold is recovered in the course of technological processing of sulfide ores. In 2011, 510 kg of gold were recovered.

The gold and arsenic mine at Złoty Stok, closed in 1960, was the last active gold mine in the Sudetes (Plate 3). Proven gold resources of the Złoty Stok deposit were estimated in 1954 at 2,000 kg in anticipated economic resources of the ore and 490 kg in the anticipated sub-economic ones. The mean content of gold is 2.8 g/t of ore. The Złoty Stok deposit was mined in the years 1954–1960 which resulted in extraction of a quarter of its resources. The resources remaining in the deposit are estimated at 537,000 tonnes of ores yielding 19,600 tonnes of arsenic and 1,500 kg of gold. The deposit has been abandoned because of a very limited arsenic demand and high toxicity of arsenic ore during processing. At present the chance for reactivation of this mining operation is negligible. Gold was also extracted from hydrothermal gold-bearing quartz-sulphide veins at Radzimowice, Klecza–Radomice, Czarnów and Wądroże Wielkie. Beside, in Lower Silesia region placer gold was also subject of extraction from Cenozoic sands and gravels. The gold-bearing sediments occurre in numerous river valleys (e.g. Bóbr, Kwisa, Kaczawa, Nysa Łużycka) in the vicinities of Złotoryja, Lwówek Śląski and Bolesławiec.

Prognostic and prospective resources of gold are estimated at almost 350 tonnes (Mikulski *et al.*, 2011b).

3.4. IRON, TITANIUM AND VANADIUM ORES

In Poland, during 1950–70s of 20th century, iron ores were exploited in several mines situated in the Częstochowa, Kielce and Łęczyca regions. Those were iron ores occurring in sedimentary rocks in the form of accumulations of siderite nodules and iron-bearing limonitic sands. Resources of the iron ores were crossed out of the registry of Polish mineral raw material deposits by decision of the Minister of Environmental Protection, Natural Resources and Forestry already in 1994 as not meeting economic criteria. Since that time no economic iron deposits were documented in Poland.

Deposits of vanadium-bearing magnetite-ilmenite ores occur in anorthosite complexes of the Proterozoic Suwałki mafic massif (north-eastern Poland) at depths from 850 to 2,300 m. The deposits became known thanks to an intense drilling exploration and appraisal drilling program launched in the 1970s. In order to classify the resources of the ores, special economic criteria were worked out and accepted in 1996. On the basis of these new criteria the ore resources of the Krzemianka and Udryń deposits were classified as sub-economic on account of low contents of metals, especially vanadium (0,26–0,31% V_2O_5 at the average) and large depth of occurrence.

At present the magnetite-ilmenite ores appear to be of interest mainly as a raw material of vanadium. According to Nieć (2003) evaluation the cut-off grade equivalent of V_2O_5 in economic ore should reach 0.73% what constitute only 1% of totally documented resources. This makes any attempt to develop the ore deposits of the Suwałki area difficult to expect in the foreseeable future and their classification as sub-economic deposits too optimistic under the present conditions. It should be added that any decision to start development of the Suwałki ore deposits would bring a very high risk of social and environmental conflicts. Therefore, the ores should be treated at present as an interesting geological object, without any practical value larger economical importance. If this is the case, it may be stated that Poland does not have any iron ore deposits which could be the source of raw material for the steel industry.

A bog iron ore deposit of the Dębe Małe area is relatively small, with resources estimated at 8,000 tonnes. Its resources appear not useful as raw material for the steel industry but easily find other industrial uses, especially as adsorbent of H_2S, CO_2 and organic compounds of sulfur in cleaning combustion flue gases and in other environmental activities.

3.5. METALS AND ELEMENTS COEXISTING IN ORES AND IN OTHER RAW MATERIALS

This group of mineral raw materials mainly comprises metals which deposits have not been hitherto discovered in Poland and the domestic demand is totally covered by import, except for some amounts which are being recovered during processing and recycling of non-mineral waste-derived from raw materials. Metals assigned to this group include aluminum, chromium, magnesium and manganese as well as several elements such as antimony, cobalt and noble metals.

The considering metallic elements occur mainly in sulfides ore deposits. In Poland exclusively from copper and zinc-lead deposits with fairly long records of various co-occurring elements. The elements, often of high market value, are already recovered or may be recoverable in the course of processing of these ores. Accumulations of some of these elements were covered by prospecting and exploration which resulted often in evaluations of their indicated/inferred and sometimes even geological resources. Further outcome of resources of these metals will depend on domestic demand and changes in prices at the international markets.

Rare earth elements and those named as dispersed elements were also found to occur in beach sands and saline waters and brines.

Table 7 shows a summary of estimations of resources of major co-occurring elements as of 31.12.2011.

Table 7. Elements co-occurring in ores and other mineral raw materials [thousand tonnes]

Elements	Copper ore deposits	Zinc and lead ore deposits	Other deposits	Total
Boron	–	–	6.00	6.00
Bromine	–	–	7.20	7.20
Brines Br–J	–	–	32.18 million m^3	32.18 million m^3
Zirconium	–	–	2.00	2.00
Cadmium	–	34.94	–	34.94
Cobalt	124.18	–	–	124.18
Molybdenium	72.04	–	–	72.04
Nickel	64.71	–	–	64.71
Sulfur	5,451.16	2,674.36	–	8,125.52
Silver	107.37	1.96	–	109.33
Titanium	–	–	12.00	12.00
Vanadium	160.19	–	–	160.19

3.6. MOLYBDENUM-TUNGSTEN-COPPER ORES

Molybdenum co-occurs with other metals of the porphyry type as well as in the stratabound copper deposits on the Fore-Sudetic Monocline and hard coal deposits in the Upper Silesian Coal Basin. However, the applied technological processes are not aimed at separation of this metal.

The Myszków deposit of molybdenum-tungsten ores with copper is situated at north-eastern margin of the Upper Silesian Coal Basin (Plate 3), in the contact zone of the Małopolska and Upper Silesian blocks separated by the Hamburg–Cracow tectonic zone. The deposit is of the Mo-W-Cu porphyry type. Its ore mineralization is of the stockworks type, forming a system of quartz veins with ore minerals sulfide and oxide related to Variscan igneous activities. Intensive drilling program from the years 1975–1992 made it possible detailed exploration of the Myszków deposit in area of 0.5 km^2 and down to the depth of 1,300 m. The exploration carried out in

1993 allowed to estimate inferred resources of the Myszków in the Polish C_2 resources category. Anticipated economic resources of ores occurring at depths down to 1,000 m were estimated at about 380 million tonnes, with 0.23 million tonnes of Mo, 0.18 million tonnes of W and 0.55 million tonnes of Cu and mean content of Mo and W equal 0.049 and 0.041%, respectively.

In the last years the economic resources of the Myszków deposit were re-evaluated to find that they are markedly larger than previously estimated, exceeding 550 million tonnes of Mo-W-Cu ores. Anticipated economic resources of the deposit were estimated at about 0.295 million tonnes of Mo, 0.238 million tonnes of W and 0.8 million tonnes of Cu, and anticipated sub-economic resources – at 0.298 million tonnes of Mo, 0.212 million tonnes of W and 0.771 million tonnes of Cu. The Myszków ores are not yet exploited. It should be added that according to the available data there are high chances for discovery of other deposits of Mo-Cu porphyry ores with tungsten in the contact zone of the Małopolska Block and Upper Silesian Block.

Numerous occurrences of Mo-W mineralization have been found in zones of Late Carboniferous granitoid intrusions in the Sudetes, but no concentrations of economic importance were found so far in this area. Molybdenum forms different genetic types of deposits which usually occur separately. Most important are porphyry type deposits (Mo-, and Cu-Mo-subtypes) and less important are skarns, greisens and hydrothermal veins, as well as Mo-bearing black shales (Mikulski *et al.*, 2012).

3.7. NICKEL ORES

Nickel ore deposits occur in the Lower Silesian region (Plate 3). These are deposits of nickel saprolitic type silicate ores formed in result of weathering of serpentinized mafic and ultramafic rocks. Exploitation of the major nickel ore deposit at Szklary in the vicinities of Ząbkowice Śląskie was phased out in 1983 as uneconomic. The remaining anticipated economic resources of that deposit were estimated at 14.64 million tonnes of ores with metallic nickel content of 117.0 thousand tonnes (limiting content of Ni in the deposit is 0.8%) (Tab. 8). The ore resources of the Grochów deposit were classified as anticipated sub-economic.

Nickel is also one of accompanying metals in copper ores from the Fore-Sudetic Monocline. The copper deposits yield about 64.71 thousand tonnes of nickel which is recovered in technological processes as nickel sulfides. In 2011, the processing of copper sulfide ores gave 2,481 tonnes of nickel sulfides.

Prognostic resources of Ni-layer silicate type ores in small and separate lenses in serpentinites waste around the Sowie Mts. Block gneisses (Lower Silesia) are estimated for *ca*. 25 thousand tonnes (Mikulski, 2012).

Table 8. Nickel ores resources in Poland

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	4	14.64 * 0.12 **	14.64 0.12	– –	22.48 0.09	– –
Including resources of non-exploited deposits						
Deposits covered by preliminary exploration	1	– –	0.00 0.00	– –	13.88 0.05	– –
Including abandoned deposits						
Total	3	14.64 0.12	14.64 0.12	–	8.60 0.03	–

* ore [million tonnes], ** metallic nickel [thousand tonnes]

3.8. TIN ORES

Tin is used for production of a wide variety of useful alloys, being most commonly alloyed with copper. Tin is also used for coating steel and other metals to prevent corrosion. Tin-plated steel cans and containers are widely used for food preservation but that application decreases due to growing replacement of tin with other materials.

Tin is mainly extracted from its base compound, usually cassiterite (SnO_2), occurring in the form of primary or secondary accumulations.

In Poland, tin ores occur in two deposits, Gierczyn and Krobica, in the Stara Kamienica Lower Paleozoic Schist Belt in the Sudetes (Plate 3). Tin resources of these deposits were classified as anticipated sub-economic because of their size and were estimated at 4.6 million tonnes of ore with Sn content about 0.5% at the average. Prospective resources of tin ore in the whole area of the Stara Kamienica Schist Belt were estimated at about 20 million tonnes, with the content of metallic tin of about 100,000 tonnes (Michniewicz, 2011).

3.9. ZINC AND LEAD ORES

The area of northern and north-eastern margin of the Upper Silesian Coal Basin has a long tradition of zinc and lead mining, dating back to the Middle Ages. Deposits occurring in that area are related to carbonate rock formations of the Silesian-Cracow region with Permo-Mesozoic successions resting monoclinally on the Paleozoic basement. Rocks hosting Zn-Pb mineralization range in age from the Devonian to Jurassic. Resources of economic importance are mainly related with ore accumulations in the so-called ore-bearing dolomites of the Muschelkalk (Middle Triassic). The ores occur in the form of pseudo-layers, sub-horizontal lenses and nest-like replacements. The Silesian-Cracow region is regarded as the world's largest area of occurrence of Zn-Pb deposits of the so-called Mississippi Valley type (MVT).

Four regions of Zn-Pb ore deposits are recognized in the Silesian-Cracow district: Chrzanów, Olkusz, Bytom and Zawiercie (Plate 3). Only the Klucze I, Olkusz and Pomorzany deposits in the Olkusz region are currently under exploitation. Zn-Pb deposits of the Bytom region are of historical and metallogenic importance only. The deposits have been exhausted in result of exploitation conducted since the Middle Ages and now comprise some sub-economic accumulations of mainly oxide ores. The same situation is recorded for the Balin-Trzebionka deposit in the Chrzanów region, where in 2010 mine was closed, because the reserves have been exhausted. Exploitation of deposits of the fourth region (Zawiercie) did not start up to now.

Zn-Pb concentrations occur also in copper ores of the Zechstein copper-silver deposits in the Fore-Sudetic Monocline. These concentrations are high enough for lead recovery in the course of copper concentrate treatment in smelters. According to the data provided by the KGHM Polish Copper S.A., in 2011 during the smelter copper processing was recovered 30 thousand tonnes of lead.

The highest increase of the sulfide Zn-Pb ore resources can be expected in the Silesian-Cracow region. Prognostic resources in Olkusz region amounted to 50 million tonnes and in the Zawiercie region to 15 million tonnes as of 31.12.2009 (Mikulski *et al.*, 2011a). Zinc oxide ore (galmans) prognostic resources are assessed to be equal 60 million tonnes, including 51 million tonnes in abandoned deposits and 9 million tonnes in mining dumps.

Estimates of Zn-Pb ores resources of the Silesian-Cracow region were markedly changing during the last 50 years. These changes resulted on one hand from intense exploration of the deposits and on the other – from crossing out the resources of zinc oxide ores (galmans) from the official records of domestic resources. This decision to cross out the resources was connected with high occupational and environmental hazards associated with technology used at that time in oxide ore processing. The problems in technology were finally solved. Therefore, it appeared necessary to introduce special criteria for classification of Zn oxide ore resources not meeting those of the sulfide ores. Such separate criteria for Zn oxide ore resources were established by the Regulation of the Minister of the Environment on classification for mineral reserves and resources of 9 January 2007. Anticipated economic resources of Zn-Pb ores as of 31.12.2011 were equal 79.01 million tonnes of ore yielding 3.52 million tonnes of zinc and 1.48 million tonnes of lead (Tab. 9).

Table 9. Zinc and lead ores resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	20	79.01 * 3.52 ** 1.48 ***	37.90 1.68 0.76	41.11 1.84 0.73	57.03 1.96 0.56	11.39 0.51 0.21
Including resources of exploited deposits						
Deposits of operating mines	3	19.42 0.81 0.31	19.42 0.81 0.31	– – –	7.45 0.25 0.13	11.39 0.51 0.21
Including resources of non-exploited deposits						
Total	13	59.59 2.71 1.17	18.49 0.86 0.44	41.10 1.85 0.73	6.19 0.23 0.06	–
1. Deposits covered by detailed exploration	6	53.29 2.45 1.04	18.49 0.86 0.44	34.80 1.59 0.60	3.50 0.11 0.03	–
2. Deposits covered by preliminary exploration	7	6.30 0.26 0.13	–	6.30 0.26 0.13	2.69 0.12 0.03	–
Including abandoned deposits						
Total	4	–	–	–	43.38 1.48 0.37	–

*ore, **metallic zinc, ***metallic lead

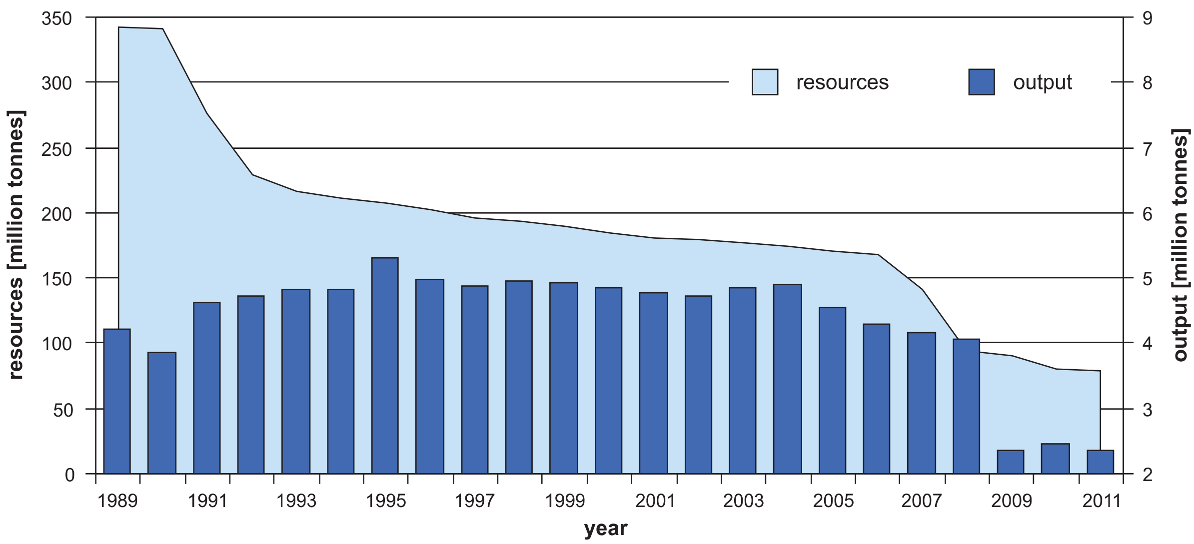

Fig. 7. Zinc and lead ores anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

In 2011, Polish mines extracted 2,345 thousand tonnes of ores yielding 82 thousand tonnes of zinc and 28 thousand tonnes of lead. The domestic production of ores is too small for full use of production potential of Zn-Pb processing plants.

The anticipated economic resources decreased in the years 1989–2011 from 343 million tonnes to below 80 million tonnes – mainly due to the changing criteria for estimating of the anticipated economic resources and excluding some resources from the Polish mineral resources balance (years: 1991, 1992, 2008) (Fig. 7). The resources drop took place also because of the exploitation and losses. The exploitation in the Balin-Trzebionka mine was ended in 2010 and the output decreased to 2.3 million tonnes in 2009 and to 2.4 million tonnes in 2010.

4. CHEMICAL RAW MATERIALS

4.1. BARITE AND FLUORSPAR

Due to high specific gravity, barite ($BaSO_4$) is currently used mainly as a weighting agent in well drilling. It is used in paper and chemical and paint industry is gradually shrinking at the advantage of artificially produced titanium white (titanium dioxide).

Fluorspar (CaF_2) is used as a flux in metallurgy (in steel production to aid the removal of impurities, and in production of aluminum) and in ceramics and chemical industry.

In recently abandoned mine operations in the Boguszów and Stanisławów deposits (Lower Silesia), barite occurs in paragenesis with fluorspar so the deposits are discussed jointly. Economic accumulations of barite also occur in the Holy Cross Mts. (Plate 4).

In the Boguszów and Stanisławów deposits, barite accumulations are related to veins of various length and width, generally very steeply dipping and representing fissure fills along faults. Mean content of $BaSO_4$ in these veins is about 80% and that of fluorite – from a few to over a dozen percent. It should be noted that content of fluorite generally increases along with depth. The mine at Boguszów was completely flooded during catastrophic flood of July 1997. The mine was abandoned in result of that damage and the deposit reclassified as potentially economic only. In the next year, also the mining operations in the Stanisławów deposit were abandoned as insufficiently profitable. Some decades ago, barite was also extracted from

Table 10. Barite and fluorspar resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
BARITE						
TOTAL RESOURCES	5	5.66	1.91	3.75	0.89	–
Including resources of non-exploited deposits						
Deposits covered by preliminary exploration	1	0.36	–	0.36	0.08	–
Including abandoned deposits						
Total	4	5.30	1.91	3.39	0.81	–
FLUORSPAR						
TOTAL RESOURCES	2	0.54	–	0.54	0.06	–
Including resources of non-exploited deposits						
Deposits covered by preliminary exploration	1	–	–	–	0.06	–
Including abandoned deposits						
Total	1	0.54	–	0.54	–	–

the Strawczynek deposit in the Holy Cross Mts. (Plate 4). In that deposit, barite occurs in the form of irregular nests and intergrowths in carbonate rocks of the Lower Devonian. The mining operation was abandoned because of low content of $BaSO_4$ (about 30%) and small resources of the deposit. Currently, the whole domestic demand for barite and fluorspar is covered by import.

Anticipated economic resources of barite are estimated at 5.66 million tonnes and those of fluorspar – at 0.54 million tonnes (Tab. 10). In view of increasing demand for barite there are plans to restart the exploitation of barite deposits (especially Stanisławów). Prognostic resources of barite amounted to 2.5 million tonnes and prospective resources to 1.67 million tonnes as of 31.12.2009 (Sroga, 2011a).

4.2. CLAY RAW MATERIALS FOR PRODUCTION OF MINERAL PAINTS

Mineral pigments are the main materials for production of mineral paints. They are also used for oil paints, varnishes, enamels, putties etc. In the production of mineral paints chalk, barite, gypsum and burnt lime are also used as mineral fillers. The most important pigments are: ochre, umbra, terra di Siena, iron minium, browns and earth green.

In Poland so far two deposits of ochre, argils and ochre claystones have been explored near the Kielce (Buk and Baczyna) (Plate 4). In these deposits, in argilic measures of Lower Jurassic, ochre makes lens accumulations. In Baczyna deposit there are three types of ochre occurring. They are documented in C_1 category: yellow – 67.5 thousand tonnes, red – 247 thousand tonnes and brown – 281.3 thousand tonnes. In Buk deposit there are only anticipated sub-economic resources documented. Both deposits are undeveloped.

4.3. DIATOMACEOUS ROCK

Diatomites are firm sedimentary rocks mainly built of diatom skeletons composed of amorphous silica – opal. A closely related is diatomaceous earth, a loose rock. Diatomites and diatomaceous earth are widely used as a filtration aid, absorbents for liquids, carriers for herbicides and fungicides and contact agent carriers in chemical industry, they are also used as thermal insulators and a mild abrasive. No typical diatomites with SiO_2 content over 80% were found in Poland. Therefore, despite of differences in origin and mineralogical composition, siliceous earth is treated as a substitute of diatomites and diatomaceous earth. The siliceous earth is discussed in a separate section of this report.

In the Leszczawka area (Carpathian Mts.) diatomite rocks with SiO_2 content equal 72% at the average occur in the Menillite Series of the Krosno Beds (Plate 4). Products obtained from that mineral raw material are of fairly limited usability. Their major uses comprise production of light building aggregates and carriers for

Table 11. Diatomaceous rock resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
Including resources of exploited deposits						
TOTAL RESOURCES	4	10.02	3.28	6.74	2.74	0.20
Deposits of operating mines	1	0.64	0.44	0.20	–	0.20
Including abandoned deposits						
Total	3	9.38	2.84	6.54	2.74	–

herbicides and fungicides. It should be noted that technological tests show that appropriate processing (grinding and calcination) may improve quality of this raw material.

Anticipated economic reserves of diatomite rocks amount to 10 million tonnes (Tab. 11). In 2011, extraction of diatomite was being carried out at a small scale at Jawornik (0.58 thousand tonnes). In previous years diatomite rocks were extracted from time to time also from the Kuźmina deposit but that operation was stopped in 2001.

Prospective resources of diatomaceous rock in the Leszczawka area are estimated at about 10 million tonnes. Chances for discovery of new large diatomite deposits seem to be the highest in the case of the Menillite Series of the Krosno Beds in areas of Godowa, Błażowa–Piątkowa–Harta–Bachórz and Dydynia–Krzywe (Podkarpackie Voivodeship).

4.4. POTASSIUM AND MAGNESIUM SALT

In Poland, distribution of potassium-magnesium salts appears limited by the extent of the Zechstein salt formation. Together with rock salt they form two separate lithostratigraphic units – the Older and Younger Potash units of the Zechstein. The units are traceable in the Polish Lowlands where they were recorded in countless drillings as well as several salt structures in central Poland and layers in south-western part of the Fore-Sudetic Monocline (Plate 4).

Anticipated economic resources of five proven deposits of potassium-magnesium salts were estimated at 670 million tonnes and anticipated sub-economic resources at 20 million tonnes (Tab. 12). The sulfate (polyhalite) salt deposits of the Bay of Puck form the bulk of these resources. The deposits of the Bay of Puck area are of the sulfate (polyhalite) salt type, with polyhalite occurring in form of early diagenetic minerals developed in anhydrite layers which underlay and intercalate and overlay the oldest rock salt bed of the Zechstein. Polyhalite inclusions are present as irregularly disseminated nests and aggregate intergrowths in depth interval from 740 to 900 m. The K_2O content ranges from 7.7 to 13.7% in that depth interval. The deposits situated along the rim of the Pucka Bay rock salt deposit were covered by preliminary exploration in the years 1964–1971. Their indicated resources were estimated at 597 million tonnes assuming regular distribution of polyhalite mineralization.

Small accumulations of potassium salts (more than 72 million tonnes) were identified along eastern margin of the Kłodawa salt pillow, where salts of the potassium chloride type (carnalite and sylvine) occur in rocks of the Younger Potash unit, steeply inclined (at the angle of 70°) and folded and locally squeezed and crumple. The chloride salts are strongly contaminated with clay matter and sulfates. Mean contents of K_2O and MgO are 8.5 and 8.1%, respectively. The potassium salt accumulations are of minimal economic interest due to high variability in thickness of the strata (from a few to 50 m) and problems in processing of the raw material. The salts were exploited seasonally till the year 2000 when 1,400 tonnes were mined. In the next years this part of the salt deposit became abandoned.

Table 12. Potassium-magnesium salt resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	5	669.84	12.38	657.47	20.32	2.74
Including resources of non-exploited deposits						
Total	5	669.84	12.38	657.47	20.32	2.74
1. Deposits covered by detailed exploration	1	72.82	12.38	60.44	1.46	2.74
2. Deposits covered by preliminary exploration	4	597.03	0.00	597.03	18.85	–

Potassium salt deposits are explored to the depth of 1,200 m. The two meters thickness is accepted as the minimum, providing that the weighted average K_2O content in the deposit is not lower than 8%. Potassium-magnesium salts resources has slightly changed since 2010 (anticipated economic resources increased by 0.73 million tonnes and anticipated sub-economic resources by 1.46 million tonnes) due to verification of Kłodawa 1 deposit resources.

In 2010 potassium-magnesium salts prognostic resources (to the depth of 1,000 m) amounted to 719.44 million tonnes, whereas prospective resources amounted to 300 million tonnes to the depth between 1,000 and 2,000 m (Czapowski, Bukowski, 2011).

Table 12 shows resources and the current state of exploration and development of potassium-magnesium salts. The data refer to exploitable resources (that is except of those remaining in safety pillars).

Potassium-magnesium salts have not been exploited in Poland since 2000 and their anticipated economic resources have not changed significantly in last 10 years. There was slight growth by 0.73 million tonnes within anticipated economic resources and by 1.46 million tonnes within anticipated sub-economic resources – due to more detailed documentation of Kłodawa 1 deposit resources.

4.5. ROCK SALT

Major Polish rock salt deposits are related to the Miocene and Zechstein halite formations.

Deposits of the Miocene formation are situated in a belt extending from the Silesian region to Wieliczka and Bochnia and further eastwards up to the Poland-Ukraine border (Plate 4) and running along and close to the present-day frontal overthrust of the Carpathian Mts. on their foredeep. In the Wieliczka area the salt was produced from the Middle Ages right through into the 20th century. Exploitation of these deposits ended in 1996 when salt mining was phased out in the Wieliczka mine. The proven resources of Miocene rock salt deposits are estimated to be over 4.36 billion tonnes, accounting for 5.13% of domestic resources. However, geological structure of these deposits is very complex due to intense folding (except for the Rybnik–Żary–Orzesze deposit which is situated in a tectonic trough). That complexity of geological structure along with markedly varying salt quality and high risks of water flooding and methane inflow to mining works were the reasons why further mining of these deposits became practically uneconomic. The Wieliczka mine was included on the UNESCO World Heritage list in 1978. Nowadays the Wieliczka and Bochnia mines are great tourist attractions and recreation centers.

The Zechstein halite formation is at present the major source of mined salt in Poland. The salt-bearing series are distributed throughout two-thirds of area of the country, mainly in the Polish Lowlands (Plate 4). In the Late Permian these areas were occupied by evaporitic epicontinental basin which was the place of accumulation of salt sediments with total thickness of over 1,000 m. Bedded rock salt accumulations were explored down to 1,000 m depth in marginal parts of the basin and in the Łeba Elevation and the Fore-Sudetic Monocline. Anticipated economic resources of these deposits are estimated at almost 25 billion tonnes, which accounts for 29.42% of domestic salt resources. In turn, in axial part of the basin (Central Poland) the salt-bearing series are buried at depths up to 7 km, locally rising almost to the surface in salt dome- and pillow-like structures. The salt structures occur in a belt stretching from Wolin in the northwest to the vicinities of Bełchatów in the south-east. Deposits of rock salt and potassium-magnesium salt were explored and proved in a number of the shallowest of these structures. Proven anticipated economic resources of deposits related to the salt structures are estimated at more than 55.6 billion tonnes, which accounts for 65.45% of domestic salt resources. Exploitation of the latter deposits gives 100% of the current domestic production of salt (excluding exploitation of rock salt deposit – within overburden of copper deposit Sieroszowice).

Large bedded rock-salt deposits were also explored in the overburden of the Sieroszowice and other copper ore deposits in the Fore-Sudetic Monocline. In that area, some production of rock salt is already carried out within the frame of surveying and development works.

Bedded rock-salt deposits are explored down to the depth of 1,200 m, providing that the deposit series (including partings) is at least 30 m thick and minimum weighted mean of NaCl in the deposit series and partings equals at least 80%. In accordance with the Polish regulations, salt deposits related to the dome and pillow salt structures are explored down to 1,400 m, providing that the distance between top surface of salt deposits and salt mirror is not smaller than 150 m. The remaining requirements are the same as in the case of the bedded deposits. At present the salt deposits begin to be treated as geological objects especially advantageous for construction of underground facilities for storage of oil and natural gas and liquid fuel (such as already operating Mogilno II and Góra) and safe disposal sites for hazardous materials.

The anticipated economic resources of rock salt (excluding those within protective pillars) in 2011 amounted to 84.98 billion tonnes, decreasing by 356 million tonnes (0.42% of domestic resources) in relation to the previous year. Economic resources in place increased by 273.9 million tonnes (mainly due to the new estimation of Kłodawa 1 deposit resources). Anticipated sub-economic resources increased by 21 million tonnes (Tab. 13).

In 2010 the Zechstein rock salt prognostic resources amounted to 192.46 billion tonnes (to the depth of 2,000 m), whereas prospective resources were estimated on 2.062 billion tonnes (Czapowski, Bukowski, 2011). Prospective resources of Miocene formation in three regions (to the depth from 1,000 to 1,500 m) are equal 2.45 billion tonnes and prospective resources of Pogórska Wola region (to the depth of 1,500–2,000 m) are estimated on 44 million tonnes. Total prognostic resources of rock salt in Poland amounted to 194.904 billion tonnes and prospective resources – 2.062 billion tonnes.

Table 13 shows resources and the current state of exploration and development of domestic rock salt deposits. Data refer to resources excluding those within protective pillars.

In 2011 about 2,718 thousand tonnes of salt were produced by solution mining method (Góra and Mogilno I and II mines), which accounts for 71.7% of domestic production. Moreover, 739 thousand tonnes of crushed salt were extracted in the Kłodawa mine (19.5% less than in the previous year) and 494 thousand tonnes of salt from the overburden of the Sieroszowice mine.

In 2005 and 2006 anticipated economic resources remained on the level of 80 billion tonnes. Within next three years resources increased and amounted to 85.4 billion tonnes, mainly due to the updating of assessments of Mogilno I and Mogilno II (in Mogilno salt dome) and Mechelinki (near Pucka Bay) resources. In 2011 resources did not exceed 85 billion tonnes (Fig. 8).

Rock salt production has been changing significantly in the analyzed period – the main factor was domestic demand for brine used to calcined soda production and crushed salt. Till 2003 production did not exceed 3.3 million tonnes per year, then there was significant growth – almost 4 million tonnes per year in 2004. In the period 2005–2009 production decreased by 25%. Increasing demand was recorded in 2010–2011 (due to the start of Underground Gas Storage Facility Kosakowo on Mechelinki deposit building) and production amounted to 3.8 million tonnes per year.

Table 13. Rock salt resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	18	84,978.01	43,519.34	41,458.67	20,698.83	1,255.17
Including resources of exploited deposits						
Deposits of operating mines	5	15,124.64	8,660.26	6,464.37	28.78	1,255.17
Including resources of non-exploited deposits						
Total	10	69,665.49	34,779.39	34,886.10	20,482.80	–
1. Deposits covered by detailed exploration	4	25,470.04	23,818.98	1,651.07	10,017.78	–
2. Deposits covered by preliminary exploration	6	44,195.45	10,960.42	33,235.03	10,465.02	–
Including abandoned deposits						
Total	3	187.88	79.68	108.20	187.25	–

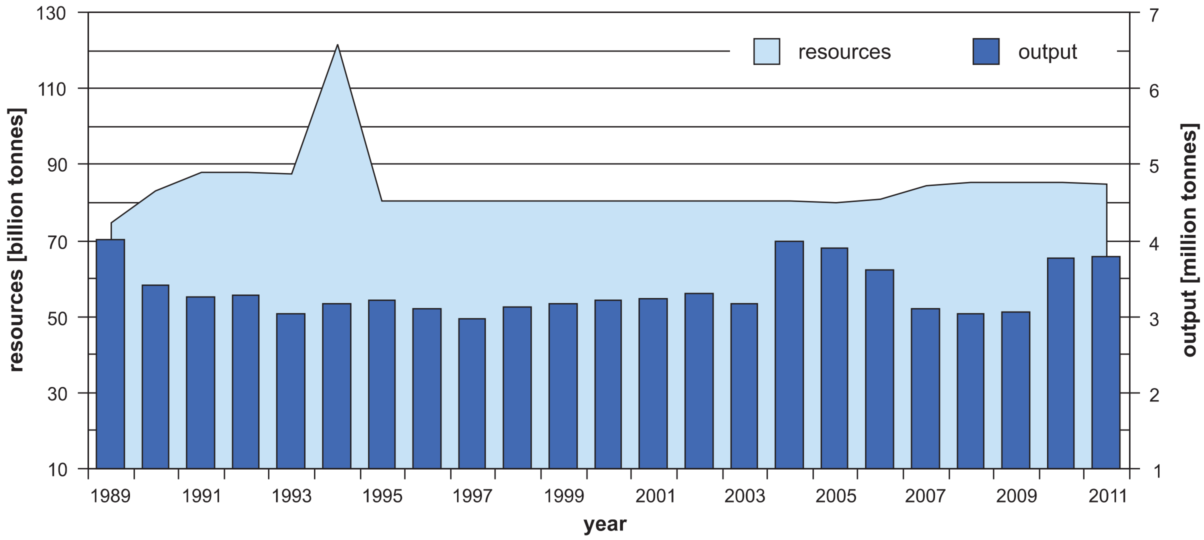

Fig. 8. Rock salt anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

In 2011 the Dębieńsko Desalination Plant Ltd. recovered 86,622 tonnes of evaporated salt with NaCl content of about 98% from treatment of brines and salty water from Upper Silesian coal mines. This means a 0.6% decrease in production in relation to the previous year (87,110 tonnes).

4.6. SILICEOUS EARTH

Siliceous earth resembles diatomites in physical features and, therefore, finds similar use in the industries. It is used as carrier for catalysts in chemical processes and for mineral fertilizers and herbicides, pesticides and fungicides in agriculture as well as raw material for refination and filtration and constituent of synthetic moulding mass. Siliceous earth differs from diatomites in the mode of origin as it is the product of decalcification of opoka sedimentary rocks and mainly built of opal, a mineraloid gel.

Deposits of siliceous earth occur mainly in tectonic troughs at the margin of the Holy Cross Mts. (Piotrowi-

Table 14. Siliceous earth resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	5	2.22	1.09	1.13	1.01	0.00
Including resources of exploited deposits						
Deposits exploited temporarily	1	0.01	0.01	–	–	0.00
Including abandoned deposits						
Total	4	2.22	1.08	1.13	1.01	–

ce and Dąbrówka deposits) and in the Lublin Upland (Lechówka), in the form of sedimentary covers overlain by Oligocene rocks (Plate 4).

The Lechówka II deposit is the only siliceous earth deposit periodically exploited in Poland and output was very low, changing from a few tonnes in 2002 to none in 2008. Exploitation of the remaining deposits has been phased out in the last decades due to unsatisfactory quality of the obtained raw material, mainly usable for making insulation powder.

Anticipated economic resources amounted to 2,223 thousand tonnes in 2011 (almost 50% in A+B+C_1 categories) (Tab. 14). Domestic demand for siliceous earth is fully covered by import.

4.7. SULFUR

Native sulfur deposits occur in the vicinities of Tarnobrzeg (Osiek, Baranów, Machów and Jeziórko deposits), Staszów (Solec and Grzybów deposits) oraz Lubaczów (Basznia deposit) in northern part of the Carpathian Foredeep (Plate 4). Sulfur occurs in the form of fillings of fissures and small cavities in Neogene rocks, mainly post-gypsum limestones. Its origin was connected with reduction of calcium sulfate (gypsum) by microorganisms in presence of hydrocarbons. Content of sulfur in these rocks may reach up to 70% at the most, ranging from 25 to 30% at the average.

Poland was one of the world's largest producers of sulfur till the 1980s. However, the growth in the recovery of sulfur from sour natural gas and crude oil caused a significant decrease in importance and value of native sulfur deposits.

The production of native sulfur is at present limited to the Osiek deposit where sulfur is mined using the Frasch hot water method. The Osiek mine remains the last large native sulfur mine in the world. Outside Poland small amounts of native sulfur are produced from deposits of volcanic origin. There are four sour gas and oil fields in Poland. Their total resources of sulfur were estimated at 571 thousand tonnes. Sulfur is recovered from sour gas and oil in the Zielin, BMB, Cychry and (from time to time) Górzyca deposits.

Recovery of sulfuric acid in processing of copper and zinc and lead ores is of limited economic importance, being conducted mainly for protection of the natural environment. Production of sulfuric acid on the basis of pyrites was given up several decades ago.

Table 15. Sulfur resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	18	512.31	455.89	56.42	35.67	26.05
Including resources of exploited deposits						
Total	5	26.43	26.43	–	0.57	26.05
1. Deposits of operating mines	4	26.43	26.43	–	0.57	26.05
2. Deposits exploited temporarily	1	–	–	–	–	0.00
Including resources of non-exploited deposits						
Total	7	256.69	201.16	55.53	14.64	–
1. Deposits covered by detailed exploration	4	158.94	158.94	–	5.89	–
2. Deposits covered by preliminary exploration	3	97.75	42.23	55.53	8.76	–
Including abandoned deposits						
Total	6	229.19	228.30	0.89	20.46	–

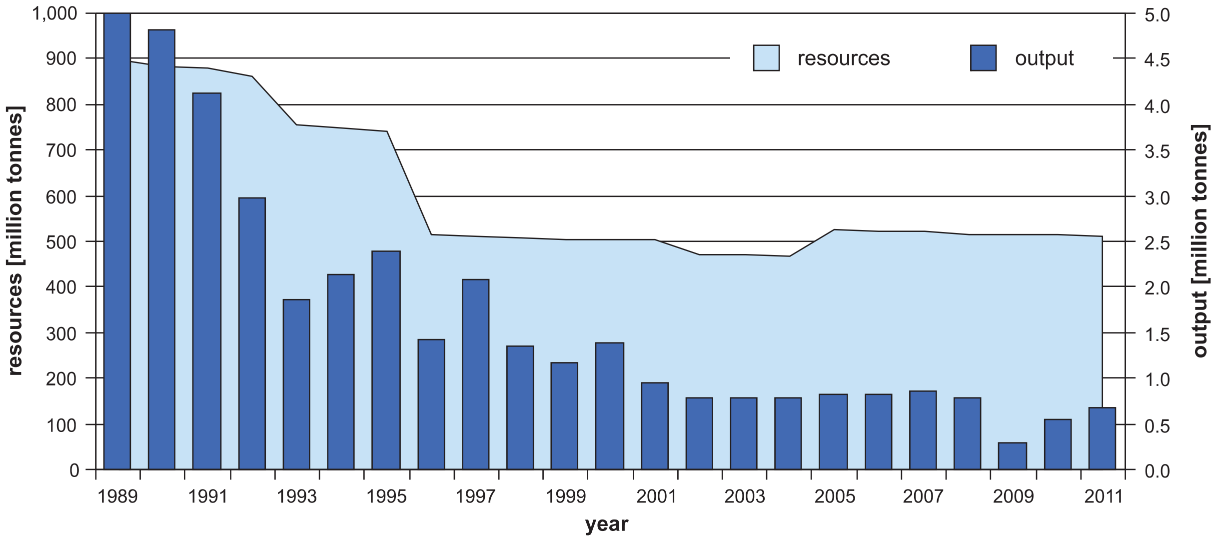

Fig. 9. Sulfur anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

Prognostic and prospective sulfur resources are relatively small and amounted to 55 and 17 million tonnes respectively (Gąsiewicz, 2011).

Anticipated economic resources amounted to 512 million tonnes in 2011 (Tab. 15). Production of sulfur in 2011 accounted for 681 thousand tonnes including 23 thousand tonnes of sulfur which was by-product of desulfurization of sour natural gas.

The domestic resources and production of native sulfur in Poland in the years 1989–2011 are presented in Figure 9. Both parameters dropped substantially in the 1990s. Then there were no significant changes within the anticipated economic resources, whereas the output declined visibly in 2009 – due to the diminished production from the Osiek deposit.

5. ROCK RAW MATERIALS AND OTHERS

5.1. AMBER

The amber ascertained in Poland occurs in Paleogene and Quaternary formations. The biggest accumulations of amber in Paleogene sediments are connected with the northern marginal zone of the Eocene Sea. In the northern zone amber has agglomerated in the sandy-silty sediments with glauconite in the Eridan river delta (the so-called chłapowsko-sambijska delta). In the southern zone of the Eocene Sea the amber-bearing sediments (silts and sands with glauconite) were also formed in the delta zone, the so-called Parczew delta. The third amber occurrence in Paleogene sediments is the Możdżanowo region near the Słupsk in northern Poland. Big amber concentrations are also encountered on the Baltic beaches from Kołobrzeg to the eastern border of Poland.

According to the law standards (in force since 1.01.2002) the maximum depth of amber deposits documentation is 30 meters and the minimum efficiency for anticipated economic resources is 80 g/m^2 and for anticipated sub-economic resources is 40 g/m^2. Anticipated economic resources as of 31.12.2011 amounted to 1,118 tonnes of amber within four deposits: Górka Lubartowska, Możdżanowo, Wiślinka I and Przeróbka-SL.

Górka Lubartowska deposit (Lubelskie Voivodeship) is explored in D category and covers the area of 295.88 ha, resources are estimated at 1,088 tonnes with the average thickness of 12.4 meters. Resources of Możdżanowo deposit are estimated at 10 tonnes of amber and prospective resources are estimated at 20 tonnes. Wiślinka I deposit has resources amounted to 2.7 tonnes (deposit has not been exploited since 2000). Przeróbka-SL deposit covers the area of 12.8 ha.

The amount of amber collected on the Baltic beaches is estimated at 4–6 tonnes/year.

5.2. BENTONITES AND BENTONITIC CLAYS

Primary bentonites are produced in result of weathering of extrusive and pyroclastic rocks and usually display parent rock structure. In turn, bentonite clays originate due to redeposition of bentonite material and often yield fairly large admixture of foreign mineral components. Bentonite clays which form a weathering mantle developed on the Jawor–Męcinka and Krzeniów basalts were explored as mineral deposits accompanying those of basalts.

Rocks rich in smectite group minerals have some common features such as: ability to swell, their susceptibility to the dispersion of water, their easy absorption of cations and organic substances from water solutions. Therefore, these rocks are utilized for example in the foundry, drilling and ceramic industries.

In Poland typical bentonites, i.e. containing more than 75% montmorillonite, occur very seldom. More common are bentonite clays, such as:

- bentonite weathering cover of basalts in Lower Silesia,
- bentonite clays in Upper Silesia,
- bentonite clays of southern fringes in the Holy Cross Mountains,
- bentonite clays in the Carpathian Mountains (Plate 7).

Anticipated economic resources of bentonites and bentonite clays were estimated at 2.71 million tonnes and the economic resources of these mineral raw materials – at 0.50 million tonnes (Tab. 16).

Table 16. Bentonites resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	7	2.71	0.99	1.72	0.25	0.50
Including resources of exploited deposits						
Deposits of operating mines	1	0.50	0.29	0.21	–	0.50
Including resources of non-exploited deposits						
Total	4	2.15	0.70	1.45	0.25	–
1. Deposits covered by detailed exploration	2	1.23	0.70	0.53	0.25	–
2. Deposits covered by preliminary exploration	2	0.92	0.00	0.92	–	–
Including abandoned deposits						
Total	2	0.07	0.01	0.06	0.01	–

At present, the only active bentonite mine is that from Krzeniów where accumulations of bentonite clays form a deposit accompanying that of basalts. Exploitation of bentonites in that mine is carried out from time to time and on a limited scale only and in 2011 amounted to 0.91 thousand tonnes.

5.3. BUILDING CERAMICS RAW MATERIALS

Mineral raw materials used in the industry of building ceramics are varying in age and origin and in Poland come from deposits ranging in age from the Permian to Quaternary. The deposits are distributed practically throughout the whole country. However, they are more common and larger in the south also their differentiation appears higher than in other parts of the country.

Main raw materials used for building ceramics production are clay rocks. Their suitability depends on their plasticity after they are mixed with water. If the plasticity is too high, the mix is corrected by adding such ingredients as sand, crushed brick and fly ash and sawdust. Clay and non-clay raw materials very often occur together – in one deposit. In loess clayey minerals content is low (couple of%), but in clays it can be 100%. Usually the content is between 40–60%. Other components are quartz sand and dust, feldspars, calcite and dolomite, iron minerals, mica minerals and organic matter. From these materials are produced ceramic bricks and breezeblocks, slates, clinker bricks, ceramic pavements.

The most important raw materials of the Quaternary age include stagnant lake sediments such as muds and clays occurring mainly in northern and central Poland as well as loess, glacial tills, alluvial sediments and those of weathering covers and sands. The most important raw materials of the Neogene age include clays of the so-called Poznań Series from south-western and central Poland and those of the Krakowiec Clays from the area of the Carpathian Foredeep in south-eastern Poland. The Triassic and Jurassic deposits are situated at the margin of the Holy Cross Mts. and in the Częstochowa and Opole regions (Plate 5).

According to the Regulation of the Minister of the Environment of the 22nd of December 2011 (Official Journal of 2011 No. 291, Item 1712) the limit values of the parameters that defines the deposit are:

- the maximum documentation depth – to the depth of possible exploitation;
- the minimum thickness of the deposit – 2 meters;
- the maximum overburden/thickness ratio – 0.5;

Table 17. Building ceramics raw materials resources in Poland [million m^3]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	1,240	2,022.35	681.64	1,340.71	52.18	161.41
Including resources of exploited deposits						
Total	263	260.06	223.52	36.54	3.99	136.77
1. Deposits of operating mines	187	196.15	169.50	26.66	3.29	100.58
2. Deposits exploited temporarily	76	63.91	54.02	9.88	0.70	36.18
Including resources of non-exploited deposits						
Total	321	1,453.78	184.30	1,269.48	22.39	1.02
1. Deposits covered by detailed exploration	247	236.40	184.30	52.09	11.80	1.02
2. . Deposits covered by preliminary exploration	74	1,217.39	0.00	1,217.39	10.60	–
Including abandoned deposits						
Total	656	308.51	273.82	34.69	25.80	23.62

- the maximum content of grains bigger than 2 mm – 1%;
- the maximum content of ceramic marl with grains diameter bigger than 0.5 mm – 0.4%;
- the shrinkage in drying minimum 6%.

Anticipated economic resources amounted to 2,022.35 million m^3 in 2011 (about 4,044.70 million tonnes) and increased by 2.28 million m^3 (about 4.56 million tonnes) – there were 23 new deposits documented whereas only 13 deposits crossed out of “The balance…” (Tab. 17).

Out of the total anticipated economic resources 12.9% are within exploited deposits, 71.9% are within non-exploited deposits and 15.3% are within abandoned deposits. Out of 1,240 known deposits of building ceramics clays, 21.2% deposits are exploited (including 15.1% deposits exploited continuously and 6.1% – exploited from time to time) and 25.9% deposits are non-exploited (including 19.9% deposits covered by detailed exploration and 6.0% – covered by preliminary exploration). The remaining 52.9% of deposits were abandoned.

Economic resources within 157 deposits amounted to 161.41 million m^3 (about 322.82 million tonnes) and decreased by 3.63 million m^3 in comparison with the previous year. In 2011, production of building ceramics clays was equal 2.31 million m^3 (about 4.62 million tonnes). This means that it was only slightly higher (by 0.15 million m^3) than in the previous year (Fig. 10).

The production in the years 2005–2011 varied in the range of 2.1–2.7 million m^3 (the average 2.4) then in 2007–008 increased significantly to about 3.3 million m^3 due to the market deficit of building materials and soaring prices. Majority of the mineral commodity is being produced in the south and in the north of Poland. About 50–60% of domestic production comes from 5 voivodeships located along the southern border (Dolnośląskie, Opolskie, Śląskie, Małopolskie, Podkarpackie), another 15–25% from voivodeships located in the central part of Poland (Mazowieckie and Świętokrzyskie), remaining 9 voivodeships account for 25% of domestic production.

In the years 2005–2011 anticipated resources increased by 36.3 million m^3. The highest increase was noted for Neogene and Quaternary varved clays mainly used for ceramic breezeblocks and for Triassic clinker commodities used for clinker bricks, slates and ceramic tiles production.

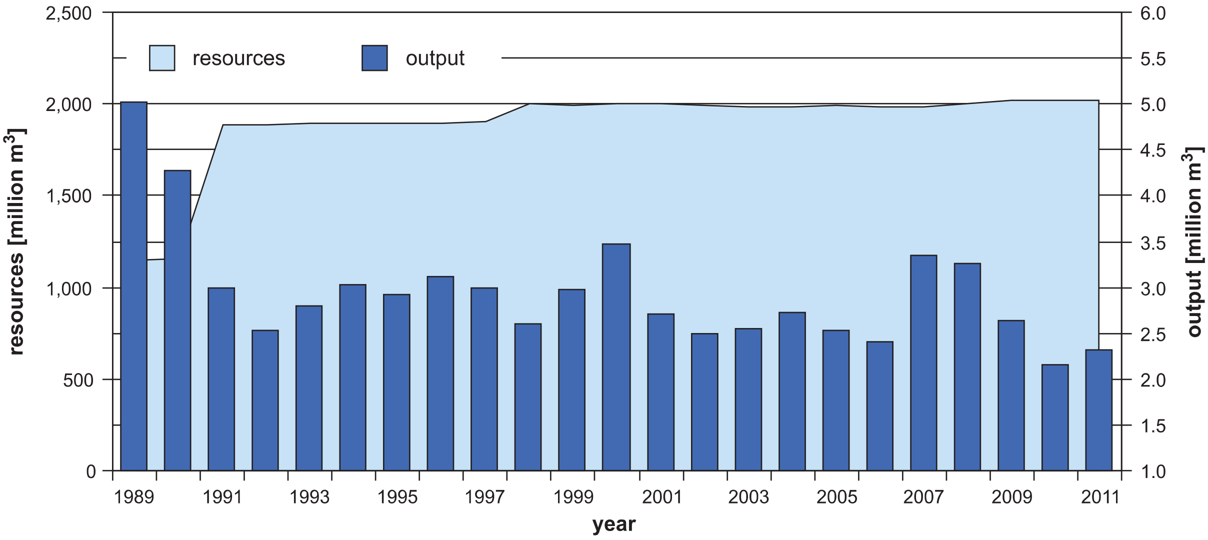

Fig. 10. Building ceramics raw materials anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

5.4. CALCITE

Calcite is used in ceramic industry. In the past, it was used in glass industry and as the fancy stone. Vein of calcite occur in Paleozoic limestones in Holy Cross Mountains and near the city of Krakow. Calcite deposits were recognized in Świętokrzyskie Voivodeship. Anticipated economic resources in four deposits are estimated at 287 thousand tonnes. Only in Radomice I deposit calcite is occurring as the main raw material, in others calcite is co-occurring with limestones as the main raw material.

There has not been calcite exploitation carried on in Poland since 1998. In Skrzelczyce deposit there are Devonian limestones exploited for road and building purposes.

5.5. CERAMIC CLAYS

Ceramic clays are generally represented by sedimentary clays of marine or lacustrine origin and with minerals of the kaolinite and illite group as the major rock-forming components. The clays, also known as kaolin rocks, are raw material for production of whiteware ceramics such as porcelain and bone china.

From the process technology point of view, the fired products may be assigned to whiteware and stoneware. Whiteware ceramic clays, attaining almost 50% whiteness when fired at temperature of 1,300°C, are used to produce porcelite and faience. In turn, stoneware products are characterized by very low level of water absorption and high mechanical and chemical resistance.

The majority of deposits of ceramic clays occur in the Lower Silesian region (Bolesławiec Clays) and the Świętokrzyskie Voivodeship (Plate 7). The Bolko II, Janina and Ocice deposits of white firing stoneware clays are related to intercalations of kaolinite clays in sandstones of the Upper Cretaceous.

The other lithological type includes ceramic clay deposits such as Nowe Jaroszowice and Janina-Zachód and Janina I. These deposits are related to poorly coherent sandstones with cement rich in kaolinite. The usable fraction is separated from these rocks by water-washing and the obtained concentrate contains about 30% of kaolinite clay.

In 2011 anticipated economic resources of whiteware ceramic clays amounted to 59.2 million tonnes and decreased by 0.14 million tonnes and production of these clays was equal 130.88 thousand tonnes and was coming from the Janina I deposit only (Tab. 18).

Table 18. Whiteware ceramic clays resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	6	59.20	2.59	56.61	0.05	0.63
Including resources of exploited deposits						
Total	1	2.19	1.50	0.70	–	0.63
Including resources of non-exploited deposits						
Total	3	56.46	0.57	55.89	–	–
1. Deposits covered by detailed exploration	1	0.57	0.57	–	–	–
2. Deposits covered by preliminary exploration	2	55.89	0.00	55.89	–	–
Including abandoned deposits						
Total	2	0.55	0.53	0.02	0.05	–

Stoneware ceramic clays occur in the Lower Silesian region and central parts of the country (Plate 7). In 2011 anticipated economic resources of stoneware ceramic clays amounted to 77.12 million tonnes (Tab. 19). Production of stoneware ceramic clays was equal 215 thousand tonnes and was coming from three deposits – Zebrzydowa Zachód, Paszkowice and Baranów.

Table 19. Stoneware ceramic clays resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	21	77.12	29.46	47.66	15.92	9.11
Including resources of exploited deposits						
Total	3	9.59	9.18	0.42	5.13	9.11
Including resources of non-exploited deposits						
Total	10	57.88	12.15	45.73	8.40	–
1. Deposits covered by detailed exploration	6	15.40	12.15	3.25	2.30	–
2. Deposits covered by preliminary exploration	4	42.48	0.00	42.48	6.11	–
Including abandoned deposits						
Total	8	9.65	8.13	1.52	2.39	–

5.6. CHALK

In Poland, chalk is the name traditionally given to two different mineral raw materials: lacustrine chalk (calcareous tufa) and proper chalk rock (still often called as "writing chalk" in Polish literature). The raw materials differ in origin and chemical composition and use.

Writing chalk is a weakly coherent and porous limestone rock, mainly used in the manufacture of rubber, paper, chemicals, dyes and cement. Cretaceous limestones of the chalk type used in production of cement (Chełm deposit) are discussed in the section dealing with limestone and marl for the cement industry. Chalk deposits found in north-eastern Poland are related to erratic of Cretaceous chalk embedded in Quaternary glacial sediments. Most deposits occur in Łosicki County (Mazowieckie Voivodeship). Single deposits are also located in Podlaskie and Pomorskie voivodeships.

Lacustrine chalk, also known as "meadow limestone" or "lacustrine limestone", is calcareous sediment of the Quaternary age, associated mainly with post-lacustrine series formed in times of the Last Glaciation. It is used in agriculture as calcareous fertilizer. Accumulations of lacustrine chalk occur mainly in northern and north-western Poland, often at the base of deposits of peat and calcareous gyttja (Plate 6).

Chalk deposits are being documented to the depth of 10 meters, with minimum deposit thickness of 1 meter, maximum overburden of 2.5 meters, maximum ratio of overburden to deposit thickness of 0.3 and minimum alkalinity (CaO) of 40%.

Anticipated economic resources of chalk in 2011 amounted to 199.16 million tonnes and increased by 283 thousand tonnes in comparison with the previous year (Tab. 20). Production of chalk sharply increased by 52 to 128 thousand tonnes. Lacustrine chalk production amounted to 16 thousand tonnes and writing chalk to 112 thousand tonnes (Fig. 11).

Table 20. Chalk resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	193	199.16	103.72	95.44	12.79	6.65
Including resources of exploited deposits						
Total	25	10.81	10.30	0.52	–	5.95
1. Deposits of operating mines	5	4.07	3.55	0.52	–	3.29
2. Deposits exploited temporarily	20	6.74	6.74	–	–	2.66
Including resources of non-exploited deposits						
Total	88	131.27	56.79	74.48	0.56	0.71
1. Deposits covered by detailed exploration	57	73.48	56.79	16.69	0.26	0.71
2. Deposits covered by preliminary exploration	31	57.80	0.00	57.80	0.31	–
Including abandoned deposits						
Total	80	57.07	36.64	20.44	12.23	–

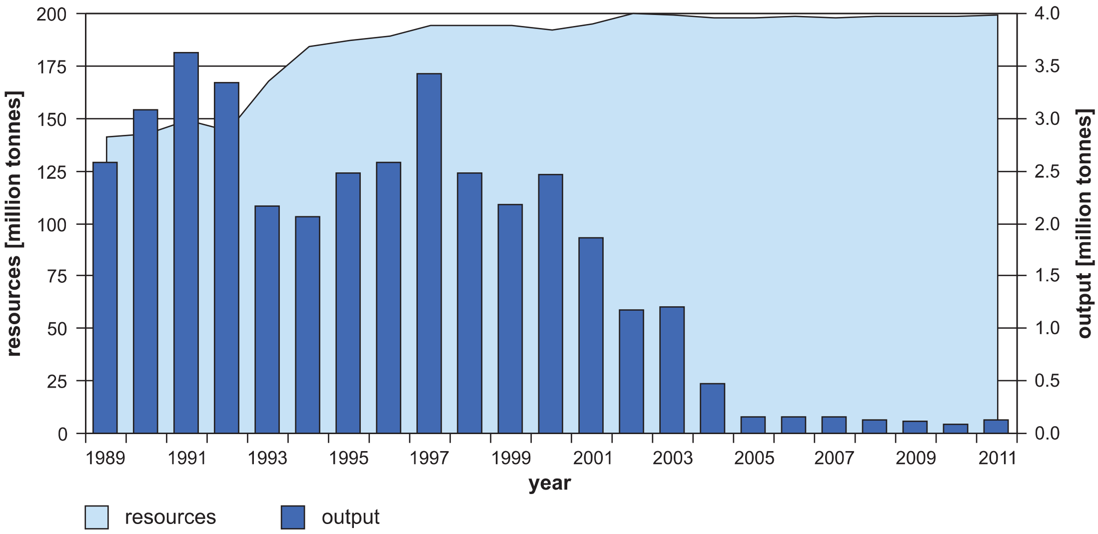

Fig. 11. Chalk anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

Total anticipated economic resources of chalk (writing chalk and lacustrine chalk) have not changed significantly in last 10 years – amounted to about 200 million tonnes. Production of chalk in the years 2005–2011 accounted for 80–160 thousand tonnes per year. The slight production of lacustrine chalk used in soil liming is caused by the liquidation of grants for production and transport of calcareous fertilizers. That is the main reason for producers to cut down their interest in chalk production. In the nineties lacustrine chalk production amounted to 3.5 million tonnes per year. The biggest production comes from the Mielnik deposit (74 thousand tonnes in 2011) and accounts for more than a half of total chalk production (lacustrine and writing chalk).

5.7. CLAY RAW MATERIALS FOR CEMENT PRODUCTION

Clay raw materials are used to provide alumina and silica to the charge for the clinker production and thus counterbalance too high content of $CaCO_3$ in limestones and marls. The optimum content of $CaCO_3$ in the kiln charge is 75–80%. When $CaCO_3$ exceeds these values, clays are added to reduce its content at the advantage of SiO_2, Al_2O_3 and Fe_2O_3.

The advancements in development and current exploitation of these raw materials are relatively low. This is due to two factors: (1) attempts to achieve the optimum composition of mined major raw material (in this case – limestones and marls) and, in this way, to diminish the problems with its correction, usually made by the operators at the development stage, and (2) replacement of natural clay raw materials with mineral waste such as ash from heat and power plants, blast furnace slag and similar ones.

Lithologically the explored deposits of raw materials for the cement industry represent loams, clays, clay siderites, loesses and silts. Anticipated economic resources of clay raw material deposits for the cement industry decreased in 2011 by 0.139 million tonnes (in comparison with 2010) and were reported to be 283.63 million tonnes (Tab. 21).

Exploitation is carrying on only in Lubelskie Voivodeship area. In 2011 output amounted to 120 thousand tonnes and decreased by 9.1% in comparison with 2010.

The Kujawy cement plant also uses sands from the Barcin–Piechcin–Pakość deposit (Kujawsko-Pomorskie Voivodeship), which is placed in the chapter “Quartz sands for production of cellular concrete and lime-sand brick” (classification according to the geological documentation).

Considering the 2004–2011 period, it should be emphasized that anticipated economic resources increased by 64.25 million m^3. That was mainly due to the recounting of the Niegowonice II deposit resources (Śląskie

Table 21. Clay raw materials for cement production resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	29	283.63	172.05	111.57	45.63	0.01
Including resources of exploited deposits						
Total	4	0.91	0.91	–	–	0.01
1. Deposits of operating mines	3	0.82	0.82	–	–	0.01
2. Deposits exploited temporarily	1	0.09	0.09	–	–	–
Including resources of non-exploited deposits						
Total	16	209.29	97.80	111.49	2.25	–
1. Deposits covered by detailed exploration	14	103.01	97.80	5.21	2.25	–
2. Deposits covered by preliminary exploration	2	106.28	0.00	106.28	–	–
Including abandoned deposits						
Total	9	73.43	73.35	0.08	43.39	–

Voivodeship) and four new documented deposits in Lubelskie Voivodeship. The production in the years 2005–2011 varied from 0.0 to 0.132 million tonnes, in last 4 years it was in the range of 0.110 and 0.130 million tonnes per year. That states for about 0.5% of the basic commodity – limestones and marls – used yearly for production of clinker cement in Poland.

5.8. CLAY RAW MATERIALS FOR LIGHTWEIGHT AGGREGATE PRODUCTION

Clay for production of light-weight aggregates in Poland may be assigned to two major types in relation to their usability:

– suitable for production of keramsite (light-weight bloated clay aggregates),
– suitable for production of agloporit (called *glinoporyt* in Poland).

Raw materials used in production of keramsite are characterized by expansion during thermal treatment. The coefficient characterizing that property, that is swelling coefficient, should be equal at least 2.5, and preferably 5.0 and more. The process of production of keramsite involves roasting of appropriately prepared and granulated clay in temperature of 1,050–1,300°C. In the course of roasting the granules increase their volume and their external layer begins to melt. The obtained product is of the porous light-weight ceramic aggregate type, characterized by low soakability, high thermal insulating properties and high resistance to several agents. Keramsite is used mainly in construction industry, horticulture and agriculture.

Resources of clays suitable for production of keramsite were proven in 8 deposits, two of which are exploited. Pliocene clays are exploited at Budy Mszczonowskie in the Mazowieckie Voivodeship and Quaternary stagnant-lake clays – at Gniew in the Pomorskie Voivodeship. Till 1995, keramsite was produced also from Oligocene clays exploited in the Bukowo (Szczecin-Płonia) deposit in the Szczecin area. The remaining deposits have not been exploited up to now.

Raw materials used in production of agloporit are not expanding in the course of during thermal treatment as their swelling coefficient is not higher than 1.0. Process of production of agloporit involves roasting of granulated clay containing easily combustible particles such as anthracite, which are mixed with clay and burnt out during firing, obtaining material highly porous. The sintered granules are subsequently crushed to obtain aggregates characterized by high open porosity and relatively low density. Such aggregates were used mainly in production of light concrete, concrete blocks and hollow bricks. Production of agloporit was phased out and deposits of that raw material became abandoned.

Agloporit clays are fairly common throughout the whole country. Quality requirements which should be matched are generally low and even lower than those put for raw materials for making simple thick-walled ceramics for building industry. The majority of proven resources of agloporit comprise Quaternary glacial tills and loesses (loess loams) and the remaining ones – Neogene Krakowiec clays and Poznań clay and Quaternary stagnant lake clays.

"Fired shales" represent a material close to agloporit. This material originates in result of spontaneous fires of stockpiles of coal waste production in mining operations. The fires turn clay shales which form large part of the coal waste stockpiles, into strong ceramic material. "Fired shales" are available at the Polish market as aggregates usable in building and road construction. They are treated as reused product from waste and thus data on their resources and supplies are omitted from this Report.

Anticipated economic resources decreased in 2011 by 0.11 million m^3 in comparison with 2010 (Tab. 22) and were reported to be 169.03 million m^3 (338.06 million tonnes). Economic resources amounted to 3.16 million m^3 (6.32 million tonnes) and output to 110,000 m^3 (increased by 15%).

The output of the raw material for keramsite production in the years 2005–2008 amounted to about 0.154 million m^3, whereas in the years 2009–2011 decreased to the level of about 0.105 million m^3. Anticipated economic resources dropped by 23.64 million m^3 where of 1 million m^3 due to the exploitation and losses and 2.614 million m^3 were crossed out because of the changeover in the destination of the area containing Bukowo deposit (Szczecin-Płonia). The largest part of the resources loss – 20.3 million m^3 – was due to deletion of 7 deposits for agloporit production from the "The balance…".

At present the resources of clays suitable for production of keramsite state for 20% of total resources whereas the resources of raw materials suitable for production of agloporit state for 80%.

Table 22. Clay raw materials for lightweight aggregate production resources in Poland [million m^3]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	41	169.03	41.34	127.69	4.60	3.16
Including resources of exploited deposits						
Total	2	16.71	16.71	–	1.28	3.16
Including resources of non-exploited deposits						
Total	37	149.56	21.86	127.69	3.32	–
1. Deposits covered by detailed exploration	9	26.89	21.86	5.03	0.06	–
2. Deposits covered by preliminary exploration	28	122.66	–	122.66	3.26	–
Including abandoned deposits						
Total	2	2.77	2.77	–	–	–

5.9. DIMENSION AND CRUSHED STONES

The group of raw minerals, assigned in this Report to the Dimension and Crushed Stones comprises 33 lithological varieties of igneous, sedimentary and metamorphic rocks displaying properties which make them useful in domestic economy. The stones are used to produce crushed aggregates – a high-grade raw material for building and road and railway construction and stone elements for road construction (stone for paving roads, stone and stone plates for sidewalks, stone street curbing and curb ramps) and building construction (stone blocks, decorative plates for elevation and facade, floor plates and slabs).

Sedimentary rocks represent about 45% of proven resources of dimension and crushed stones and igneous rocks – 41% of the resources. The share of metamorphic rocks is much smaller, not exceeding 14% of the resources.

Igneous and metamorphic rocks explored as dimension and crushed stones occur mainly in the Lower Silesian region where they are represented by basalts, granites, gabbros, syenites, melaphyres, porphyres, amphibolites, gneisses, migmatites, serpentinites and marbles) and form a few deposits in the Małopolskie Voivodeship (diabases, melaphyres, porphyres and porphyric tuffs) (Fig.12). Sedimentary rocks matching requirements for that use are much more common. Limestones and dolomites form numerous deposits in the Holy Cross Mts. and the Silesian-Cracow region and sandstone deposits were proven in the Carpathian region and Holy Cross Mts. and Lower Silesia. In turn, deposits of limestones, opokas and marls were proven in the Lublin Upland (Plate 6).

According to: Regulation of the Minister of the Environment (which were obligatory between 1.01.2002 and 31.12.2011) and the limit values of the parameters that defines the deposit (obligatory since 1.01.2012) dimension and crushed stones are explored to the depth of opencast exploitation system. For dimension stones the most important is geological divisibility stated for any type of rock: 5% of volume for marls and serpentinites, 10% for syenite, gabbro, granodiorite, 20% for granite, tuff and sandstone. For crushed stones average compression strength should be more than 80 MPa and abradability in Los Angeles drum should be maximum 35%.

Deposits of mineral raw materials for road and building construction are explored down to the depth to which their exploitation is technically and economically justified exploitation.

Table 23. Dimension and crushed stones resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	731	10,424.97	7,003.48	3,421.49	571.96	3,372.25
Including resources of exploited deposits						
Total	315	5,223.86	4,082.13	1,141.72	148.66	3,253.98
1. Deposits of operating mines	256	4,806.21	3,787.25	1,018.96	148.25	2,939.64
2. Deposits exploited temporarily	59	417.65	294.88	122.77	0.41	314.34
Including resources of non-exploited deposits						
Total	256	4,578.24	2,374.79	2,203.45	382.93	101.21
1. Deposits covered by detailed exploration	207	2,801.12	2,374.79	426.33	125.78	101.21
2. Deposits covered by preliminary exploration	49	1,777.13	0.00	1,777.13	257.15	–
Including abandoned deposits						
Total	160	622.87	546.56	76.31	40.38	17.06

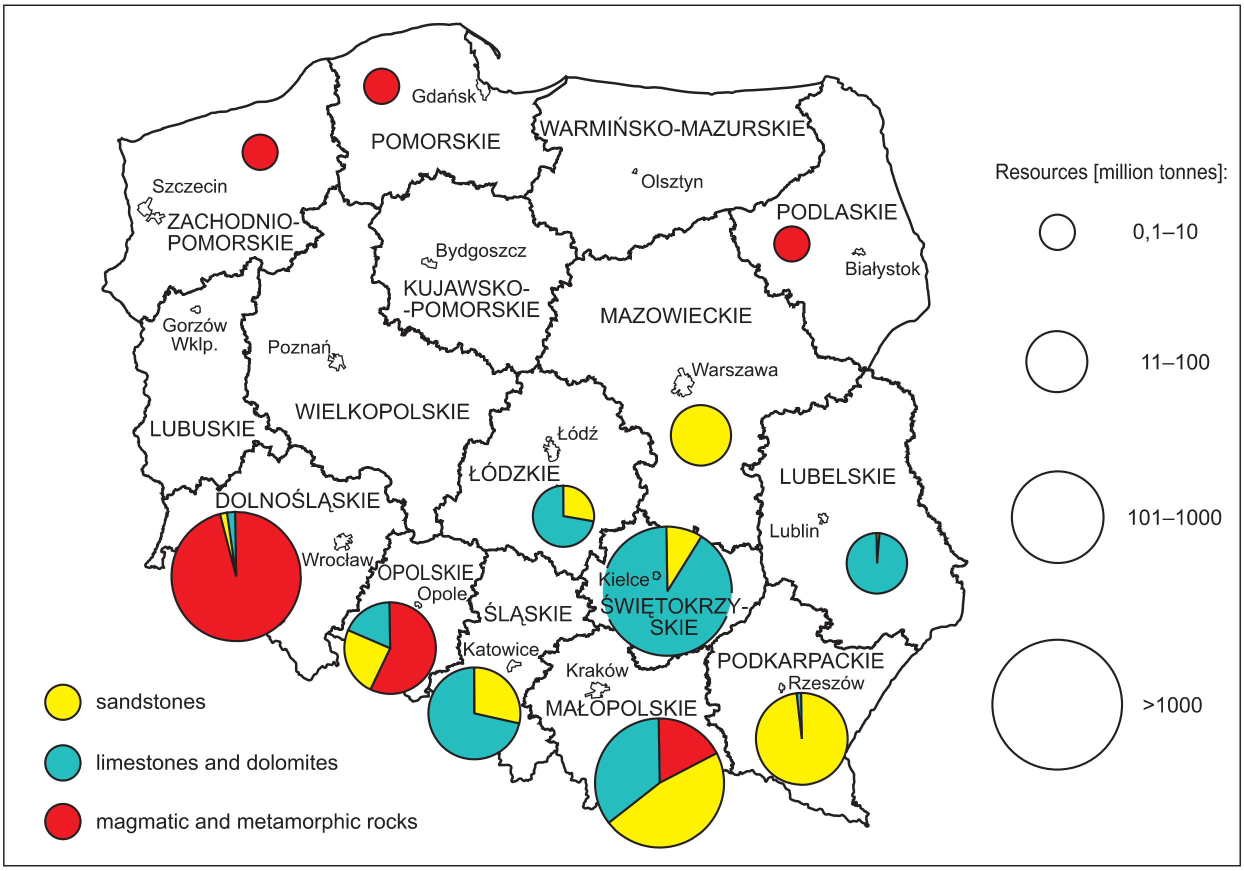

Fig. 12. Distribution of resources and principal lithological types of dimension and crushed stones in Poland in 2011

Anticipated economic resources, documented within 731 deposits, amounted to 10,424.97 million tonnes in 2011, 251.18 million tonnes bigger than in 2010 (Tab. 23). There were 26 new deposits documented in 2011 and 2 deposits crossed out of the "The balance…". Resources of exploited deposits states for 49% (5,223.86 million tonnes) of total anticipated economic resources and are documented within 315 deposits.

Economic resources amounted to 3,372.25 million tonnes in 2011 and increased by 190.68 million tonnes in comparison with 2010. According to data provided by operators of exploited deposits, production of dimension and crushed stones in 2011 rose to 84.58 million tonnes and was 21.35 million tonnes higher than in the previous year. The highest increase was noted in the case limestone production (by 71%), then granites (38%), basalt (35%), dolomites (27%), melaphyre (26%) and sandstone (20%). The production is concentrated within the area of two voivodeships: Dolnośląskie and Świętokrzyskie with the share in Polish output of dimension and crushed stones of 42 and 34%, respectively.

Dimension and crushed stones are exploited also from overburden of brown coal deposits. In 2011 there were 5.06 thousand tonnes of erratic boulder, 193.01 thousand tonnes of limestone and 4.71 thousand tonnes of sandstone extracted from Bełchatów and Szczerców fields (KWB Bełchatów SA mine). The output of KWB Adamów SA mine amounted to 1.27 thousand tonnes of erratic boulder.

The anticipated economic resources of dimension and crushed stones in the years 1989–2005 were quite stable and remained at the level of 8 billion tonnes (7.9–8.26 billion tonnes). During the last six years, due to new documentations, the resources base has been increasing and amounted to 10.42 billion tonnes in 2011 (Fig. 13). About 46% of the total resources are located in limestones, granite and sandstones deposits.

The long-lasting drop in dimension and crushed stones output started in 1989 with the minimum quantity of 13.8 million tonnes noted in 1993 (decrease from 31.6 million tonnes in 1989). Only in 2005 the level from 1989 was achieved. In the years 2003–2010 the output was increasing gradually – the total growth in

Table 24. Resources and production of lithological types of rocks used as road and building stones [thousand tonnes]

Lithological types of rocks	Resources	Production	Number of deposits
TOTAL RESOURCES	**10,424,969**	**84,577**	**731***
IGNEOUS ROCKS	4,302,946	34,468	191
Basalt	586,743	11,555	55
Diabase	23,645	439	2
Gabbro	491,504	3,447	5
Erratic boulders	603	–	4
Granite	1,697,056	11,332	77
Granodiorite	151,927	280	9
Melaphyre	487,319	4,993	17
Porphyry	777,943	1,620	14
Syenite	56,281	802	6
Porphyric tuff	29,925	–	2
METAMORPHIC ROCKS	1,417,896	7,252	62
Amphibolite	176,104	1,030	9
Gneiss	466,083	1,857	17
Hornfels	2,922	–	3
Cristalline schist	1,808	–	2
Marble	252,865	17	15
Dolomitic marble	182,268	596	8
Migmatite	217,674	2,693	2
Serpentinite	80,357	1,059	4
Greenstone	37,815	–	2
SEDIMENTARY ROCKS	4,704,127	42,857	503
Chalcedonite	31,041	143	3
Dolomite	1,041,296	11,432	45
Schist	590	–	1
Menillite schist	1,182	93	5
Marl	1,709	–	1
Opoka	5,545	8	10
Sandstone	1,455,336	6,822	287
Quartzitic sandstone	181,690	2,749	6
Graywacke	55,615	310	3
Travertine	2,255	146	1
Limestone	1,705,489	17,643	131
Dolomitic limestone	16,899	211	1
Limestone and dolomite	183,381	3,300	7
Conglomerate	22,099	–	2

* Two or three types of rocks co-occur in over a dozen deposits

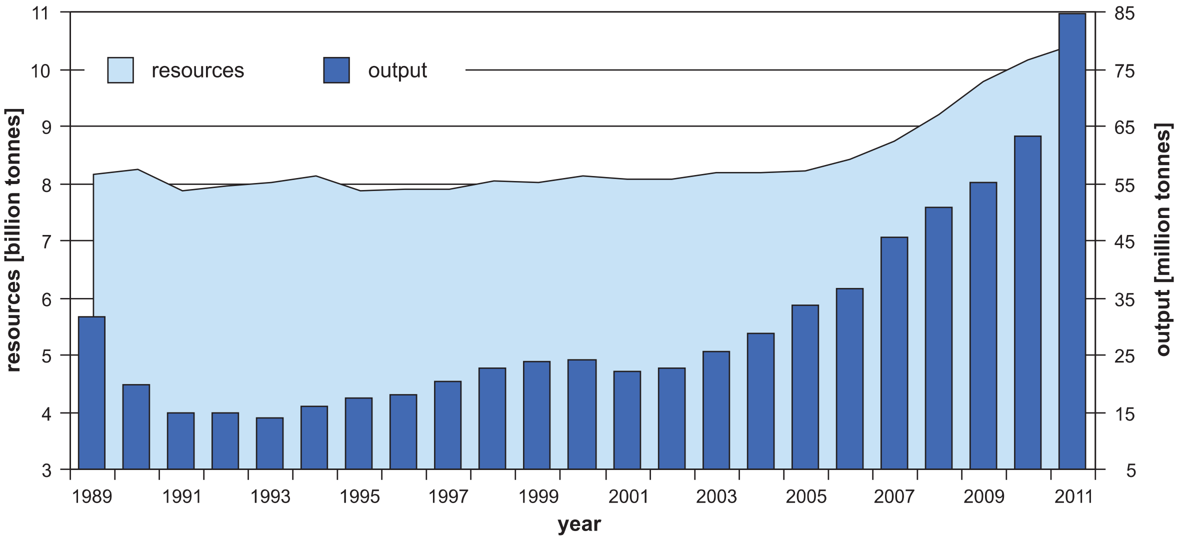

Fig. 13. Dimension and crushed stones anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

this period hit 150%. The maximum output (84.6 million tonnes) was noted in 2011 as a result of growing demand (by 34%) for crushed aggregates in road construction sector.

Table 24 shows the current state of exploration and development and production with breakdown of individual lithological types of rocks used in road and building construction.

5.10. DOLOMITES

Dolomite is widely used in glass and ceramic industry, as a flux for smelting iron and steel, and in production of fireproof raw materials and cement. Moreover, it is also used in agriculture for production of calcium-magnesium mineral fertilizers. Dolomite is also used in construction industry and road construction as crushed aggregates. These uses are discussed in the section on dimension and crushed stones.

The majority of pure dolomite deposits occur in areas of the Silesian and Lower Silesian regions and Małopolskie Voivodeship. Raw materials from these deposits are characterized by the best quality and match economic criteria of a flux for smelting iron and steel. The deposits are of the stratified type and Devonian or Triassic in age, as for examples those from Żelatowa, Brudzowice and Ząbkowice Będzińskie (Plate 6).

Deposits of dolomites usable as a raw material for ceramic industry occur in the Lower Silesian region. The dolomites form lenses in metamorphic schists. The best known of these dolomite deposits is situated at Rędziny in the vicinities of Jelenia Góra and in the area of the Kłodzko Basin (Plate 6).

Anticipated economic resources amounted to 343.94 million tonnes in 2011 and decreased by 3.8 million tonnes in comparison with the previous year. Economic resources of pure dolomites decreased by 3.8 million tonnes and are equal 65.05 million tonnes (Tab. 25). Production of dolomite was equal 3,568 thousand tonnes in 2011, increasing for about 466 thousand tonnes in relation to that in previous year.

In 2005–2011 anticipated economic resources slightly decreased (by 3 million tonnes) mainly due to the output (Fig. 14). The output increased by 0.7 million tonnes – the main factor was the increasing demand for the material for roads building sector. The highest increase was noted in 2007 and 2011.

Table 25. Dolomites resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	12	343.94	264.01	79.93	5.87	65.05
Including resources of exploited deposits						
Total	4	145.77	130.12	15.65	5.33	65.05
Including resources of non-exploited deposits						
Total	6	164.28	100.00	64.28	0.55	–
1. Deposits covered by detailed exploration	4	113.81	100.00	13.81	0.55	–
2. Deposits covered by preliminary exploration	2	50.47	0.00	50.47	–	–
Including abandoned deposits						
Total	2	33.89	33.89	–	–	–

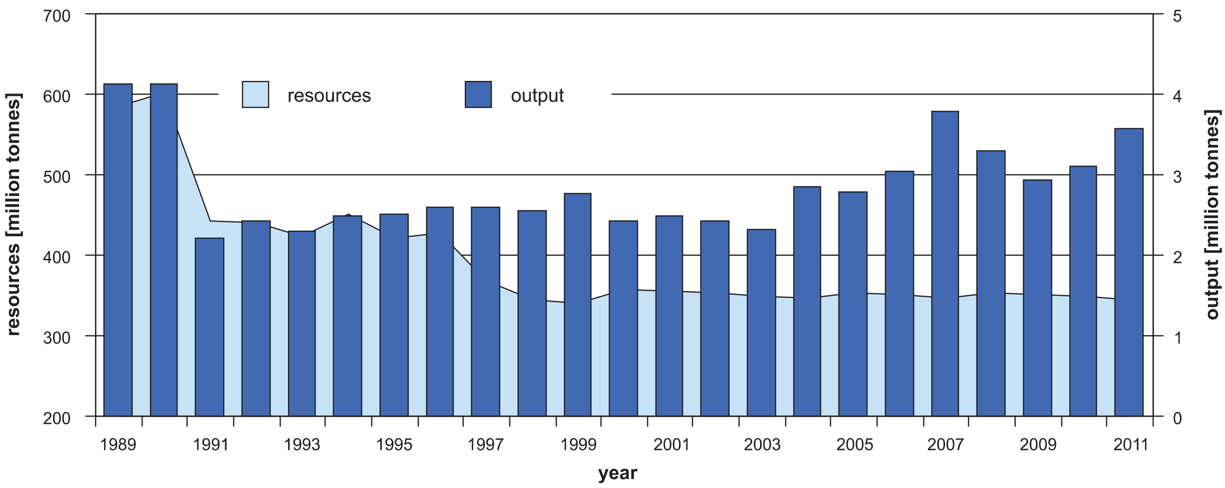

Fig. 14. Dolomite anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

5.11. FELDSPAR RAW MATERIALS

Deposits of feldspar raw material represent natural accumulations of various kinds of feldspar and feldspar-quartz rocks rich in alkali (Na_2O + K_2O equal at least 6.5%). The rocks include leucogranites occurring in the vicinities of Strzeblów (Pagórki Wschodnie deposit) and the Izera Mts. (Kopaniec deposit) and other parts of the Lower Silesian region. Other feldspar raw materials are represented by feldspars of porphyry varieties of the Karkonosze granites from the vicinities of Karpniki, Maciejowa and Góra Sośnia in the Jelenia Góra Basin (Sudetes) and potassium trachyte from Siedlec and Kwaczała arcose from Wygiełzowa in the Silesian-Cracow region (Plate 6).

Feldspars are one of the major raw materials in the ceramic industry. It is used in the form of various powders and feldspar-quartz aggregates in the manufacture of high-class porcelain and bone china, ceramic tiles, sanitary ceramics and enamel materials and in glass industry. Feldspars are also recovered as by-products in quarrying granites rich in potassium feldspar.

Table 26. Feldspar raw materials resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	11	137.04	64.77	72.27	13.18	5.23
Including resources of exploited deposits						
Total	3	14.16	11.39	2.77	–	5.23
1. Deposits of operated mines	2	3.78	3.78	–	–	2.64
2. Deposits exploited temporarily	1	10.38	7.61	2.77	–	2.59
Including resources of non-exploited deposits						
Total	8	122.88	53.38	69.50	13.18	–
1. Deposits covered by detailed exploration	5	61.50	53.38	8.12	–	–
2. Deposits covered by preliminary exploration	3	61.38	0.00	61.38	13.18	–

Anticipated economic resources decreased due to output and losses by 0.2 million tonnes and amounted to 137.04 million tonnes in 2011 (Tab. 26). The economic resources of developed deposits were estimated at 5.23 million tonnes. Production of feldspar raw materials decreased in 2011 in relation to that from the previous year (Karpniki deposit was not exploited) and amounted to 25.79 thousand tonnes.

The substantial increase of the anticipated economic resources of feldspar in the period 1989–2011 took place in the years 2005–2008 – the resources increased by 50% (Fig. 15). The four new deposits were recognized in this period. The output was highest in the years 2003–2008. The growth of the resources and high production was connected with the demand from the ceramic and glass industries.

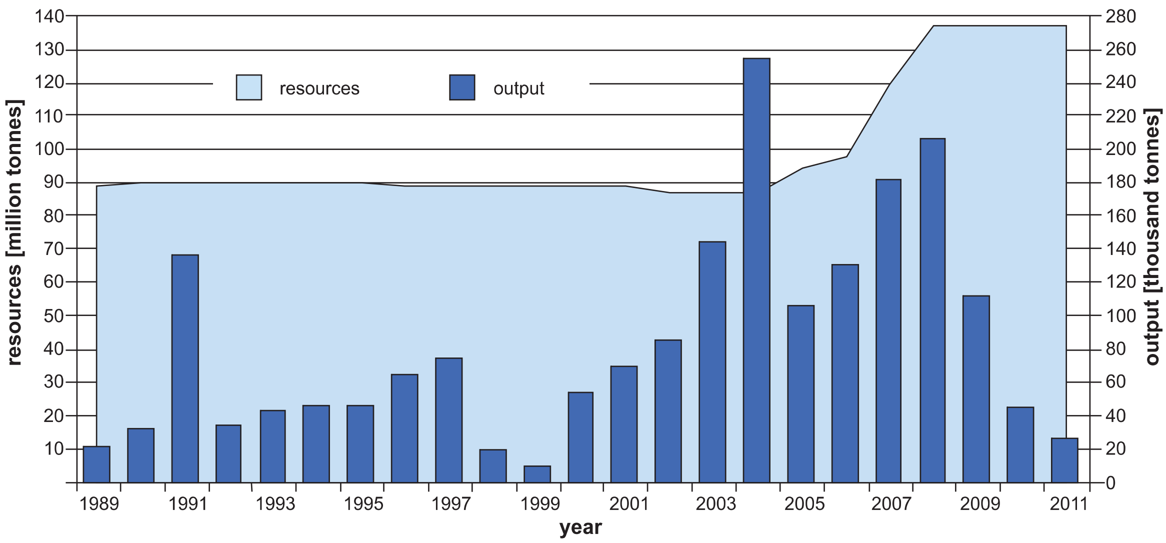

Fig. 15. Feldspar raw materials anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

The domestic production of feldspar is used mainly in the manufacture of ceramic tiles. Therefore, the imported feldspar material is characterized by parameters allowing its use in ceramic industry (pottery and sanitary ceramics) and electrotechnical and glass branches of industry. This material is rich in alkali whereas content of coloring oxides is low.

5.12. FILLING SANDS

Filling sand is used in making hydraulically placed fill – a mixture of sand and water to fill voids created by underground mining. This has over the last few decades been the most popular form of underground mining backfill. Proven backfill sand deposits are situated mainly in areas of intense underground mining, especially those of hard coal and copper mining in the Upper Silesian Coal Basin and Legnica-Głogów Copper District. One of the major requirements which sand deposits should meet to be classified as filling sands is location in distance less than 50 km from the place where the raw material is to be used.

The majority of filling sand deposits are situated around the Upper Silesian Coal Basin (Plate 8). Three main deposit areas are differentiated: eastern, western and northern. The eastern area, which is the center of production of that raw material, extends from Kuźnica Warężyńska through the Pustynia Błędowska Desert as far as the vicinities of Jaworzno. It is characterized by occurrence of sands of fluvioglacial and locally eolian origin attaining up to 70 m in maximum thickness in the Pustynia Błędowska Desert. The second area with the largest resources comprises the Pleistocene valley of the Odra River in a part of the Racibórz Basin and western part of the Silesian Upland and its sand deposits are 15 to 20 m thick at the average. The northern area comprises the Mała Panew River valley with its sand deposits up to 40 m in thickness. The deposits are well explored but still undeveloped.

The currently exploited filling sand deposits with the largest resources include Pustynia Błędowska – blok IV, Kotlarnia pole północne, Siersza-Misiury, Obora and Szczakowa pole I deposits.

Table 27. Filling sands resources in Poland [million m^3]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	34	2,633.00	2,128.85	504.15	705.00	147.05
Including resources of exploited deposits						
Total	10	537.10	476.85	60.25	177.73	147.05
1. Deposits of operating mines	8	441.43	381.18	60.25	97.75	135.52
2. Deposits exploited temporarily	2	95.67	95.67	–	79.98	11.53
Including resources of non-exploited deposits						
Total	17	1,797.41	1,408.87	388.54	269.55	–
1. Deposits covered by detailed exploration	13	1,496.22	1,406.05	90.16	129.70	–
2. Deposits covered by preliminary exploration	4	301.19	2.82	298.38	139.85	–
Including abandoned deposits						
Total	7	298.49	243.13	55.36	257.72	–

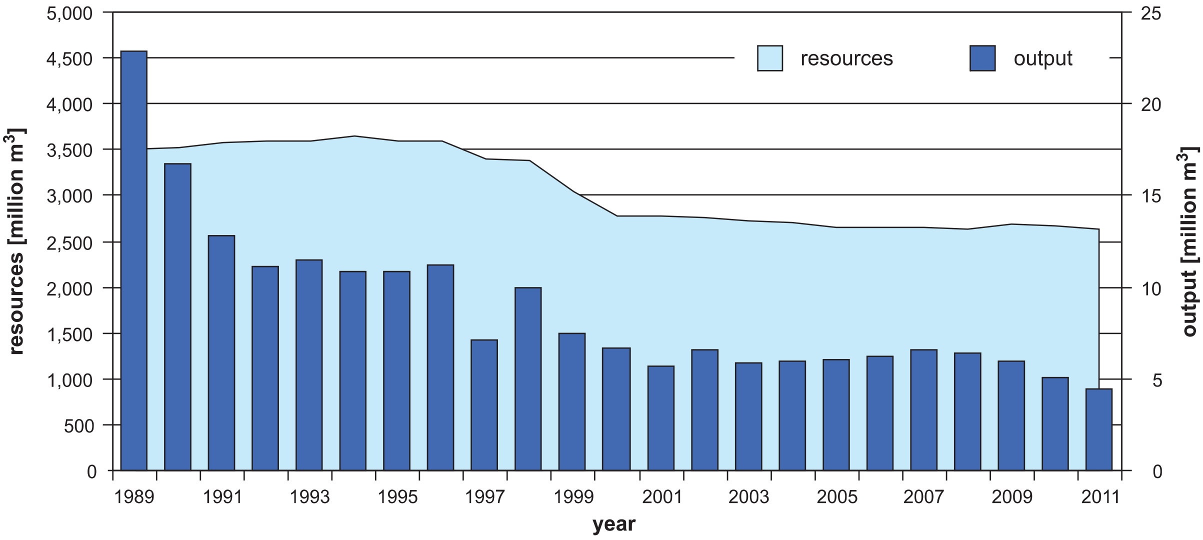

Fig. 16. Filling sand anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

In 2011, anticipated economic resources of filling sand totaled 2,633 million m^3 (or about 4,476 million tonnes – as recalculated using weight-to-volume ratio 1.7 t/ m^3) (Tab. 27). Resources decreased by 36 million m^3. In 2011, production of filling sand totaled 4,405 million m^3 (or about 7.49 million tonnes as recalculated using weight-to-volume ratio 1.7 t/m^3), being 686,000 m^3 smaller than in the previous year. It was the fourth consecutive year of the declining production (Fig. 16).

In the years 1989–2011 the output of filling sands decreased due to the hard coal production decreasing in this period and the fact that substitutes of electric power dust mainly has been used in larger scale.

5.13. FLINTSTONES

Flintstones are silica concretion balls of spherical or oval or irregular shape. They usually occur as banks among carbonate rocks of the Jurassic or Cretaceous ages. The main constituent is chalcedony. Ground flintstones are used in glass and ceramic industry. They are also used for production of facings, millstones for rolling mills and flint abrasives. Striped flintstones are used to make some jewellery and stone fancy products.

The most famous accumulation is Krzemionki Opatowskie, located near Ostrowiec Świętokrzyski, where flintstones were extracted during 3,500–1,600 BC.

The only two explored deposits of flintstones (Bocheniec and Tokarnia) near Kielce (in the Świętokrzyskie Voivodeship) have not been exploited so far. The total anticipated economic resources of these deposits amount to 28 thousand tonnes.

5.14. FOUNDRY SANDS

Foundry sands are the basic raw material for making moulds and cores used in metal casting. The sands have to be characterized by high sintering temperatures as the sintering temperature required for making cast steel is 1,400°C, for cast iron – 1,350°C, and for non-ferrous casting alloys – 1,200°C. Two kinds of foundry sands are differentiated on the basis of content of cement and carbonates: pure quartz sands and natural foundry sands. Deposits of foundry sands are situated mainly in central and southern Poland and usually have the form of sand sheet deposits. The sand deposits range in age from the Quaternary and Neogene to Cretaceous and even Jurassic and Triassic.

Table 28. Foundry sands resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	76	336.60	185.98	150.62	5.99	35.04
Including resources of exploited deposits						
Total	8	88.15	88.15	–	1.41	33.64
1. Deposits of operating mines	6	75.00	75.00	–	0.44	28.29
2. Deposits exploited temporarily	2	13.15	13.15	–	0.97	5.35
Including resources of non-exploited deposits						
Total	38	192.07	45.22	146.85	2.23	1.40
1. Deposits covered by detailed exploration	17	49.17	45.22	3.95	2.10	1.40
2. Deposits covered by preliminary exploration	21	142.90	–	142.90	0.13	–
Including abandoned deposits						
Total	30	56.38	52.61	3.77	2.35	–

In the vicinities of Częstochowa (Plate 7), small natural foundry sand deposits of varying thickness represent infills of karst forms developed in Upper Jurassic limestones. Foundry sand deposits from the area between Gorzów Śląski and Żarki are represented by fine- to medium-grained sands and sandstones of the Lower Jurassic age. In turn, weakly cemented sandstones or locally loose sands of the Middle Jurassic age form foundry sand deposits found in the vicinities of Szydłowiec, Wąchock, Skarżysko-Kamienna and Jagodna as well as Opoczno and Iłża.

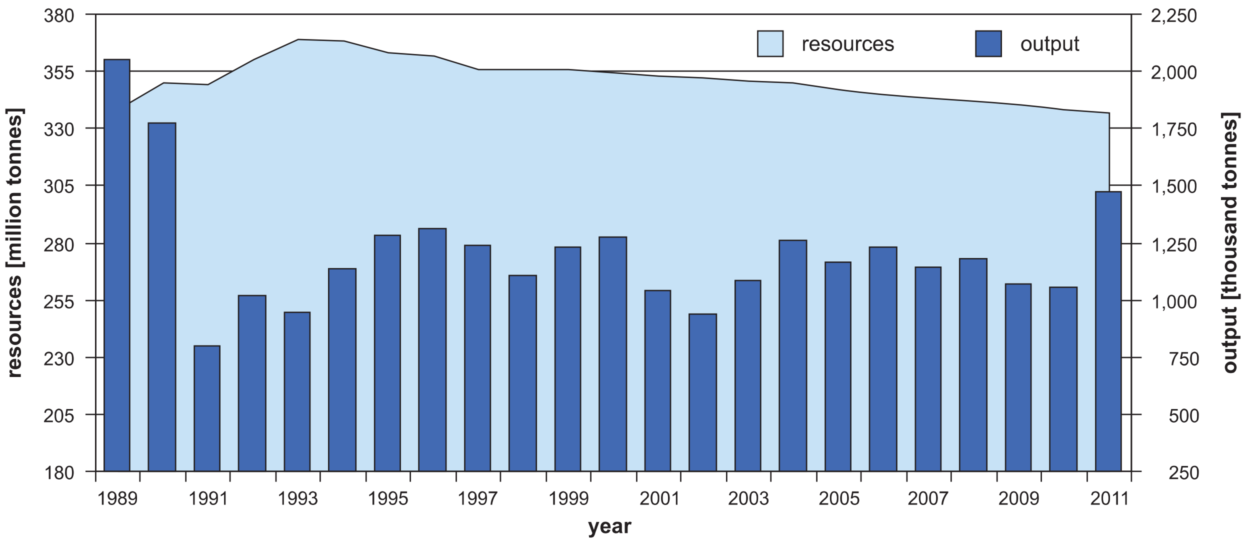

Fig. 17. Foundry sands anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

Cretaceous deposits of foundry sands are known mainly from the Tomaszów Basin (central Poland) where they co-occur with those of glass sands as well as from the Bolesławiec Basin and vicinities of Krzeszówek in the Lower Silesian region (Plate 7). Foundry sand deposits formed of Neogene sands deposited in land environments occur in the Konin area, at the margin of the Holy Cross Mts. and in Pomerania, and those formed of Neogene sands of marine origin – in the Lublin Upland. Foundry sand deposits of the Quaternary age occur in the northern Poland and are formed of sands of dune fields or fluvioglacial terrace accumulations.

Raw material from some deposits of foundry sands may also find other uses. Pure quartz sands are used also in glass industry and sometimes in construction and road building.

Anticipated economic resources amounted to 336.6 million tonnes in 2011 and decreased by 1.77 million tonnes in comparison with the previous year but those resources on developed deposits are equal 88.2 million tonnes accounting for 26% of total anticipated economic resources (Tab. 28).

In 2011 production of foundry sands was equal 1.475 million tonnes (Fig. 17).

5.15. GLASS SANDS AND SANDSTONES

Quartz sand is the main raw material in commercial glass production. In that process, sands pass through preparation and mixing in the glass batch to be transported to the furnace and melted. The resulting glass contains about 70 to 74% silica by weight (72% in the case of the float glass). Sand for glass production comes from deposits of quartz sands and weakly cemented quartz sandstones with appropriate granulation and negligible content of coloring oxides.

In Poland, deposits of sands and sandstones occur in 10 voivodeships: Dolnośląskie (Bolesławiec area), Lubelskie, Lubuskie, Łódzkie (vicinities of Tomaszów Mazowiecki), Mazowieckie, Podkarpackie, Pomorskie, Świętokrzyskie, Wielkopolskie and Zachodniopomorskie (Plate 8). Resources of the Biała Góra deposits from the vicinities of Tomaszów Mazowiecki have the largest share in domestic resources. In turn, sands from the vicinities of Bolesławiec best match

Table 29. Glass sands and sandstones resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	31	633.36	375.33	258.02	136.77	196.10
Including resources of exploited deposits						
Total	8	204.24	184.74	19.50	57.06	143.80
1. Deposits of operating mines	7	189.28	184.74	4.54	57.06	130.80
2. Deposits exploited temporarily	1	14.96	0.00	14.96	–	13.00
Including resources of non-exploited deposits						
Total	19	426.97	188.44	238.53	79.69	52.30
1. Deposits covered by detailed exploration	11	230.26	188.44	41.82	42.02	52.30
2. Deposits covered by preliminary exploration	8	196.70	–	196.70	37.67	–
Including abandoned deposits						
Total	4	2.15	2.15	–	0.02	–

quality requirements of raw material for glass production.

Miocene glass sand deposits from the area of Tarnobrzeg and sands occurring in the Lubelskie, Lubuskie (vicinities of Żary), Mazowieckie, Podkarpackie, Pomorskie, Wielkopolskie and Zachodniopomorskie voivodeships are less important for the raw material base. The deposits of the Miocene or Quaternary age which is suitable for production of a low-quality glass only (class 3–6).

Anticipated economic resources decreased by 3.81 million tonnes in comparison with the previous year and amounted to 633.36 million tonnes in 2011 (Tab. 29). Anticipated economic resources of exploited deposits are equal 204.24 million tonnes, accounting for 32% of total anticipated economic resources.

In 2011, glass sand production increased and was equal 2.290 thousand tonnes.

5.16. GYPSUM AND ANHYDRITE

Gypsum ($CaSO_4 \cdot 2H_2O$) is a product of evaporation and sea water in temperatures lower than those necessary for precipitation of anhydrite ($CaSO_4$). Gypsum may originate also in result of hydration of anhydrite. Alabaster is a fine-grained variety of gypsum. Finer kinds of alabaster are used mainly as ornamental and decorative stone and by sculptors.

Calcined gypsum is one of the most common and ancient mortar of buildings. At present it is widely used in production of various building materials and prefabricates. It is also used in production of moulds for ceramic industry and is added to Portland cement as a component preventing cement flash setting. Some amounts of gypsum are used in the paint, lacquer and varnish industries and its especially pure varieties – in surgery and dental clinics. Clear colorless gypsum crystals (selenite) were used to make optical instruments. Anhydrite is currently added to Portland cement and in production of self-leveling floors.

In Poland, deposits of calcium sulfates (gypsum and anhydrite) are associated with saline (halite and potassium-magnesium salts) series of the evaporate formations of the Miocene and Zechstein. Their resources in 15 major deposits were estimated in 2011 at almost 259 million tonnes (increased by 0.5% since 2010) and the resources of five exploited deposits – at over 127 million tonnes (Tab. 30).

Miocene gypsum deposits of economic importance are situated mainly along northern margin of the Carpathian Foredeep, especially in the Nida Basin (Plate 6).

Table 30. Gypsum and anhydrite resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	15	258.97	189.40	69.56	25.42	107.71
Including resources of exploited deposits						
Deposits of operating mines	5	127.17	98.23	28.94	6.24	107.71
Including resources of non-exploited deposits						
Total	7	128.23	87.70	40.52	19.13	–
1. Deposits covered by detailed exploration	5	94.97	87.70	7.26	17.90	–
2. Deposits covered by preliminary exploration	2	33.26	0.00	33.26	1.23	–
Including abandoned deposits						
Total	3	3.57	3.48	0.10	0.05	–

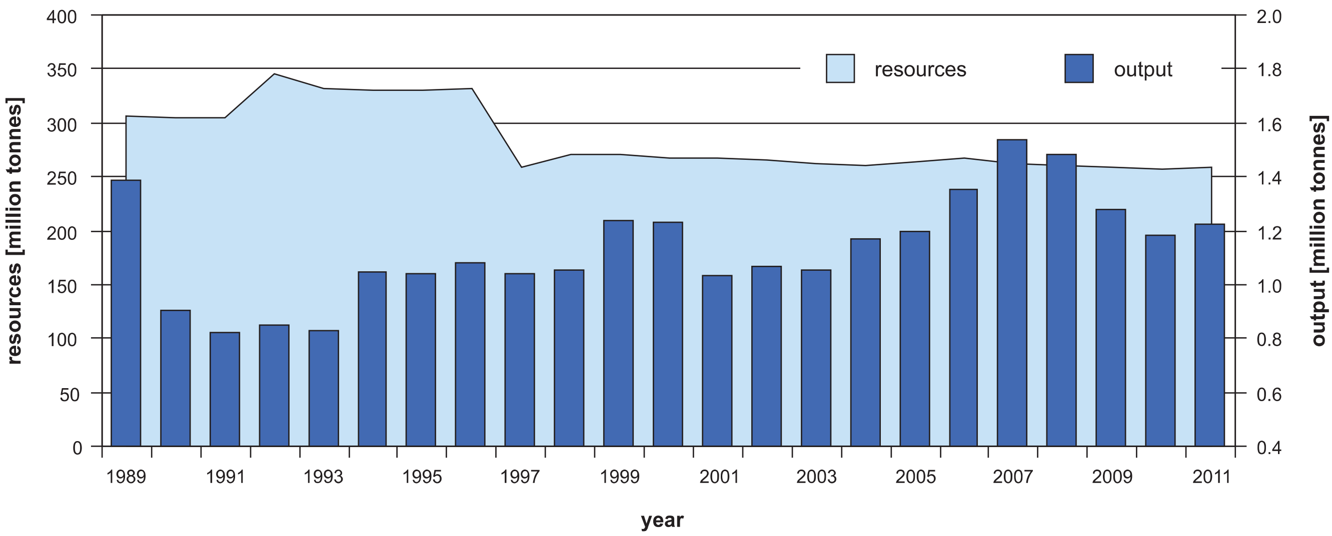

Fig. 18. Gypsum and anhydrite anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

In these areas gypsum forms a thick, extensive bed, gently inclined and slightly disturbed tectonically. The gypsum bed crops out at the surface or is covered with a sedimentary blanket a few to over a dozen meters thick. The deposit series is 3 to 46 m thick and is characterized by fairly uniform of the mineral raw material and content of $CaSO_4 \cdot 2H_2O$ ranging from 85 to 95%. Deposits exploited in this region include Borków-Chwałowice and Leszcze.

Demonstrated deposits of Zechstein sulfates from the Lower Silesian region (Plate 6) are characterized by markedly more complex geological conditions (strong tectonic disturbances) and variability in quality of mineral raw material. These are mainly deposits of anhydrites and secondary gypsum formed in result of gypsification of anhydrite in zones of infiltration of aggressive groundwater. Three deposits are exploited in that region: Lubichów, Nowy Ląd and Nowy Ląd-Pole Radłówka. The deposits occur at the depths of 25 to 400 m, their thickness changes from 1.7 to 50.3 m and content of $CaSO_4 \cdot 2H_2O$ ranges from 56% to 95.3%. Moreover, resources of shallow-seated parts of non-exploited gypsum and anhydrite deposits which are associated with copper ores of the Lubin-Głogów Copper Area and made accessible by mining works of the copper mines are estimated at 57 billion tonnes.

In accordance with domestic regulations, gypsum deposits are explored down to the depth of 50 m and those of anhydrite – down to 400 m. The minimum thickness accepted for gypsum deposits is 2 m and for those of anhydrite – 5 m. The accepted minimum content of usable components equals 60% for anhydrite and 80% for gypsum and the maximum ratio of thickness of cap rock to that of the deposit is 0.5 in the case of gypsum deposits.

Production of gypsum and anhydrite amounted to 1,226 thousand tonnes in 2011 (including 1,067.65 thousand tonnes of gypsum from 3 deposits and 157.02 thousand tonnes of anhydrite also from 3 deposits) and increased in comparison with 2010 by 4%.

In the analyzed period (2004–2011) anticipated, economic resources of gypsum and anhydrite where quite stable in the range of 258–268 million tonnes with the significant growth recorded in the years 2005–2006 thanks to the new estimations of Leszcze and Nowy Ląd deposits resurces (Fig. 18). In the years 2001–2003 yearly output of gypsum and anhydrite amounted to 1 million tonnes. In the next four years it increased to 1.5 million tonnes – due to the increasing demand in housing. Then, because of the crisis in this sector, demand for gypsum and anhydrite decreased and the output dropped to 1.23 million tonnes in 2011.

5.17. KAOLIN

In Poland the name kaolin is referred to white to yellowish soft clay rock mainly built of minerals of the kaolinite group. Kaolin originates in result of weathering or hydrothermal decomposition of igneous and metamorphic rocks rich in feldspars. From the point of view of origin, differentiation is made between residual kaolin that is derived from *in situ* decomposition of parent rocks and sedimentary kaolin, formed in result of wash down of weathered parent rock and transport and deposition of weathering products in other place. The name of kaolin raw material is also referred to Upper Cretaceous sandstones with kaolinite cement which occur in the North Sudetic Depression.

Polish deposits of kaolin originated in result of a regional kaolinization which affected acid igneous and metamorphic rocks throughout vast areas in the foreland of the Sudetes, especially the Strzegom-Sobótka and Strzelin granitoid massifs as well as some parts of the Sowie Mts. and Izerskie Mts. (Plate 7). In the Neogene times the weathering processes gave rise to origin of thick weathering covers and, in this way, kaolin deposits. Two types of kaolin deposits are recognized here: the deposits comprising residual material and those sedimentary in nature. In both cases the deposits appear spatially related to parent rocks and confined to areas of the above mentioned massifs of granites and metamorphic rocks.

Anticipated economic resources of kaolin amounted to 213.16 million tonnes in 2011 but resources of exploited deposits amounted to 80.5 million tonnes (38% of anticipated economic resources) (Tab. 31). In the year 2011, production of kaolin raw materials was higher than in the previous year and was equal 285 thousand tonnes.

High-quality kaolin materials, that are those representing fraction below 15 µm, are used in the manufacture of ceramics, rubber, polymers and fiberglass. In turn, coarser fractions find use in making recently fashionable ceramic wall and floor tiles of "gres porcellanato" type, production of which requires washed kaolin with very low content of coloring oxides such as TiO_2 and Fe_2O_3. Kaolin is also used as raw material for the manufacture of stoneware ceramics, white cement and fire-proof products.

The demand for kaolin raw materials is largely covered by production from domestic deposits so the share of import remains relatively small. Kaolin is also being obtained as by-product in exploitation of glass sands and foundry sands.

Table 31. Kaolin resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	14	213.16	139.61	73.55	46.05	72.44
Including resources of exploited deposits						
Deposits of operating mines	2	80.50	80.50	–	–	72.44
Including resources of non-exploited deposits						
Total	10	123.46	49.91	73.55	41.67	–
1. Deposits covered by detailed exploration	5	52.22	49.91	2.31	29.67	–
2. Deposits covered by preliminary exploration	5	71.24	–	71.24	12.00	–
Including abandoned deposits						
Total	2	9.20	9.20	–	4.38	–

5.18. LIMESTONES AND MARLS FOR CEMENT AND LIME INDUSTRIES

This section deals with deposits of limestones and marls for use in lime and cement industries. Hard varieties of limestone used in production of dimension and broken stone are discussed in a separate section, similarly as lacustrine limestone (lacustrine chalk) and proper chalk raw material used in industries other than the cement and lime ones. Marly limestones and marls are used in the cement industry only.

Limestones used in the lime industry are pure limestones with high content of $CaCO_3$ (>90%). Such rocks also find use in the chemical and food industries and metallurgy. When used in the manufacture of cement clinker, they should be supplemented with addition of clays. Some soft limestone varieties and waste rock from quarrying are used in production of powdered calcium carbonate for reducing soil acidity in agriculture.

Limestones and marl for the cement and lime industries are quite common in various geological formations in southern and central Poland and some other regions. Most resources occur in four regions: Świętokrzyski, Krakowsko-Częstochowsko-Wieluński, Lubelski i Opolski. In northern Poland Jurassic limestones were documented within the Barcin-Piechcin area near Inowrocław (Plate 6). In a couple of deposits (Bratkowszczyzna, Kodrąb-Dmenin, Górażdże, Strzelce Opolskie I, Tarnów Opolski-Wschód, Bukowa and Gliniany-Stróża) both types of raw material occur.

Limestones and marl deposits are explored down to the depth capabilities governed by the equipment and method limitations for open cast mining. According to economic criteria and law standards, established for this group of deposits, overburden may be up to 15 m thick at the most and maximum proportion of overburden to deposit thickness should not exceed 0.3. An additional requirement introduced limestone deposits operating for the needs of the lime industry refers to the mean content of $CaCO_3$ over 90% in the whole vertical section of a given deposit.

Table 32. Limestones and marls for cement industry resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	71	12,550.09	6,766.69	5,783.41	892.40	2,178.46
Including resources of exploited deposits						
Total	19	4,217.34	3,185.09	1,032.25	80.80	2,178.46
1. Deposits of operating mines	16	3,832.45	2,996.95	835.50	76.05	1,894.15
2. Deposits exploited temporarily	3	384.89	188.14	196.75	4.75	284.30
Including resources of non-exploited deposits						
Total	49	8,325.76	3,576.21	4,749.55	809.76	–
1. Deposits covered by detailed exploration	34	4,356.20	3,576.21	779.99	37.09	–
2. Deposits covered by preliminary exploration	15	3,969.56	0.00	3,969.56	772.67	–
Including abandoned deposits						
Total	3	7.00	5.39	1.60	1.84	–

Table 33. Limestones for lime industry resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	116	5,606.52	3,201.28	2,405.23	850.92	977.23
Including resources of exploited deposits						
Total	19	1,859.02	1,745.02	114.01	4.17	957.90
1. Deposits of operating mines	16	1,826.07	1,715.23	110.84	–	927.48
2. Deposits exploited temporarily	3	32.96	29.79	3.17	4.17	30.43
Including resources of non-exploited deposits						
Total	57	3,560.75	1,280.40	2,280.36	787.72	0.22
1. Deposits covered by detailed exploration	39	1,550.84	1,217.60	333.23	697.54	0.22
2. Deposits covered by preliminary exploration	18	2,009.92	62.79	1,947.12	90.18	–
Including abandoned deposits						
Total	40	186.74	175.87	10.87	59.02	19.11

Anticipated economic resources of limestones and marls amounted to 18,156.61 million tonnes, including 12,550.09 million tonnes (69%) within 71 deposits for cement industry and 5,606.52 million tonnes (31%) within 116 deposits for lime industry (Tab. 32, 33). These resources decreased by 143.74 million tonnes in comparison with 2010 and resources of limestones for lime industry decreased by 43.77 million tonnes. Anticipated economic resources of exploited deposits state for 33.6% of total resources for cement industry

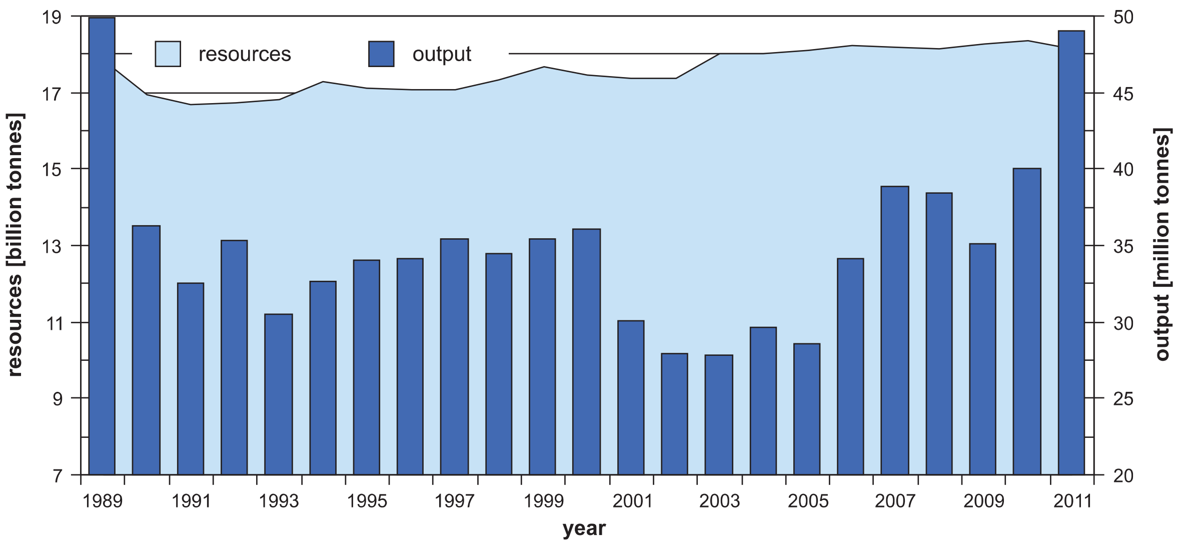

Fig. 19. Limestones and marls for the cement and lime industries anticipated economic resources and output in Poland in 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

and 33.1% of total resources for lime industry. Production of both raw materials amounted to 49 million tonnes in 2011 (increased by 8.98, including 4.87 million tonnes of limestones and marls for cement industry and 4.11 million tonnes of limestones for lime industry).

The anticipated economic resources have not been changing significantly for the last 21 years (Fig. 19). It remained within the range of 16.7–17.7 billion tonnes till 2003 then slightly increased and exceeded 18 billion tonnes. The maximum output of limestones and marls was noted in 1989 (50 million tonnes), in subsequent years the quantity fluctuated very clearly. The most significant drop took place in the years 2001–2005 when yearly output fell below 30 million tonnes. Since 2006 the output started to increase and amounted to 40 million tonnes in 2010. The most visible growth – to 49 million tonnes – was in 2011 due to growing demand in building sector.

5.19. MAGNESITES

Magnesite (magnesium carbonate – $MgCO_3$) originates from decay of magnesium-rich igneous rocks under hydrothermal conditions and forms white accumulations.

Polish magnesite deposits are related to the Sobótka, Szklary, Grochowa-Braszowice massifs of Precambrian serpentinites and the Gogołów-Jordanów Massif of ultramafic rocks in the Lower Silesian region (Plate 7). Up to the present, six magnesite deposits have been proven in this region. The deposits are of the vein type, with individual veins attaining up to 3 meters in thickness and characterized by complex geological structure and high variability in quality of the raw material. Magnesite is currently exploited in an open strip mine at Braszowice only. Prospective resources are assessed to be equal 3.25 million tonnes (Sroga, 2011b).

Magnesite is used mainly as semi-manufactured material in production of multi-component artificial fertilizers, in purification of potable water and sewage treatment and as mineral additive to animal feed.

Anticipated economic resources for the end of 2011 were estimated at 14.57 million tonnes (Tab. 34). In 2011, domestic production of magnesite was equal 75 thousand tonnes, increasing in comparison with the previous year by 12 thousand tonnes.

Table 34. Magnesites resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	6	14.57	4.64	9.92	2.18	3.89
Including resources of exploited deposits						
Deposits of operating mines	1	4.36	4.36	–	–	3.89
Including resources of non-exploited deposits						
Deposits covered by preliminary exploration	4	6.10	–	6.10	2.18	–
Including abandoned deposits						
Total	1	4.11	0.28	3.83	–	–

5.20. MINERAL RAW MATERIALS FOR ENGINEERING WORKS

Mineral raw materials for engineering works are usually clayey-sandy and clayey rocks, but also others – sandstones and limestones. These raw materials are utilized in road industry for road embankments building or in waste disposal packing and reclamation.

Usually (about 70%) resources of mineral raw materials for engineering works are documented as accompanying raw material – these are the parts of deposits which do not meet the criteria of the main raw material, i.e. parts of sand and gravel deposits with too high dust content or parts of dimension and crushed stones deposits with too low strength.

Anticipated economic resources increased in 2011 by 2.24 million m^3 (36.8%) in comparison with the previous year (Tab. 35).

In the 2005–2011 period anticipated economic resources of these raw materials increased by 7.96 million m^3 and the number of deposits increased by 31. The production was rising rapidly and amounted to 0.706 million m^3 in 2011 (436% of the 2010 volume). Both accretions were caused by the growing demand for raw materials of that kind for road construction.

Table 35. Mineral raw materials for engineering works resources in Poland [million m^3]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	37	8.34	7.96	0.38	0.07	3.53
Including resources of exploited deposits						
Total	18	4.36	4.03	0.34	0.07	3.12
1. Deposits of operating mines	16	4.19	3.85	0.34	0.07	3.07
2. Deposits exploited temporarily	2	0.17	0.17	–	–	0.05
Including resources of non-exploited deposits						
Total	15	3.25	3.25	–	–	0.41
1. Deposits covered by detailed exploration	15	3.25	3.25	–	–	0.41
Including abandoned deposits						
Total	4	0.72	0.69	0.04	–	–

5.21. PEAT

Peat is an organic matter of the Quaternary age, most often Holocene. It is an accumulation of partially decayed vegetation. The process of origin of peat requires high groundwater level and acidic and anaerobic conditions which inhibit decay of plant material. According to genetic features there are three types of peat distinguished: low, high and medium. The richest in food ingredients is low peat occurring in river valleys and lake edges. High peat (with the lowest food ingredients content) occurs in watershed divides, whereas medium peat has features of both previous types.

Geological and quality criteria which define a peat deposit are:

- thickness of deposit not smaller than 1 m;
- maximum ratio of overburden thickness to mineral deposit – 0.5;
- maximum ash content – 30%.

There are several quality parameters deciding on peat use:

- grade of decomposition (according to von Post: H1 – not decomposed; H10 – totally decomposed);
- ash content (organic matter content in 100 g of dry mass);
- pH;
- wetness;
- bacteriological valuation (coli titer).

Peat is used in gardening and in agriculture as organic fertilizer and a medium added to a soil to improve its physical properties. It is also used in balneology (peat baths and poultices and mud wraps), medicine and therapeutics. Peat is no longer used as a fuel in Poland. Peat used in gardening has better quality – ash content below 15% and lower decay of organic matter; peat for agriculture is well-decayed with acidity above 4 and ash content below 25%. Moreover, in gardening and agriculture there are also used mixtures of peat, mineral fertilizers and minor elements. Peats used in medicine are therapeutical muds which have to be clean microbiologically, with high content of active organic compounds, advanced decay of organic matter, smooth mud consistency, moisture content over 75% and should not be affected by freezing and defreezing.

More than 50% of peatlands are located in northern part of Poland (about 70%). They cover an area of about 1.2 million hectares (around 4.2% of area of the country) and their volume is estimated at over 17 billion m^3. Up to the present, about 50,000 peatlands have been catalogued by the Institute for Land Reclamation and Grassland Farming. About 36% of them form a potential resource basis for peat harvesting.

In 2011, anticipated resources of peat were estimated at 74.18 million tonnes (Tab. 36), decreasing by about 2.14 million tonnes in relation to the previous year as a result of crossing out three deposits of the resources amounted to 267,000 m^3. The output of peat amounted to 1.214 million m^3 in 2011 and increased by 229 thousand m^3 (23%).

Table 36. Peat resources in Poland [million m^3]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	256	74.18	61.63	12.55	7.08	29.52
Including resources of exploited deposits						
Total	96	46.72	46.61	0.11	4.97	27.68
1. Deposits of operating mines	65	41.71	41.60	0.11	4.37	25.61
2. Deposits exploited temporarily	31	5.01	5.01	–	0.60	2.07
Including resources of non-exploited deposits						
Total	110	23.40	11.19	12.20	1.24	1.84
1. Deposits covered by detailed exploration	91	11.21	11.19	0.01	1.08	1.84
2. Deposits covered by preliminary exploration	19	12.19	0.00	12.19	0.17	–
Including abandoned deposits						
Total	50	4.06	3.82	0.23	0.87	–

5.22. PHYLLITE, QUARTZ AND MICACEOUS SCHISTS

Metamorphic phyllite, quartzitic and mica schists are used in the building construction as the major component of fine gravel cover of roll tar paper (phyllite and mica schists), in agriculture as inert dust carrier of pesticides, and in the manufacture of fire-proof materials as one of the major components of fire-proof cement (crystalline schists).

The three deposits of phyllite schists from the Opolskie Voivodeship are the only proven deposits in Poland (Plate 7): Chomiąża, Dewon-Pokrzywna and Dewon--Pokrzywna 2. Anticipated economic resources of phyllite schists in Poland were estimated in 2011 at about 18.08 million tonnes and production (from Dewon-Pokrzywna deposit) 157 thousand tonnes. Production increased by 100 thousand tonnes in comparison with 2010.

Quartzitic schists occur only within the Strzelin granite massif at Jegłowa in the Lower Silesian region (Plate 7). The Jegłowa deposit is still the only deposit of that raw material which has been proven in Poland. Its anticipated resources were estimated in 2011 at about 5.93 million tonnes and economic resources at 3.78 thousand tonnes. Production of quartzitic schists in 2011 was equal 40 thousand tonnes (increased by 38 thousand tonnes). The Jedłowa deposit is widely known for occurrences of beautiful quartz crystals, especially clear and colorless rock crystals.

Micaceous schists occur in the Orłowice deposit located near Lwówek Śląski and in the Jawornica deposit in the Kłodzko area (Plate 7). Total anticipated economic resources of that mineral raw material as of 31.12.2011 were estimated at 6.67 million tonnes, and economic resources at 4.41 million tonnes. In 2011, production of these schists from Orłowice deposit increased to 4.79 thousand tonnes and from Jawornica deposit decreased to 0.52 thousand tonnes (schists from this deposit are used as crushed stones).

5.23. QUARTZ SANDS FOR PRODUCTION OF CELLULAR CONCRETE AND LIME-SAND BRICK

Sands are widely used in production of cellular concrete and bricks and sand lime blocks in the whole area of Poland. Raw material suitable for that production has to be sufficiently pure and fine-grained and well sorted. These requirements are met by Quaternary sands of glacial and fluvioglacial origin and river and eolian sands. Sands most suitable for these purposes include mainly fluvioglacial and eolian sands characterized by high degree of roundness of grains and low content of extraneous matter.

According to criteria of Polish classification of reserves/resources adopted in 2005 and to the Regulation of the Minister of the Environment of the 22nd of December 2011 (Official Journal of 2011 No. 291, Item 1712), exploitable quartz sand deposits require a minimum content of quartz grains (90%), maximum content of silts (5%), thickness minimum 2 m and the ratio of cover to deposit series not higher than 0.5.

It should be stated that accuracy of prospecting and exploration of these sand deposits has been satisfactory. The deposits are fairly evenly distributed throughout the whole area of the country, except for the Carpathian Mts. In the latter region, resources of sand deposits (especially quartz sands of good quality) appear clearly insufficient to cover the local needs (Plate 8).

Anticipated economic resources of these sands are of the order of 145.69 million m^3 (Tab. 37), increased by 2.90 million m^3 in comparison with previous year. Economic resources within exploited deposits amounted to 19.46 million m^3 (56.1% of total anticipated economic resources). Production of quartz sands for production of cellular concrete totaled 414,000 m^3, being 17,000 m^3 bigger than in the previous year.

Anticipated economic resources of the sand deposits remain at the level of 260–280 million tonnes since quite a few years (Tab. 38). In 2011, resources of quartz sands for production of lime-sand brick decreased (by 2.47 million m^3) and amounted to 270.46 million m^3. Economic resources within exploited deposits amounted to 21.58 million m^3 (45.7% of total anticipated economic resources). In 2011, production of these quartz sands increased by 169,000 m^3, to 780,000 m^3.

Total anticipated economic resources of quartz sands for production of cellular concrete and lime-sand brick amounted in 2011 to 416.16 million m^3 (749.08 million tonnes).

Anticipated economic resources of quartz sands for production of cellular concrete varied from 132 to 153 million m^3 till 2008 (Fig. 20), then increased significan-

Table 37. Quartz sands for production of cellular concrete resources in Poland [million m^3]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	59	145.69	55.29	90.40	1.62	20.03
Including resources of exploited deposits						
Total	14	34.68	29.84	4.84	0.27	19.46
1. Deposits of operating mines	11	30.27	25.44	4.84	0.27	17.60
2. Deposits exploited temporarily	3	4.41	4.41	–	–	1.87
Including resources of non-exploited deposits						
Total	38	105.76	20.20	85.57	0.82	0.47
1. Deposits covered by detailed exploration	14	26.09	20.20	5.90	0.34	0.47
2. Deposits covered by preliminary exploration	24	79.67	0.00	79.67	0.47	–
Including abandoned deposits						
Total	7	5.25	5.25	–	0.53	0.10

Table 38. Quartz sands for production of lime-sand brick resources in Poland [million m^3]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	104	270.46	143.26	127.20	5.81	21.58
Including resources of exploited deposits						
Total	29	47.18	45.65	1.53	0.11	21.58
1. Deposits of operating mines	22	37.41	35.88	1.53	0.11	16.67
2. Deposits exploited temporarily	7	9.77	9.77	–	–	4.91
Including resources of non-exploited deposits						
Total	50	189.56	68.63	120.93	2.10	–
1. Deposits covered by detailed exploration	27	68.10	66.66	1.43	2.10	–
2. Deposits covered by preliminary exploration	23	121.47	1.97	119.50	–	–
Including abandoned deposits						
Total	25	33.72	28.98	4.74	3.60	–

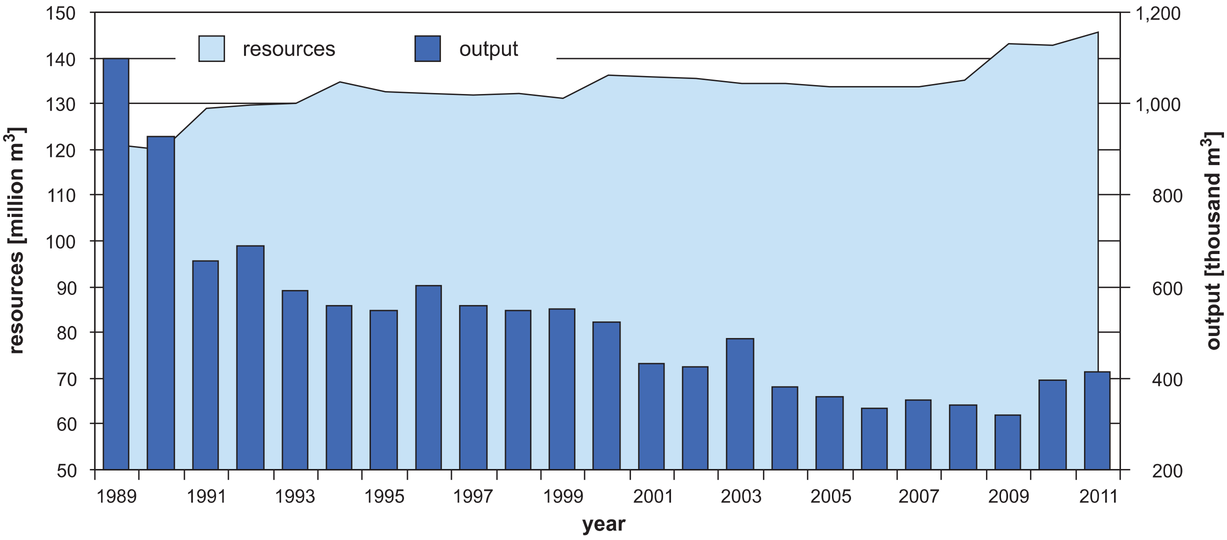

Fig. 20. Quartz sands for production of cellular concrete – anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

tly in the years 2009–2011 due to the documentation of new deposits and amounted to 146 million m^3. New resources were explored not only within deposits already documented – Studzienice deposit in Pomorskie Voivodeship (+8.5 million m^3) but also in new deposits – Brzeziny-1 in Lubelskie Voivodeship (+1.1 Mm^3).

Despite the increasing resources base the production has not grown in the last few years – it varied from 320,000 to 414,000 m^3 as a result of the crisis in building material sector and production limitation and due to the fact that other raw materials such fly ash from power stations or building sands were used for cellular concrete production. Nevertheless, Poland remains the European leader in production of articles made of cellular concrete.

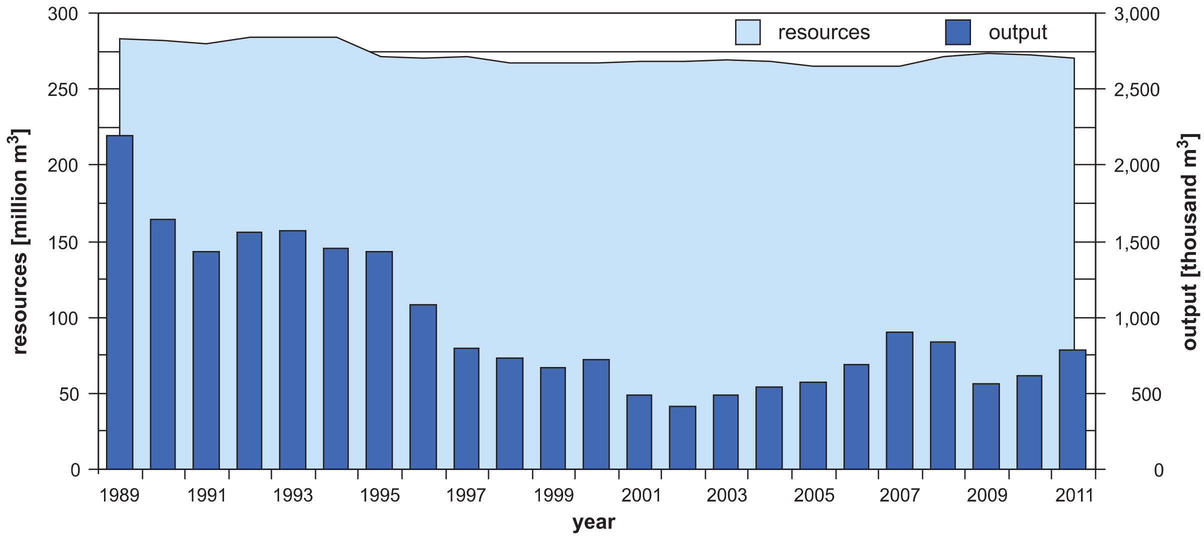

Fig. 21. Quartz sands for production of lime-sand brick – anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

Anticipated economic resources of quartz sands for production of lime-sand brick have been quite steady and remain within the range of 265–273 million m^3 with the slight negative tendency (Fig. 21). The increase of the new documented resources is bridged by the output. The production depends on demand for building materials. This raw material is utilized locally, in production plants located in the neighborhood of deposits. During the last ten years the output varied from 411,000 m^3 in 2002 to 905,000 m^3 in 2007. After the production declined in 2009 to 561,000 m^3 due to the global crisis, in the last two years there has been important growth noted.

5.24. REFRACTORY CLAYS

Kaolinite clays called as refractory clays are an indispensable raw material for production of fire resistant materials. Such clays originate in result of wash down of outcropping and near-surface kaolinized rocks and redeposition of kaolinite, connected with separation of quartz grains and marked improvement of fire resistance properties of that raw material.

Kaolinite clays are characterized by high plasticity and when fired at temperatures over 1,500°C they form ceramic bodies with high mechanical strength. Very low content of calcium and magnesium compounds is very advantageous as it results in a rise of melting point of these clays. In turn, presence of iron compounds results in yellow to brownish and red color of the fireproof clays.

The single exploited deposit of refractory clays, the Rusko-Jaroszów deposit, is situated in the Lower Silesian region. The second largest deposit is called Kryzmanówka and is located in the Mazowieckie Voivodeship (Plate 7). This deposit was not exploited in 2011. Other refractory clays deposits are not exploited at present.

Anticipated economic resources amounted to 54.75 million tonnes in 2011 and were by 0.11 million tonnes lower than in 2010. Economic resources are equal 2.81 million tonnes (5% of total anticipated economic resources) (Tab. 39).

In 2011 production of refractory clays was equal 109 thousand tonnes and increased by 38 thousand tonnes in comparison with the previous year. The exploited raw material may be used without any processing or after firing, as the so-called fired clays.

Table 39. Refractory clays resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	17	54.75	54.03	0.71	110.36	2.81
Including resources of exploited deposits						
Total	3	4.87	4.66	0.20	0.91	2.81
1. Deposits of operating mines	1	1.71	1.51	0.20	–	1.63
2. Deposit exploited temporarily	2	3.16	3.16	–	0.91	1.18
Including resources of non-exploited deposits						
Total	6	48.62	48.47	0.15	106.02	–
1. Deposits covered by detailed exploration	6	48.62	48.47	0.15	106.02	–
Including abandoned deposits						
Total	8	1.26	0.90	0.36	3.44	–

5.25. REFRACTORY QUARTZITES

Quartzite is a compact hard metamorphic rock which was originally sandstone. Pure quartzite is recrystallized sandstone with siliceous cement, often over 99% SiO_2 and almost exclusively built of quartz grains cemented with silica. In the insulating material industry, that name of fire-proof quartzite is used for both pure quartzite and other silica-rich rocks such as quartzitic sandstones and schists.

Refractory quartzites are used in metallurgy for making ferroalloys and in insulating material industry for making siliceous fire-proof materials.

In Poland, quartzite deposits occur in two regions: the Lower Silesian region and the Holy Cross Mts. (Plate 7). In the Lower Silesia, proven deposits occur in area between Bolesławiec, Lubań and Lwówek Śląski and in the vicinities of Strzelin. They are form-

Table 40. Refractory quartzites resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	18	6.88	3.85	3.03	4.74	–
Including resources of non-exploited deposits						
Total	7	5.95	3.23	2.72	3.84	–
1. Deposits covered by detailed exploration	6	5.25	3.23	2.02	3.84	–
2. Deposits covered by preliminary exploration	1	0.70	–	0.70	–	–
Including abandoned deposits						
Total	11	0.93	0.62	0.31	0.90	–

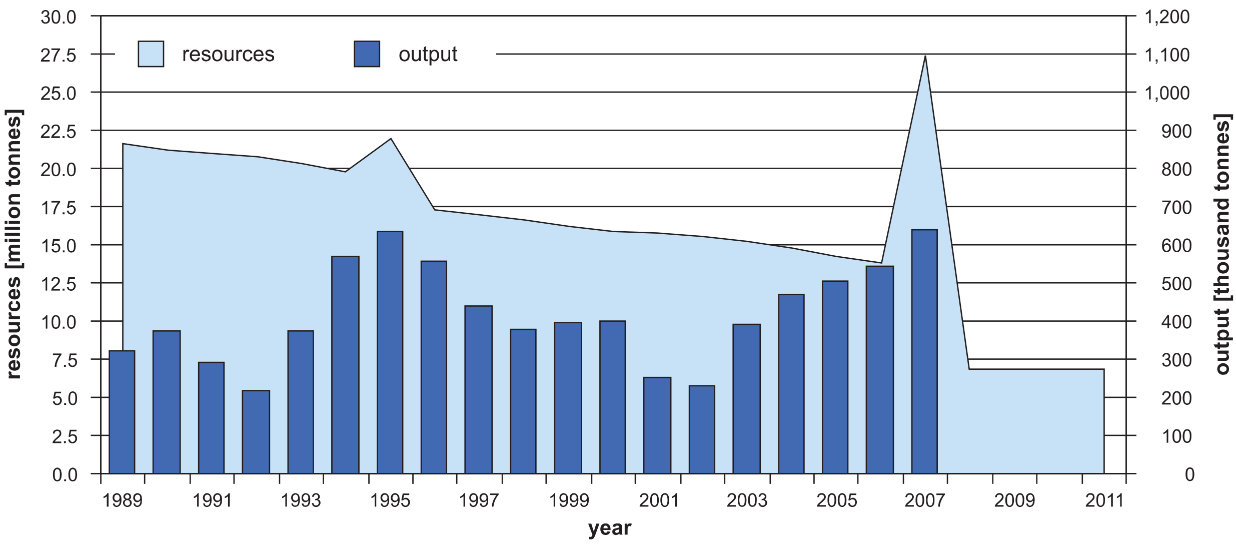

Fig. 22. Refractory quarzites anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

ed of irregular quartzitic layers and lenses dated at the Neogene. The majority of these sites were exploited in the past so the abandoned deposits still comprise some relict resources. It should be added here that two quartzite deposits from Milików still have to be developed.

Quartzite deposits occurring in the Holy Cross Mts. are formed by quartzite intercalations in clays and clay shales of the Paleozoic age. The deposits were explored in the 1950s but only one of them (the Bukowa Góra) is still being exploited. The raw material of that deposit has not been classified as fire-proof quartzite but quartzitic sandstone. Therefore, the Bukowa Góra deposit is discussed in the section on dimension and crushed stones.

Anticipated economic resources of the refractory quartzites were at the same level as in the previous year and were equal 6.88 million tonnes (Tab. 40).

The Figure 22 shows resources and production of refractory quartzites in Poland in the years 1989– 2011. The new resources were documented in one of the deposits in 1995 and one of the deposits was excluded from the Polish mineral resources balance in 1996. The boundary of the Bukowa Góra deposit was extended so resources of this deposit increased in 2007. The Bukowa Góra deposit has been classified as the crushed and dimension stones deposit since 2008. Any output of the refractory quartzites is registered because the Bukowa Góra deposit was the only exploited deposit in the refractory quartzites group.

5.26. SAND AND GRAVEL

Two major groups of natural sand-gravel aggregates are differentiated: coarse aggregate group, comprising gravels and sand-gravel mix, and that of fine aggregates – comprising sands. Natural aggregates are used mainly in the building (concrete fill) and road construction (embankment and highway fill and road surfacing).

The demand for natural coarse aggregates is the largest, especially as distribution of their resources is far from uniform. The resources of natural coarse aggregates are generally small in central parts of the country, not covering the local demand (Plate 8).

The bulk of Polish natural aggregate deposits are of the Quaternary age. The share of deposits of the Pliocene, Miocene and Lower Jurassic age is subordinate.

The quality of raw material (especially its homogeneity) depends largely on genetic type of a given deposit. Deposits of fluvial origin clearly predominate in the Carpathian-Sudetic zone (southern Poland). In the Sudetes, the most common deposits are those of sandy-gravel higher terraces of the Pleistocene age, built mainly of detritus of sandstones and crystalline rocks. In turn, in the Carpathian region the raw material basis mainly comprises gravel and sandy gravel deposits occurring on flood-plain terraces as well as valley side terraces rising above flood plains. The Carpathian deposits are characterized by predominance of material coming from disintegration of flysch rocks, except for those of the Dunajec River valley, showing fairly high contribution of crystalline rocks from the Tatra Mts.

In northern and central Poland (Polish Lowlands region), the most important deposits are of glacial (accumulation platform of front moraine) and fluvioglacial (outwash plain and esker) origin and resulting from river accumulation. Deposits from northern part of that area represent gravel-sandy accumulations mainly comprising Scandinavian material – debris of crystalline rocks and limestones with admixture of quartz and sandstones. In central and southern parts of this region, the deposits are mainly formed of sandy sediments with significant share of debris of local rocks (Plate 8).

According to criteria of Polish classification of reserves/resources adopted in 2005 and to the Regulation of the Minister of the Environment of the 22nd of December 2011 (Official Journal of 2011 No. 291 Item 1712), sand and gravel deposits should be characterized by content of grains of silt fraction below 15%, minimum thickness of 2 m and the ratio of cover to deposit series not higher than 1.0.

Anticipated economic resources of natural aggregates totaled 17,232.56 million tonnes in the end of 2011 (Tab. 41). That means an increase by 480.14 million tonnes in relation to the previous year. Economic resources amounted to 3,030.71 million tonnes and increased by 327.1 million tonnes in comparison with the previous year.

The identification and management structure of the resources are shown in Figure 23. Frequency of the occurring of various magnitude deposits of sand and gravel in Poland is shown in Figure 24.

The highest number (50%) of sand and gravel deposits in Poland has the resources located in the range of 50–500 thousand tonnes but these deposits account for only 4.9% of total resources and for 18.2% of the output in Poland. The largest exploitation (57.7%) takes place from the deposits with resources between

Table 41. Sand and gravel resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	A+B+C_1	C_2+D		
TOTAL RESOURCES	8,628	17,232.56	9,194.75	8,037.80	362.88	3,030.71
Including resources of exploited deposits						
Total	3,387	4,715.38	4,013.20	702.18	49.46	2,527.95
1. Deposits of operating mines	2,565	4,100.03	3,476.40	623.64	33.50	2,212.64
2. Deposits exploited temporarily	822	615.35	536.81	78.54	15.95	315.31
Including resources of non-exploited deposits						
Total	3,352	11,238.04	4,262.43	6,975.61	233.90	485.87
1. Deposits covered by detailed exploration	3,012	4,583.90	4,226.75	357.15	114.42	415.17
2. Deposits covered by preliminary exploration	340	6,654.14	35.68	6,618.47	119.48	70.70
Including abandoned deposits						
Total	1,889	1,279.14	919.12	360.01	79.52	16.89

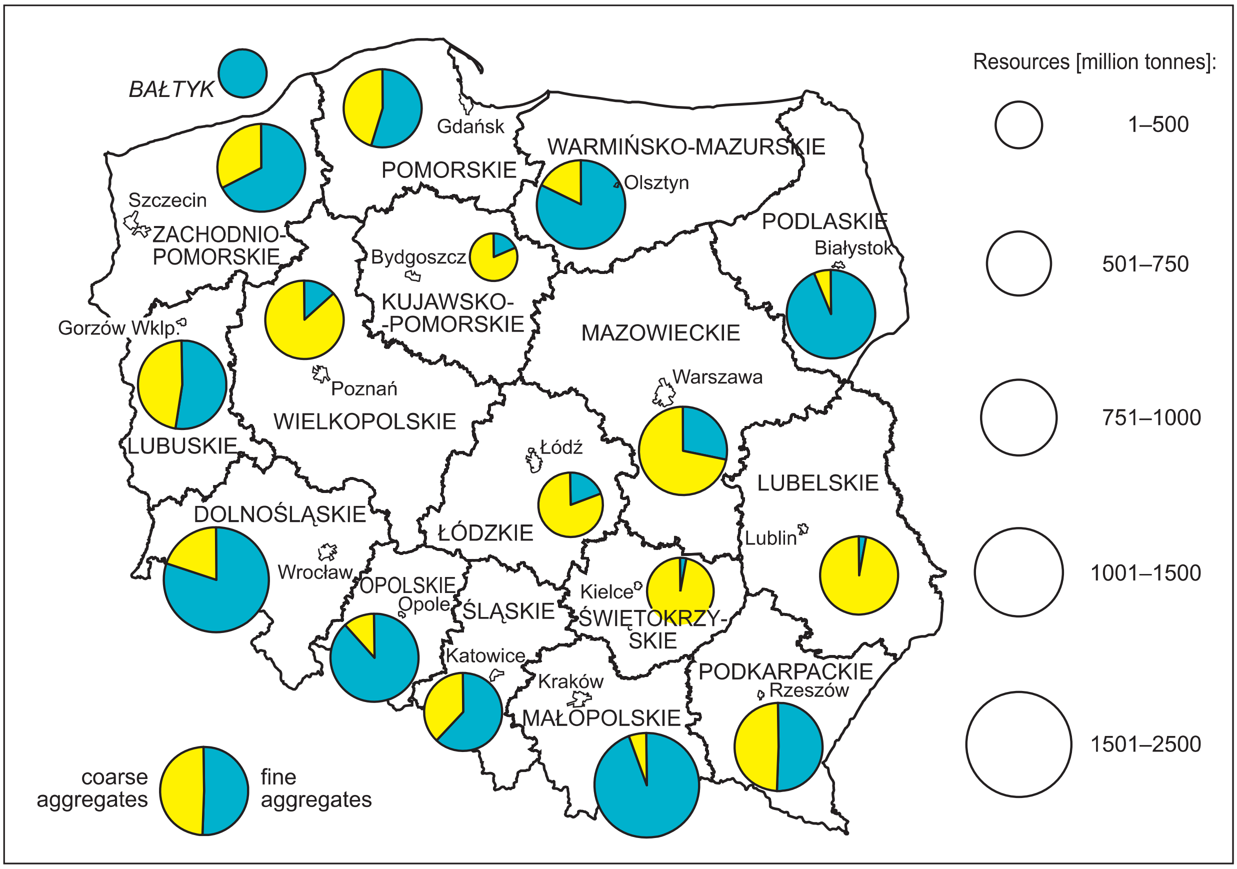

Fig. 23. Distribution of sand and gravel resources in Poland in 2011

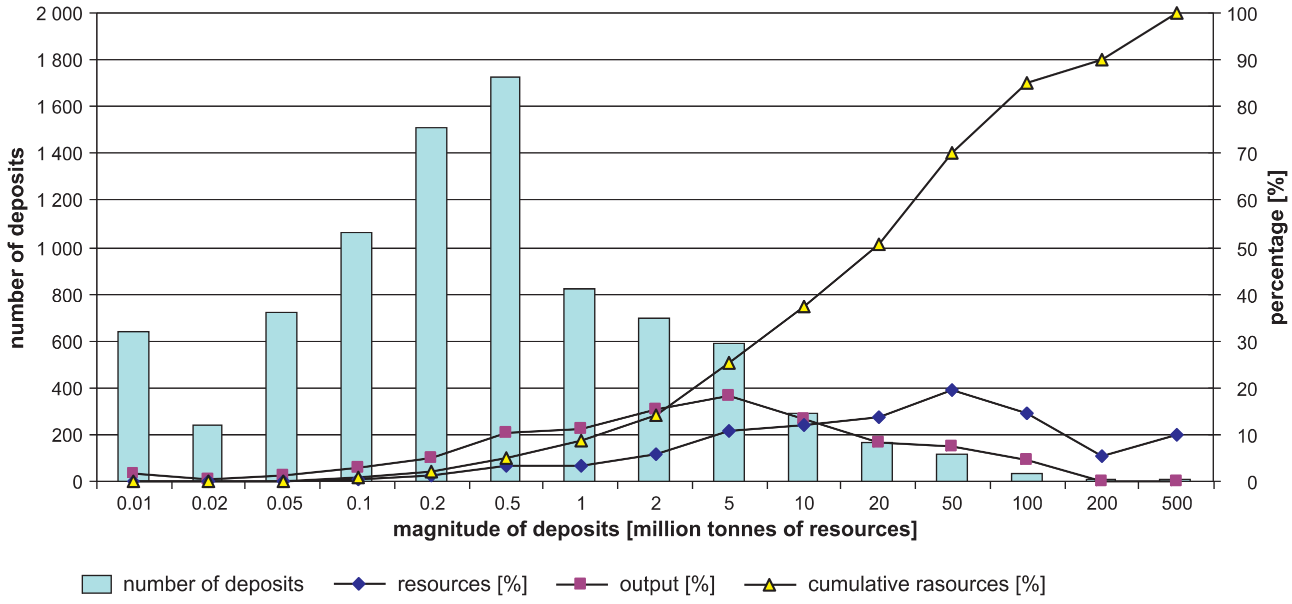

Fig. 24. Frequency of resources magnitude in sand and gravel deposits in Poland in 2011

500 thousand tonnes to 10 million tonnes (such deposits account for 27.8% of the total number of sand and gravel deposits in Poland) – their resources states for 32% of the total sand and gravel resources in Poland.

In 2011, production of natural sands and gravel rose to 248.7 million tonnes, increasing by 85.2 million tonnes that are 52.2% in relation to the previous year. The production increased in 15 voivodeship (out of 16). Natural sand and gravel are also obtained during the exploitation of brown coal. In 2011 from Bełchatów deposit the output of sand and gravel amounted to 486 thousand tonnes.

Figure 25 shows changes in domestic resources and production of sand and gravel in Poland in the years 1989–2011. Anticipated economic resources did not changed significantly till 2005. Within the next six years the resources increased by 11.2% and amounted to 17.2 billion tonnes in 2011. That is due to the incre-

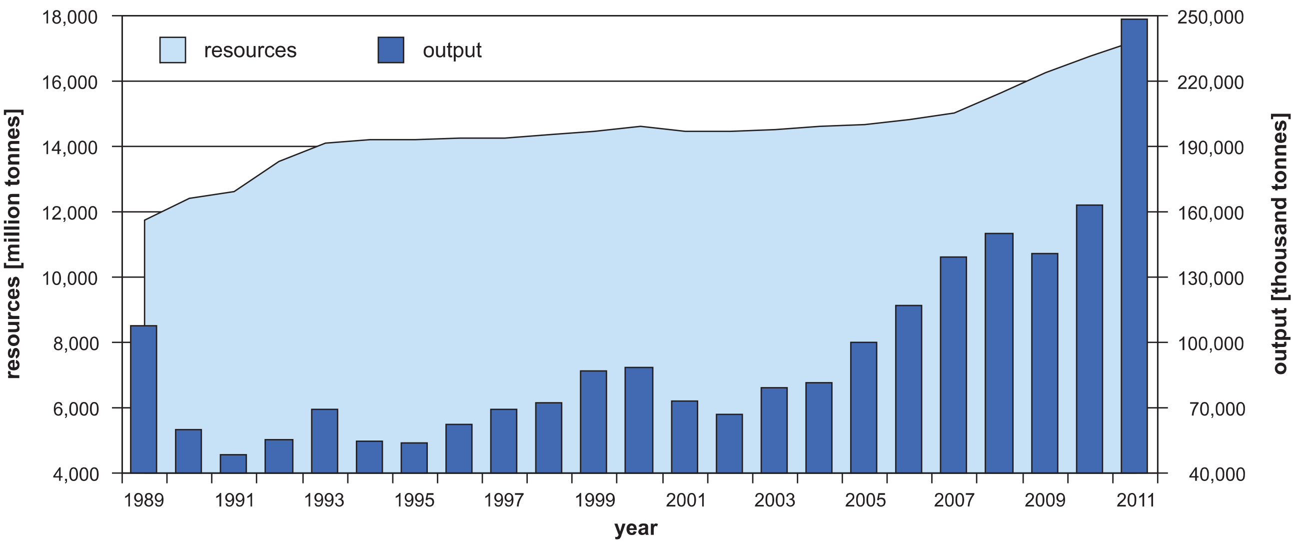

Fig. 25. Sand and gravel anticipated economic resources and output in Poland in the years 1989–2011

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish) (Przeniosło, ed., 1989–2005; Przeniosło, Malon, eds., 2006; Gientka, Malon, Tymiński, eds., 2007; Gientka, Malon, Dyląg, eds., 2008; Wołkowicz, Malon, Tymiński, eds., 2009–2010; Szuflicki, Malon, Tymiński, eds., 2011)

asing demand for natural aggregates exploitation as they widely used in road construction sector (e.g. successive stretches of A2, A4 and A1 highways) and therefore its new sources have to be prospected and explored. It should be emphasized that the resources increase was visible despite the significant growth of the production.

The sand and gravel production has been increasing since 2005 (the level of 116.7 million tonnes) by a dozen or so to twenty million tonnes per year and amounted to 248.7 million tonnes in 2011. That is also due to the growing requirement for road construction, especially in a highway sector. The most visible increase was noted within these regions where highways were built (A2 – Łódzkie Voivodeship; A1 – Kujawsko-Pomorskie Voivodeship and A4 – Podkarpackie Voivodeship).

5.27. VEIN QUARTZ

Quartz (SiO_2) is the commonest mineral occurring in the magmatic, metamorphic and sedimentary rocks. Under conditions favorable for crystallization, such as voids in magmatic or metamorphic rocks, it forms sharp-pointed hexagonal long and slender crystals which are widely used as a popular ornamental stone and also a gemstone in jewellery. Depending on admixture of coloring oxides, several varieties of these gemstones are differentiated: clear and colorless rock crystal, yellow to orange citrine, pink to rose red rose and pink quartz, purple to violet amethyst, brown to gray smoky quartz and black morion.

Quartz also forms veins and lenses in metamorphic and igneous rocks. Quartz vein deposits originate in result of hydrothermal activity as an infill of open fissures and fractures cutting a given rock massif. The quartz infills are characterized by high content of silica (SiO_2) and low content of coloring oxides (Fe_2O_3 and TiO_2). Quartz crystal from these occurrences due to its piezoelectric properties is one of the basic electronic raw materials. It is also widely used in the optics and production jewellery. Its purest varieties are used in manufacturing high-quality glass and are also the source of high-quality quartz powder and grits to production of ferrosilicon.

In Poland quartz veins occur mainly in crystalline rock massifs of the Precambrian and Paleozoic in the Sudetes (Plate 6). The deposits are characterized by a high variability in thickness and quality of raw material as well as in generally high dip of veins and lenses. Prognostic resources of vein quartz are assessed to be equal 2.87 million tonnes and prospective resources 1.33 million tonnes (Wołkowicz, Sroga, 2011).

The largest anticipated economic resources hitherto discovered are 3.3 million tonnes in the Stanisław deposit located south-west of Jelenia Góra and 1.5 million tonnes in the Krasków deposit from the vicinities of Świdnica, Sudetes (Plate 6). There are possibilities

Table 42. Vein quartz resources in Poland [million tonnes]

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		anticipated economic			anticipated sub-economic	
		total	$A+B+C_1$	C_2+D		
TOTAL RESOURCES	7	6.56	4.45	2.11	0.35	3.23
Including resources of exploited deposits						
Deposit exploited temporarily	3	5.35	3.52	1.83	0.30	3.23
Including resources of non-exploited deposits						
Deposits covered by detailed exploration	2	0.28	0.22	0.06	–	–
Including abandoned deposits						
Total	2	0.94	0.72	0.22	0.05	–

to discovery of some new deposits as potential resources are estimated at about 4 million tonnes. The known minor deposits were found to be characterized by very good quality of quartz veins. There are three out of all deposits at the Sudetes region developed: Krasków, Stanisław and Taczalin. Economic resources of these deposits amounted to 3.23 million tonnes (Tab. 42). In the year 2011, any of these deposits has not been extracted.

5.28. BRINES, CURATIVE AND THERMAL WATER

In the terms of the Act of 4 February 1994 Geological and Mining Law (Official Journal 2005, No. 228, Item 1947, with subsequent amendments), according to article 5 section 4, brines, curative and thermal waters were minerals. This was due to their special advantages: their mineralization, physical and chemical properties, quantity and conditions of occurrence. In article 5, section 5 and 6, the Council of Ministers were authorized to specify by way of an ordinance the groundwater deposits classified as brines, curative and thermal waters.

According to the Regulation of 14 February 2006 of the Council of Ministers about groundwater deposits classified as brines, curative and thermal waters and others curative minerals and also about classifying some deposits of common minerals to basic minerals (Official Journal No. 32, Item 220, with subsequent amendments) only one deposit was classified as brine and 72 deposits were classified as curative waters. All waters of any geological unit, having the temperature of 20°C at the outflow, were classified as thermal waters, excluding drainage waters from mining areas.

Since 1 January 2012 the new Act of 9 June 2011 Geological and Mining Law (Official Journal of 2011, No. 163, Item 981) has been legislated. According to this Act, groundwater is considered as brines, curative or thermal waters only on the basis of their specific physical and chemical properties. There is no authorization for the Council of Ministers to specify in the separate ordinance, the particular (named) deposits of groundwater classified as brines, curative and thermal waters. The information given in the following chapter about brines, curative and thermal waters refer to the obligatory regulations in 2011.

Brine: groundwater with total solid dissolved minerals at least 35 g/dm^3. Taking the purpose of exploitation into consideration, the Ordinance of the Council of Ministers classified only the deposit in Łapczyca in Małopolskie Voivodeship as brine. This brine, occurring in Miocene sandstone formation, is used for therapeutic purposes and bath salt production. Groundwaters with similar composition (strongly mineralized waters of Cl-Na or Cl-Na-Ca type, with higher amount of iodine ion) are common in the area of Polish Lowlands. They occur in very deep formations, at depth of some thousand meters.

Curative water: According to the Ordinance of the Council of Ministers dated on 14.02.2006 curative water was considered as groundwater with no chemical and microbiological contamination, with natural diversity of physical and chemical properties, meeting at least one of the following requirements:

- total solid dissolved mineral content at least 1,000 mg/dm^3;
- ferrous ion content – at least 10 mg/dm^3 (ferruginous waters);
- fluoride ion content – at least 2 mg/dm^3 (fluoride waters);
- iodine ion content – at least 1 mg/dm^3 (iodide waters);
- bivalent sulphur ion content – at least 1 mg/dm^3 (sulphide waters);
- meta-silicic acid content – at least 70 mg/dm^3 (silicic waters);
- radon content – at least 74 Bq (radon waters);
- carbon dioxide content – at least 250 mg/dm^3 (250–999 mg/dm^3 carbonic acid waters, ≥1,000 mg/dm^3 carbonated water),

and occurring as deposits in the area of 72 health resorts and towns, mentioned in the Ordinance of the Council of Ministers. Curative waters were also all carbonic acid waters and carbonated waters of other deposits not mentioned in the above mentioned ordinance.

Most of curative waters – over 70% occur in health resorts and towns of southern Poland, in Sudetes and Carpathian region (together with Carpathian Depression). The rest of deposits occur in Western Pomerania and in Polish Lowlands. Curative waters are used mainly for balneologic (baths, inhalations, drinking treatment) and bottling purposes (i.e. Krynica-Zdrój, Muszyna, Piwniczna-Zdrój, Wysowa, Polanica-Zdrój, Busko-Zdrój) but also for salt, lye and mud production and pharmaceutic preparations (i.e. Ciechocinek, Dębowiec, Iwonicz-Zdrój, Rabka-Zdrój).

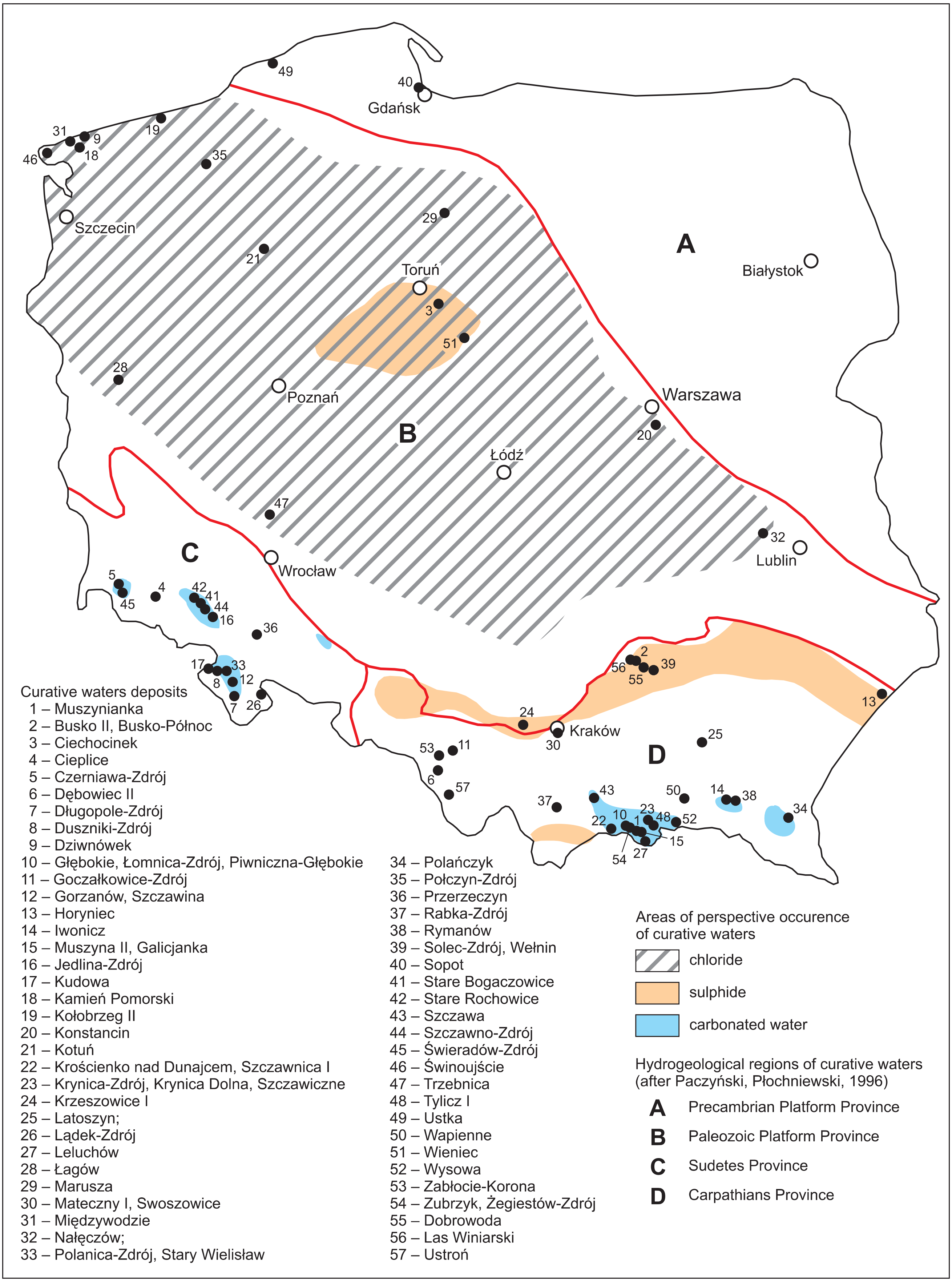

Fig. 26. Occurrence of particular chemical types of curative and mineralised waters (Paczyński, 2002; simplified)

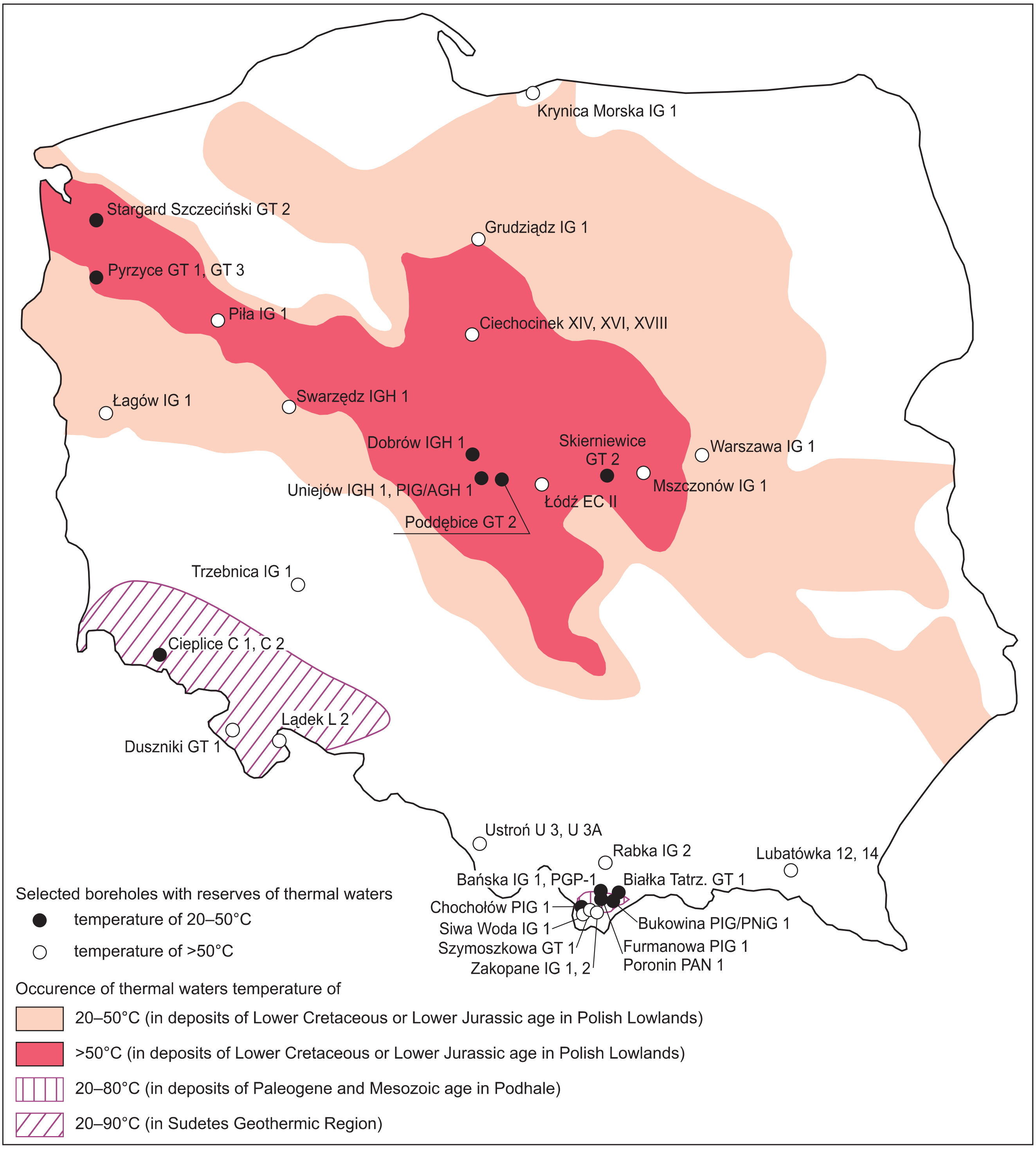

Fig. 27. Occurrence of thermal waters in Poland (Kapuściński *et al.*, 1997; simplified with additions)

Mineralised and specific groundwater (with total solid dissolved minerals over 1,000 mg/dm^3 (Dowgiałło *et al.*, 2002), not considered as curative, occur commonly in Poland at various depths, more often deeper than ordinary waters. The variety of chemical composition of these waters (Fig. 26) is caused by diversity of geological and hydrogeological conditions. The following types are distinguished:

- strongly mineralised chloride waters, mainly of Cl-Na, (J) type;
- bicarbonate waters, mainly of HCO_3-Ca-(Mg), (Fe) type;

– specific waters of various mineralization: Fe, F, J, S, H_2SiO_3, Rn, CO_2, thermal.

Thermal water: groundwater in all geological units having the temperature of 20°C at the outflow, excluding drainage waters from mining areas. They occur in Poland in the area of Polish Lowlands within the large reservoirs of regional importance, also in Carpathians and Sudetes (Fig. 27).

In the area of Polish Lowlands, thermal waters from Lower Cretaceous and Lower Jurrasic formations are the most prospective for use. They occur in widespread hydrogeological basins (covered structures). In Carpathians thermal waters occur in Cretaceous, Paleogene and Neogene formations and also in Triassic deposits of Podhale Trough, which is characterized by small area and strong tectonic influence (i.e. Bańska, Biały Dunajec, Białka Tatrzańska, Bukowina Tatrzańska). In the Carpathians Forehead, thermal waters occur in Cambrian, Devonian, Carboniferous, Jurassic, Cretaceous and Miocene formations. In Sudetes the most prospective formation is Carboniferous aquifer in the vicinity of Jelenia Góra (Cieplice Śląskie-Zdrój). Thermal waters are also in Lądek-Zdrój, Duszniki-Zdrój and Grabin in the vicinity of Niemodlin. Thermal waters are used for heating, relaxation and balneologic purposes.

In 2011 reserves of groundwater classified as minerals were calculated as 4,225.31 m^3/h in 89 deposits. The reserves of thermal waters were 2,545.70 m^3/h, curative waters – 1,675.91 m^3/h and brines 3.70 m^3/h.

The amount of brines, curative and thermal waters intake in 2011 was calculated on 8,062,837.26 m^3/year. In comparison to the previous year it has decreased of about 81,776.51 m^3.

6. EXPORTS AND IMPORTS OF MINERAL RAW MATERIALS

Information on the trade turnover in exports and imports of raw materials in Poland was prepared on the basis of data collected by Polish Custom Service. These data come from special custom statements – SAD (in case of the trade turnover by European Union countries to/from non-EU countries) and INTRASTAT (in case of export and import within EU). Information is prepared according to Combined Nomenclature (CN), which is deeply connected with the international classification system named Harmonized System – HS. Combined Nomenclature is the obligatory one in Polish Customs Tariff since 1991. The Combined Nomenclature is the part of the Integrated Tariff of the European Communities (TARIC) which was established by virtue of Article 2 of Council Regulation (EEC) No. 2658/87 of 23 July 1987 on the tariff and statistical nomenclature and on the Common Customs Tariff. Regulation (EC) No. 1789/2003 of 11 October 2003 amended the Regulation mentioned above. The Regulation established in 2003 is the obligatory one in Poland since the 1st of May 2004.

In 2011 summary statistic for minerals and mineral commodities in Poland was presented in four groups: fuels, metals, chemicals and rocks. The total magnitude and value of imports–exports of the raw materials as well as for the particular groups of raw materials are presented in Table 43.

The data on raw materials turnover in 2006–2011 do not cover natural gas. Data on natural gas export and import are not available since 2006 due to the confidentiality of the information – according to the Regulation (EC) No 638/2004 of the European Parliament and of the Council of 31 March 2004 on Community statistics relating to the trading of goods between Member States and repealing Council Regulation (EEC) No. 3330/91. Natural gas export in Poland amounts only to dozens million cubic metres annually and the lack of data does not affect the total balance of raw materials

Table 43. Imports and exports of mineral raw materials in 2011

Group of raw materials	Import/ Export				Balance	
	quantity [thousand tonnes]	%	value [PLN thousand]	%	quantity [thousand tonnes]	Value [PLN thousand]
TOTAL	*73,351** *30,533***	100.0 100.0	*100,127,176* *53,468,605*	100.0 100.0	*–42,818*	*–46,658,571*
Fuels	*45,300* *19,466*	*61.8* *63.8*	*78,937,495* *25,704,744*	*78.8* *48.1*	*–25,834*	*–53,232,751*
Metals	8,469 3,025	11.5 9.9	13,479,581 21,846,818	13.5 40.9	–5,444	+8,367,237
Chemicals	5,096 4,683	6.9 15.3	4,912,270 4,162,294	4.9 7.8	–413	–749,977
Rocks	14,486 3,359	19.7 11.0	2,797,830 1,754,750	2.8 3.3	–11,127	–1,043,080

* import, ** export, *italic* – excluding natural gas

turnover. The lack of data on natural gas import to Poland (about 6–7 billion m^3 with total value of PLN 5–6 billion) brings down the total magnitude and value of raw materials brought to Poland. Therefore, the balance of mineral raw materials turnover will be higher than the balance taking into account these figures.

The total value of the raw materials exports increased by 32.28% in comparison with the previous year and amounted to PLN 53,469 million (USD 18,244 million) in 2011. The imports value amounted to PLN 100,127 million (USD 34,080 million) and was by 34.76% higher than in 2010. The exports–imports turnover balance was still negative and amounted to PLN 46,659 million in 2011 (excluding natural gas).

The most important, regarding the value of the raw materials exports in 2011, were: petroleum products (23.09%), hard coal and coal derivatives (21.59% of the total import value), raw materials and products of copper metallurgy (18.22%), silver (7.68%), iron and ferroalloys (7.04%), nitrogen and multi-component fertilizers (4.77%), aluminum (3.31%), zinc (1.57%) and salt and sodium compounds (1.45%).

The highest values of imports, causing negative balance of the turnover value, related to such raw materials as: crude oil (52.76% of the total import value), petroleum products (17.42%), hard coal and coal derivatives (6.40%), iron (4.10%), aluminum (4.01%) and copper ores (2.12%), potassium raw materials (1.16%), nitrogen and multi-component fertilizers (1.16%), dimension and crushed stones (1.06%), phosphorites (0.93%), refractory materials (0.35%), cement (0.28%) and insulating materials (0.27%).

The total quantity of the raw materials imports increased significantly (by 12%) in 2011 and amounted to 73,351 thousand tonnes, while the export quantity dropped by 4.47% and amounted to 30,533 thousand tonnes.

Figure 28 shows the structure of exports and imports in Poland, i.e. total values and shares of various groups of commodities in the international turnover.

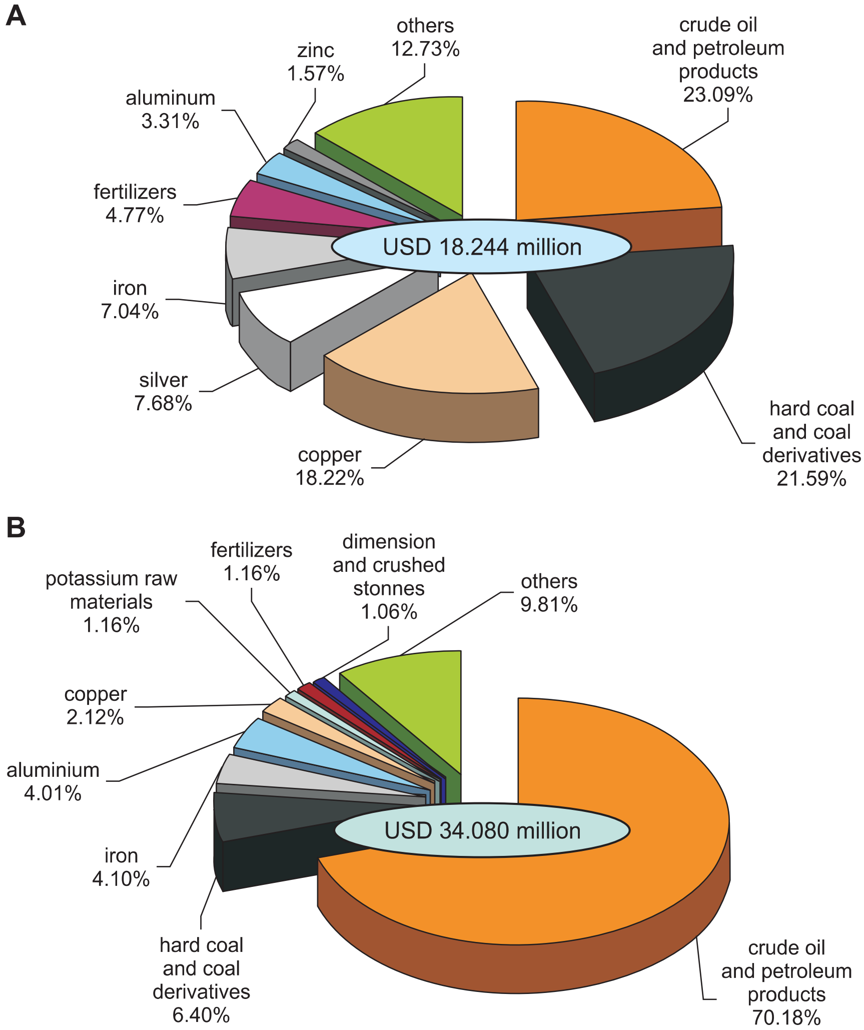

Fig. 28. The structure of mineral raw materials exports (A) and imports (B) in Poland in 2011

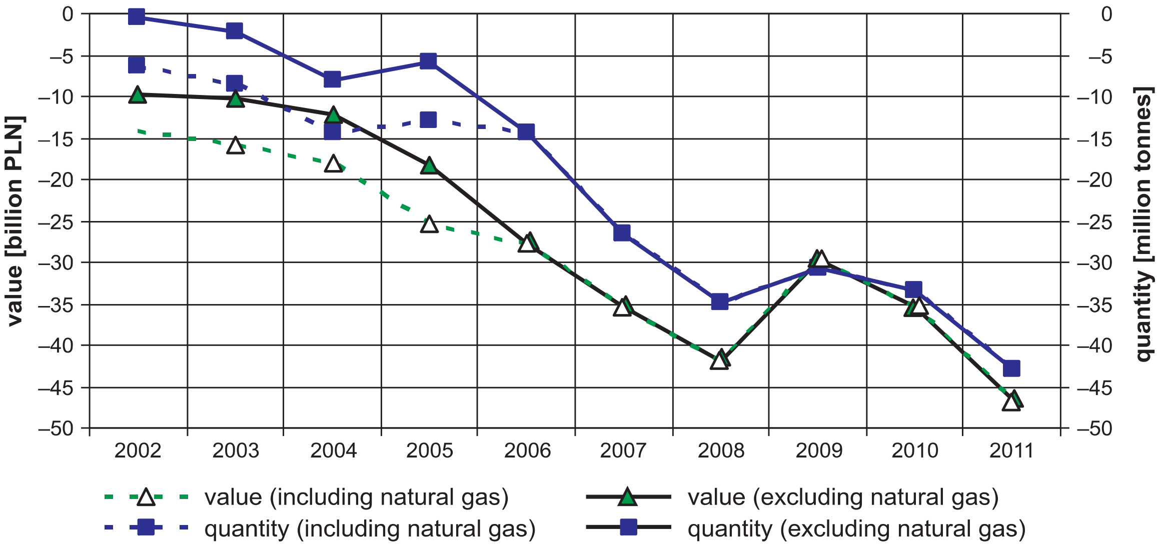

Fig. 29. Balance of Polish imports and exports in terms of value and quantity of mineral raw materials

The variation of the imports–exports balance by value and quantity for the last 10 years is shown in Figure 29. Due to the lack of data on natural gas there are two versions of the graph presented in the figure – first reflecting natural gas (till 2005) and the second one excluding natural gas.

The quantity balance has been declining till 2004 and in the years 2006–2008. There were only two years when it rose – 2005 and 2009. In 2011 it declined to –42.82 million tonnes. The value balance has been quite constant in 2002–2004, and then it decreased substantially. It amounted to PLN –39.15 billion in 2008 then it rose to PLN –27.75 billion in 2009 and declined to PLN –46.66 billion in 2011.

The percentage contributions of the particular groups of raw materials to the value of exports and imports in 2005–2011 are presented in Figure 30. Fuels are still the most important group especially in Polish imports (due to the crude oil and petroleum products) but they are also contributing strongly in exports value (mainly thanks to the petroleum products and hard coal).

The contributions to the export value have been oscillating significantly in three mineral groups during last seven years, only rock raw materials export was pretty constant in the analyzed period. The highest increases of the value with respect to the previous year were noted in 2006 and 2009 within metallic raw materials exports (by 9.6 and 8.0% respectively). There were also significant growths within fuels – in 2008 by 4.3% and in 2010 by 4.0%. Fuels are still the most important group in polish exports value mainly thanks to the petroleum products and hard coal exports. The highest decreases of the export value were observed within fuels in 2006 (by 7.8%) and within metals in 2008 (by 6.9%). Chemical raw materials export increased by 3.7% in 2008, then dropped by 3.6% and remained quite constant till 2011.

The contribution to the import value was stable chemical and rocks in the preceding period of time. In contrast, it has been changing within other mineral groups. Fuels import dropped successively in 2006 and 2007 (by 4.1% and 2% respectively), then it has been increasing since 2008 and amounted to 78.8% in 2011. Metallic raw materials import increased in 2006–2007, then decreased by 4.2% and has not changed significantly since 2008.

Regarding quantity of raw materials exports it can be seen that fuels export has been decreasing for four years – it dropped from the level of 27.6 million tonnes in 2005 to 16.6 million tonnes in 2009. The highest increase within fuels was noted in 2010 (by 5.4 million tonnes) (Fig. 31A). Other three groups of raw materials remained quite constant in the analyzed period, with rock raw materials export decreasing in 2007–2010 period.

Fuels import has been increasing strongly since 2006 and amounted to 45.3 million tonnes in 2011 (the highest level in the analyzed period). Metals import varied within the range of 6.0 to 11.0 million tonnes, with the highest decreased in 2009 (by 4.46 million tonnes). Chemical raw materials import re-

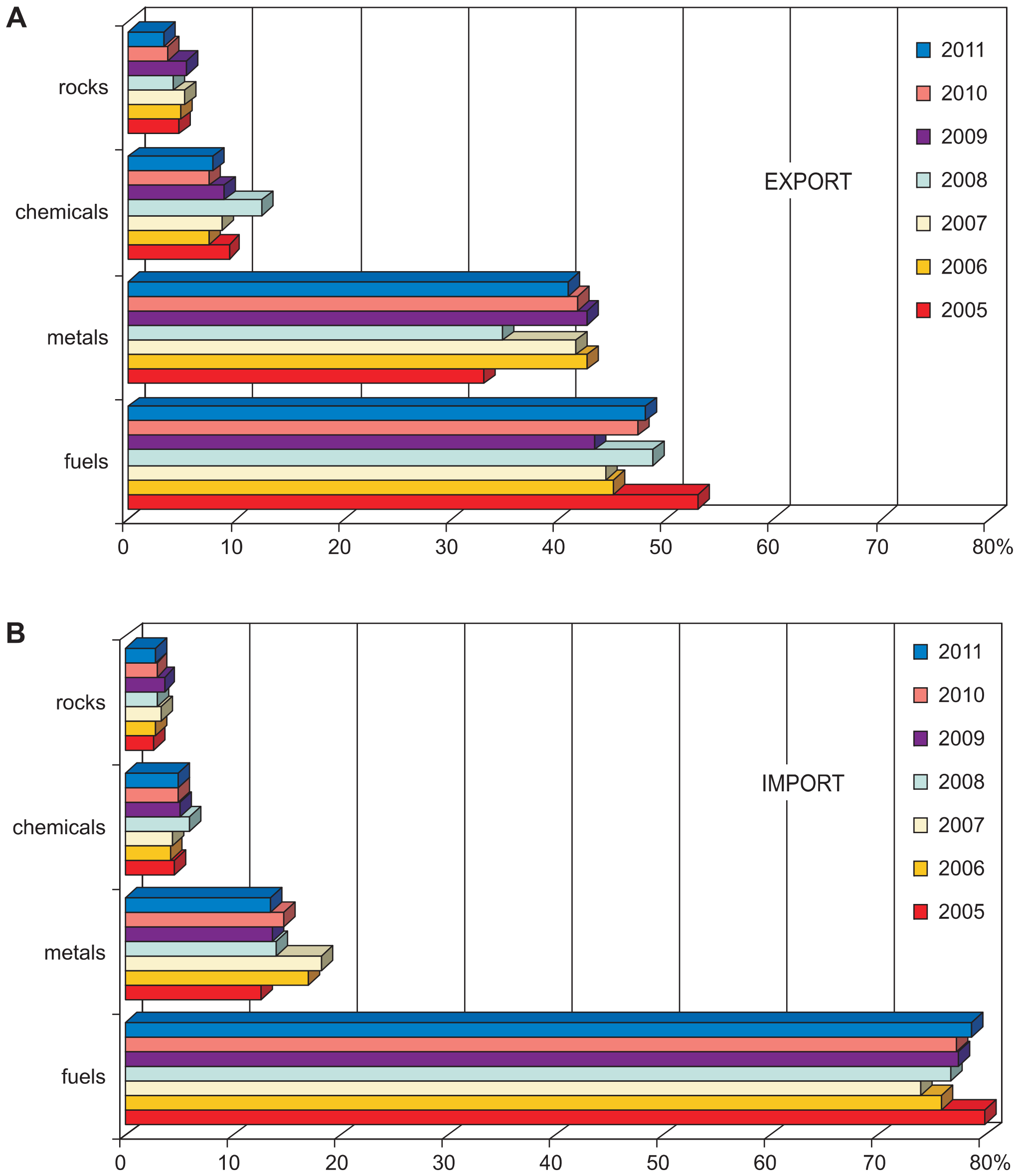

Fig. 30. Contribution of mineral raw materials to the value of Polish exports (A) and imports (B) in the years 2005–2011 (2006–2011 – excluding natural gas)

mained on the level of 4.0 to 5.0 million tonnes, while rock raw materials import has been changing visibly – it increased by 5.92 million tonnes in 2005–2008, dropped in 2009 and 2010 and then increased to the highest level of 14.49 million tonnes in 2011 (Fig. 31B).

Tables given below show the comparison between export/import values (Tab. 44) and quantities (Tab. 45) in 2010–2011.

Total import value in 2011 increased by 34.76% and export value by 32.38% in comparison with 2010. The highest import value increase was noted for fuels (by 37.38%) but there were also significant growths within chemical (by 31.11%), rock (by 30.44%) and metallic raw materials (by 23.09%). Export value rose by 38.63% within chemicals, 34.38% in fuels, 29.72% in metals and only 21.09% in rock raw materials.

Total import magnitude in 2011 increased by 12.00% and export decreased by 4.47% in comparison with 2010. The import quantity increased by 66.36% within rock raw materials, by 9.68% within chemicals and by 4.28% within fuels. There was a little drop in metallic raw materials import (by 0.22 million tonnes – 2.53%). The export quantity increased significantly within two groups of mineral raw materials – by 19.37% in metals and 12.00% in rocks. Chemical raw materials export increased by only 4.00% and there was considerable drop within fuels – by 2.47 million tonnes (11.26%).

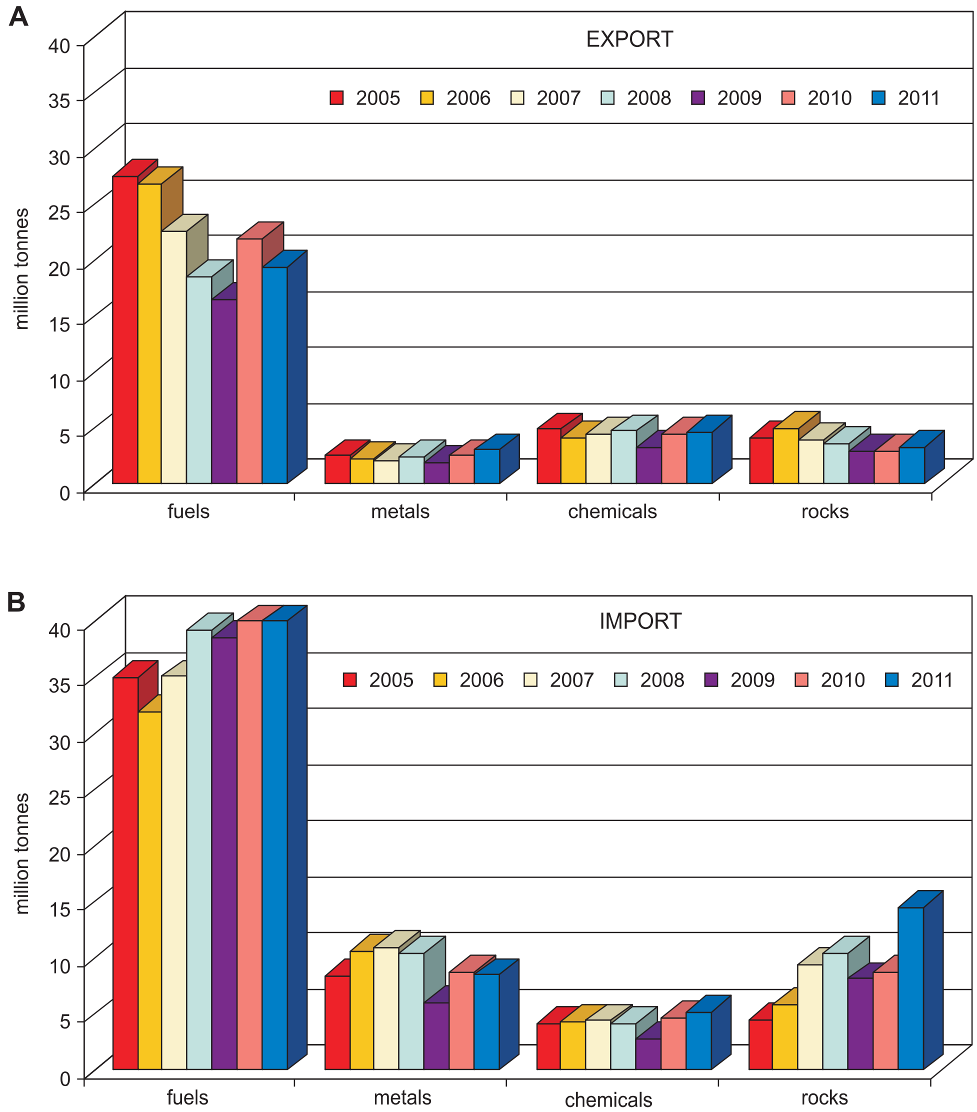

Fig. 31. Magnitude of mineral raw materials exports (A) and imports (B) in the years 2005–2011 [million tonnes] (2006–2011 – excluding natural gas)

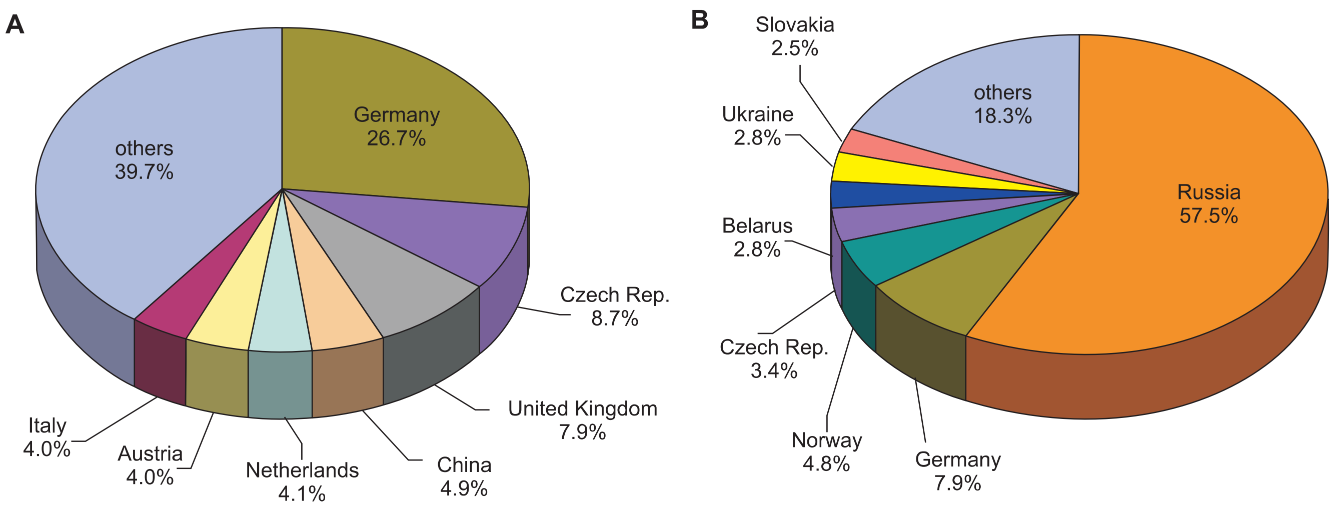

Fig. 32. Polish raw materials import in 2011, by countries

Table 44. Comparison between export/import values in the years 2010–2011 [PLN million]

Group of raw materials	2010		2011		Comparison	
	value	%	value	%	absolute value 2011 – 2010	% 2010 = 100
Total	_74,302.04*_	100.0	_100,127.18_	100.0	_25,825.14_	_134.76_
	_40,420.84**_	100.0	_53,468.61_	100.0	_13,047.77_	_132.28_
Fuels	_57,459.35_	_77.3_	_78,937.50_	_78.8_	_21,478.15_	_137.38_
	_19,127.74_	_47.3_	_25,704.74_	_48.1_	_6,577.00_	_134.38_
Metals	10,951.04	14.7	13,479.58	13.5	2,528.54	123.09
	16,841.40	41.7	21,846.82	40.9	5,005.42	129.72
Chemicals	3,746.81	5.0	4,912.27	4.9	1,165.46	131.11
	3,002.55	7.4	4,162.29	7.8	1,159.74	138.63
Rocks	2,144.84	2.9	2,797.83	2.8	652.99	130.44
	1,449.15	3.6	1,754.75	3.3	305.60	121.09

* import, **export; _italic_ – excluding natural gas

Table 45. Comparison between export/import quantities in the years 2010–2011 [million tonnes]

Group of raw materials	2010		2011		Comparison	
	quantity	%	quantity	%	absolute quantity 2011 – 2010	% 2010 = 100
Total	_65.49*_	100.0	_73.35_	100.0	_7.86_	_112.00_
	_31.96**_	100.0	_30.53_	100.0	_–1.43_	_95.53_
Fuels	_43.44_	_66.3_	_45.30_	_61.8_	_1.86_	_104.28_
	_21.94_	_68.6_	_19.47_	_63.8_	_–2.47_	_88.74_
Metals	8.69	13.3	8.47	11.5	–0.22	97.47
	2.53	7.9	3.02	9.9	0.49	119.37
Chemicals	4.65	7.1	5.10	6.9	0.45	109.68
	4.50	14.1	4.68	15.3	0.18	104.00
Rocks	8.71	13.3	14.49	19.7	5.78	166.36
	3.00	9.4	3.36	11.0	0.36	112.00

* export, ** import; _italic_ – excluding natural gas

Regarding the exports directions, the highest value reached raw materials export to Germany. The export value to this country was PLN 14,284 million, which constituted 26.72% of the total Polish raw materials exports value. Other important countries with significant contribution to the total Polish raw materials exports value were Czech Republic (8.66%) and United Kingdom (7.85%) (Fig. 32A). The total export value to these three countries amounted to PLN 23,115 million.

The major part of the mineral raw materials imports in 2011 came from Russia. The import value was PLN 57,605 million, which constitutes 57.53% of the total mineral raw materials imports value in Poland. Other important countries were Germany (7.87%) and Norway (4.78%) (Fig. 32B). The total import value from these three countries amounted to PLN 70,269 million.

7. UNITED NATIONS FRAMEWORK CLASSIFICATION (UNFC) AND POLISH CLASSIFICATION OF RESOURCES – COMPARISON

7.1. UNFC – HISTORY

The United Nations Framework Classification for Fossil Energy and Mineral Resources (UNFC) is a universally applicable scheme for classifying petroleum and solid minerals (including energy minerals) reserves and resources. It is designed to allow the incorporation of currently existing terms and definitions into this framework and thus to make them comparable and compatible (UN ECE, 2009). The latest version of this classification (UNFC-2009) was obtained as a result of the long process.

In the 1990s Economic Commission for Europe (ECE) took the initiative to develop a simple and uniform system for classifying and reporting reserves and resources of solid fuels and mineral commodities. The result of these reports was the creation of the United Nations Framework Classification for Reserves and Resources of Solid Fuels and Mineral Commodities (UNFC-1997). Then, in 2004, the system was extended to also apply to oil, natural gas and uranium (UNFC for fossil Energy and Mineral Resources 2004). The latest version of the Classification (United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009) was prepared by the Expert Group on Resource Classification (former name: the Ad Hoc Group of Experts on Harmonization of Fossil Energy and Mineral Resources Terminology) which was directed by the ECE Committee on Sustainable Energy. UNFC-2009 was developed thanks to the cooperation of ECE and non-ECE member countries, agencies and international organizations, the private sector and individual experts. The UNFC-2009 authors hope that this system will facilitate the availability of reliable information on energy reserves and resources.

7.2. UNFC – BASIC RULES

UNFC-2009 is a system in which quantities are classified on the basis of the three criteria of economic and social viability (E), field project status and feasibility (F) and geological knowledge (G), using a numerical and language independent coding scheme. Combinations of these criteria create a three-dimensional system. Categories (e.g. E_1, E_2, E_3) are defined for each of the three criteria (UN ECE, 2010).

The first set of categories (the E axis) designates the degree of favorability of social and economic conditions in establishing the commercial viability of the project, including consideration of market prices and relevant conditions. The second set (the F axis) designates the maturity of studies and commitments necessary to implement mining plans or development projects. The third set of categories (the G axis) designates the level of confidence in the geological knowledge and potential recoverability of the quantities.

A class is uniquely defined by selecting from each of the three criteria a particular combination of a category or a sub-category (or groups of categories/ sub--categories). Since the codes are always quoted in the same sequence (i.e. E, F, G) the letters may be dropped and just the numbers retain. In theory there can be 48 classes of resources marked out, but usually on the international market there are only some of them being used (Fig. 33).

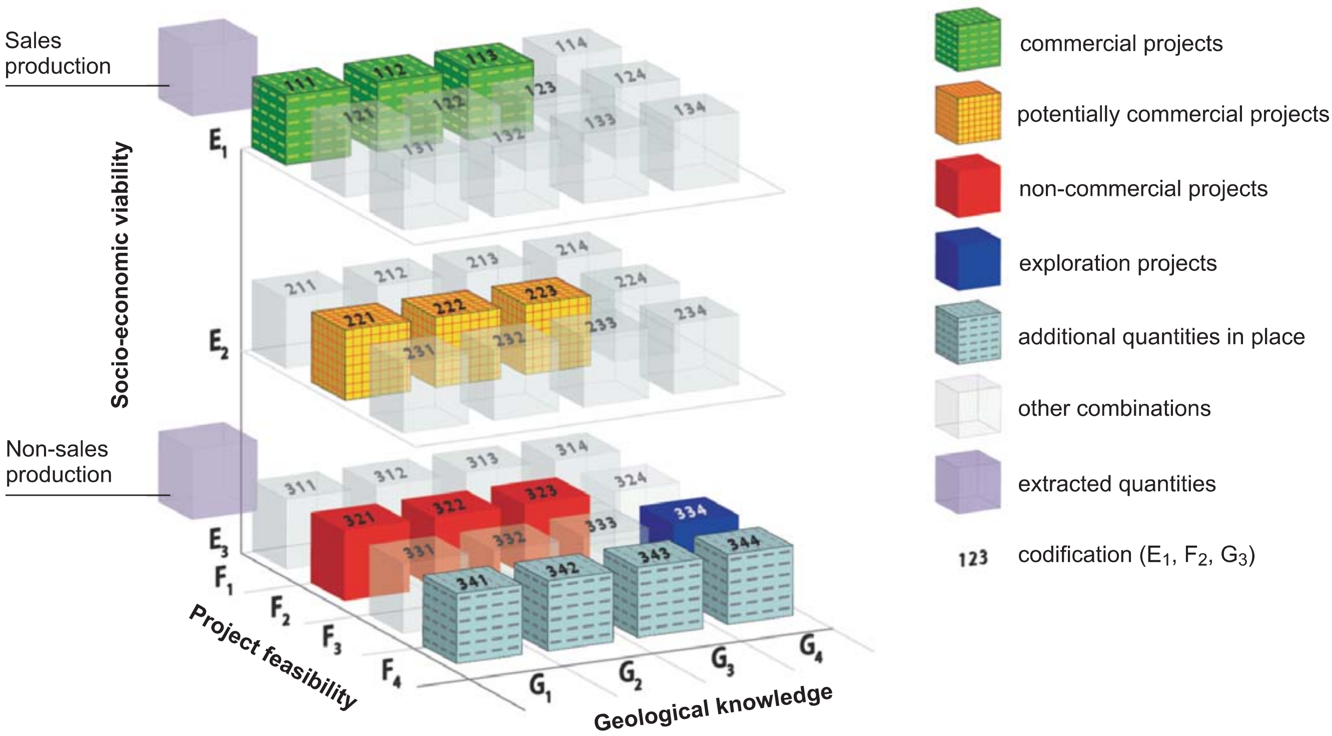

Fig. 33. UNFC-2009 categories and example of classes

UNFC-2009 is a simplified version in comparison with the UNFC-2004 and contains generic high-level definitions. The definitions are designed to ensure alignment with other widely used systems such as: Committee for Mineral reserves International Reporting Standards (CRIRSCO), Template and the Society of Petroleum Engineers (SPE), World Petroleum Council (WPC) or American Association of Petroleum Geologists (AAPG). UNFC-2009 can also be mapped with other (national) classification systems. The definitions of categories and sub-categories have been simplified and are presented in the separate chapter.

7.3. POLISH CLASSIFICATION SYSTEM AND THE UNFC-2009

The adaptation of Polish terminology to the UNFC standards is a continuation of such attempts carried out by I. Grzybek, S. Przeniosło, M. Piwocki and M. Nieć who were participating in meetings organized by the ECE and presented successive versions of the UNFC in their publications.

Polish classification is based on similar rules as UNFC and with some assumptions respective classes of UNFC can be found. UNFC-2009 distinguishes four grades of deposits exploration: G_1, G_2, G_3 and G_4. These grades combine with Polish categories: A+B, C_1, C_2 and D (Nieć, 2010b):

UNFC	Categories used in Poland (admissible error of estimate)
G_4	E (D_3), D_2 (officially not used)
	D (D_1) (>40%)
G_3	C_2 (up to 40%)
G_2	C_1 (up to 30%)
G_1	B (up to 20%)
	A (up to 10%)

There are economic resources in UNFC (E_1 category) which mean exploitable resources allocated for selling (111, 112, 113 classes). These resources correspond to Polish extractable (in Polish *operatywne*) resources in A+B, C_1 and C_2 categories. UNFC does not distinguish a category which in Polish system means economic resources in place (in Polish *przemysłowe*) resources. There is E_2 category in UNFC, which – for hydrocarbons – means exploitable resources and – for solid fuels and mineral commodities – means exploitable resources or resources in deposit *in situ*. Providing these resources are planned to be exploited we can assume that in Polish system:

- 211, 212, 213 classes are economic resources in place which are qualified for exploitation in deposit development plan;

Table 46. The comparison between Polish classification system and UNFC-2009 (Nieć, 2010a)

Polish classification	UNFC-2009		
	geological report		feasibility study
	deposits licensed for mining	deposits not licensed for mining	
Prognostic and prospective resources (in Polish *zasoby prognostyczne i perspektywiczne*)	resources 334	resources 344	
Anticipated economic resources (*zasoby bilansowe*)	resources	resources	
D (D_1), C_2	223	233	
C_2, C_1	222	232	
A+B	221	231	
Anticipated sub-economic resources (*zasoby pozabilansowe*)	resources	resources	resources
D (D_1), C_2	323	333	313
C_2, C_1	322	332	312
A+B	321	331	311
Sub-economic resources (*zasoby nieprzemysłowe*)			resources
C_2			313
C_1			312
A+B			311
Economic resources (*zasoby przemysłowe*)			resources
C_2			213
C_1			213
A+B			211
Extractable resources (*zasoby operatywne*)			resources (“economic”)
C_2			113
C_1			112
A+B			111
Reserves (*zasoby eksploatacyjne*)			
C_2			
C_1			
A+B			

- 221, 222, 223 classes are anticipated economic (in Polish *bilansowe*) resources which possibly can be exploited but are not qualified to the economic resources in place or sub-economic (in Polish *nieprzemys*łowe) resources in exploited deposits (those can be resources within non-available levels or beyond concession area);
- 231, 232, 233 classes are anticipated economic resources in non-exploited deposits;
- UNFC does not also distinguish resources which are not qualified for exploitation. Anticipated sub-economic (in Polish *pozabilansowe*) resources and sub-economic resources are contained in one category – E_3. It seems that lost (in Polish *tracone*) resources should also be contained in this category. It should be emphasized that resources recognized as lost resources (losses) are not taking into account in UNFC and are not distinguished.

The substantial difference between Polish system and the UNFC is the mode of presentation of resources and reserves data: hierarchical in Poland and complementary in the UNFC (Nieć, 2009). Hierarchical system in Poland means that resources are distinguished according to their economic usability within the total amount of resources called as geological resources in place. Geological resources in place are divided into anticipated economic resources and anticipated sub-economic resources. Anticipated economic resources are divided into economic resources in place and sub-economic resources and then economic resources in place are divided into extractable resources and losses of economic resources. UNFC distinguishes exploitable resources and other resources (containing: sub-economic resources, anticipated sub-economic resources and anticipated economic resources not qualified to economic and sub-economic resources). This difference is important because data on resources in Poland can not be comparable to other systems. Therefore, to obtain full compatibility between Polish and UNFC, the data on Polish resources should be released separately (Nieć, 2009):

- in exploited deposits – economic resources in place (21x), sub-economic resources (31x), anticipated economic resources not qualified to economic and sub-economic resources (22x), anticipated sub-economic resources (32x);
- in non-exploited deposits – anticipated economic resources (23x), anticipated sub-economic resources (33x) and prognostic and prospective resources (234 or 334).

Therefore, economic resources in place can be presented as:

$$21x = 11x + 31x \text{ (only losses)},$$

where x means G_1, G_2 or G_3 categories.

The comparison between the system used in Poland and the UNFC-2009 is presented in Table 46.

According to the rules specified in the present chapter resources of raw materials in Poland can be presented in line with the UNFC-2009. Table 47 shows the resources of selected raw materials in Poland as of 31.12.2011.

Extractable resources of Polish raw materials presented in the Table 47 were calculated on the basis of economic resources applying special indicators (economic resources x indicator = extractable resources). The indicators were obtained:

- for hard coal (indicator 0.6) and brown coal (0.9) on the basis of feasibility studies (in Polish *Projekt zagospodarowania złoża*) prepared for each exploited deposit;
- for other raw materials – rock salt (0.3), sulfur (0.5) and others (0.75) (Galos *et al*., 2012).

Table 47. The resources of selected raw materials in Poland according to the UNFC-2009 as of 31.12.2011 [million tonnes; silver – thousand tonnes]

Raw material	National classification								UNFC						
	deposits licensed for mining						deposits beyond concessions areas		deposits licensed for mining					deposits beyond concessions areas	
	anticipated economic resources (in Polish *bilansowe*) including: economic resources + sub-economic resources	economic resources (in Polish *przemysłowe*): extractable resource + losses	economic resources: extractable resources (in Polish *operatywne*)	economic resources: losses (in Polish *straty*)	sub-economic resources (in Polish *nieprzemysłowe*)	anticipated sub-economic resources (in Polish *pozabilansowe*)	anticipated economic resources (in Polish *bilansowe*)	anticipated sub-economic resources (in Polish *pozabilansowe*)	extractable resources 11x	economic resources 21x	anticipated economic resources 22x	sub-economic resources and losses 31x	anticipated sub-economic resources 32x	anticipated economic resources 23x	anticipated sub-economic resources 33x
Copper ores	1,494.85	1,251.81	938.86	312.95	243.04	2.98	291.81	809.91	938.86	0.00	0.00	555.99	2.98	291.81	809.91
Ag	88.22	74.87	56.15	18.72	13.35	0.08	18.07	41.43	56.15	0.00	0.00	32.07	0.08	18.07	41.43
Cu	29.45	24.73	18.55	6.18	4.72	0.03	5.15	13.16	18.55	0.00	0.00	4.75	0.03	5.15	13.16
Zinc and lead ores	19.42	11.39	8.54	2.85	8.03	7.45	59.59	6.19	8.54	0.00	0.00	10.88	7.45	59.59	6.19
Pb	0.31	0.21	0.16	0.12	0.10	0.13	1.17	0.06	0.16	0.00	0.00	0.22	0.13	1.17	0.06
Zn	0.81	0.51	0.38	0.29	0.30	0.25	2.71	0.23	0.38	0.00	0.00	0.59	0.25	2.71	0.23
Hard coal	17,606.03	4,178.45	2,507.07	1,671.38	6,543.29	8,080.17	26,906.29	11,478.46	2,507.07	0.00	6,884.29	8,214.67	8,080.17	26,906.29	11,478.46
Brown coal	1,668.42	1,287.03	1,158.33	128.70	245.46	101.10	20,985.39	3,445.84	1,158.33	0.00	135.93	374.16	101.10	20,985.39	3,445.84
Rock salt	15,124.64	1,255.17	376.55	878.62	12,493.62	28.78	69,665.49	20,482.80	376.55	0.00	1,375.86	13,372.24	28.78	69,665.49	20,482.80
Sulfur	26.43	26.05	13.03	13.02	0.28	0.57	256.69	14.64	13.03	0.00	0.10	17.55	0.57	256.69	14.64
Building ceramics raw materials	260.06	136.77	102.58	34.19	34.45	3.99	1,453.78	22.39	102.58	0.00	88.84	68.64	3.99	1,453.78	22.39
Gypsum and anhydrite	127.17	107.71	80.78	26.93	15.26	6.24	128.23	19.13	80.78	0.00	4.20	51.67	6.24	128.23	19.13
Sand and gravel	4,715.38	2,527.95	1,895.96	631.99	432.34	49.46	11,238.04	485.87	1,895.96	0.00	1,755.09	1,064.33	49.46	11,238.04	485.87
Dimension and crushed stones	5,223.86	3,253.98	2,440.49	813.49	617.13	148.66	4,578.24	101.21	2,440.49	0.00	1,352.75	1,430.62	48.66	4,578.24	101.21

The recalculation of resources from Polish classification to UNFC-2009 – the case of hard coal:
UNFC-2009 class 33x = in Polish *pozabilansowe* resources in deposits beyond concessions areas (11,478.46 million tonnes)
UNFC-2009 class 23x = *bilansowe* resources in deposits beyond concessions areas (26,906.29 million tonnes)
UNFC-2009 class 32x = *pozabilansowe* resources in deposits licensed for mining (8,080.17 million tonnes)
UNFC-2009 class 31x = *nieprzemysłowe* resources plus *straty* (6,543.29 + 1,671.38 = 8,214.67 million tonnes)
UNFC-2009 class 22x = *bilansowe* resources in deposits licensed for mining minus *nieprzemysłowe* and *przemysłowe* resources (17,606.03 – 6,543.29 – 4,178.45 = 6,884.29 million tonnes)
UNFC-2009 class 21x = *przemysłowe* resources in deposits licensed for mining minus *operatywne* resources and *straty* (4,178.45 – 2,507.07 – 1,671.38 = 0.00 million tonnes)
UNFC-2009 class 11x = *operatywne* resources in deposits licensed for mining (2,507.07 million tonnes)

8. GLOSSARY

UNFC-2009 DEFINITION (ACCORDING TO ANNEX I AND ANNEX II WHICH FORM AN INTEGRAL PART OF UNFC-2009)

Table 48. Definition of categories and supporting explanations

Category	Definition *	Supporting explanation **
1	2	3
E1	Extraction and sale has been confirmed to be economically viable ***	Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions. All necessary approvals/ contracts have been confirmed or there are reasonable expectations that all such approvals/ contracts will be obtained within a reasonable timeframe. Economic viability is not affected by short term adverse market conditions provided that longer term forecasts remain positive
E2	Extraction and sale is expected to become economically viable in the foreseeable future	Extraction and sale has not yet been confirmed to be economic but, on the basis of realistic assumptions of future market conditions, there are reasonable prospects for economic extraction and sale in the foreseeable future
E3	Extraction and sale is not expected to become economically viable in the foreseeable future or evaluation is at too early a stage to determine economic viability	On the basis of realistic assumptions of future market conditions, it is currently considered that there are not reasonable prospects for economic extraction and sale in he foreseeable future; or, economic viability of extraction cannot yet be determined due to insufficient information (e.g. during the exploration phase).Also included are quantities that are forecast to be extracted, but which will not be available for sale
F1	Feasibility of extraction by a defined development project or mining operation has been confirmed	Extraction is currently taking place; or, implementation of the development project or mining operation is underway; or, sufficiently detailed studies have been completed to demonstrate the feasibility of extraction by implementing a defined development project or mining operation
F2	Feasibility of extraction by a defined development project or mining operation is subject to further evaluation	Preliminary studies demonstrate the existence of a deposit in such form, quality and quantity that the feasibility of extraction by a defined (at least in broad terms) development project or mining operation can be evaluated. Further data acquisition and/or studies may be required to confirm the feasibility of extraction
F3	Feasibility of extraction by a defined development project or mining operation cannot be evaluated due to limited technical data	Very preliminary studies (e.g. during the exploration phase), which may be based on a defined (at least in conceptual terms) development project or mining operation, indicate the need for further data acquisition in order to confirm the existence of a deposit in such form, quality and quantity that the feasibility of extraction can be evaluated
F4	No development project or mining operation has been identified	*In situ* (in place) quantities that will not be extracted by any currently defined development project or mining operation
G1	Quantities associated with a known deposit that can be estimated with a high level of confidence	For *in situ* (in place) quantities, and for recoverable estimates of fossil energy and mineral resources that are extracted as solids, quantities are typically categorized discretely, where each discrete estimate reflects the level of geological knowledge and confidence associated with a specific part of the deposit. The estimates are categorized as G1, G2 and/or G3 as appropriate. For recoverable estimates of fossil energy and mineral resources that are extracted as fluids, their mobile nature generally precludes assigning recoverable quantities to discrete parts of an accumulation. Recoverable quantities should be evaluated on the basis of the impact of the development scheme on the accumulation as a whole and are usually categorized on the basis of three scenarios or outcomes that are equivalent to G1, G1+G2 and G1+G2+G3
G2	Quantities associated with a known deposit that can be estimated with a moderate level of confidence	
G3	Quantities associated with a known deposit that can be estimated with a low level of confidence	

Table 48 cont.

1	2	3
G4	Estimated quantities associated with a potential deposit, based primarily on indirect evidence.	Quantities that are estimated during the exploration phase are subject to a substantial range of uncertainty as well as a major risk that no development project or mining operation may subsequently be implemented to extract the estimated quantities. Where a single estimate is provided, it should be the expected outcome but, where possible, a full range of uncertainty in the size of the potential deposit should be documented (e.g. in the form of a probability distribution). In addition, it is recommended that the chance (probability) that the potential deposit will become a deposit of any commercial significance is also documented

* The term "extraction" is equivalent to "production" when applied to petroleum

** The term "deposit" is equivalent to "accumulation" or "pool" when applied to petroleum

*** The phrase "economically viable" encompasses economic (in the narrow sense) plus other relevant "market conditions", and includes consideration of prices, costs, legal/fiscal framework, environmental, social and all other non-technical factors that could directly impact the viability of a development project

Table 49. Definition of sub-categories

Category	Sub-category	Sub-category definition
E1	E1.1	Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions
	E1.2	Extraction and sale is not economic on the basis of current market conditions and realistic assumptions of future market conditions, but is made viable through government subsidies and/or other considerations
E2	No sub-categories defined	
E3	E3.1	Quantities that are forecast to be extracted, but which will not be available for sale
	E3.2	Economic viability of extraction cannot yet be determined due to insufficient information (e.g. during the exploration phase)
	E3.3	On the basis of realistic assumptions of future market conditions, it is currently considered that there are not reasonable prospects for economic extraction and sale in the foreseeable future
F1	F1.1	Extraction is currently taking place
	F1.2	Capital funds have been committed and implementation of the development project or mining operation is underway
	F1.3	Sufficiently detailed studies have been completed to demonstrate the feasibility of extraction by implementing a defined development project or mining operation
F2	F2.1	Project activities are ongoing to justify development in the foreseeable future
	F2.2	Project activities are on hold and/or where justification as a commercial development may be subject to significant delay
	F2.3	There are no current plans to develop or to acquire additional data at the time due to limited potential

DEFINITION USED IN POLISH CLASSIFICATION SYSTEM

Resources definition (according to Regulation of the Minister of the Environment (Official Journal of 2011, No. 291 Item 1712) and Regulation of the Minister of the Environment (Official Journal of 2012, Item 511))

Deposit resources ("geological resources" = anticipated economic resources and anticipated sub-economic resources) – total resources of mineral commodity/ commodities within the deposit boundaries

The limit values of the parameters that defines the deposit – values of deposit parameters delineating the deposit geological boundaries

Anticipated economic resources ("balance resources") – deposit resources (or part of deposit) meeting the limit values of the parameters that defines the deposit

Anticipated sub-economic resources ("sub-balance resources") – deposit resources (or part of deposit) not meeting the limit values of the parameters that defines the deposit

Economic resources in place ("industrial resources") – part of anticipated economic resources or anticipated sub-economic resources or – in case of brines, curative and thermal water – exploitable resources, within the designed mining area or detached part of the deposit designed for exploitation, which can be designed for mining according to detailed technical and economical analysis taking into account law requirements, including environmental restraints

Sub-economic (marginal) resources ("not-industrial resources") – part of anticipated economic resources not-classified as economic resources within the area designed for exploitation, which can be designed for mining as a result of technical or economical or law requirements changes, including environmental restraints

Extractable resources – part of economic resources in place which is obtained when reducing economic resources by technical losses

Exploitable resources – crude oil or natural gas resources, which are supposed to be extracted by applying current exploitation technology

Resources categories definition (according to Regulation of the Minister of the Environment (Official Journal of 2011, No. 291, Item 1712))

Solid mineral commodities

D – inferred resources – mineral deposit boundaries, geological feature and anticipated resources are evaluated on the basis of available geological data, in particular from isolated excavations or natural outcrops, geological interpretation of geophysical measurements. The admissible error of average deposit parameters and deposit resources estimation may exceed 40%

C_2 – inferred resources – mineral deposit boundaries are evaluated on the basis of available data from isolated excavations, natural outcrops, interpolation or extrapolation of geophysical measurements; main structural and geological features and tectonics are recognized; geological-mining conditions of exploitation are preliminary evaluated; quality of mineral commodity is evaluated on the basis of regular sampling in the full range of commodity usage. The admissible error of average deposit parameters and deposit resources estimation can not exceed 40%

C_1 – indicated resources – mineral deposit boundaries are evaluated on the basis of available data from exploratory excavations, natural outcrops or interpolation or extrapolation of geophysical measurements; the grade of deposit exploration allows to prepare the prefeasibility study of economic mining, including the detailed delineation of structural and geological features, tectonics and quality of mineral commodity in the deposit, geological-mining conditions of exploitation, and allows to asses the influence of the intended exploitation on environment. The admissible error of average deposit parameters and deposit resources estimation can not exceed 30%

B – measured resources – mineral deposit boundaries are delineated in details on the basis of the specially carried out exploratory excavations or geophysical measurements, the delineation of structural and geological features, correlation of strata, main tectonics features has to be unambiguous, quality and technological properties of mineral commodity should be confirmed by the sampling results in pilot-scale tests or commercial scale. The admissible error of average deposit parameters and deposit resources estimation can not exceed 20%

A – measured resources – mineral deposit is explored to the extend which allows the current planning and carrying out the exploitation with the maximum possible rate of resources absorption; the delineation of structural and geological features, tectonics, resources on the basis of the opening-out, preparing and mining excavations, the type, quality and technological properties of mineral commodity on the basis of regular excavations sampling and data from the current production is required. The admissible error of average deposit parameters and deposit resources estimation in particular blocks can not exceed 10%

Hydrocarbons

C – inferred resources – mineral field boundaries are delineated on the basis of geophysical measurements and geological interpretation and such data allow to plan other works which are necessary to continue field exploration or its exploitation, when there is gas, oil or methane flow from at least one well in the amount of economic value or, in the case of the multi-horizontal fields, when the hydrocarbons saturation of gas and oil horizons is known on the basis of the drilling geophysics logging with gas, oil or methane flow from at least one well in the amount of economic value. The admissible error of average field parameters and field resources estimation can not exceed 50%

B – indicated resources – the result of geological works carrying out are the basis to define the field geological structure, field boundaries and reservoir parameters of oil bearing and gas bearing formations as well as their variability in details; such data allow to plan other works which are necessary to continue field exploration or its exploitation, when there is gas, oil or methane flow from at least one well in the amount of economic value. The admissible error of average field parameters and field resources estimation can not exceed 35%

A – measured resources – data for category B are defined on the basis of exploitation results. The admissible error of average field parameters and resources estimate is up to 20%

Definition of Mineability Assessment Stages

Mining report – is understood as the current documentation of the state of development and exploitation of a deposit during its economic life including current mining plans. The operator of the mine generally makes it. The study takes into consideration the quantity and quality of the minerals extracted during the reporting time, changes in Economic Viability categories due to changes in prices and costs, development of relevant technology, newly imposed environmental or other regulations, and data on exploration conducted concurrently with mining.

It presents the current status of the deposit, providing a detailed and accurate, up-to-date statement on the remaining reserves and resources

Feasibility study – document which would be an equivalent to the whole range of Feasibility Study is not prepared

Prefeasibility study – provides a preliminary assessment of the Economic Viability of a deposit and forms the basis for justifying further investigations (Detailed Exploration and Feasibility Study). It usually follows a successful exploration campaign, and summarizes all geological, engineering, environmental, legal and economic information accumulated to date on the project.

In projects that have reached a relatively advanced stage, the Prefeasibility Study should have error limits of 25%. In projects less advanced, higher errors are to be expected. Various terms are in use internationally for Prefeasibility Studies reflecting the actual accuracy level. The data required to achieve this level of accuracy are reserves/resources figures based on Detailed and General Exploration, technological tests at laboratory scale and cost estimations e.g. from catalogues or based on comparable mining operations

Geological study (geological documentation) – an initial evaluation of Economic Viability. This is obtained by applying meaningful cut-off values for grade, thickness, depth, and costs estimated from comparable mining operations.

Economic Viability categories, however, cannot in general be defined from the Geological Study because of the lack of detail necessary for an Economic Viability evaluation. The estimated resource quantities may indicate that the deposit is of intrinsic economic interest, i.e. in the range of economic to potentially economic.

A Geological Study is generally carried out in the following four main stages: Reconnaissance, Prospecting, General Exploration and Detailed Exploration (for definition of each stage see below). The purpose of the Geological Study is to identify mineralization, to establish continuity, quantity, and quality of a mineral deposit, and thereby define an investment opportunity

Definition of Geological Study Stages

Reconnaissance – a reconnaissance study identifies areas of enhanced mineral potential on a regional scale based primarily on results of regional geological studies, regional geological mapping, indirect methods as well as geological inference and extrapolation. The objective is to identify mineralized areas worthy of further investigation towards deposit identification. Estimates of quantities should only be made if sufficient data are available and when an analogy with known deposits of similar geological character is possible, and then only within an order of magnitude

Prospecting – the systematic process of searching for a mineral deposit by narrowing down areas of promising enhanced mineral potential. The utilized methods are outcrop identification, geological mapping, and indirect methods such as geophysical and geochemical studies. Limited trenching, drilling, and sampling may be carried out. The objective is to identify a deposit that will be the target for further exploration. The estimations of quantities are inferred, based on interpretation of geological, geophysical and geochemical results

General exploration – involves the initial delineation of an identified deposit. The used methods include surface mapping, widely spaced sampling, trenching and drilling for preliminary evaluation of mineral quantity and quality (including mineralogical tests on laboratory scale if required), and limited interpolation based on indirect methods of investigation. The objective is to establish the main geological features of a deposit, giving a reasonable indication of continuity and providing an initial estimate of size, shape, structure and grade. The degree of accuracy should be sufficient for deciding whether a Detailed Exploration is warranted

Detailed exploration – involves the detailed three-dimensional delineation of a known deposit achieved through sampling, such as from outcrops, trenches, boreholes, shafts and tunnels. Sampling grids are such closely spaced that size, shape, structure, grade, and other relevant characteristic of the deposit are established with a high degree of accuracy. Processing tests involving bulk may be required. A decision whether to conduct a Feasibility Study can be made from the information provided by Detailed Exploration

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Plate 1

OIL AND GAS DEPOSITS

Resources:

0.2 2 million tonnes — oil deposits

0.2 2 10 million tonnes — oil and gas deposits

0.2 2 10 billion m³ — gas deposits

2 10 billion m³ — natural nitrogenous gas deposits

0.2 2 billion m³ — underground gas stores

areas of prospects for CBM occurrence

Occurrence of oil- and gas-bearing formations:

- oil- and gas-bearing rocks of the Carpathian Foredeep
- oil- and gas-bearing rocks of the Carpathian area
- Permian (Zechstein) oil- and gas-bearing formations
- Carboniferous oil- and gas-bearing formations
- Pre-Carboniferous oil- and gas-bearing formations
- areas without prospects for oil and gas occurrence (after Depowski *et al.*, 1993)
- boundary of Zechstein formation (after Wagner, 1978)

Plate 2

HARD COAL AND BROWN COAL DEPOSITS

Hard coal:

U S C B Upper Silesian Coal Basin

extent of deposits

L C B Lublin Coal Basin

deposits in exploitation

not exploited deposits

Brown coal:

deposits in exploitation

not exploited deposits

Occurrence of coal-bearing formations:

Paleogene lignite-bearing formations (after Piwocki, 1993)

Carboniferous hard coal-bearing formations

areas without prospects for coal and lignite occurrences

extent of coal-bearing Carboniferous formation

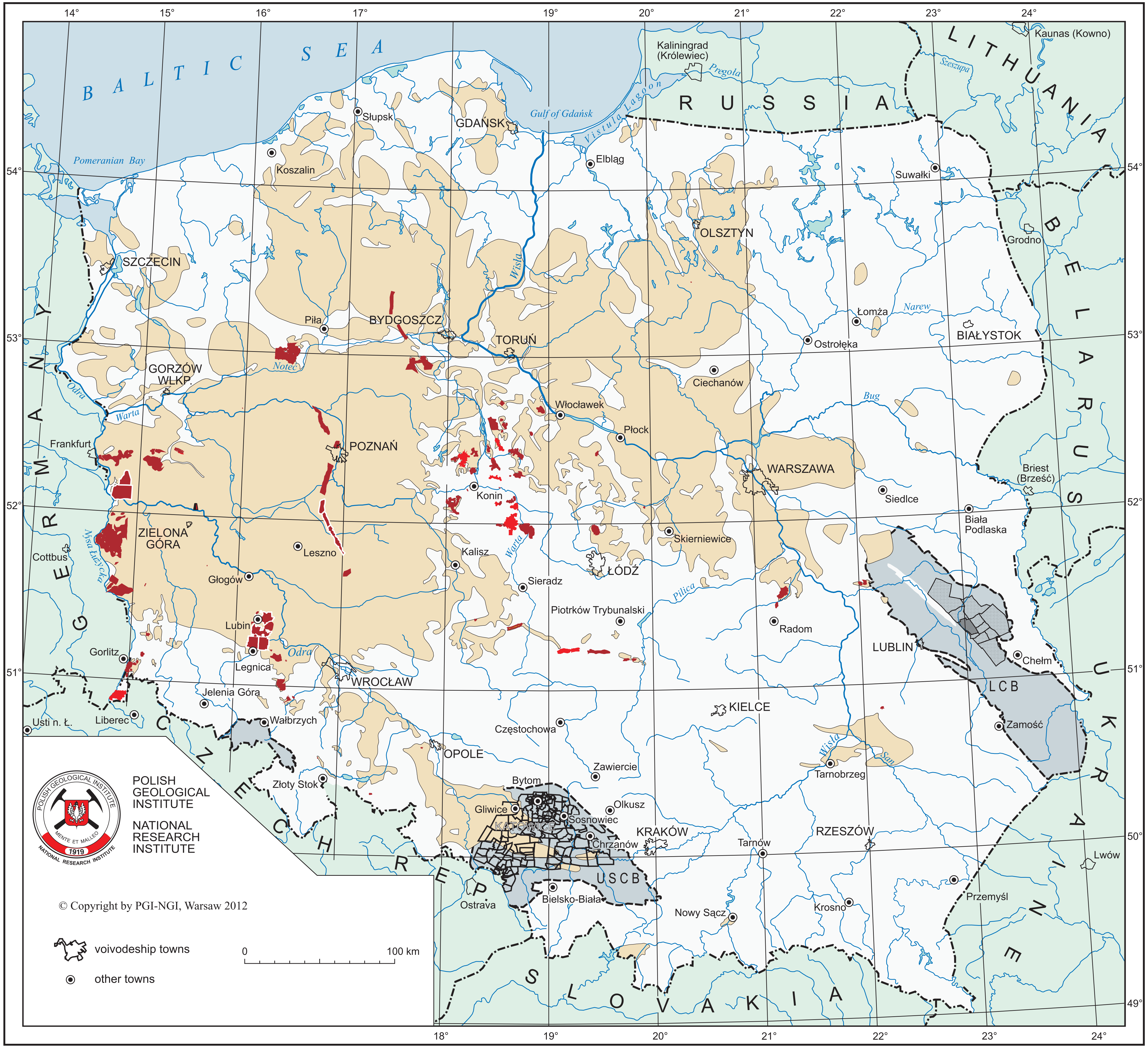


Plate 3

METALLIC RAW MATERIALS DEPOSITS

- copper ore deposits
- zinc and lead ore deposits
- molybdenum-tungsten-copper ore deposits
- nickel ore deposits
- tin ore deposits
- arsenic and gold ore deposits
- deposits in exploitation

Areas of deposits occurrence:

- Paleogene formations of the Carpathian Foredeep
- Carpathian area
- Triassic ore-bearing dolomites
- other Mesozoic formations
- Permian (Zechstein) formations
- Carboniferous formations
- Paleozoic rocks of the Sudetes and the Holy Cross Mountains
- Pre-Cambrian platform formations
- boundary of the Kupferschiefer formation
- boundary of the dolomite-limestone transition zone a – sure, b – uncertain
- boundary of the Upper Silesian Coal Basin

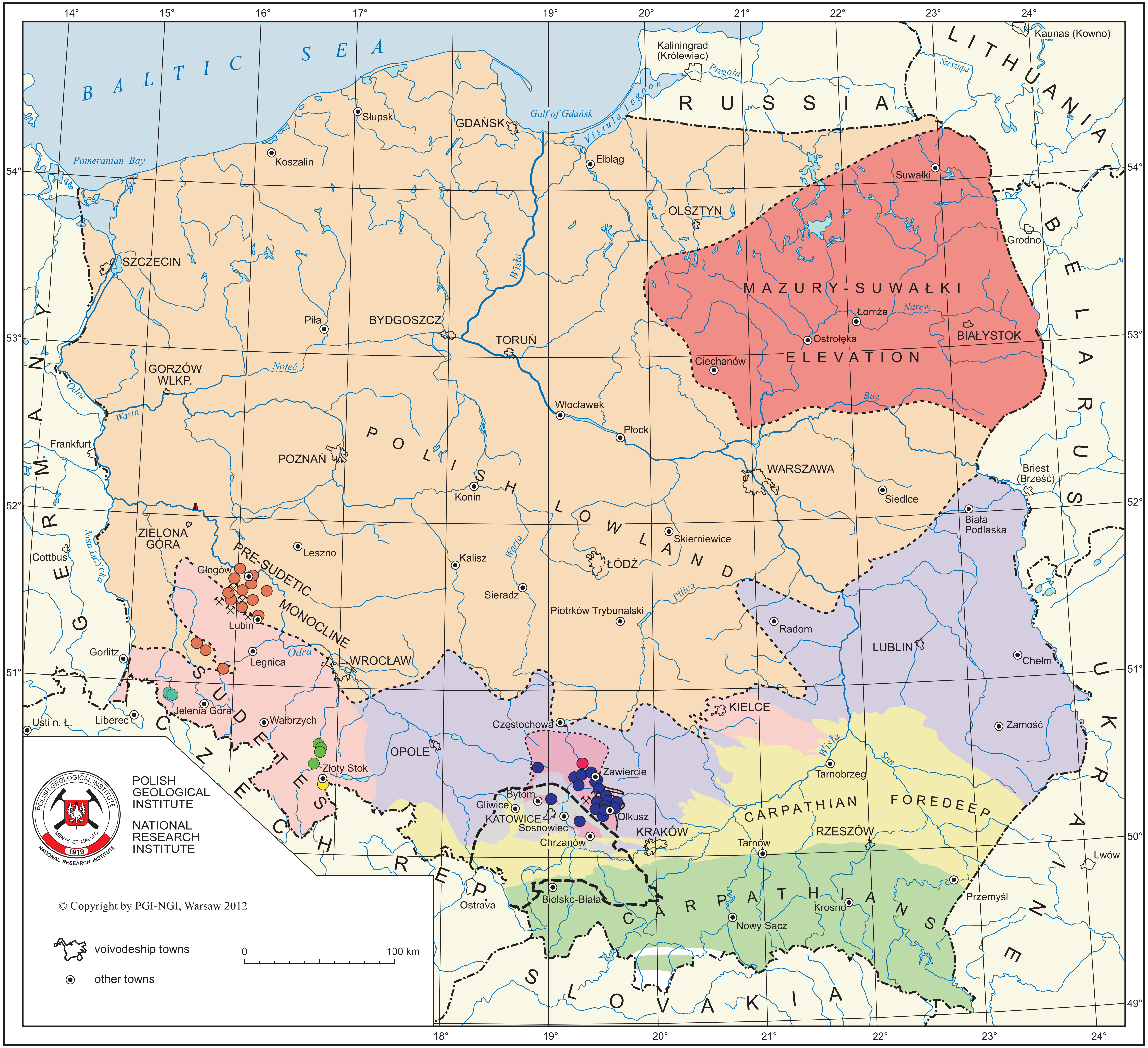
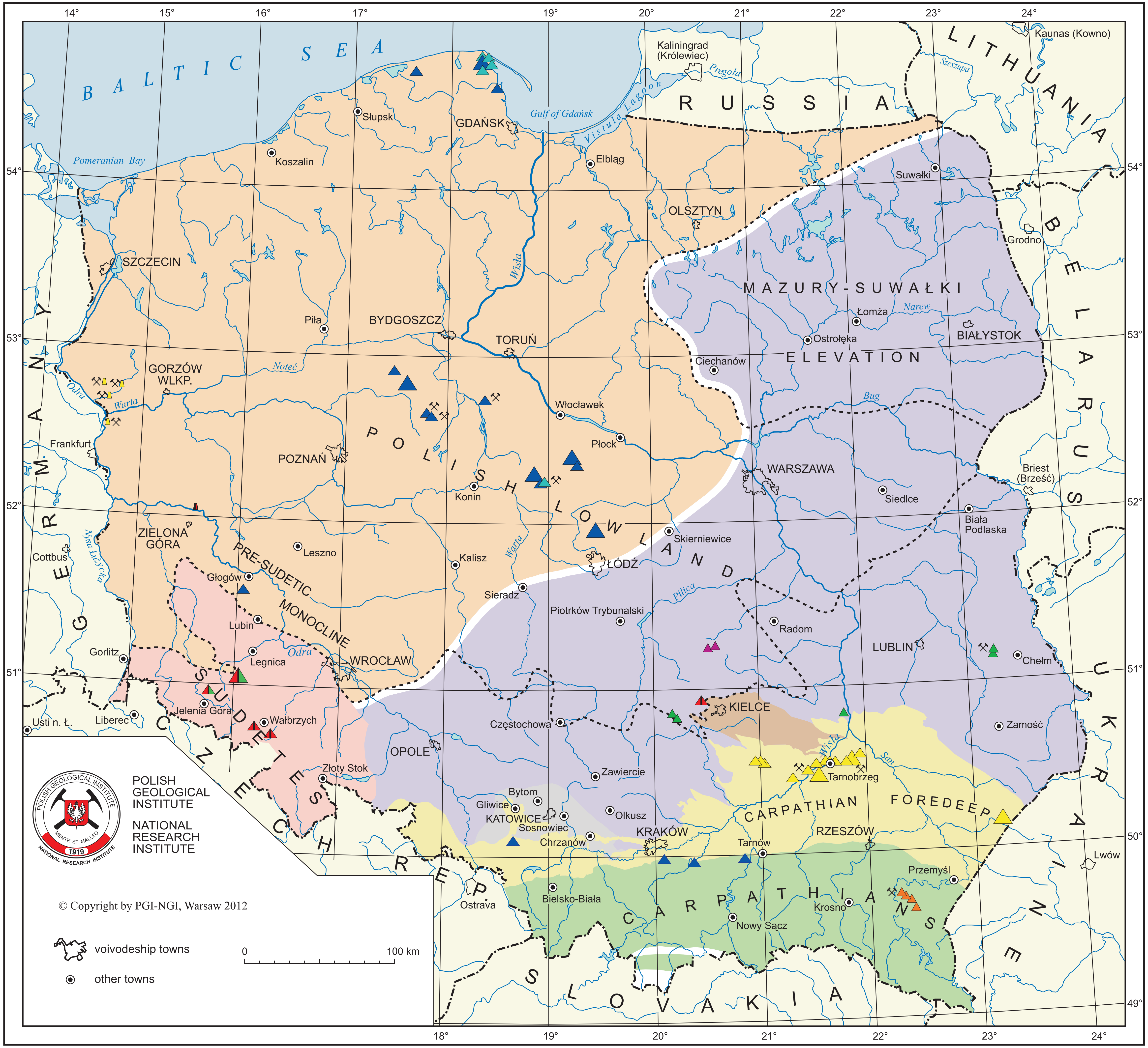


Plate 4

CHEMICAL RAW MATERIALS DEPOSITS



Resources:

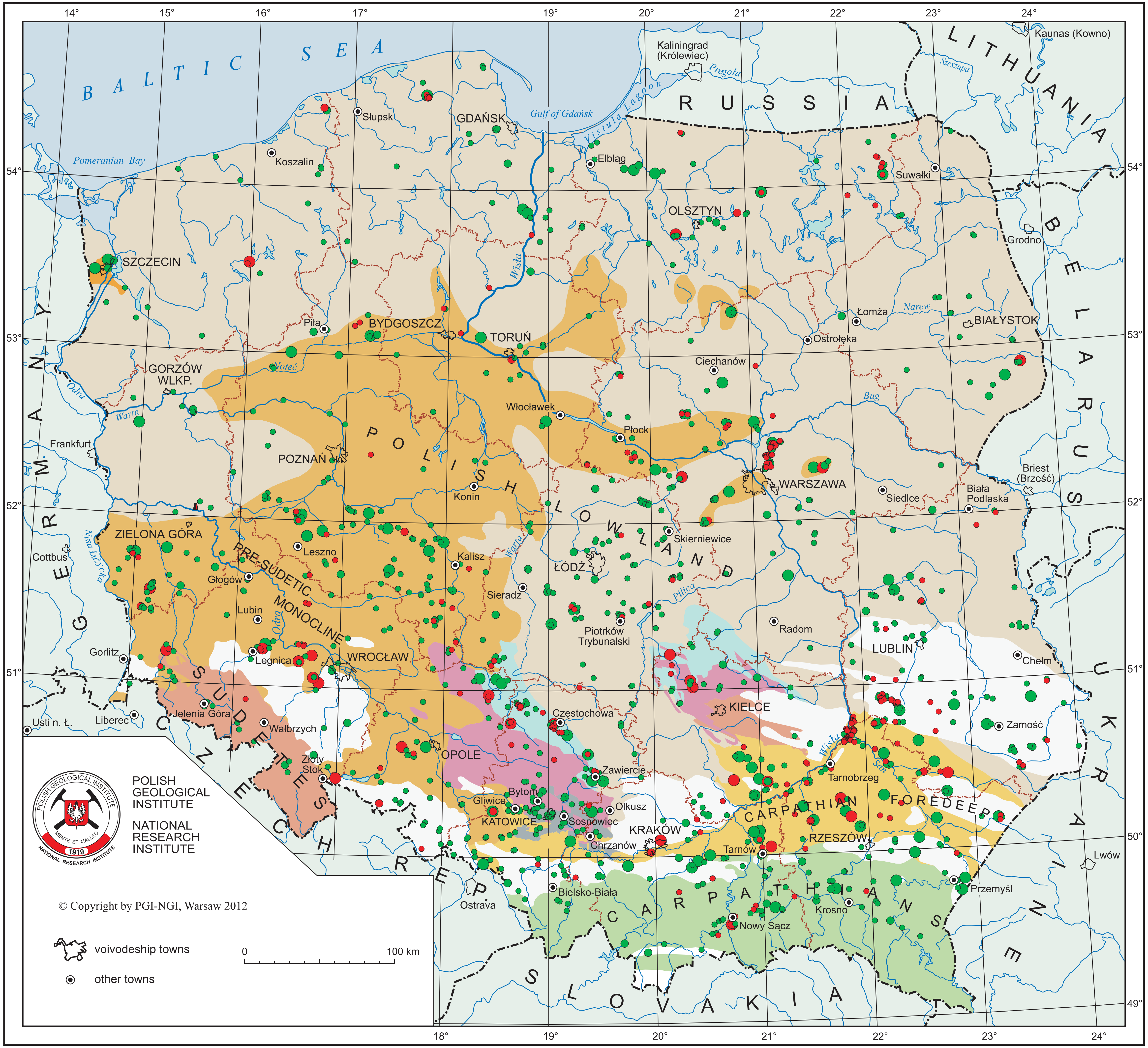
- 100 million tonnes — native sulfur deposits
- sulfur in natural gas deposits
- 4000 million tonnes — rock salt deposits
- 400 million tonnes — potassium salt deposits
- 4 million tonnes — barite deposits
- 4 million tonnes — barite and fluorspar deposits
- siliceous earth deposits
- diatomaceous rock deposits
- deposits of clay raw materials for production of mineral paints
- deposits in exploitation

Areas of deposits occurrence:

- Paleogene formations of the Carpathian Foredeep
- Carpathian area
- Mesozoic formations
- Permian (Zechstein) formations
- Carboniferous formations
- Paleozoic core of the Holy Cross Mountains
- crystal rocks of the Sudetes
- boundary of Zechstein formations occurrence
- boundary of the Zechstein and Mesozoic deposits occurrence

Plate 5

BUILDING CERAMICS RAW MATERIALS DEPOSITS



Deposits with resources:

In exploitation
- <1.5 million m^3
- 1.5–3 million m^3
- >3 million m^3

Not exploited
- <1.5 million m^3
- 1.5–3 million m^3
- >3 million m^3

Areas of deposits occurrence:

- loess and loess loam
- Quaternary (glacial till, clay and marginal lake silt, river aggradations)
- Miocene-Pliocene (clays and silts)
- Paleogene of the Carpathian Foredeep (marine clays)
- Oligocene (septarian clay)
- Carpathian flysch (clay-slate)
- Jurassic (claystones and siltstones)
- Triassic (claystones and siltstones)
- Upper Paleozoic (clays and clay-slate)
- Paleozoic rocks of the Sudetes and the Holy Cross Mountains (claystones and residual clays)

Plate 6

COMPACT ROCK RAW MATERIALS DEPOSITS

Resources:

- 50 million tonnes — dolomites deposits
- 20 million tonnes — gypsum and anhydrite deposits
- 1 10 million tonnes — chalk deposits
- vein quartz deposits
- 10 million tonnes — feldspar raw materials deposits
- 10 200 million tonnes — deposits of limestones and marls for cement industry
- 10 100 million tonnes — deposits of limestones for lime industry

Dimension and crushed stones deposits:

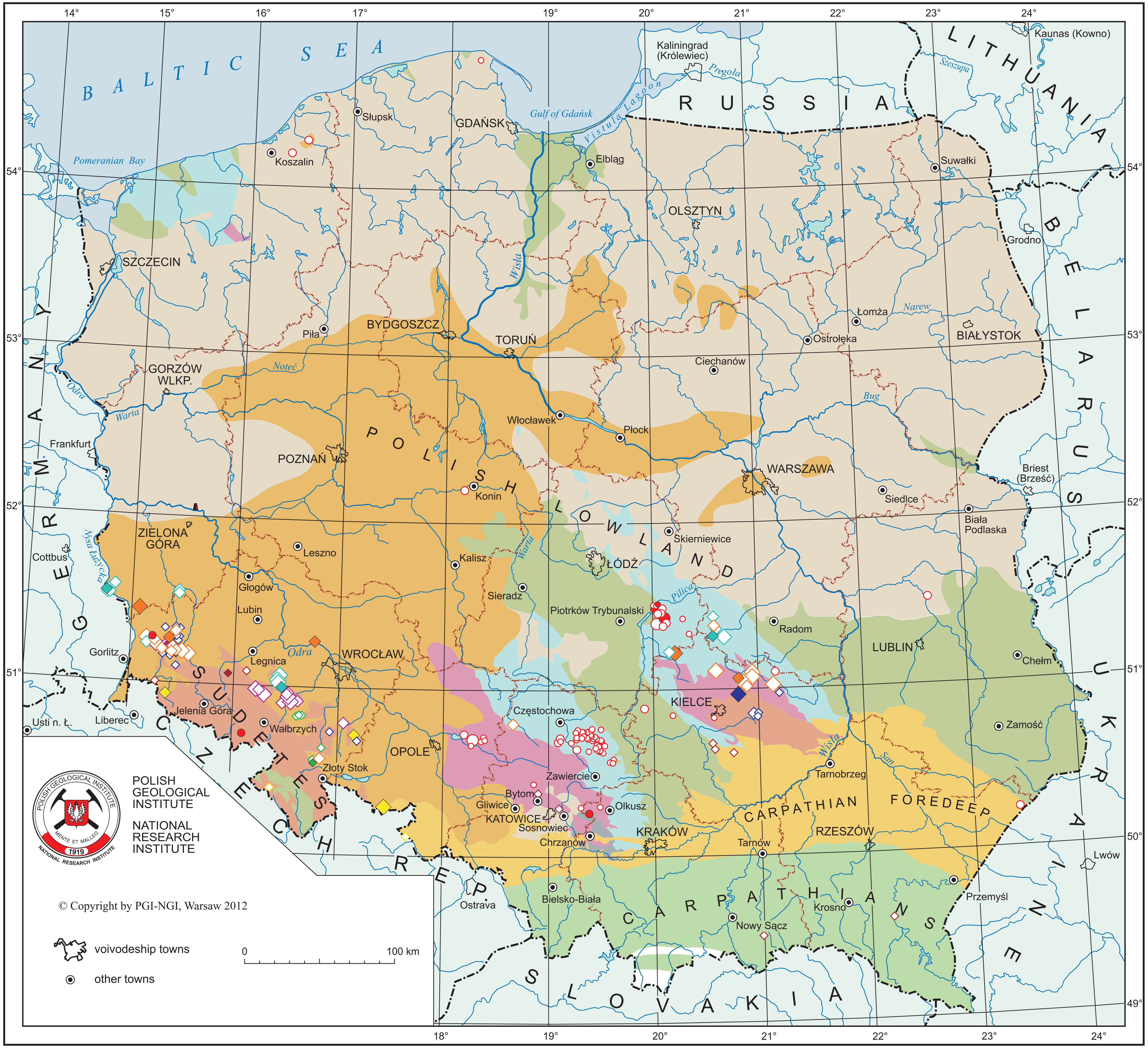
- 10 25 million tonnes — sedimentary rocks
- 10 25 million tonnes — metamorphic rocks
- 10 25 million tonnes — magmatic rocks
- deposits in exploitation
- not exploited deposits

Areas of deposits occurrence:

- Quaternary
- Miocene–Pliocene
- Paleogene of the Carpathian Foredeep
- Carpathian flysch
- Cretaceous
- Jurassic
- Triassic
- Upper Paleozoic
- Paleozoic rocks of the Sudetes and the Holy Cross Mountains

Plate 7

CERAMIC AND REFRACTORY RAW MATERIALS DEPOSITS



Resources:

- bentonitic raw materials deposits
- ceramic clays deposits (3 million tonnes)
- foundry sands deposits (2, 20 million tonnes)
- kaolin raw materials deposits (10 million tonnes)
- magnesites deposits
- refractory clays deposits (3 million tonnes)
- refractory quartzites deposits (1.5, 3 million tonnes)
- schists deposits (5, 10 million tonnes)
- deposits in exploitation
- not exploited deposits

Areas of deposits occurrence:

- Quaternary
- Miocene–Pliocene
- Paleogen of the Carpathian Foredeep
- Carpathian flysch
- Cretaceous
- Jurassic
- Triassic
- Upper Paleozoic
- Paleozoic rocks of the Sudetes and the Holy Cross Mountains

Plate 8

CLASTIC ROCK RAW MATERIALS DEPOSITS

Resources:

- 2 20 200 million tonnes — sand and gravel deposits
- 20 million tonnes — glass sands and sandstones deposits
- 10 100 million m^3 — filling sands deposits
- 2 million tonnes — quartz sands for production of cellular concrete
- 2 million tonnes — quartz sands for production of lime-sand brick
- deposits in exploitation
- not exploited deposits

Areas of deposit occurrence:

- glacial and fluvioglacial accumulation of the North Polish Glaciation and also fluvial and aeolian ones
- glacial and fluvioglacial accumulation of the Middle Polish Glaciation and also fluvial and aeolian ones
- fluvial accumulation and also area with extraglacial and outwash fan sediments in the Holy Cross Mountains and the Cracow-Częstochowa Jurassic
- fluvial and aeolian accumulation on Cretaceous bedrock
- fluvial and aeolian accumulation of the Carpathian Foredeep
- fluvial accumulation (Carpathians and Sudetes)
- boundary of the North Polish Glaciation
- boundary of the Middle Polish Glaciation