MINERAL RESOURCES OF POLAND

Polish Geological Institute
National Research Institute
Warsaw 2017

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Foreword

The Polish Geological Institute – National Research Institute (PGI-NRI) has been conducting studies on the geological structure of the country for almost a century. Apart from scientific activities, the PGI-NRI as a state geological survey supports the central government administration by performing state tasks in the area of geology. The primary task of the survey is recognition of the geological structure of the country in order to identify mineral deposit resources and to replenish the country's mineral raw material base.

Information derived from several hundred thousand wells that is stored and processed by the PGI-NRI has made it possible to reconstruct the shallow and deep geological structure of the country in detail. This has made it possible to gain profound knowledge of the distribution of prospective deposits and mineral raw material resources.

Extensive studies conducted by the PGI-NRI led to the discovery of several mineral deposits of remarkable importance to the national economy. These discoveries greatly contributed to economic growth through opening possibilities for increasing the scale of mineral raw material exploitation and, consequently, strengthening security of the supply of mineral raw materials for the national economy.

Recent years have witnessed Poland's growing involvement in international cooperation in the area of mineral raw materials. A main goal of the PGI-NRI as the state geological survey is dissemination of knowledge of the domestic base of mineral resources and possibilities of their exploitation. To fulfil this task, the PGI-NRI has been publishing Mineral Resources of Poland for 20 years. The target group of this publication includes foreign investors and operators potentially interested in cooperation with Poland in mineral resource management. Such cooperation may take place at the stage of prospecting and development of deposits, as well as extraction of mineral raw materials. Information presented in Mineral Resources of Poland should facilitate a preliminary evaluation of the possibilities of such cooperation.

Poland is open to cooperation and has huge human potential. A large team of highly qualified geologists and miners applying international standards in their everyday work markedly increases chances of successful economic and scientific cooperation. Therefore, in the current edition we present the key for comparison and conversion of mineral resources from Polish mineral classification system into UNFC classification. Additionally, Chapter 1 describes the Polish legal and economic base for geological and mining activity. For a better understanding of Polish economic and legal conditions of the mineral business, Appendixes also present specimens of agreements and administrative decisions granted by the Minister of Environment.

On behalf of the Board of Directors of the PGI-NRI, I wish you pleasant reading and hope that you will find this publication a good introduction to the potential of mineral deposits in our country. I sincerely hope that Mineral Resources of Poland will encourage our readers to invest in Poland.

Dr Sławomir Mazurek
Director of the Polish Geological Institute – National Research Institute

Introduction

There are two crucial elements for investors in the raw materials sector and their business decisions throughout the world: the results of analysis of resource base (the number of deposit and their size, deposit quality, geological structure) as well as legal and economic factors (the scope of operation licensing, deposit ownership, activity and investment climate). On a European scale, Poland is characterised by large mineral raw material resources. Some of them have global significance (copper ores, native sulfur, hard coal). Therefore, in the age of globalisation and concentration, Poland is increasingly perceived as a country for new attractive investment possibilities. Many foreign companies including leading mineral corporations were or still are present in Poland in prospecting and exploitation. In contrast to previous editions of Mineral Resources of Poland, the current one is much more focused on legal and economic factors. The following issues are discussed: legal regulations of geological and mining projects, ownership of mineral resource deposits, the concession system and the geological and mining administration and its responsibilities. Two other important issues underscored in the publication are geological documentation and requirements for candidates seeking a certificate of licensed geologist in Poland. The scope of economic and financial duties (taxes, levies) based on the Geological and Mining Law are also addressed. Moreover, geological information sources in Poland are presented together with their use at the geological and mining stages.

The monograph also contains detailed information on the resources of particular mineral raw material deposits. Very important data relate to Polish geo-potential and possibilities for starting prospecting projects.

The presented information can serve as a basis for preliminary analyses by mineral companies when making decisions on their investment directions. In the case of Poland as their final choice, more details can be obtained from sources indicated in this publication.

Poland, with its long-standing geological and mining tradition, experience and achievements can be a very attractive country for such companies. We hope that Mineral Resources of Poland will outline all important requirements surrounding geological and mining activity in Poland. It should facilitate the understanding of Polish regulations – different than in other countries – and compare them to international standards. Importantly, the presented information originates from the latest documents and reports. Nevertheless, legal aspects within the geological area continue to evolve and may change during the course of publication reading to the time of an investment decision. Moreover, the English translation of selected topics of geological and mining law and other acts is only an unauthorised version and cannot be treated as official. We prepared it for foreign investors to make the Polish legal system comprehensible before final decisions on activity in Poland are made. Thus, such law translations should be treated only as helpful and informational, and not as binding.

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Abbreviations

List of abbreviations and units of measure and terms used in the book

µm	micrometre
bn	billion
bnm³	billion cubic metres
bnt	billion tonnes (= 1,000,000,000,000 kg)
Bq	becquerel
Btu	British thermal unit (equal to about 1,055 joules)
CBM	coal bed methane
cm³	cubic centimetre
dm³	cubic decimetre
EUR	European Union currency
g	gram
GML	Geological and Mining Law adopted on 9 June 2011 (Official Journal of 2016, Item 1131, unified text, later reapproved; hereinafter referred as **the Act**)
ha	hectare
HNNG	high nitrogenous natural gas
kg	kilogram
kha	thousands of hectares (= 1,000 ha)
kt	thousand tonnes (= 1,000,000 kg)
LCB	Lublin Coal Basin
LSCB	Lower Silesian Coal Basin
m	metre
M	million
m³	cubic metre
mbsl	metre below surface level
MEUR	million EUR
mg	milligram
Mha	million hectares (= 1,000,000 ha)
Mm³	million cubic metres (= 1,000,000 m³)
Mt	million tonnes (= 1,000,000,000 kg)
MUSD	million USD
PLN	Polish currency (in Polish "Złoty")
PLN bn	billion PLN
PLN M	million PLN
RME	Regulation of the Minister of the Environment on geological documentation of mineral deposits, excluding hydrocarbons (dated 1 July 2015 – Official Journal of 2015, Item 987)
t	tonne (= 1,000 kg)
tr oz	31.1034768 grams
USCB	Upper Silesian Coal Basin
USD	United States currency (dollar)

Glossary

A. Malon, K. Szamałek, M. Tymiński

UNFC-2009 definition according to Annex I and Annex II which form an integral part of UNFC-2009 (UNECE, 2013)

Definition of categories and supporting explanations

Cat.	Definition*	Supporting Explanation**
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 the 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.

* 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

Cat.	Definition	Supporting Explanation
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.

Cat.	Definition	Supporting Explanation
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 [*continuation on the next page*]

G2	Quantities associated with a known deposit that can be estimated with a moderate level of confidence	[*continuation*] 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.
G3	Quantities associated with a known deposit that can be estimated with a low level of confidence	
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.

Definition of sub-categories

Cat.	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

Cat.	Sub-Category	Sub-Category Definition
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

Definitions used in Polish classification system

Resources definition according to a:

- **Regulation of the Minister of the Environment on geological documentation of mineral deposits, excluding hydrocarbons (dated 1 July 2015 – Official Journal of 2015 Item 987) – RME;**
- **Regulation of the Minister of the Environment on geological-investment documentation of a hydrocarbon field (dated 1 July 2015 – Official Journal of 2015 Item 968);**

- **Regulation of the Minister of the Environment on detailed requirements of a mineral deposit development plan (dated 24 April 2012 – 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 deposit boundaries.

Limit values of parameters that define a deposit – values of deposit parameters delineating mineral deposit geological boundaries.

Anticipated economic resources ("balance resources") – mineral deposit resources (or part of a deposit) meeting limit values of parameters that define a deposit.

Anticipated sub-economic resources ("sub-balance resources") – mineral deposit resources (or part of a deposit) not meeting limit values of parameters that define a deposit.

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

Sub-economic (marginal) resources ("not-industrial resources") – part of anticipated economic mineral resources not-classified as economic resources within an area designated for exploitation, which can be designated for mining as a result of technical or economical or legal requirement changes, including environmental restraints.

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

Exploitable resources – crude oil or natural gas resources, which should be extracted by applying current exploitation technology.

Resources categories definition according to a:

- **Regulation of the Minister of the Environment on geological documentation of mineral deposits, excluding hydrocarbons (dated 1 July 2015 – Official Journal of 2015 Item 987) – RME.**

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 initially 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 cannot 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 a prefeasibility study of economic mining, including detailed delineation of structural and geological features, tectonics and quality of mineral commodity in a deposit, as well as geological-mining conditions of exploitation, and allows evaluation of the influence of intended exploitation on the environment. The admissible error of average deposit parameters and deposit resources estimation cannot exceed 30%.

B (measured resources) – mineral deposit boundaries are delineated in details on the basis of specially carried out exploratory excavations or geophysical measurements, whereby the delineation of structural and geological features, correlation of strata, and main tectonics features have to be unambiguous and the quality and technological properties of a mineral commodity should be confirmed by sampling results in pilot-scale tests or on a commercial scale. The degree of deposit exploration is sufficient enough to elaborate a mine management plan. The admissible error of average deposit parameters and deposit resources estimation cannot exceed 20%.

A (measured resources) – a mineral deposit is explored to an extent allowing current planning and exploitation with a maximum possible rate of resource absorption; delineation of structural and geological features, tectonics, resources on the basis of opening-out, preparation and mining excavations, as well as type, quality and technological properties of mineral commodity on the basis of regular excavations sampling and data from current production are required. The degree of deposit exploration is sufficient enough to elaborate a mine management plan. The admissible error of average deposit parameters and deposit resources estimation in particular blocks cannot exceed 10%.

Resources categories definition according to a:

- **Regulation of the Minister of the Environment on geological-investment documentation of a hydrocarbons field (dated 1 July 2015 – Official Journal of 2015 Item 968).**

Hydrocarbons

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

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

A (measured resources) – data for category A 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 according to a:

- **Regulation of the Minister of the Environment on geological documentation of mineral deposits, excluding hydrocarbons (dated 1 July 2015 – Official Journal of 2015 Item 987) – RME;**
- **Regulation of the Minister of the Environment on detailed requirements of a mineral deposit development plan (dated 24 April 2012 – Official Journal of 2012 Item 511).**

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

Mineral deposit development plan (called also "prefeasibility study" – Nieć, 2010b) – It 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 a project.

Various terms are in use internationally for Prefeasibility Studies reflecting an actual accuracy level. Data required to achieve this level of accuracy are reserves/resources figures based on a Detailed and General Exploration, technological tests at a laboratory scale and cost estimations e.g. from catalogues or based on comparable mining operations.

Geological study (geological documentation) – The Geological Study is 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 be generally defined from a Geological Study due to the lack of detail necessary for an Economic Viability evaluation. Estimated resource quantities may indicate that a 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. The purpose of a 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 and the state of mineral deposit development according to:

- **Nieć (2012) The methodology of solid minerals documentation. Part IV. Guidebook – Resources estimating (in Polish); with author modifications:**

Perspective resources (D_2) – A probable deposit occurrence was indicated. The deposit is expected to occur on the basis of localized evidences (geophysical, geochemical anomalies, isolated showings of raw material, outcrops, etc.). Possible resources are estimated on the basis of general geological data by analogical methodology. The admissible error of deposit resources estimation is not defined.

Prognostic resources (D_1) – Raw material occurrence whose accumulation may form a deposit is confirmed. Resources are assessed on the basis of sparse, rare points of raw material (deposit) occurrence (outcrops) and on the interpretation of geophysical data that enables approximate delineation of a deposit area. The admissible error of deposit resources estimation may exceed 40%.

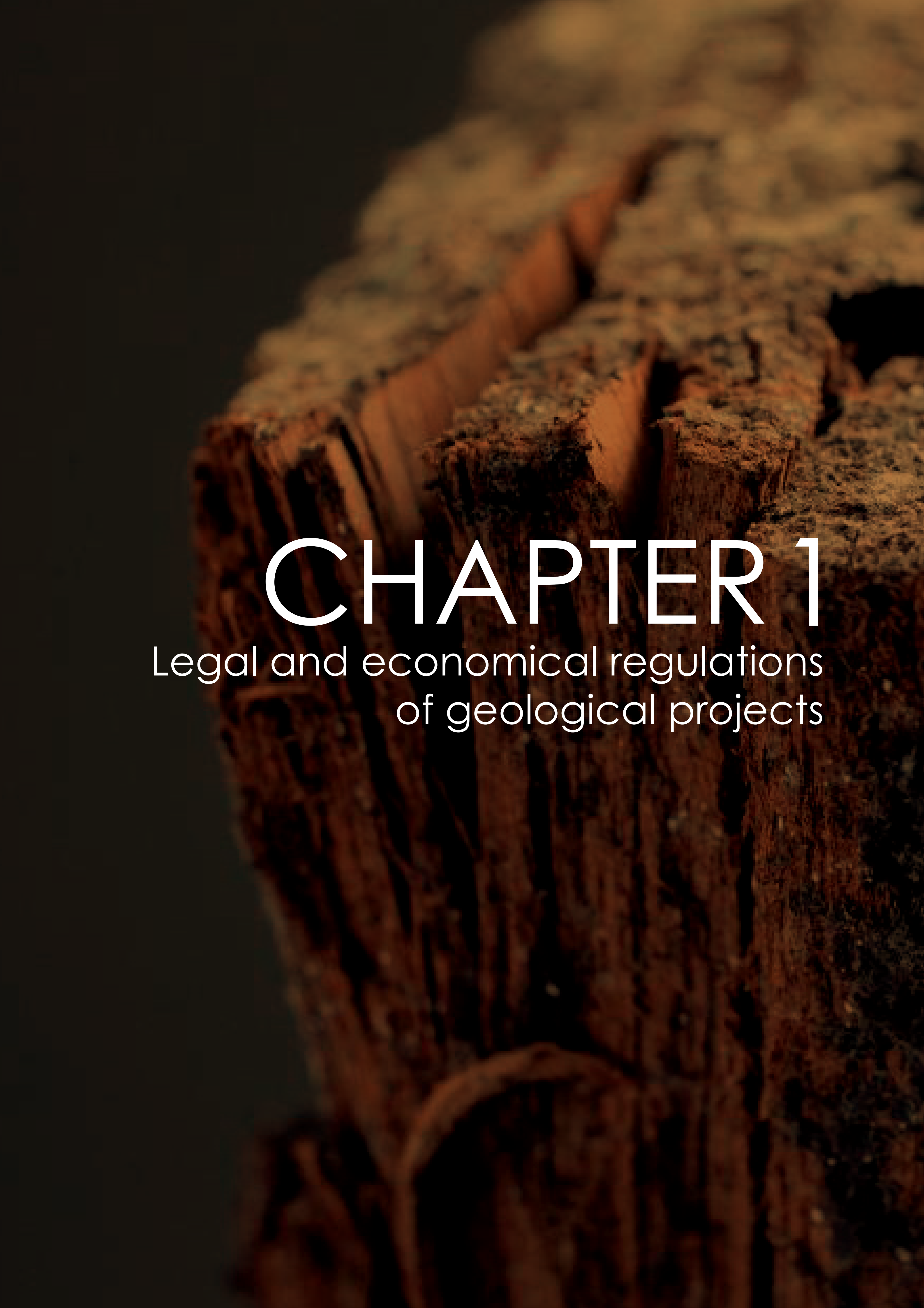
General exploration – means the identification of a deposit and its preliminary exploration. Data on a deposit originates from natural exposures, spare boreholes and mining excavations allowing preliminary determination of deposit occurrence conditions and its range. Variant interpretation of a deposit construction, its setting and tectonics is allowed. Data on raw material is obtained on the basis of laboratory tests of samples collected from all evaluative points (exposures, boreholes, excavations). Technological features are assessed on the basis of analogical methodology. In "The balance of mineral resources deposits in Poland" deposits covered by general exploration are in categories D and C_2 for solid minerals and in category C for hydrocarbons.

Detailed exploration – means deposit exploration to an extent allowing elaboration of its consecutive development stages. Boreholes and mining excavations are located regularly within a deposit area. Deposit occurrence conditions, its form and tectonics can be determined unambiguously. On the basis of collected systematically samples, main raw material types and their distribution within a deposit can be identified. Technological, hydrogeological, geological-engineering and gaseous tests of raw material are also carried out. In "The balance of mineral resources deposits in Poland" deposits covered by detailed exploration are in categories C_1, B and A for solid minerals and in categories A and B for hydrocarbons.

Deposits of operating mines (exploited deposits) – deposits with a valid exploitation concession issued if output is carried out regularly (each year).

Deposits exploited temporarily – deposits with a valid exploitation concession issued if output is carried out intermittently.

Abandoned deposits – deposits where exploitation has been halted.



CHAPTER 1

Legal and economical regulations of geological projects

1. Geological and Mining Law

K. Szamałek, M. Młynarczyk

Mineral law in the Republic of Poland is far more formalised in contrast to mineral regulations in common law countries. Therefore, in this chapter we present only the most important rules of the Polish law. Currently, geological and mining activity in Poland is regulated by the Geological and Mining Law adopted on 9 June 2011 (Official Journal of 2016, Item 1131 – unified text, later reapproved – hereinafter referred as the Act) – GML. In addition, some issues fall within the scope of regulation of other laws such as the Polish environment protection law or law on mining waste. The evolution of the Polish legal system in the areas of geology and mining in recent decades was presented by Szamałek (2015).

The GML (adopted on 9 June 2011) defines the terms and conditions for initiation, execution and completion of activities in the scope of:

- geological works,
- mineral extraction from deposits,
- non-reservoir storage of substances in the subsurface,
- storage of waste in the subsurface,
- storage of carbon dioxide in the subsurface.

Additionally, the Act sets out requirements for protection of mineral deposits, groundwater, and other components of the environment in connection with the above activities. The Act also determines supervision and control of the above activities. The scope of the Act also covers:

- construction, development and maintenance of drainage systems of liquidated mining plants;
- excavation work carried out in closed underground mining plants mainly for tourist, curative and recreational purposes;
- underground work conducted for scientific, research, experimental and training purposes for geology and mining;
- tunnelling with use of mining techniques;
- decommissioning of the above entities, equipment and installations.

The Act shall not apply to:

- the use of water (regulated by a Water Law);
- the digging (beyond mining areas) of pits and boreholes to a depth of 30 m in order to use Earth heat;
- the digging (beyond the mining areas) of pits and boreholes to a depth of 30 m in order to use groundwater in amounts up to 5 m^3;
- research and teaching carried out without geological operations;
- acquisition of samples of minerals, rocks and fossils for scientific, collection and teaching purposes without mining operations;
- operations related with artificial supply of the shoreline zone with sand from sea bottom sediments of maritime areas of Poland;
- aggregate extraction to the extent necessary to complete urgent work to prevent flooding during a natural disaster;
- determination of geotechnical conditions of the foundation of buildings without mining operations.

The Act concerns mineral deposits, but water is excluded from minerals. Only curative and thermal water as well as brines are treated as minerals.

In Poland, the geological profession is regulated by law (the Act). The Act states that a person undertaking operations consisting of execution, supervision and direction of geological works should have appropriate certificate granted by geological administration. There are 10 classes of professional certificates specified in the Act as follows: economic geology (3 types), hydrogeological (2 types), engineering-geological (2 types), geophysical, geological mapping, and direction of field geological work. Confirmation of geological qualifications is provided by a certificate issued by the minister of environment (9 types) and by the province marshal (1 type). A candidate who would like to receive a certificate of qualified geologist should have adequate education, professional practice and must pass an exam.

2. Ownership of mineral resources

K. Szamałek, M. Młynarczyk

The Polish legal system determines two types of mineral deposit ownership: state ownership (State Treasury) and land ownership. State ownership concerns mineral deposits described as covered by so-called mining ownership.

Mining ownership (state ownership) concerns deposits of hydrocarbons, hard coal, methane occurring as accompanying mineral, lignite, metal ores with the exception of bog iron ores, native metals, ores of radioactive elements, native sulfur, rock salt, potassium salt, potassium-magnesium salt, gypsum and anhydrite and gemstones. State ownership of the above minerals does not depend of the place of their occurrence, as it also covers deposits of curative and thermal water and brines. Deposits of minerals not indicated in the Act belong to a land owner. The Act introduces a very important rule, so-called mining usufruct (term adequate to mining lease) which only concerns minerals owned by the state. In connection with this rule, the Minister of the Environment, on behalf of the state and with the exclusion of other persons, can benefit from the subject of mining properties or dispose of its right to state-owned minerals exclusively by establishing mining usufruct. Mining usufruct does not apply to geological works that do not require a concession. The establishment of mining usufruct shall take place in the form of a written agreement and requires predetermined remuneration of the state. State remuneration concerns geological and mining activities carried out in mass rock. A mining usufruct agreement enters into force on the date of received concession. The establishment of mining usufruct may be preceded by a tender, particularly when more than one entity seeks it. In the case of hydrocarbons, the establishment of mining usufruct must be preceded by a concession tender

Mining usufruct expires in case of withdrawal of a concession or expiry or loss of its validity, regardless of reason.

Anyone exploring a mineral deposit (excluding hydrocarbons) under mining ownership (State Treasury ownership) and documented sufficiently to enable preparation of a mineral deposit development plan and who has obtained a decision approving geological documentation of a deposit may demand the establishing of mining usufruct for its own benefit with priority over other parties. The priority right shall expire three years from the date of notification of a decision approving geological documentation. An entity with a priority right can declare willingness to receive a mining usufruct agreement. In such case, the agreement should be established within three months from the date of declaration.

3. Concession system

K. Szamałek, M. Młynarczyk

Polish law (the Act) requires a concession for the following activities:

- prospecting or exploration of mineral deposits owned by the State Treasury,
- prospecting or exploration of mass rock for underground storage of carbon dioxide,
- exploitation of minerals from deposits,
- prospecting or exploration or extraction of hydrocarbons deposits,
- non-reservoir storage of substances in the subsurface,
- storage of waste in the subsurface,
- storage of carbon dioxide in the subsurface.

A concession is granted for a minimum period of 3 years and a maximum of 50 years, unless an entrepreneur submitted an application to grant a concession for a shorter period. Only prospecting and exploration of state-owned minerals requires a concession. In the case of prospecting and exploration of minerals owned by a land owner, a geological works plan approved by the geological administration authority is required. In both cases, i.e. state owned minerals as well as land owner minerals, a concession for mineral extraction (irrespective of extraction method – wells, open pits, underground mines) is required.

There are three concession authorities: the minister of the environment (assisted by the chief national geologist), the provincial marshal (assisted by chief provincial geologist) and the county chief (assisted by county geologist). The responsibilities of these concession authorities are divided as follows:

- the minister has the right to issue concessions for: prospecting, exploration and extraction of state-owned minerals (also for all minerals in the Polish sector of sea territory) and subsurface storage of waste and substances;
- a county chief has the right to issue concessions for extraction of minerals belonging to land property if: the area of documented deposit is less than 2 ha, annual mineral extraction does not exceed 20 kt, and mining is with the open pit method without explosives;
- the marshal has the right to issue a concession for activities other than listed above.

A concession authority has the right to refuse a concession. Article 29.1 of the Act describes cases when it is possible. The geological authority may refuse to issue concession when intended activity would be detrimental to the public interest, particularly in relation to national security or environmental protection, including rational management of mineral deposits. This right also applies if intended activity prevents the use of real estate in accordance with purposes specified respectively by a local urban spatial development plan or separate regulations and, in the absence of a local urban spatial development plan, prevents the use of real estate as defined in the study of conditions and directions of spatial management of a municipality. The Act also describes other cases when a concession authority can refuse a concession (art. 29 1a, 2 and 3).

The concession should specify:

- the type and manner of intended activity;
- boundaries of rock mass space where intended activity is to take place;
- the concession period;
- the commencement date of activities specified by a concession and, if necessary, conditions in which the activity will start.

A concession may stipulate other requirements applying to activities covered by a concession, in particular, general safety and environmental protection.

A concession for prospecting/exploration of minerals also lists the following requirements:

- purpose, scope and nature of intended geological works (including geological operation), minimum category of deposit recognition;
- scope and schedule for a transfer of geological information and samples obtained from geological works;
- amount of charge to activities specified in a concession.

The maximum area covered by a single concession for prospecting/exploration cannot exceed 1,200 km^2.

A concession for mineral extraction from a deposit can also determine minimum resource utilisation and operations necessary for rational development of a deposit.

4. Geological and mining administration

K. Szamałek, M. Młynarczyk

The Polish geological administration is composed of the minister of the environment (assisted by chief national geologist), the provincial marshal (assisted by chief provincial geologist) and the county chief (assisted by the county geologist). These administration authorities are independent because the minister represents the government, whereas the marshal and county chief represent local self government. Responsibilities divided among geological administration are as follows. The minister of environment is responsible for issues tied to the approval of geological works projects and geological documentation concerning:

- state owned mineral deposits;
- Polish sea territory;
- regional hydro-geological research;
- setting of hydro-geological conditions in connection with establishing underground water reservoir protection areas;
- determination of hydro-geological and engineering conditions for underground no-tank storage of substances and underground waste disposal;
- determination of hydro-geological and engineering conditions for prospecting/exploring of underground storage carbon dioxides;
- regional study of the geological structure of the country;
- regional geological cartography works;
- drill holes for examining the structure of deep ground, unrelated to mineral deposit documentation;
- water engineering of structures of a damming exceeding 5 m in height.

The county chief is responsible for issues related to approval of geological works projects and geological documentation concerning:

- mineral deposits belonging to a land owner if an area up to 2 ha is dedicated to opencast annual mining up to 20,000 m^3 and without explosives;
- intakes of groundwater when predicted or fixed resources do not exceed 50 m^3/h;
- engineering and geological research carried out for needs of a local spatial development and conditions of constructing foundation systems (excluding supra-provincial linear investments);
- building drains with maximum capacity of 50 m^3/h;
- geological works to exploit the Earth heat;
- hydro-geological conditions in connection with intended implementation of projects that may adversely affect ground water, including contamination; projects classified as projects that may affect the environment significantly and for which the obligation to report on project impact on the environment may be required with the exception of projects that may adversely affect curative water.

Cases not described in obligations of the minister or county chief lie with marshal responsibilities.

The Polish Geological Institute – National Research Institute (PGI-NRI) performs tasks of the state geological survey. Its responsibilities are described in article 162 of the Act.

Mining authorities are comprised of the President of the State Mining Authority and directors of regional mining authorities. The structure of mining authorities is vertical, whereby regional mining authorities are supervised by the President of the State Mining Authority.

5. Financial regulations

K. Szamałek, M. Młynarczyk

Geological and mining activity is subject to a number of taxes, levies and other financial duties. Some of them have a general nature such as income tax (CIT, PIT), VAT, local taxes, social insurance fees etc. Some financial instruments are introduced by the Act and have a specific nature (Tab. 5.1). This concerns concession fees (production activity does not require concession fees), exploitation fees (royalties), and charge for establishing mining usufruct (mining lease). The payment for mining usufruct is determined by a representative of the State Treasury (minister of environment or marshal).

A concessioner (for prospecting/exploring of mineral deposits) must pay a charge as a product charge rate expressed in square kilometres of land area covered by a concession. The formula for concession fee calculation is as follows:

$$C_f = S \cdot P_c$$

where:

C_f – total concession fee [PLN]
S – area covered by a concession [sq. km]
P_c – charge rate set for a given type of mineral [PLN].

The charge for prospecting of hard coal and uranium ores is set at PLN 574.88, PLN 229.97 for lignite, PLN 216.14 for hydrocarbons and PLN 115.00 for other minerals covered by mining property (state ownership). The charge for exploration and common prospecting and exploration is calculated as twice the above rates. A charge is calculated once and is payable within 14 days from the date when a concession becomes final. Other individual rates are dedicated for underground storage of waste and other substances.

An entrepreneur obtaining a concession for mineral extraction of deposits pays a charge to be set as the product of its rate and quantity for mineral extraction with balance sheet and off-balance sheet deposits in the trading period.

The formula for calculating the extraction fee is as follows:

$$E_f = R_c \cdot V$$

where:

E_f – total extraction fee [PLN]
R_c – rate of charge set for a type of mineral, rates indicated in an Appendix to the Act [PLN/m³, t, g – respectively]
V – extraction in a one-half year period [m³, t, g – respectively].

Charge rates for particular types of mineral are set in an annex to the Act. The extraction charge is 50% for accompanying minerals and contaminant minerals extracted from deposits of hydrocarbons. The extraction charge for selected minerals is as follows: barite – 5.98 PLN/t, basalt – 1.17 PLN/t, gypsum – 1.88 PLN/t, kaolin – 3.34 PLN/t, Zn-Pb ores – 1.28 PLN/t, Cu ores – 3.47 PLN/t, hard coal – 2.38 PLN/t and lignite – 1.88 PLN/t. Additionally, an entrepreneur obtaining a concession for mineral extraction

Table 5.1. **Types of special financial instruments dedicated to geological and mining activities**

Type of financial taxes and levies introduced by the Act
FEE FOR ESTABLISHING MINING USUFRUCT
CONCESSION FEE
EXTRACTION FEE
ADDITIONAL FEE
INCREASED FEE
REMUNERATION FOR USING GEOLOGICAL INFORMATION
MANDATORY CONTRIBUTION FOR THE MINING PLANT CLOSURE FUND
FINES

of deposits or underground storage of waste, substances and carbon dioxide must create a special fund for mining plant closure (art. 128 of the Act). The method of contribution calculation for the special closure fund differs from open-pit and underground mining. For underground mining that contribution is equivalent to at least 3% of fixed asset amortisation and for open-pit mining – to at least 10% of the extraction fee.

Flagrant violation of conditions set in a concession or approved geological works plan shall be subject to an additional charge. Such charge is set by a concession authority and can be up to five times higher than a regular charge.

By contrast activity undertaken without a required concession or approved geological works plan is subject to a higher charge. The authority responsible for setting an increased charge is the minister of environment or mining authority, respectively. For example, the increased charge is set at PLN 50,000 for each square kilometre covered by such illegal activity (prospecting/exploration of state-owned minerals). The increased charge for illegal extraction is calculated as 40 times the regular extraction charge rate (multiplied by the amount of extracted mineral). Revenue from the mining usufruct and extraction fees is presented in Tables 5.2 and 5.3.

Table 5.2. Revenue from the mining usufruct fee and use of geological information (Brodziński, 2014, *in:* Czerniawska, 2015)

I. Revenues from mining ownership				II. Revenues from agreements signed in 2014 on access to geological information (State Treasury)
Type of mineral raw materials	**Prospecting and exploration of mineral raw material deposits [PLN]**	**Extraction of raw materials [PLN]**	**Total revenues from mining ownership [PLN]**	**Fee for access to geological information on the basis of agreements signed in 2014 [PLN]**
HARD COAL	1,079,455.94	1,964,371.02	3,043,826.96	16,508,011.04
LIGNITE	110,103.76	173,147,902.00	173,258,005.76	64,496.60
HYDROCARBONS, INCLUDING:	51,243,999.35	3,111,151.31	54,355,150.66	–
Crude oil				–
High methane natural gas				–
Natural gas				22,372.90
ROCK SALT	123,115.97	139,280.40	262,396.37	724,805.50
SULFUR	–	–	–	67,867.94
URANIUM ORES	7,957.00	–	7,957.00	–
COPPER ORES	435,405.79	29,858,480.10	30,293,885.89	1,893,546.60
ZINC AND LEAD ORES	60,000.00	794,102.07	854,102.07	106,812.72
POLYMETALLIC ORES	31,252.00	–	31,252.00	–
GYPSUM AND ANHYDRITE	–	540,900.90	540,900.90	–
ROCK AGGREGATES ON THE SEA TERRITORY	–	30,843.90	30,843.90	–
CURATIVE AND THERMAL WATER	29,899.20	–	29,899.20	37,472.79
TOTAL	**53,121,189.01**	**209,587,031.70**	**262,708,220.71**	**19,425,386.09**

Table 5.3. Revenue of extraction fee in 2014 (Brodziński, 2014, *in:* Czerniawska, 2015)

Type of mineral raw materials	III. Extraction fees		
	Total fee [PLN]	Including	
		Fee for the National Fund for Environmental Protection and Water Management [PLN]	Fee for counties [PLN]
HARD COAL	146,983,962.00	58,793,584.80	88,190,377.20
LIGNITE	117,234,496.00	46,893,798.40	70,340,697.60
HYDROCARBONS, INCLUDING:	62,467,034.00	28,553,596.40	33,913,437.60
Crude oil	33,882,288.00	17,092,185.60	16,790,102.40
High methane natural gas	9,452,328.00	3,780,931.20	5,671,396.80
Other natural gas	18,711,237.00	7,484,502.00	11,226,735.00
CO-OCCURRING NATURAL GAS AND OTHER CO-OCCURRING RAW MATERIALS	421,181.00	195,977.60	225,203.40
ROCK SALT	5,293,210.00	2,117,284.00	3,175,926.00
SULFUR	966,772.00	386,708.80	580,063.20
COPPER ORES	101,756,447.00	40,702,578.80	61,053,868.20
ZINC AND LEAD ORES	2,756,338.00	1,102,535.20	1,653,802.80
GYPSUM AND ANHYDRITE ROCK AGGREGATES ON THE SEA TERRITORY	2,603,542.00	1,301,059.60	1,302,482.40
ROCK RAW MATERIALS CO-OCCURRING IN LIGNITE DEPOSITS	77,359.00	30,943.60	46,415.40
TOTAL	**440,139,160.00**	**179,882,089.60**	**260,257,070.40**

Section X of the Act presents a system of fines setting. The President of the State Mining Authority is responsible for imposing a financial penalty upon an investor who engaged in activities against the GML.

The use of geological information (geological, seismic profiles) is for charge. An investor who intends to use geological information belonging to the state for preparation of an application for a concession or geological documentation pays a fee calculated according to rules set in an order prepared by the Minister of the Environment.

6. Classification of mineral resources

A. Malon, M. Tymiński

6.1. United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009)

UNFC-2009 – history

The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources (UNFC-2009) is an universally applicable scheme for classifying petroleum and solid mineral reserves and resources (Fig. 6.1.1). It was elaborated by the United Nations Economic Commission for Europe (UNECE) and is recommended by the United Nations Economic and Social Council (ECOSOC) in Decision No. 2004/33 issued on 18 July 2004. The UNFC-2009 is designed to allow the incorporation of currently existing terms and definitions into this framework and thus to make them comparable and compatible. The latest version of the classification was obtained following a long process.

During the 1990s, the Economic Commission for Europe (ECE) took the initiative to develop some 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 Classifi-

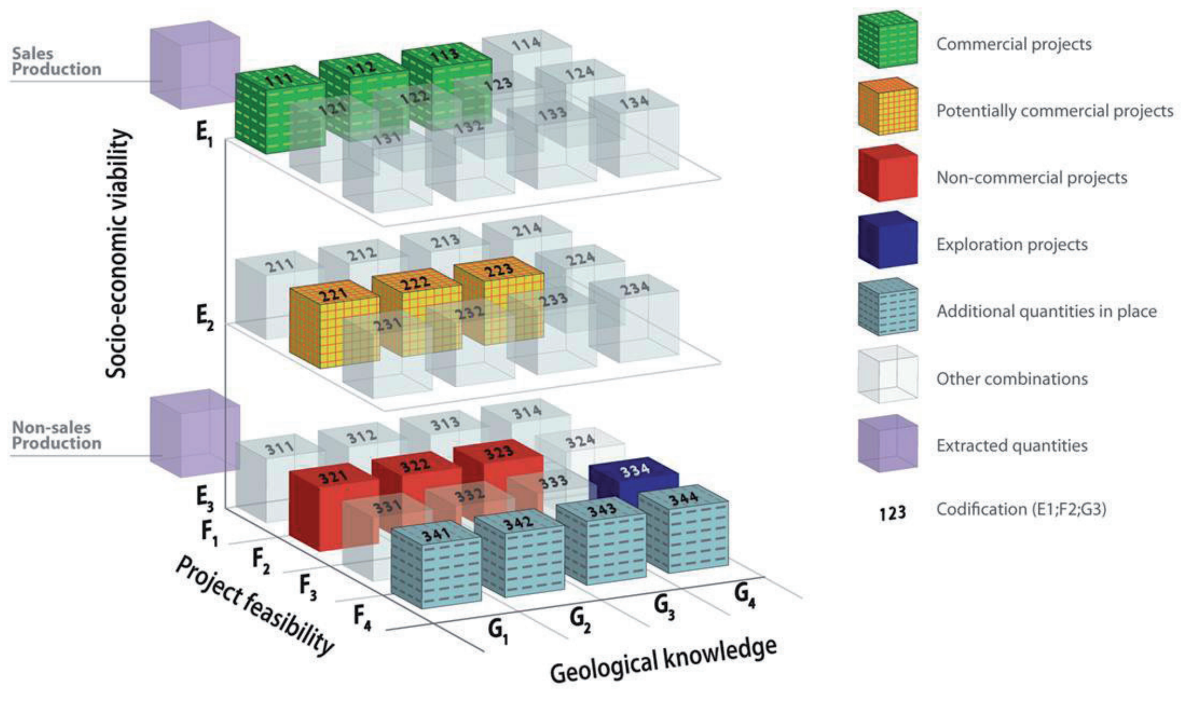


Fig. 6.1.1 **UNFC-2009 categories and example of classes (UNECE, 2013)**

cation for Reserves and Resources of Solid Fuels and Mineral Commodities (known as UNFC-1997). Then, in 2004, the system was extended to also apply to hydrocarbons and uranium (UNFC for fossil Energy and Mineral Resources 2004). In order to facilitate worldwide application of the Classification, the ECE Committee on Sustainable Energy directed the Ad Hoc Group of Experts on Harmonisation of Fossil Energy and Mineral Resources Terminology (now called the Expert Group on Resource Classification). This Group is composed of United Nations Member States, international organisations and United Nations regional commissions. The final effect of efforts was a simpler and revised UNFC version called UNFC-2009 that was prepared in 2013. Moreover, specifications and rules of application were developed. The active and substantive contribution of Polish representatives to all these efforts (I. Grzybek, M. Nieć, S. Przeniosło, M. Piwocki, K. Szamałek) should be emphasized.

UNFC-2009 – basic rules

UNFC-2009 is a three-dimensional system in which quantities are classified on the basis of three criteria by using a numerical and language independent coding scheme (Fig. 6.1.1). The categories (e.g. E1, E2, E3) are defined for each of the three criteria. These basic criteria are:

- economic and social viability (E) – it designates the degree of favourability of social and economic conditions in establishing commercial viability of a project, including consideration of market prices and relevant legal, regulatory, environmental and contractual conditions;
- field project status and feasibility (F) – it designates the maturity of studies and commitments necessary to implement mining plans or development projects. These extend from early exploration efforts before a deposit or accumulation has been confirmed to exist through to a project that is extracting and selling a commodity;
- geological knowledge (G) – it designates the level of confidence in geological knowledge and potential recoverability of quantities.

On the basis of this criteria, resource categories are distinguished, defined and indicated by numbers. Therefore, each resource class can be presented as a 3-digit number where digits are designated to the E, F, G criteria. Theoretically, there can be 48 resource classes, but only some of them used in practice. There can also be sub-categories if necessary.

6.2. Polish classification system and the UNFC-2009

The Polish classification is based on similar rules as UNFC-2009 and with some assumptions respective UNFC classes can be found. Some are not formally used in Poland, for example, exploitable resources of solid raw materials (Nieć, 2009). UNFC-2009 distinguishes four grades of deposit exploration: G1, G2, G3, G4 and these grades combine with Polish categories: A+B, C_1, C_2, D and D_1–D_3 (Fig. 6.2.1):

As for the E-axis (Fig. 6.1.1), some resource types in Poland can relate to the UNFC-2009. From an economic standpoint, the most important in UNFC-2009 are resources within the E1 category (111, 112, 113 classes) – these are the economic resources that are to be sold. These resources correspond to Polish extractable resources (in Polish “operatywne”) in A+B, C_1 and C_2 categories. The only question mark applies to 111 class (C_2 cat.) due to the small accuracy of deposit data – an economic assessment of a deposit in this category is not allowed in international classification systems (also in UNFC) because the data only enables assessment of the resources as inferred (Nieć, Młynarczyk, 2014). However, the contribution of resources within category C_2 to total resources of exploited deposits in Poland is significant. For hard coal resources it was 33.7% of anticipated economic resources and 16.1% of economic resources as of 31 XII 2015. Particularly hard coal basins, it amounted to 34.2% of anticipated economic resources within an exploited deposit in the Upper Silesian Coal Basin (USCB) and 22% in the Lublin Coal Basin (LCB). It suggests that resources in the C_2 category should be taken into account in this analysis. UNFC-2009 does not distinguish a category that in the Polish system means economic resources in place (in Polish “przemysłowe”). The E2 category means resources whose extraction and sale is expected to be economically viable in the foreseeable future. That means exploitable resources for hydrocarbons, whereas for solid minerals it is not defined if resources are exploitable or in deposit – *in situ* (Nieć, 2009). Thus:

- 211, 212, 213 classes would indicate economic resources defined in a mineral deposit development plan;
- 221, 222, 223 classes mean anticipated economic resources (in Polish “bilansowe”) which can possibly be exploited, but which are not qualified for economic resources in place or sub-economic resources (in Polish “nieprzemysłowe”) in exploited deposits (those can be

resources beyond a concession area or within non-available levels);
- 231, 232, 233 classes are anticipated economic resources in non-exploited deposits.

The E3 category covers anticipated sub-economic resources (in Polish "pozabilansowe"). It seems that lost resources (in Polish "tracone"; losses from economic resources) should also be in this category (Nieć, 2009).

The equivalents of field project status and feasibility (F axis) in the Polish classification system are documents related to a particular deposit. There is no clear connection for the F4 category – possible counterparts are regional reports on prospective raw material resources. In general, geological documentation can be assigned to the F3 category, mineral deposit development plan to the F2 category and a mining report to the F1 category. If considering category definitions, geological documentation responds to the F2 category since a deposit has an issued exploitation concession and mineral deposit development plan responds to the F1 category since exploitation starts. Therefore, geological documentation can be assigned to both the F3 and F2 categories and the mineral deposit development plan to both the F2 and F1 categories.

A comparison between the system used in Poland and the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources from 2009 is presented in Figure 6.2.2 and in Table 6.2.1.

Substantial differences between Polish system and the UNFC-2009 are (Nieć, 2009):
- the mode of presentation of resource data: hierarchical in Poland, which means within the total magnitude of geological resources. Thus, geological resources are divided into anticipated economic 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. UNFC-2009 – similarly to other international systems – is complementary, which means that it distinguishes extractable (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;
- important role of economic resources in-place in the Polish system that are not distinguished in UNFC-2009;
- the division of resources that are not qualified for justified exploitation (in the Polish system);
- the lack of formal assignation of exploitable resources in Poland, which in Anglo-Saxon terminology are called "reserves".

Therefore, to obtain full compatibility between the Polish system and UNFC, data on Polish resources should be released separately:
- in exploited deposits (deposits licensed for mining) – economic resources in place (21x according to UNFC-2009), sub-economic resources (31x), anticipated economic resources not qualified for economic and sub-economic resources (22x), anticipated sub-economic resources (32x);
- in non-exploited deposits (beyond concession areas) – anticipated economic resources (23x), anticipated sub-economic resources (33x).

Therefore, economic resources in place can be presented as: 21x (economic resources) = 11x (extractable resources) + 31x (losses).

Table on the page 33 presents resources of selected raw materials in Poland (as of 31 XII 2015) in comparison with UNFC-2009. The number of raw materials is reduced only to those where exploitation is carried out. Data originates from the publication "The balance of mineral resources deposits in Poland as of 31 XII 2015" and from the System of management and protection of mineral resources in Poland MIDAS carried out by the Department of Deposits and Mining Area Information of PGI-NRI. To make data compatible with UNFC-2009 resources were divided into resources of deposits licensed for mining and resources of deposits not-licensed for mining.

UNFC	**categories used in Poland** (admissible error of estimate)
G4	E (D_3), D_2, D_1 (officially not used)
G3	D (>40%)
	C_2 (up to 40%)
G2	C_1 (up to 30%)
G1	B (up to 20%)
	A (up to 10%)

Fig. 6.2.1. **A comparison of the geological knowledge of a deposit between UNFC-2009 and the Polish classification system (Nieć, 2010b)**

Table 6.2.1. A comparison of the Polish classification system and UNFC-2009 (Nieć, 2010a, with author adjustments)

<table>
<tr><th rowspan="3">Polish classification</th><th colspan="3">UNFC-2009</th></tr>
<tr><th colspan="2">Geological documentation</th><th rowspan="2">Mineral deposit development plan</th></tr>
<tr><th>Deposits licensed for mining</th><th>Deposits not licensed for mining (beyond concession areas)</th></tr>
<tr><td>Resources
perspective D_2
prognostic D_1</td><td></td><td>Resources
344
334</td><td></td></tr>
<tr><td>Anticipated economic resources
D, C_2
C_1
A+B</td><td colspan="2">Resources
223, 233
222, 232
221, 231</td><td></td></tr>
<tr><td>Anticipated sub-economic resources
D, C_2
C_1
A+B</td><td colspan="2">Resources
323, 333
322, 332
321, 331</td><td></td></tr>
<tr><td>Sub-economic resources
D, C_2
C_1
A+B</td><td colspan="2"></td><td>Resources
313, 323
312, 322
311, 321</td></tr>
<tr><td>Economic resources
D, C_2
C_1
A+B</td><td colspan="2"></td><td>Resources
213
212
211</td></tr>
<tr><td>Extractable resources
D, C_2
C_1
A+B</td><td colspan="2"></td><td>Resources (“economic”)
113, 123
112, 122
111, 121</td></tr>
<tr><td>Reserves
C_2
C_1
A+B</td><td colspan="2"></td><td></td></tr>
</table>

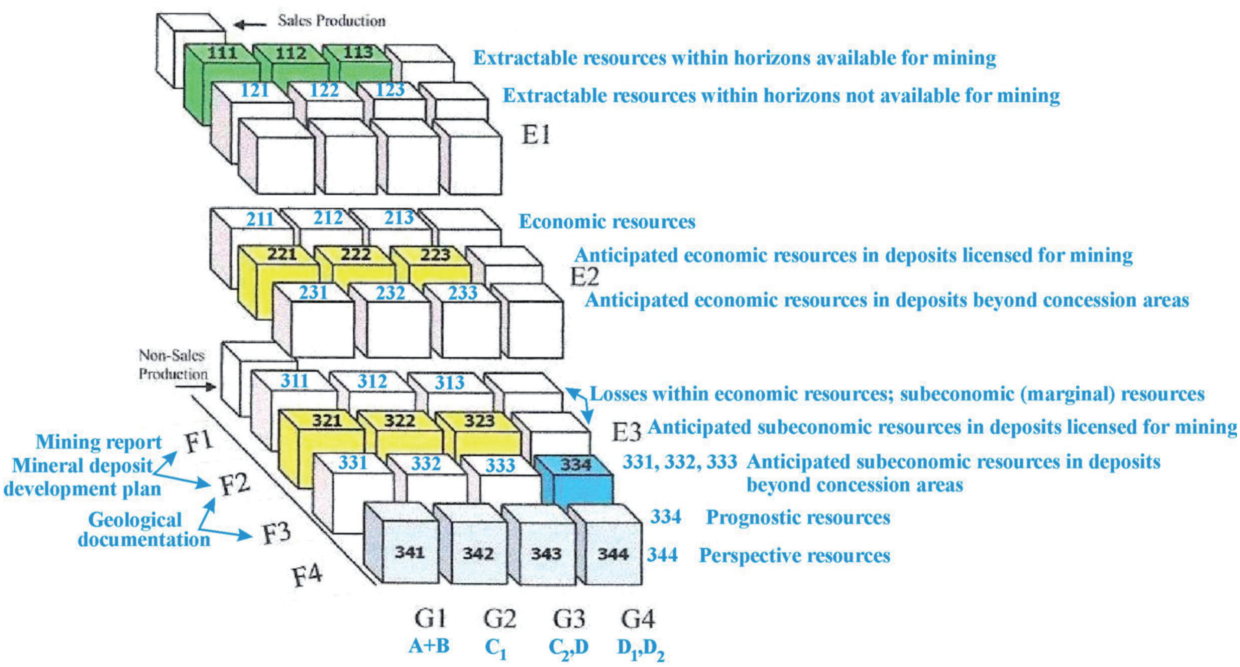


Fig. 6.2.2. Ties between the Polish and international (UNFC-2009) classification systems (Nieć, 2009, with author adjustments)

Due to the fact that data on resources collected in "The balance…" do not contain information on extractable resources, relevant factors were assumed for economic resources. In that manner, economic resources were reduced by losses. Factors for particular raw materials were:

- high nitrogenous natural gas – 1.00, crude oil – 1.00, natural gas – 1.00, coal bed methane – 1.00 (Nieć, Galos, 2015);
- copper and silver ores – 0.75, zinc and lead ores – 0.75 (Nieć, Galos, 2015);
- hard coal – 0.70 (Sobczyk, 2009; Kulczycki, Sowa, 2010), lignite – 0.90;
- rock salt – 0.35, sulfur – 0.50, diatomaceous rock – 0.75 (Nieć, Galos, 2015);
- bentonites, dolomites, gypsum and anhydrite, whiteware ceramic clays, stoneware ceramic clays, dimension and crushed stones, chalk, vein quartz, schists, magnesites, foundry sands, sand, gravel, quartz sands for cellular concrete and lime-sand brick production, filling sands, raw materials for engineering works, building ceramics raw materials, clayey raw materials for cement production, clayey raw materials for lightweight aggregate production, kaolin, feldspar raw materials, glass sands and sandstones, peat, limestones and marls – 0.75 (Nieć, Galos, 2015).

The methodology of comparing the Polish classification system with UNFC-2009 – the case of hard coal – is presented in the table. The same method was used for other raw materials.

Criteria from "The balance…" were used to divide deposits into licensed for mining and beyond concession areas. Therefore, deposits licensed for mining cover exploited deposits (symbol E used in "The balance…"), deposits exploited temporarily (T), mines in the course of a building process – for solid minerals; and mines prepared for exploitation or with trial exploitation – for hydrocarbons (B). However, economic resources are also being estimated for deposits that are not treated as exploited. These are deposits with a valid exploitation concession, but where production has not yet started. Aside from a concession, there is no knowledge of real deposit development (the start of work on a deposit). It applies to:

- deposits explored in C_2+D (for solid minerals) or C category (for hydrocarbons) – these are deposits covered by preliminary exploration and marked with "P" in "The balance…";
- deposits explored in A+B+C_1 categories (for solid minerals) or A+B (for hydrocarbons) – these are deposits covered by detailed exploration and marked with "R" in "The balance…".

Economic resources are also assessed for some deposits defined as abandoned in "The balance…" (Z). These deposits have not been exploited for years, but an exploitation concession is still valid. It is assumed that such a deposit is treated as licensed for mining only formally, but that there is no exploitation carried out. Therefore, deposits marked with "Z" are not included in the UNFC-2009.

Table 6.2.2. Economic resources of P and R deposits (beyond UNFC-2009; according to "The balance..." as of 31 XII 2015)

Raw material	Economic resources beyond UNFC-2009	The percentage contribution to the total economic resources
NATURAL GAS	3,906.90 Mm^3	7.66%
COAL BED METHANE	604.00 Mm^3	10.38%
CRUDE OIL	116.88 kt	0.82%
LIGNITE	16.83 kt	1.49%
HARD COAL	12.22 kt	0.34%
DIMENSION AND CRUSHED STONES	172.58 kt	5.10%
SAND AND GRAVEL	551.38 kt	14.98%
QUARTZ SANDS FOR CELLULAR CONCRETE PRODUCTION	0.47 Mm^3	2.61%
QUARTZ SANDS FOR LIME-SAND BRICK PRODUCTION	4.06 Mm^3	20.99%
BUILDING CERAMICS RAW MATERIALS	9.64 Mm^3	6.14%
PEAT	0.60 Mm^3	1.72%
LIMESTONES FOR LIME INDUSTRY	0.22 kt	0.02%

Therefore, some economic and sub-economic resources featured in "The balance…" will stay beyond UNFC-2009. This applies to several raw materials (Tab. 6.2.2 – as of 31 XII 2015):

Moreover, it is difficult to include resources of raw materials in UNFC-2009 that are exploited on the basis of a concession issued by a county chief. Such deposits do not require an economic and sub-economic resource estimation – as according to art. 26 point 3 of the GML there is no obligatory mineral deposit development plan elaboration. Thus, anticipated economic resources of such deposits that are exploited become *de facto* extractable resources plus losses. Deposits licensed for mining by a county chief refer to such raw materials as: dimension and crushed stones (72 deposits), chalk (5), foundry sands (1), sand and gravel (1,953), quartz sands for cellular concrete and lime-sand brick production (6), mineral raw materials for engineering works (5), building ceramics raw materials (108), clayey raw materials for cement production (3), peat (27) and limestone for the lime industry (3). The Table 6.2.3 shows the part of anticipated economic resources licensed for mining from which no economic resources were allocated.

Table 6.2.3. Analysis of the so-called "county chief's" deposit resources of selected raw materials (according to "The balance..." as of 31 XII 2015 and the System of management and protection of mineral resources in Poland MIDAS)

Raw material	Anticipated economic resources of deposits licensed for mining (with concession issued by a county chief) [Mt]	Anticipated economic resources of deposits licensed for mining (with concession issued by a county chief and Marshal) [Mt]	The percentage contribution of so-called county chief resources (column 1/2)	Anticipated economic resources reduced by the county chief's deposit (column 2–1; 22x in UNFC) [Mt]	Extractable resources, excluding county chief deposits) [Mt]	Extractable resources calculated from the anticipated economic resources for the county chief deposit (column 1×0,75 factor [Mt]	The percentage contribution of extractable resources calculated for the county chief deposit (column 6/5)	Extractable resources enlarged by the county chief deposit (column 5+6; 11x in UNFC) [Mt]
0	1	2	3	4	5	6	7	8
DIMENSION AND CRUSHED STONES	41.30	1,684.17	**2.45**	1,642.87	2,407.13	30.98	**1.29**	2,438.11
CHALK	1.11	1.83	**60.66**	0.72	3.26	0.83	**25.46**	4.09
FOUNDRY SANDS	0.21	0.91	**23.08**	0.70	16.78	0.16	**0.95**	16.94
SAND AND GRAVEL	402.64	2,019.68	**19.94**	1,617.04	2,346.82	301.98	**12.87**	2,648.80
QUARTZ SANDS FOR CELLULAR CONCRETE PRODUCTION	0.04	17.26	**0.23**	17.22	23.66	0.03	**0.13**	23.69
QUARTZ SANDS FOR LIME-SAND BRICK PRODUCTION	3.56	33.88	**10.51**	30.32	20.63	2.67	**12.94**	23.30
BUILDING CERAMICS RAW MATERIALS	19.24	224.77	**8.56**	205.53	221.07	14.43	**6.53**	235.50
CLAYEY RAW MATERIALS FOR CEMENT PRODUCTION	0.43	0.43	**100**	0	0	0.32	**–**	0.32
PEAT [Mm^3]	0.65	7.68	**8.46**	7.03	25.64	0.49	**1.91**	26.13
LIMESTONE FOR THE LIME INDUSTRY	5.51	595.27	**0.93**	589.76	720.46	4.13	**0.57**	724.59

The third issue in presenting national raw material resources according to UNFC-2009 is the legal possibility of estimating economic resources within anticipated sub-economic resources – according to a Regulation of the Minister of the Environment on detailed requirements of a mineral deposit development plan (dated 24 April 2012 – Official Journal of 2012, Item 511). Therefore, the anticipated sub-economic resources (which – by definition – do not meet limits of specifications that define a deposit) may sometimes qualify for further stages of estimating resources to be exploited and – consequently – may be the subject of output. In contrast, one UNFC-2009 assumption was qualifying anticipated sub-economic resources as resources not considered for future exploitation (Nieć, 2009). Such difficulty arises only with copper and silver ores. The sum of economic and sub-economic resources of deposits licensed for mining (1,390.59 Mt of ore) at the end of 2015 is greater than anticipated economic resources (1,389.12 Mt) by 1.47 Mt. That constitutes only 0.1% of total anticipated economic resources. Economic and sub-economic resources of deposits licensed for mining, as estimated in mineral deposit development plans, have been allocated within anticipated economic resources – assessed in geological documentation/supplement to documentation. However, with exploitation and better deposit exploration, particular resource types can be reclassified with the resulting sum of economic and sub-economic resources exceeding anticipated economic resources. Therefore, anticipated economic resources of copper and silver ores (22x in UNFC-2009), remaining after allocation of economic and sub-economic resources have been assumed as zero (Tab. 6.2.4) – despite the fact that using a calculation (below Tab. 6.2.4) they amount to –1.47 Mt.

As for natural gas and crude oil resources, data on anticipated economic and anticipated sub-economic resources collected by PGI-NRI and provided in “The balance…” refer to exploitable resources, whereas sub-economic resources are determined both within exploitable and geological resources. Therefore, sub-economic resources can solely exceed the sum of anticipated economic and anticipated sub-economic resources. The remaining anticipated sub-economic resources (column "Anticipated sub-economic resources 32x" in Table 6.2.4) – obtained by reducing them by sub-economic resources – would be negative, so in UNFC-2009 they were assumed to be zero.

Assuming that the future issues of "The balance…" will cover the attempt to present domestic resources of raw materials according to the UNFC-2009 (in the form of aggregate table with particular raw material types – as presented in Table 7) and taking into account all restrictions noted above, it seems appropriate that:

- deposits licensed for mining contain deposits marked with “E”, “T” and “B” in “The balance…”;
- deposits marked “P” and “R” with economic resources are treated as beyond concession areas (not-licensed for mining) and their economic resources should be bypassed in the UNFC-2009;
- abandoned deposits (marked with “Z”) should be treated as deposits with completed exploitation and omitted in the UNFC-2009;
- total anticipated economic resources for deposits with no assessed economic resources (concessions issued by county chiefs) should be treated as extractable resources and losses, whereby this prevents direct comparison of data from “The balance...” with UNFC-2009 classes (such operation is performed only for the needs of UNFC-2009);
- as for copper and silver ores, anticipated economic resources in UNFC-2009 (22x) remaining after allocation of economic and sub-economic resources should be treated as zero;
- as for natural gas and crude oil fields, anticipated sub-economic resources in UNFC-2009 (32x) remaining after assignment of sub-economic resources should be assumed as to be zero;
- resources of Polish raw materials should be presented according to the UNFC-2009 only for raw materials covered by mining ownership.

Table 6.2.5 presents a comparison of the two classification systems in terms of definitions of categories.

Table 6.2.4. **Resources of selected mineral raw materials in Poland in comparison with UNFC-2009 – as of 31 XII 2015 (according to "The balance..." as of 31 XII 2015 and the System of management and protection of mineral resources in Poland MIDAS)**

[Mt]; silver – [kt]; high nitrogenous natural gas, natural gas, coal bed methane – [bnm³], peat – [Mm³]; natural gas and crude oil – anticipated economic and anticipated sub-economic resources within exploitable resources). All explanations are given below the table

Raw material	National classification								UNFC-2009						
	Deposits licensed for mining						Deposits beyond concession areas		Deposits licensed for mining					Deposits beyond concession areas	
	Anticipated economic resources (in Polish "bilansowe"), including*: Economic resources + Sub-economic resources					Anticipated sub-economic resources (in Polish "pozabilansowe")	Anticipated economic resources (in Polish "bilansowe")	Anticipated sub-economic resources (in Polish "pozabilansowe")	Extractable resources 11x 12x	Economic resources 21x	Anticipated economic resources 22x	Sub-economic resources and losses 31x 32x	Anticipated sub-economic resources 32x	Anticipated economic resources 23x	Anticipated sub-economic resources 33x
		Economic resources (in Polish "przemysłowe"): extractable resources + losses			Sub-economic resources (in Polish "nieprzemysłowe")										
			Extractable resources (in Polish "operatywne")	Losses (in Polish "straty")											
High nitrogen. natural gas	11,506.75	920.65	920.65	–	10,586.10	–	3.30	–	920.65	0.00	0.00	10,586.10	–	3.30	–
Natural gas	101,679.10	51,006.78	51,006.78	–	117,675.06	663.04	20,775.83	1,421.68	51,006.78	0.00	50,672.32	117,675.06	**–	21,140.92	1,557.66
Crude oil	22.26	14.07	14.07	–	82.41	0.01	0.51	0.33	14.07	0.00	8.19	82.41	**–	0.56	0.39
Coal bed methane	36,413.05	5,214.78	5,214.78	–	10,922.10	380.22	51,254.93	10,521.29	5,214.78	0.00	20,276.17	10,922.10	380.22	51,254.93	10,521.29
Cu and Ag ores	1,389.12	1,162.24	871.68	290.56	228.35	1.81	563.15	782.18	871.68	0.00	0.00	518.91	1.81	563.15	782.18
Ag	81.95	69.15	51.86	17.29	12.84	0.06	24.42	41.10	51.86		0.00	30.13	0.06	24.42	41.10
Cu	27.18	22.77	17.08	5.69	4.42	0.02	8.14	12.96	17.08		0.00	10.11	0.02	8.14	12.96
Zn and Pb ores	13.94	5.53	4.15	1.38	8.41	7.17	69.88	9.43	4.15	0.00	0.00	9.79	7.17	69.88	9.43
Pb	0.22	0.10	0.08	0.02	0.12	0.13	1.20	0.15	0.08		0.00	0.14	0.13	1.20	0.15
Zn	0.55	0.23	0.17	0.06	0.32	0.24	3.02	0.41	0.17		0.00	0.38	0.24	3.02	0.41
Hard coal	21,107.05	3,561.47	2,493.03	1,068.44	13,546.79	6,862.85	31,199.31	8,935.43	2,493.03	0.00	3,998.79	14,615.23	6,862.85	31,199.31	8,935.43
Lignite	1,418.70	1,112.23	1,001.01	111.22	288.83	48.31	22,081.18	3,447.62	1,001.01	0.00	17.64	400.05	48.31	22,081.18	3,447.62
Rock salt	15,112.70	1,735.79	607.53	1,128.26	10,710.99	–	70,077.82	–	607.53	0.00	2,665.92	11,839.25	–	70,077.82	–
Sulfur	19.81	19.44	9.72	9.72	0.29	0.66	262.75	–	9.72	0.00	0.08	10.01	0.66	262.75	–
Diatomaceous rock	0.64	0.20	0.15	0.05	0.44	–	–	–	0.15	0.00	0.00	0.49	–	–	–
Bentonites	0.49	0.34	0.26	0.08	–	–	2.33	0.25	0.26	0.00	0.15	0.95	–	2.33	0.25

Table 6.2.4. Cont.

Raw material	National classification								UNFC-2009						
	Deposits licensed for mining						Deposits beyond concession areas		Deposits licensed for mining					Deposits beyond concession areas	
	Anticipated economic resources (in Polish "bilansowe"), including*: Economic resources + Sub-economic resources					Anticipated sub-economic resources (in Polish "pozabilansowe")	Anticipated economic resources (in Polish "bilansowe")	Anticipated sub-economic resources (in Polish "pozabilansowe")	Extractable resources 11x 12x	Economic resources 21x	Anticipated economic resources 22x	Sub-economic resources and losses 31x 32x	Anticipated sub-economic resources 32x	Anticipated economic resources 23x	Anticipated sub-economic resources 33x
		Economic resources (in Polish "przemysłowe"): extractable resources + losses			Sub-economic resources (in Polish "nieprzemysłowe")										
			Extractable resources (in Polish "operatywne")	Losses (in Polish "straty")											
Dolomites	237.59	125.49	94.12	31.37	21.38	6.53	260.21	0.55	94.12	0.00	90.72	52.75	6.53	260.21	0.55
Gypsum and anhydrite	126.84	109.22	81.92	27.30	13.41	0.82	56.46	–	81.92	0.00	4.21	40.71	0.82	56.46	–
Whiteware ceramic clays	1.67	0.56	0.45	0.11	–	–	56.46	–	0.45	0.00	1.11	0.11	–	56.46	–
Stoneware ceramic clays	5.72	4.48	3.36	1.12	0.10	5.10	57.52	8.40	3.36	0.00	1.14	1.22	5.10	57.52	8.40
Refractory clays	2.68	1.65	1.24	0.41	0.26	–	48.62	106.02	1.24	0.00	0.77	0.67	–	48.62	106.02
Dimension and crushed stones	5,526.97	3,209.51	2,407.13	802.38	633.29	109.56	4,406.16	391.06	2,438.11	0.00	1,642.87	1,435.67	109.56	4,406.16	391.06
Chalk	6.26	4.35	3.26	1.09	0.08	–	131.38	0.70	4.09	0.00	0.72	1.17	–	131.38	0.70
Vein quartz	3.83	1.72	1.29	0.43	2.11	0.31	0.28	–	1.29	0.00	0.00	2.54	0.31	0.28	–
Quartzites	5.93	–	–	–	–	3.84	0.66	0.12	–	0.00	5.93	–	3.84	0.66	0.12
Phyllite schists	14.55	5.04	3.78	1.26	0.88	–	2.26	–	3.78	0.00	8.63	2.14	–	2.26	–
Quartz schists	8.70	2.77	2.08	0.69	1.02	–	–	–	2.08	0.00	4.91	1.71	–	–	–
Micaceous schists	6.66	4.40	3.30	1.10	2.26	–	–	–	3.30	0.00	0.00	3.36	–	–	–
Magnesites	3.97	3.97	2.98	0.99	–	–	5.92	2.18	2.98	0.00	0.00	0.99	–	5.92	2.18
Foundry sands	36.55	22.37	16.78	5.59	13.27	0.43	192.64	2.79	16.94	0.00	0.70	18.86	0.43	192.64	2.79
Sand and gravel	5,470.05	3,129.09	2,346.82	782.27	321.28	57.78	11,740.60	241.64	2,648.80	0.00	1,617.04	1,103.55	57.78	11,740.60	241.64

Table 6.2.4. **Cont.**

Raw material	National classification								UNFC-2009						
	Deposits licensed for mining						Deposits beyond concession areas		Deposits licensed for mining					Deposits beyond concession areas	
	Anticipated economic resources (in Polish “bilansowe”), including*: Economic resources + Sub-economic resources					Anticipated sub-economic resources (in Polish “pozabilansowe”)	Anticipated economic resources (in Polish “bilansowe”)	Anticipated sub-economic resources (in Polish “pozabilansowe”)	Extractable resources 11x 12x	Economic resources 21x	Anticipated economic resources 22x	Sub-economic resources and losses 31x 32x	Anticipated sub-economic resources 32x	Anticipated economic resources 23x	Anticipated sub-economic resources 33x
		Economic resources (in Polish “przemysłowe”): extractable resources + losses			Sub-economic resources (in Polish “nieprzemysłowe”)										
			Extractable resources (in Polish “operatywne”)	Losses (in Polish “straty”)											
Quartz sands for cellular concrete production (1.8***)	54.34	31.54	23.66	7.88	5.54	0.49	185.99	1.48	23.69	0.00	17.22	13.42	0.49	185.99	1.48
Quartz sands for lime-sand brick production (1.8***)	76.52	27.50	20.63	6.87	15.14	0.20	348.64	4.63	23.30	0.00	30.32	22.01	0.20	348.64	4.63
Filling sands (1.7***)	896.63	141.08	105.81	35.27	232.65	286.89	2,959.97	319.84	105.81	0.00	522.90	267.92	286.89	2,959.97	319.84
Building ceramics raw materials (2.0***)	564.76	294.76	221.07	73.69	45.23	9.20	2,878.82	47.34	235.50	0.00	205.53	118.92	9.20	2,878.82	47.34
Clayey raw materials for cement production	0.43	–	–	–	–	–	201.39	2.25	0.32	–	0.00	–	–	201.39	2.25
Clayey raw materials for lightweight aggregate production (2.0***)	32.66	5.30	3.98	1.32	1.17	2.56	299.12	6.64	3.98	0.00	26.19	2.49	2.56	299.12	6.64
Kaolin	79.41	71.36	53.52	17.84	8.05	–	123.46	41.67	53.52	0.00	0.00	25.90	–	123.46	41.67

Table 6.2.4. Cont.

Raw material	National classification								UNFC-2009						
	Deposits licensed for mining						Deposits beyond concession areas		Deposits licensed for mining					Deposits beyond concession areas	
	Anticipated economic resources (in Polish "bilansowe"), including*: Economic resources + Sub-economic resources	Economic resources (in Polish "przemysłowe"): extractable resources + losses	Extractable resources (in Polish "opera-tywne")	Losses (in Polish "straty")	Sub-economic resources (in Polish "nieprze-mysłowe")	Anticipated sub-economic resources (in Polish "pozabi-lansowe")	Anticipated economic resources (in Polish "bilan-sowe")	Anticipated sub-economic resources (in Polish "pozabi-lansowe")	Extractable resources 11x 12x	Economic resources 21x	Anticipated economic resources 22x	Sub-economic resources and losses 31x 32x	Anticipated sub-economic resources 32x	Anticipated economic resources 23x	Anticipated sub-economic resources 33x
Feldspar raw materials	14.43	5.49	4.12	1.37	1.53	–	122.88	13.18	4.12	0.00	7.41	2.90	–	122.88	13.18
Glass sands and sandstones	142.31	54.54	40.91	13.63	18.20	23.92	444.61	100.58	40.91	0.00	69.57	31.83	23.92	444.61	100.58
Peat	47.63	34.19	25.64	8.55	5.76	4.74	38.65	1.11	26.13	0.00	7.03	14.31	4.74	38.65	1.11
Limestones and marls for cement industry	4,331.10	1,720.37	1,290.28	430.09	780.37	73.59	8,494.78	877.88	1,290.28	0.00	1,830.36	1,210.46	73.59	8,494.78	877.88
Limestones for lime industry	1,873.31	960.61	720.46	240.15	317.43	16.90	3,462.10	1,043.93	724.59	0.00	589.76	557.58	16.90	3,462.10	1,043.93

* For natural gas, crude oil and copper ores the part of economic resources was allocated within anticipated sub-economic resources, according to a Regulation of the Minister of the Environment on detailed requirements of a mineral deposit development plan (dated 24 April 2012 – Official Journal of 2012, Item 511)

** There are no exploitable anticipated sub-economic resources provided because their total magnitude was classified as sub-economic resources; sub-economic resources are estimated within geological resources (anticipated economic and anticipated sub-economic) and therefore also include total exploitable resources (anticipated economic and anticipated sub-economic)

*** Resources recalculated from Mm^3 to Mt according to the density given in brackets

Recalculation of resources from Polish classification to UNFC-2009 – the case of hard coal:

UNFC-2009 class **33x** = anticipated sub-economic resources in deposits beyond concession areas (in Polish "pozabilansowe") (**8,935.43 Mt**)

UNFC-2009 class **23x** = anticipated economic resources in deposits beyond concession areas (in Polish "bilansowe") (**31,199.31 Mt**)

UNFC-2009 class **32x** = anticipated sub-economic resources in deposits licensed for mining (in Polish "pozabilansowe") (**6,862.85 Mt**)

UNFC-2009 class **31x, 32x** = sub-economic resources and losses in deposits licensed for mining (in Polish "nieprzemysłowe" and "straty") (13,546.79 + 1,068.44 = **14,615.23 Mt**)

UNFC-2009 class **22x** = anticipated economic resources in deposits licensed for mining minus minus sub-economic and economic resources (in Polish "bilansowe" minus "nieprzemysłowe" and "przemysłowe") (21,107.05 – 3,561.47–13,546.79 = **3,998.79 Mt**)

UNFC-2009 class **21x** = economic resources in deposits licensed for mining minus extractable resources and losses (in Polish "przemysłowe" minus "operatywne" and "straty") (3,561.47–2,493.03–1,068.44 = **0.00 Mt**)

UNFC-2009 class **11x**, **12x** = extractable resources in deposits licensed for mining (in Polish "operatywne") (**2,493.03 Mt**)

Table 6.2.5. Definitions of: UNFC-2009 categories and Polish national system – comparison between the two classification systems

UNFC-2009				Polish classification system		
Cat.	**Definition***	**Supporting Explanation****	**Possible classes**	**Resources**	**Definitions********	**Possible classes**
E1	Extraction and sale 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	111 112 113 121 122 123	Extractable resources	A part of economic resources in place obtained when reducing economic resources by technical losses (solid minerals)	111 112 113 (within horizons available for mining)
				Exploitable resources	Crude oil or natural gas resources, which should be extracted by applying current exploitation technology	111 112 113 (within horizons available for mining) 121 122 123 (within horizons currently not available for mining)
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	211 212 213 221 222 223 231 232 233	Economic resources	A part of anticipated economic resources or anticipated sub-economic resources or – in the case of brines, curative and thermal water – exploitable resources within a designated mining area or detached part of a deposit designed for exploitation, which can be designated for mining according to detailed technical and economic analysis taking legal requirements into account, including environmental restraints	211 212 213
				Anticipated economic resources	Deposit resources (or part of a deposit) meeting limit values of parameters that define a deposit	221 222 223 (in deposits licensed for mining) 231 232 233 (in deposits beyond concession areas)
E3	Extraction and sale is not expected to become economically	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,	311 312 313 321	Losses within economic resources	A part of economic resources slated to be left in a deposit, which cannot be exploited in the foreseeable future (in a economically and technically justified manner) due to the exploitation method	311 312 313 (in deposits licensed for mining)

Table 6.2.5. Cont.

UNFC-2009				Polish classification system		
Cat.	**Definition***	**Supporting Explanation****	**Possible classes**	**Resources**	**Definitions********	**Possible classes**
E3 cont.	viable in the foreseeable future or evaluation is at too early a stage to determine economic viability***	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	322 323 331 332 333 334	Sub-economic (marginal) resources	A part of anticipated economic resources not-classified as economic resources within an area designated for exploitation, which can be designated for mining as a result of technical or economical or legal requirement changes, including environmental restraints	321 322 323 (in deposits licensed for mining)
			341 342 343 344	Anticipated sub-economic resources	Deposit resources (or part of a deposit) not meeting limit values of parameters that define a deposit	331 332 333 (in deposits beyond concession areas)
				Prognostic resources	Raw material occurrence whose accumulation may form a deposit is confirmed. Resources are assessed on the basis of sparse, rare points of raw material (deposit) occurrence (outcrops) and on the interpretation of geophysical data that enables approximate delineation of a deposit area. The admissible error of deposit resources estimation may exceed 40%	334
				Perspective resources	A probable deposit occurrence was indicated. The deposit is expected to occur on the basis of localized sings (geophysical, geochemical anomalies, isolated showings of raw material, outcrops, etc.). Possible resources are estimated on the basis of general geological data by analogical methodology. The admissible error of deposit resources estimation is not defined	344

* 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
**** Limits of specifications that define a deposit – values of deposit specifications delineating deposit geological boundaries

Table 6.2.5. Cont.

UNFC-2009				Polish classification system		
Cat.	**Definition***	**Supporting Explanation****	**Possible classes**	**Resources**	**Definitions******	**Possible classes**
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	111 112 113 211 212 213 311 312 313	Mining report/Mineral deposit development plan	The Mining Report is understood as current documentation on the state of development and exploitation of a deposit during its economic life, including current mining plans. The operator of a mine generally drafts it. The study addresses the quantity and quality of minerals extracted during a reporting period, changes to Economic Viability categories due to changes in prices and costs, development of relevant technology, newly imposed environmental or other regulations, as well as data on exploration conducted concurrently with mining Mineral deposit development plan – see a definition below	111 112 113 211 212 213 311 312 313 (classes according to changes on the E or G axis – still on F1)
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	121 122 123 221 222 223 321 322 323	Mineral deposit development plan (Prefeasibility study)/ Geological documentation	Mineral deposit development plan 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 a project Various terms are in use internationally for Prefeasibility Studies reflecting an actual accuracy level. Data required to achieve this level of accuracy are reserves/resources figures based on a Detailed and General Exploration, technological tests at a laboratory scale and cost estimations e.g. from catalogues or based on comparable mining operations Geological documentation – see a definition below	121 122 123 221 222 223 321 322 323 (classes according to changes on the E or G axis – still on F2)
F3	Feasibility of extraction by a defined development project or mining operation cannot be	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,	231 232 233 331 332 333	Geological study (geological documentation)	The Geological Study is 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 be generally defined from a	231 232 233 331 332 333

Table 6.2.5. Cont.

UNFC-2009				Polish classification system		
Cat.	**Definition***	**Supporting Explanation****	**Possible classes**	**Resources**	**Definitions******	**Possible classes**
F3 cont.	evaluated due to limited technical data	quality and quantity that the feasibility of extraction can be evaluated	334		Geological Study due to the lack of detail necessary for an Economic Viability evaluation. Estimated resource quantities may indicate that a 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. The purpose of a Geological Study is to identify mineralization, to establish continuity, quantity, and quality of a mineral deposit, and thereby define an investment opportunity	(classes according to changes on the E or G axis – still on F3)
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	341 342 343 344		There is no corresponding document in the Polish classification system – the closest one would be a regional case study with an assessment of perspective resources	344

UNFC-2009				Polish classification system		
Cat.	**Definition***	**Supporting Explanation****	**Possible classes**	**Resources**	**Definitions******	**Possible classes**
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	111 121 131 211 221 231 311 321 331	For solid minerals: Measured resources – A and B	For solid minerals: A – a mineral deposit is explored to an extent allowing current planning and exploitation with a maximum possible rate of resource absorption; delineation of structural and geological features, tectonics, resources on the basis of opening-out, preparation and mining excavations, as well as type, quality and technological properties of mineral commodity on the basis of regular excavations sampling and data from current production are required. The degree of deposit exploration is sufficient enough to elaborate a mine management plan. The admissible error of average deposit parameters and deposit resources estimation in particular blocks cannot exceed 10%. B – mineral deposit boundaries are delineated in details on the basis of specially carried	111 121 211 221 231 311 321 331 (classes according to changes on the E or F axis – still on G1)

Table 6.2.5. Cont.

UNFC-2009				Polish classification system		
Cat.	**Definition***	**Supporting Explanation****	**Possible classes**	**Resources**	**Definitions********	**Possible classes**
G1 cont.		whole and are usually categorized on the basis of three scenarios or outcomes that are equivalent to G1, G1+G2 and G1+G2+G3		 For hydrocarbons: Measured resources – A Indicated resources – B	out exploratory excavations or geophysical measurements, whereby the delineation of structural and geological features, correlation of strata, and main tectonics features have to be unambiguous and the quality and technological properties of a mineral commodity should be confirmed by sampling results in pilot-scale tests or on a commercial scale. The degree of deposit exploration is sufficient enough to elaborate a mine management plan. The admissible error of average deposit parameters and deposit resources estimation cannot exceed 20% For hydrocarbons: A – 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%. B – the result of geological works carried out are the basis to define the field a geological structure, field boundaries and reservoir parameters of oil bearing and gas bearing formations as well as their variability in details; such data allow planning of other works necessary to continue field exploration or its exploitation if there is gas, oil or methane flow from at least one well in an amount of economic value. The admissible error of average field parameters and field resources estimation cannot exceed 35%	
G2	Quantities associated with a known deposit that can be estimated with a moderate level of confidence		112 122 132 212 222 232 312 322 332 342	For solid minerals: Indicated resources – C_1	C_1 – 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 a prefeasibility study of economic mining, including detailed delineation of structural and geological features, tectonics and quality of mineral commodity in a deposit, as well as geological-mining conditions of exploitation, and allows evaluation of the influence of intended exploitation on the environment. The admissible error of average deposit parameters and deposit resources estimation cannot exceed 30%	112 122 212 222 232 312 322 332 (classes according to changes of the E or F axis – still on G2)

Table 6.2.5. Cont.

UNFC-2009				Polish classification system		
Cat.	**Definition***	**Supporting Explanation****	**Possible classes**	**Resources**	**Definitions******	**Possible classes**
G2 cont.				For hydrocarbons: Inferred resources – C	C – hydrocarbons field boundaries are delineated on the basis of geophysical measurements and geological interpretation; such data allow planning of other works necessary to continue field exploration or its exploitation if there is gas, oil or methane flow from at least one well in an amount of economic value or, in the case of multi-horizontal fields, if hydrocarbon saturation of gas and oil horizons is known on the basis of drilling geophysics logging with gas, oil or methane flow from at least one well in an amount of economic value. The admissible error of average field parameters and field resources estimation cannot exceed 50%	
G3	Quantities associated with a known deposit that can be estimated with a low level of confidence		113 123 133 213 223 233 313 323 333 343	For solid minerals: Inferred resources – C_2 and D	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 initially 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 cannot exceed 40% D – 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%	113 123 213 223 233 313 323 333 (classes according to changes of the E or F axis – still on G3)
				For hydrocarbons: Inferred resources – C	C – hydrocarbons field boundaries are delineated on the basis of geophysical measurements and geological interpretation; such data allow planning of other works necessary to continue field exploration or	

Table 6.2.5. **Cont.**

UNFC-2009				Polish classification system		
Cat.	**Definition***	**Supporting Explanation****	**Possible classes**	**Resources**	**Definitions******	**Possible classes**
G3 cont.					its exploitation if there is gas, oil or methane flow from at least one well in an amount of economic value or, in the case of multi-horizontal fields, if hydrocarbon saturation of gas and oil horizons is known on the basis of drilling geophysics logging with gas, oil or methane flow from at least one well in an amount of economic value. The admissible error of average field parameters and field resources estimation cannot exceed 50%	
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	334 344	Prognostic resources – D_1*	Raw material occurrence whose accumulation may form a deposit is confirmed. Resources are assessed on the basis of sparse, rare points of raw material (deposit) occurrence (outcrops) and on the interpretation of geophysical data that enables approximate delineation of a deposit area. The admissible error of deposit resources estimation may exceed 40%	334
				Perspective resources – D_2*	A probable deposit occurrence was indicated. The deposit is expected to occur on the basis of localized sings (geophysical, geochemical anomalies, isolated showings of raw material, outcrops, etc.). Possible resources are estimated on the basis of general geological data by analogical methodology. The admissible error of deposit resources estimation is not defined	344

* Informal (not stated in law) allocations of resource categories – according to Nieć (2002)

7. Geological information

M. Sokołowski

7.1. Information definition and its sources

The basic and most important issue in balancing raw material resources is access to complete, verified and credible information, especially broadly defined geological information. Significantly, the definition of geological information stated in Polish law narrows the meaning of this definition only to information obtained from geological works. The GML defines geological information as geological data and samples together with the results of their processing and interpretation, especially presented in geological documentations and saved on IT data storage media. Moreover, regulations provided a "geological data" definition as the outcome of direct observations and measurements gained in the process of geological work. Anyone carrying out geological work in Poland on the basis of a relevant permit required by law (concession for prospecting or exploration of a deposit or mass rock for underground storage of carbon dioxide, decision approving a geological works project or geological works project application) is governed by operational documentation of a geological work process, including geological operations and their results. If activity falls within the range described above and concerns:

- prospecting or exploration of mineral deposits owned by the State Treasury;
- prospecting or exploration of mass rock for underground storage of carbon dioxide;
- boreholes designed to explore deep-seated basement conditions;
- regional studies of the geological structure of Poland;
- definition of hydro-geological and geological-engineering conditions for underground non-reservoir storage of substances in the subsurface, storage of waste in the subsurface or storage of carbon dioxide in the subsurface;

whoever conducts such activity must forward all geological data obtained from geological works on an on-going basis to the state geological survey as well as samples collected during geological operations within the range defined in a concession together with the results of examinations of such samples. Geological data and the results of sample examinations should be forwarded within 14 days from the date of their receipt, whereas samples should be provided within 60 days from the date of their receipt.

Regardless of the type of activity, the final results of any geological work together with their interpretation and the degree success should be presented in the form of geological documentation of a relevant type – deposit, hydro-geological, geological-engineering or other. Geological documentation of one of the first three types must be approved by a relevant geological administration body, whereas the fourth type only has to be forwarded to the geological administration. Geological administration bodies together with the state geological survey collect, record, archive, protect and provide geological information in forwarded documents, samples and other geological data storage media.

7.2. Entitlement to geological information

Under the current law, the entitlement to any geological information is owned by the State Treasury. At the same time, it is guaranteed that anyone financing geological work and who obtained geological information has the prerogative to unpaid use of such information. Moreover, during the three-year period (from the date of delivery of a decision approving geological documentation) such party has the right to use the information in order to seek the activity within the scope of mineral output, underground non-reservoir storage of substances, storage of waste and storage of carbon dioxide in the subsurface as well as any other activity for which aquatic legal permission is required. Such exclusivity is valid throughout the entire time of activity and two years after its cessation, wherein the latest privilege does not apply to cases when activity consists of hydrocarbon. Then, exclusivity expires on the date when a decision on activity expires.

According to current law, the right to geological information is held by the State Treasury with the proviso that a subject with the mentioned above rights can dispose of such information within limits defined by this law.

7.3. Use of geological information

In principle, the use of geological information for which rights are owned by the State Treasury is free of charge. The exception is use of information to conduct activity within the scope of mineral output, underground non-reservoir storage of substances, storage of waste and carbon dioxide in the subsurface as well as any other activity for which aquatic legal permission is required. Then, use can be permitted on the basis of a remuneration agreement. Moreover, if the subject of use is geological samples, regardless of the purpose, an agreement to use geological information is also required during examination causing their damage, destruction or consumption. The same rule applies when using geological information in the form of geological data dealing with minerals under mining ownership originating from boreholes to geological deep-seated basement conditions or regional studies of the geological structure of Poland or when exploration and data become the result of geophysical measurements. The basis for compensation is an appraisal prepared by an entitled geologist that defines the costs of design, implementation and documentation of geological work. Appraisal costs are covered by a subject applicant for information use and the State Treasury verifies an appraisal before an agreement is concluded. On behalf of the State Treasury, the Minister of the Environment is responsible for issues related to mineral output, underground non-reservoir storage of substances, storage of waste and carbon dioxide in the subsurface, samples and geological data. Provincial marshals are entitled bodies within the scope of using geological information for purposes of aquatic legal permits. Details on requirements for geological information use, manner of applications, methods of geological information value estimations and appraisal requirements are defined in an order of the Minister of the Environment dated 20 December 2011 (Journal of Laws, pos. 1724).

7.4. Provision of geological information

The geological administration and state geological survey provide geological information from collected documentations, samples and other data storage media.

The main national archive of geological information constituting the basis for the geological administration, the state geological survey and the state hydrogeological survey is the National Geological Archive managed by the PGI-NRI as a state geological survey task. The National Geological Archive collects, preserves and provides geological, hydro-geological and geophysical documents, maps and geological samples. Its resources contain almost 600,000 geological documents and 812,000 samples. It grows by 10,000 documents and 25,000 samples annually. There are National Geological Archive branches in every PGI-NRI branch offices and there is also a network of nine local Borehole and Geological Sample Archives in Halinów near Warsaw and the Cartographic Materials Archive in Rzeczyca Księża near Kraśnik (vicinities of Lublin).

Geological information is made available in a traditional manner – upon application, in the form of collected document copies and datasets and through a modern method using ICT that provides access to processed, systematised and personalised information. In principle, geological information is free of charge and charges levied during its preparation and provision cover only costs of solidification and transfer or its additional processing on a special request. The geological administration obtains information free of charge in case of its collection for statutory tasks, but such information cannot be used for commercial purposes or passed on to other subjects.

7.4.1. Geological information collected in the National Geological Archive

Access to National Geological Archive collections can take place in several forms. One is review – free of charge acquaintance with original archive materials, their copies and digital datasets, but without the right to reproduce, transcribe, copy, photocopy etc. and without the right to samples. Review is only possible in the National Geological Archive reading room on the basis of an application – entry in the reading room register, whereas review of geological samples (cores, clastic samples) takes place on the basis of an application at local storages of Borehole and Geological Samples Archives. In the case of an application to disclose information – understood as provision of geological information in the form of copies, paper or digital reproductions – fees and provision are charged. If geological information is held by the State Treasury and is to be used for payable purposes, an application should include an agreement on the provision of geological information to the State Treasury. Geological materials, originally elaborated and published, are available to any interested parties in the system of geological publications distribution.

All information on PGI-NRI collections, including those of the National Geological Archive, is available to clients through ICT systems operating on PGI-NRI servers on its website. Access to geological and hydro-geological information published on the PGI-NRI website is free of charge and does not require any additional formalities. Terms of information use are regulated on the website.

Particular interest is focused on cartographic elaborations presented in the form of raster files and available as WMS and WFS services. The most important are serial maps on a scale 1:50,000 elaborated for: basic geology – a Detailed Geological Map of Poland; hydrogeology – a Hydrogeological Map of Poland in several information options; economic and environmental geology – a Geo-environmental Map of Poland.

7.4.2. Digital databases

The main sources of data in the National Geological Archive are geological documentations forwarded by geological administration authorities and geological companies conducting geological works, as well as the results of tests performed by PGI-NRI. The obligation to transfer samples, data and documentations stems from the GML and its orders. Materials are collected in the National Geological Archive in a traditional manner, but are digitally processed and recorded for availability on the Internet. There are many metadata on geological objects, description data, spatial data and services allowing data presentation on the PIG-PIB website free of charge.

The main broadly available service is the Central Geological Database (in Polish: Centralna Baza Danych Geologicznych – CBDG) accessible at website baza.pgi.gov.pl. Detailed data are contained in particular discipline systems such as MIDAS, Mineral Resources of Poland, InfoGeoSkarb and others. Separate collections are hydro-geological data available on Polish Hydrogeological Survey (PHS) websites (www.psh.gov.pl and www.spdpsh.pig.gov.pl).

The Central Geological Database is the largest Polish metadata collection of geological documentations, objects and digital geological data. This database allows access to a viewer of archival geological documents, boreholes and other different objects. Data are available free of charge through the CBDG Web applications and through the geographical viewer (GIS) also prepared for mobile devices. Basic sub-systems of Central Geological Database are:

- DOCUMENTS – catalogue of data of archival geological reports, maps, aerial and satellite photographs from archives throughout the country;
- BOREHOLES – information obtained from boreholes in Poland;
- DRILL CORES – detailed data on drill core stored in Repositories;
- RESEARCH POINTS – data on any points of research (that are not boreholes), closely associated with the ANALYSES subsystem;
- ANALYSES – analytical and measurement data obtained from boreholes or research points;
- GEOPHYSICS – information on different types of geophysical surveys and data obtained.

A detailed description of data, their collection systems and processes for balancing mineral raw material resources is presented in the Chapter 8.

8. Databases of mineral resources

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8.1. Database on Polish mineral raw material deposits – MIDAS

Registration, storage and processing of data on resources and production of mineral raw materials in Poland is a main task of the Polish Geological Institute – National Research Institute (PGI-NRI). PGI-NRI conducts the state geological survey according to art. 163 of the GML. One of the tasks performed by the state geological survey is to run a national balance of mineral resources (art. 162 of the GML). It is necessary to possess an appropriate database to complete this task. Such data base – **the System of Management and Protecting of Polish Mineral Raw Materials MIDAS** – is maintained by the Department of Deposits and Mining Areas Information of the PGI-NRI. The MIDAS system has been systematically updated since 1988 and contains information on all mineral raw material deposits and resources bases as well as on the output and development possibilities.

There are two sources of information for the MIDAS system:

- geological documentation collected in the National Geological Archive (NGA) of the PGI-NRI (prepared according to a Regulation of the Minister of the Environment dated 1 July 2015 – Official Journal of 2015, Item 987) – covering basic information on a deposit such as location, structure, hydro-geological conditions, raw material types and parameters, deposit resources;
- statistical forms prepared by concession holders and sent annually to the PIG-NRI (by 15 March – according to art. 101 of the GML) – with information on annual output and resource changes in a deposit.

All data mentioned above are entered in the database regularly. The service can be found on the website http://geoportal.pgi.gov.pl/portal/page/portal/MIDASGIS/start. It is available only in Polish and provides access to three groups of information: deposits, mining areas and mining protective areas as well as related concessions, and mineral resource management. Anyone interested in Polish mineral resources should select "viewing data" (which forwards to http://geoportal.pgi.gov.pl/midas-web) and then "Złoża" on the left side of the website and will be directed to a website where particular deposit can be found. Upon selection of a single deposit (by name or by number), detailed information can be gained and analysed. It contains: deposit location (town or village, province), number of documentation(s) of a deposit collected in the NGA, deposit concession holder(s), type of area above a deposit, underground levels (depth, quality), raw material data – thickness and depth, shape, qualitative parameters, resources and output, exploitation system, raw material processing (ore dressing), and land reclamation planned for the future. A deposit can also be presented on a map and in a special report (in Polish "karta złoża") with all necessary information on a deposit generated and downloaded in .pdf format.

Spatial data presented on the MIDAS website relating to: mineral deposits, mining area, mining damage zone are – among other data collected by PGI-NRI – available as a SHP files on the website http://dm.pgi.gov.pl/dm/DownloadManager_v1.aspx?lang=en.

The MIDAS system is the very important tool for fulfilling the tasks placed on PGI-NRI. Its main uses are as follows:

- data source for the publication "The balance of mineral resources deposits in Poland" ("Bilans zasobów złóż kopalin w Polsce" – only in Polish),
- basis for the publication "Mineral Resources of Poland",
- basis for the website Mineral resources of Poland,

- important source of information for local and central government administration.

"The balance of mineral resources deposits in Poland" is compiled each year as a task of the state geological survey and issued by 30 June (according to the GML) by order of the Ministry of the Environment. It is financed by the National Fund for Environmental Protection and Water Management. The publication has been issued since 1953 and its latest edition (as of 31 XII 2015) contains data on 13,586 Polish mineral raw material deposits. "The balance…" presents mineral raw materials within 4 groups: energy, metallic, chemical and rock raw materials. These groups are selected on the basis of raw material utility as a mineral commodity. Each raw material is described in a separate chapter. It provides information on raw material occurrence in Poland, types of deposits, raw material quality and its usage. There are also usually 2 types of tables presented in a chapter – one with data on the national level (with resource types, resources categories and the state of deposit development) and another with information on the regional or administrative level (where deposits with their resources and output are listed). Until the 2010 edition (as on 31 XII 2010), data was also provided on potable and industrial groundwater resources, waste from exploitation and processing of raw materials and on export and import. Presently, "The balance…" covers only information on brines, curative and thermal water, whereas data on export and import are presented on the website "Mineral resources of Poland".

"Mineral Resources of Poland" is a publication prepared at the Department of Mineral Resources and Mining Areas Information of the PGI-NRI approximately every five years (published in 1996 with data on 1995, 2000/1999, 2005/2004, 2012/2011). The current edition is the fifth. Similarly to the Polish edition, it divides raw materials into 4 main groups and each raw material is described in a separate chapter. The publication contains four-year period analysis with a table presenting the magnitude of raw material resources, state of their identification and management (on a national scale) and a graph showing the resource base and output in a representative period of time. There is also a set of maps presenting mineral raw material deposits in Poland.

Mineral resources of Poland is presented on the PGI-NRI website – http://surowce.pgi.gov.pl – established in 2011 on the basis of the MIDAS system and "The balance…" and updated annually by the Department of Mineral Resources and Mining Areas Information. It is presented in Polish and English version and provides the most important information on resources of mineral raw material deposits in Poland, the stage of their development and output. The portal also includes:

- a set of maps presenting distribution of mineral raw material deposits in Poland
- a set of maps of concessions;
- information on export and import of mineral raw materials;
- archival editions of "The balance…" (in Polish) – from 2007 to the latest one (in .pdf format);
- definitions of resources and resource categories as required by Polish law (according to Regulations of the Minister of the Environment – Official Journal, 2012, Item 511 and Official Journal, 2015, Items 968 and 987);
- 2 editions – 2012 and 2013 – of the Minerals Yearbook of Poland (and also its Polish version "Bilans Gospodarki Surowcami Mineralnymi Polski i Świata") reviewing mineral commodity production and use in Poland.

The distribution maps on the website (updated annually) cover: hard coal deposits in the Upper Silesian Coal Basin, hard coal deposits in the Lublin Coal Basin, copper and silver ore deposits, zinc and lead ore deposits, dimension and crushed stone deposits in south-western Poland, dimension and crushed stone deposits in south-eastern Poland, oil and gas fields, hard coal, lignite and peat deposits, metal ores and chemical raw material deposits, compact rock raw material deposits (excluding dimension and crushed stone), ceramic and refractory raw material deposits (excluding building ceramics raw materials), building ceramics raw material deposits, and clastic rock raw material deposits. All of these maps can be downloaded in .jpg format.

Concession maps are prepared monthly in a set of maps comprising a: Map of concessions for hydrocarbon exploration and production, and non-reservoir storage of substances in the subsurface and storage of wastes in the subsurface, Map of concessions for "shale gas" exploration, Map of concessions for prospecting, exploration and production of rock, chemical and metal deposits, Map of concessions for hard coal and CBM prospecting, exploration and production in the USCB, Map of concessions for hard coal and CBM prospecting, exploration and production in the LCB, Map of concessions for hard coal and CBM prospecting, exploration and production in the LSCB, Map of concessions for prospecting, exploration and production of lignite deposits, and a Map of concessions for prospecting, exploration and production of curative and thermal waters and brines and project of geological works for prospecting or exploration of waters considered as minerals.

Information on trade turnover in exports and imports of mineral raw materials in Poland is elaborated in the MIDAS system on the basis of data collected by the Polish Custom Service. These data come from special custom statements – SAD (in the case of trade turnover by European Union countries to/from non-EU countries) and INTRASTAT (in the case of export and import within the EU). Information is prepared according to the Combined Nomenclature (CN), which is deeply tied to the international classification system called Harmonised System – HS. Data on export and import involves the value and magnitude of particular raw materials and, on the national scale, the balance of turnover and trade directions. There are detailed data covering the last year, but also long-term information in the form of tables or graphs. Until 2009, information was collected in the PRICESMIN database, but since then has been elaborated in one of the modules of the modernised MIDAS system called the Economy of raw materials (in Polish "Gospodarka surowcami"), available on the MIDAS website.

The website Mineral resources of Poland, which provides all important information on mineral raw material deposits in Polish as well as English and allows users to download data of interest, has become a substantial source of knowledge about this sector in Poland. It is regularly visited – in the 4th quarter of 2016 the number of entries exceeded 6,400 (and the number of views 23,500) with almost 24,500 entries and 95,000 views in all of 2016.

8.2. Spatial data

Spatial data on deposits boundaries, mining areas and mining are of special importance and their collection, processing and making them available for the users is a main task of the state geological survey. Such data are provided: by prepared mapping compositions (mapping components of the MIDAS and InfoGeoSkarb systems, geographical viewer of the Central Geological Database (CBDG), mobile application GeoLOG) in raster form through the WMS service and in vector form in the Shapefile format.

The website with the MIDAS system presenting, among others, spatial data which are related to documented raw material deposits, mining areas and mining damage zone is available at http://www.midas.pgi.gov.pl. The interface enables any user to gain quick and easy access to the geo-information. The MIDAS system is a reference database, where, *inter alia*, spatial data are collected, then used in other applications and services or exported to the Shapefile format. The current view of data entering into the database is secured only by the online MIDAS service, whereby other described sources providing spatial data are updated on a 24 hour basis.

Spatial data are also presented in the InfoGeoSkarb system available at http://geoportal.pgi.gov.pl/igs. The application contains coordinates of contour points of documented deposits boundaries, mining areas and mining damage zone in coordinate systems binding in Poland, including the WGS84 system.

Spatial layers of the MIDAS system with data from the entire country are also available in the form of Shapefile files – a format supported by most programs of GIS spatial information systems. Detailed information on such files is available on the MIDAS system website in the "Spatial data" part (http://geoportal.pgi.gov.pl/portal/page/portal/midas/dane_przestrzenne).

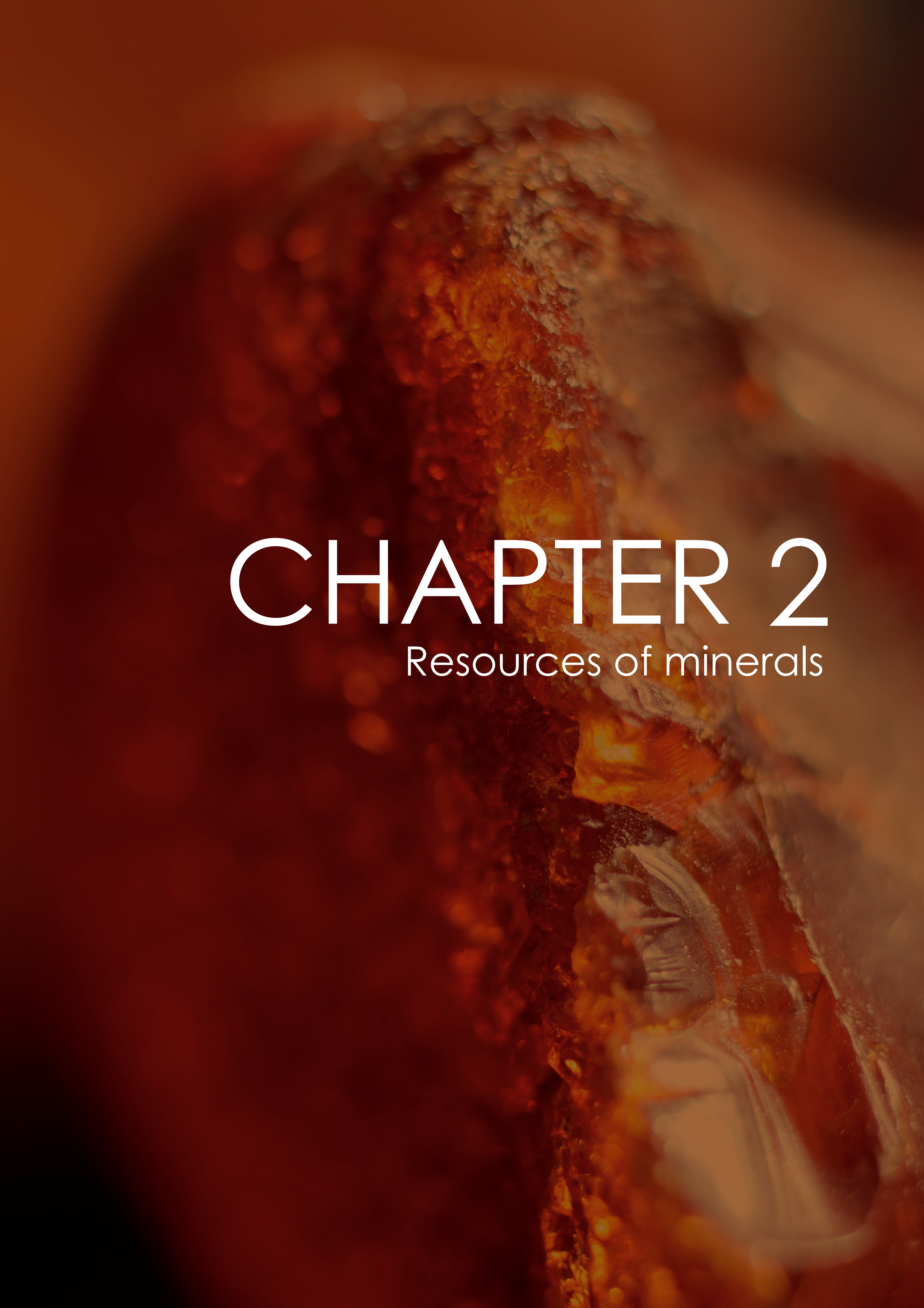
Anyone interested in spatial information can also use the mapping service WMS published by the PGI-NRI – established according to the open, international standard OGC (Open Geospatial Consortium). The user can therefore review spatial data in the form of raster on any geo-portal or programme adjusted for supporting web services. Detailed information on WMS services is available on the MIDAS system website in the "Spatial data" part (http://geoportal.pgi.gov.pl/portal/page/portal/midas/dane_przestrzenne).

Public access to spatial data is also offered by the PGI-NRI geo-portal – geographical viewer of CBDG http://bazagis.pgi.gov.pl/website/cbdg/viewer.htm and the application GeoLOG http://m.bazagis.pgi.gov.pl/cbdg/#/landing which is mainly used on mobile devices.

The above source offer a quick information search of a selected area, generation of profiles and reports and, most importantly, any analysis and interpretation of presented spatial information. The online complete and updated spatial data on documented raw material deposits are the basis for decision-making on mineral policy in Poland (support to geological administration) and provide any user data on a selected area (support for investments, environmental, economic and other decisions).

8.3. Data Bank of Groundwater Classified as a Raw Material – Curative Water Data Bank

A specific data collection is the Data Bank of Groundwater Classified as a Raw Material – Curative Water Data Bank. This database contains information on brines, curative and thermal water intakes, conditions of intakes and also their deposit protection. There is also information on over 1,800 objects such as intakes and springs in the Data Bank. On one hand, such data relate to hydro-geological objects described in the same manner as objects in the HYDRO bank (spdpsh.pgi.gov.pl). On the other hand, they constitute an except from the "mineral" dataset in which the methodology and scope of information collection and processing is determined by principles and needs related to mineral resource balancing (epsh.pgi.gov.pl).



CHAPTER 2

Resources of minerals

1. Energy raw materials

1.1. Lignite

M. Tymiński, K. Szamałek

Brown coal means lower grades of coal (intermediate in qualification between hard coal and peat), with calorific value below 24 MJ/kg. It is divided into subbituminous coal (with calorific value above 17.5 MJ/kg – hard form) and lignite (below 17.5 MJ/kg – soft form). In Poland, lignite deposits occur in the central and western part of the country (Plate 2), in young geological formations, mainly from the Paleogene to Neogene in age. Older brown coal deposits are known to also occur in the Jurassic, Carboniferous and locally even Cretaceous and Triassic formations in several places in the world.

Lignite properties were markedly influenced by the type of parent plant material and environment in which it was formed. Lignite deposits originated in both platform areas and sedimentary basins in orogenic belts. Coals form extensive seams or lenses a few to several dozen metres in thickness. Small overburden thickness makes opencast mining of the deposits possible. Seams of older brown coals are often situated too deep for opencast mining and require underground mining. This is also the case of coal seams in glacitectonic folds. Underground mining methods have been used early in Poland to mine coals in the Babina and Sieniawa deposits.

Lignite resources are calculated to a maximum depth of deposit base of 350 m, minimum brown coal layer thickness in a bed of 3 m and a maximum overburden/deposit thickness ratio of 12. The minimum weighted-average calorific value in bed (with intercalations) should equal 6.5 MJ/kg (at brown coal humidity of 50%). These are the basic criteria for energy coals that are common in Polish deposits.

Taking into account these criteria, prognostic brown coal resources were calculated to be 27,540.71 Mt as of 31 XII 2009 (Kasiński, 2011). These resources are more than 21% larger than total anticipated economic resources calculated as of 31 XII 2011. Prognostic resources occur in 90 prognostic deposits or prognostic areas near documented deposits within 7 coal-bearing regions: Bełchatów, Konin, Legnica, Łódź, North-Western, Wielkopolska and Western. The most important are prognostic resources in satellite deposits for lignite extraction in future.

Poland's anticipated economic resources of lignite amounted to 23,516.19 Mt at the end of 2015 (Tab. 1.1.1). Resources comprise 23,515.55 Mt of energy coals, whereby remaining 0.64 Mt are bituminous coals. There were also coals usable for production of briquettes and suitable for production of coal tar and liquid fuel through distillation documented in the past. Nevertheless, all these coals are used and treated as energy coals only. Anticipated economic resources within exploited deposits amounted to 1,418.70 Mt (6% of total anticipated economic resources). Economic resources of brown coal as of 31 XII 2015 amounted to 1,129.06 Mt.

Lignite is exploited by five mines: Bełchatów, Turów, Adamów, Konin and Sieniawa. Strip mining of brown coal from the Czempin, Krzywin and Gostyń deposits with total resources of 3,690 Mt is presently precluded on environmental grounds and due to the high class and value of agricultural land in the area of planned open strip mining. These are the main issues to be resolved by local associations, environmental organizations and potential mining companies before exploitation of these deposits starts.

Lignite production in 2015 amounted to 63,135 kt. Most output came from the Bełchatów deposit (Bełchatów field 25.05 Mt and Szczerców field 17.03 Mt). These accounted for 39.7% and 27.0% of domestic production, respectively.

Figure 1.1.1 shows changes in resources and production of lignite in Poland in 1989–2015. Resources increased in 1992 (better exploration of the Turów deposit and documentation of new deposits – Torzym, Rzepin, Dęby Szlacheckie). In the next 16 years resources did not change significantly, with important growth in 2009–2011. That was due to 16 new documented deposits with total resources of 7,236.61 Mt: Gubin 1, Gubin-Zasieki-Brody, Lubsko, Łęki Szlacheckie, Mosina, Nakło, Naramowice, Oczkowice, Radomierzyce, Radziejów, Ruja, Sieniawa 2, Szamotuły,

Table 1.1.1. Lignite resources [Mt]

	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	**91**	**23,516.19**	**6,067.91**	**17,448.29**	**3,522.44**	**1,129.06**
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	9	1,418.70	1,406.82	11.89	48.31	1,112.23
Including resources of non-exploited deposits						
TOTAL	74	22,081.18	4,645.43	17,435.75	3,447.62	16.83
1. DEPOSITS COVERED BY DETAILED EXPLORATION	35	5,838.66	4,645.43	1,193.23	872.64	16.83
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION*	39	16,242.52	0.00	16,242.52	2,574.98	–
Including abandoned deposits						
ABANDONED DEPOSITS	8	16.30	15.66	0.64	26.51	–

* Including resources of deposits in an area of the so-called Poznań Trough (3,690 Mt)
The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 31

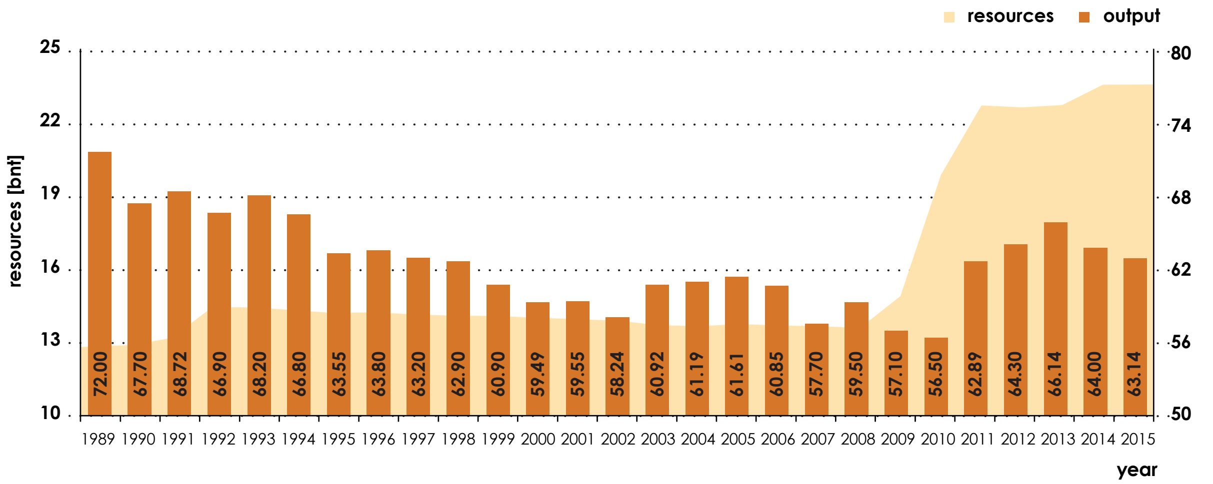


Fig. 1.1.1. Lignite anticipated economic resources and output in 1989–2015

According to: "The balance of mineral resources deposits and groundwater resources in Poland" (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al*., 2007, 2008; Wołkowicz *et al*., 2009–2010; Szuflicki *et al*., 2011); "The balance of mineral resources deposits in Poland" (in Polish; Szuflicki *et al*., 2012–2015)

Węglewice, Więcbork and Władysławów II. The last 4 years were characterized by resource growth (by 932.36 Mt) and varying output. Growth stemmed from approval of new documentation with recalculated resources for the Oczkowice deposit (853.25 Mt) in 2014. In 2015, one new deposit was documented – Gubin 2 (1,033.8 Mt), but at the same time new documentation elaborated and accepted for 3 other deposits, Gubin, Gubin 1 and Izbica Kujawska, caused a resource decrease for 1,018.92 Mt.

Lignite output generally decreased in 1990–2010 with slightly growth in 2003–2006. Much larger output was generated in 2011–2013 (mainly from the Bełchatów – pole Szczerców, Pątnów IV, Władysławów, Koźmin and Tomisławice deposits) and reached a level of 66 Mt. Then, production decreased significantly in 2014 and 2015 (from the Turów, Adamów and Drzewce deposits) – by 2,137 kt and 867 kt, respectively.

1.2. Coal bed methane (CBM)

A. Malon, M. Tymiński

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 desorption of CBM and its release from coal and surrounding rocks to work areas of a coal mine. The release of methane is a serious concern for safety of mining works as it creates 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 a face and reduction of a methane concentration to an acceptable level through ventilation of work areas.

Recent decades witnessed development in technology of draining methane from coal beds by multiple boreholes drilled from the surface. The drainage technology involves hydrofracturing of coal beds and surrounding rocks and the filling up of fissures with a 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, which is necessary for a start of desorption, emission and migration of CBM. Draining of CBM by production wells is treated as natural gas production from an unconventional source.

Coal-bed methane has been documented only in coal deposits of the Upper Silesian Coal Basin (USCB), especially those from its southern and western parts. CBM concentrations in coal deposits of the Lower Silesian Coal Basin (LSCB) appear to be much smaller than in the USCB. The economic importance of CBM occurrences in the Lublin Coal Basin (LCB) is still to be established.

Documented recoverable CBM resources occur within 60 exploited coal deposits in the area of the USCB. Recoverable CBM resources, that is resources for which there are economic incentives for production, were estimated at 90,772.84 Mm^3 as of 31 XII 2015. That amount comprises 43,705.73 Mm^3 in areas of exploited coal deposits, 20,973.09 Mm^3 in hitherto undeveloped coal deposits and 26,094.02 Mm^3 in deposits where CBM is documented as the main raw material. Economic resources of coal-bed methane established for 27 developed coal fields are 5,718.92 Mm^3. Prognostic and perspective resources of coal bed methane in USCB amounted to approximately 107 bnm^3 as of 31 XII 2009 (Kwarciński, 2011). Perspective resources in the LCB and LSCB are much lower and amounted to approximately 15 bnm^3 and 1.75 bnm^3, respectively.

Coal-bed methane output was 320.49 Mm^3 in 2015. This figure covers the amount of CBM that is picked up by every hard coal mine in Poland. There is also CBM emitted from mine airing systems that amounted to 522.62 Mm^3 in 2015.

The 2012–2015 period was characterized by a resource drop in 2012 and 2013 and growth in 2014 and 2015. Resources in 2012 decreased by 1,515.03 Mm^3 (due to the deletion of four deposits from "The balance…") and in 2013 by 2,181.85 Mm^3 (mainly due to new documentation accepted for the Paniowy-Mikołów-Panewniki deposit). Then, resources increased significantly in 2014–2015 (by 5,340.27 Mm^3) which resulted, among others, from:

- documentations of new deposits: Barbara-Chorzów 2 (25.33 Mm^3), Brzezinka 3 (134.05 Mm^3) and Bzie Dębina 2 (645.72 Mm^3) – all of them with CBM as a co-occurring raw material, Studzienice 1 (1,765.53 Mm^3) and Żory-Suszec 1 (35.53 Mm^3) – documented beyond areas of hard coal exploitation, Jankowice-Wschód (17.74 Mm^3) and Mszana (57.40 Mm^3) – with CBM as the main raw material;
- recalculations of resources accepted for the Brzeszcze (726.80 Mm^3), Knurów (1,768.28 Mm^3), Borynia (1,232.42 Mm^3) and Halemba II (1,196.30 Mm^3) deposits;
- the adjustment of resources estimated for the Jankowice deposit (348.22 Mm^3).

Output (CBM picked up by mines) after a slight drop in 2013 (by 3.75 Mm^3), increased significantly in the years 2014 and 2015 by 19.19 Mm^3 and 27.09 Mm^3, respectively; whereas CBM emitted from the airing system decreased in 2013 by 5 Mm^3 it was followed by growth – 14.19 Mm^3 and 51.45 Mm^3 in the next two years.

1.3. Crude oil

D. Brzeziński

In 2015, there were 86 crude oil fields documented in Poland, including: 29 fields situated in the Carpathians, 12 in the Carpathian Foredeep, 43 within the Polish Lowlands and two in the Polish economic zone of the Baltic Sea. Oil fields in the Carpathians and Carpathian Foredeep have had a long history as this is the area of the world's first commercial production of crude oil. However, these fields are now almost completely exhausted. Nowadays, Polish oil fields with the largest economic importance are situated in the area of the Polish Lowlands. In 2015, resources of the Polish Lowlands accounted for 74% of total exploitable crude oil resources in Poland. Resources of the Polish economic zone in the Baltic Sea were the second largest, accounting for 20% of total exploitable resources. Resources of the Carpathian Foredeep and Carpathians accounted for 4% and 2% respectively.

In the Polish Lowlands, oil fields are related to traps in Permian, Carboniferous and Cambrian rocks. These oils are of medium paraffin type, with paraffin content ranging from 4.3% to 7.4%, sulfur content slightly above 1.0% and density ranging from 0.857 g/cm^3 to 0.870 g/cm^3. The most of these traps are of the massive type, with gas cap expansion drive and with passive role of water. The Barnówko-Mostno-Buszewo (BMB) oil and gas field is the largest in Poland. Its resources of crude oil were found to be twice as large as total domestic resources before its discovery. Other large oil fields situated in this region include the Lubiatów, Grotów and Cychry fields.

In the Carpathians, oil fields occur in several tectonic units, mainly in the Silesian unit. Oil fields relate to traps of a structural or sometimes structural-lithological type, mainly with the layer type surrounded by water. Production is initially driven by expansion of natural gas dissolved in oil and subsequently by gravity driven drainage. Carpathian crude oils represent an oil-gas type and are considered "sweet" due to negligible content of sulfur. Their density is 0.750–0.943 g/cm^3 and content of paraffin from 3.5% to 7.0%. Resources of Carpathian oil fields are generally small, depending on the size and character of structures to which they relate. Resources are largely exhausted as a result of many years of exploitation.

The Carpathian Foredeep oil fields are related to traps in sedimentary rocks of the Miocene and Mesozoic (Jurassic carbonate rocks and sometimes Cretaceous sandstone series) of a platform type, usually sealed with impermeable Miocene clays. Most fields are of the layer type, stratigraphic, lithological or tectonically shielded. Crude oil density ranges from 0.811 g/cm^3 to 0.846 g/cm^3, content of paraffin from 2.32% to 9.37% and sulfur content from 0.45% to 0.85%.

In 2015, exploitable resources of crude oil and condensate totalled 23.22 Mt (anticipated economic and sub-economic resources, whereby resources of developed oil fields account for 96% of total domestic resources), decreasing by 706.99 kt in relation to the previous year (Tab. 1.3.1).

Domestic production of crude oil and condensate from onshore and offshore fields totalled 898.87 kt in 2015, decreasing by 19.88 kt in relation to the previous year.

The Figure 1.3.1 shows changes in resources and production of crude oil in Poland in 1989–2015 and prices of crude oil (Brent type).

In 1989–1995, anticipated economic resources remained at a stable level of 4.5–5.6 Mt. They increased rapidly in 1996 and amounted to 14.3 Mt due to the documentation of a new field – BMB. Resources declined within the next six years followed by significant growth in 2003–2004 (by 7 Mt) due to the documentation of a new field – Lubiatów and incorporation of the Polish economic zone of the Baltic Sea into "The balance...". Resources increased from 21.63 Mt in 2005 to 25.58 Mt in 2011 (by 18%). The most significant growth in 2006 was due to enlargement of BMB field resources (by 2 Mt) and documentation of the Dzieduszyce field (0.5 Mt). The growth in 2009 resulted from better exploration of already documented fields (resources of B 8 field increased by 3 Mt). Since 2012, resources have been systematically declining at a rate of 3.2% per year.

Until 1999, crude oil output was quite stable and varied in the range of 174 kt per year. In the 2000–2004 period, output increased rapidly to 866 kt. Then, it declined systematically (except in 2008) from 818.70 kt in 2005 to 601.99 kt in 2011. This one-year growth was the result of intensive exploitation of the off shore B 8 field. Output enhancement in 2012 and 2013 (by 10% and 40%, respectively) came

Table 1.3.1. Crude oil resources [kt]

total
oil
condensate

	Number of deposits	Exploitable resources				Economic resources in place as part of anticipated economic resources
		Anticipated economic			Anticipated subeconomic	
		Total	A+B	C		
TOTAL RESOURCES	**86**	**22,824.28** 21,338.91 1,485.37	**9,496.80** 9,473.22 23.58	**13,327.48** 11,865.69 1,461.79	**395.40** 395.40 –	**14,191.12** 14,131.10 60.02
Including resources of exploited fields						
TOTAL	64	22,260.68 20,931.13 1,329.55	9,378.91 9,378.91 –	12,881.77 11,552.22 1,329.55	9.76 9.76 –	14,074.24 14,014.22 60.02
BALTIC SEA	2	4,654.27 4,654.27 –	1,059.10 1,059.10 –	3,595.17 3,595.17 –	–	4,518.44 4,518.44 –
CARPATHIANS	27	547.18 547.18 –	441.18 441.18 –	106.00 106.00 –	6.55 6.55 –	47.35 47.35 –
POLISH LOWLAND	29	16,682.91 15,353.36 1,329.55	7,652.79 7,652.79 –	9,030.12 7,700.57 1,329.55	3.21 3.21 –	9,460.43 9,400.41 60.02
CARPATHIAN FOREDEEP	6	376.32 376.32 –	225.84 225.84 –	150.48 150.48 –	–	48.02 48.02 –
Including resources of non-exploited fields						
TOTAL	8	507.03 363.03 144.00	108.29 89.29 19.00	398.74 273.74 125.00	329.53 329.53 –	116.50 116.50 –
POLISH LOWLAND	5	391.10 247.10 144.00	108.29 89.29 19.00	282.81 157.81 125.00	–	116.50 116.50 –
CARPATHIAN FOREDEEP	3	115.93 115.93 –	–	115.93 115.93 –	329.53 329.53 –	–
Including abandoned fields						
TOTAL	14	56.57 44.75 11.82	9.60 5.02 4.58	46.97 39.73 7.24	56.11 56.11 –	0.38 0.38 –
CARPATHIANS	2	1.50 – 1.50	–	1.50 – 1.50	3.75 3.75 –	–
POLISH LOWLAND	9	50.49 44.75 5.74	5.02 5.02 –	45.47 39.73 5.74	1.43 1.43 –	0.38 0.38 –
CARPATHIAN FOREDEEP	3	4.58 – 4.58	4.58 – 4.58	–	50.93 50.93 –	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 31

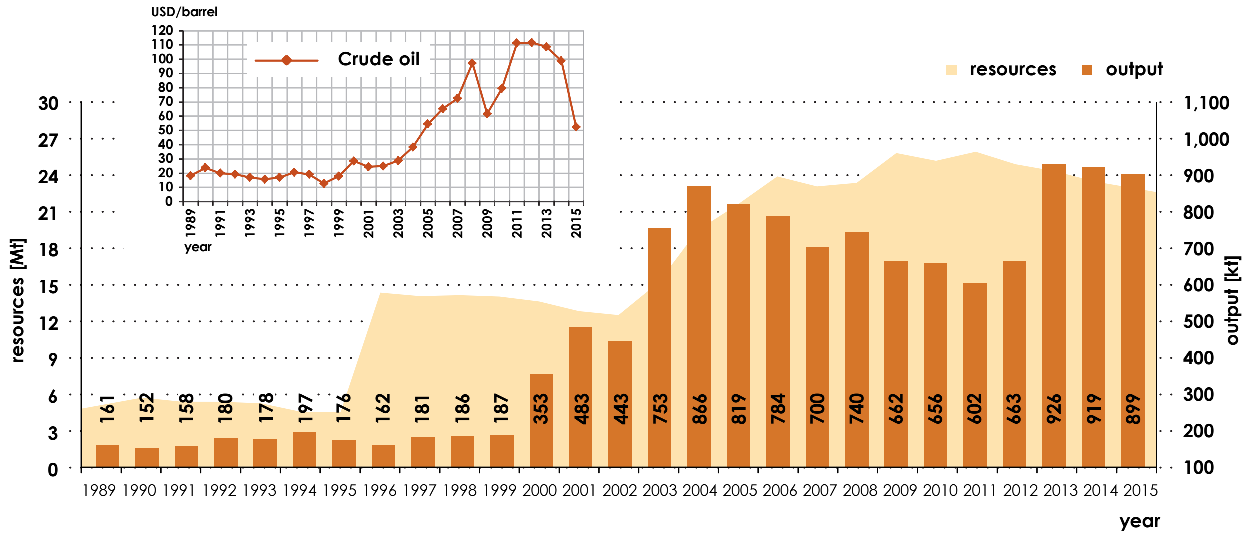


Fig. 1.3.1. Crude oil anticipated economic resources, output and annual prices in 1989–2015 (spot prices of Brent oil)

Resources and output according to: "The balance of mineral resources deposits and groundwater resources in Poland" (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); "The balance of mineral resources deposits in Poland" (in Polish; Szuflicki *et al.*, 2012–2015)
Prices according to BP Statistical Review of World Energy, June 2016

from greater exploitation of the Lubiatów field. The last two years were characterized by an output drop (with a yearly average of 1.5%). More than 90% of crude oil resources have been exploited from fields located in the Polish Lowland and the Polish economic zone of the Baltic Sea.

Crude oil prices remained in the range of 10–30 USD/barrel and began to increase in 2004 to reach a level of almost 100 USD/barrel. The main reasons were: the war on terrorism in the Middle East, uncertainty on the Russian market (nationalization of private firms), and the political situation in Venezuela and Nigeria. Growing global demand was also an important factor. The 2009-drop was caused by the global economic crisis. Then, prices rose following an OPEC cut of 4.2 million b/d in January 2009 supported by rising demand in Asia. In late February 2011, prices jumped as a consequence of the loss of Libyan exports in the wake of the Libyan civil war. The sustained excess of crude oil supply over global demand resulted in much lower crude oil prices in 2015 – they fell to a level below the 2009 average.

1.4. Hard coal

A. Malon, M. Tymiński

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 belt of paralic coal basins that were developing along margin of a sea in depressions along the front of the Variscan fold belt that formed in that time, and that of limnic basins with coals accumulating in closed basins and intermontane depressions with disconnected internal river systems. In Poland, coal deposits from the Carboniferous age occur in three basins (Plate 2): two basins of the paralic type – the Upper Silesian Coal Basin (USCB) and the Lublin Coal Basin (LCB), and in one of the limnic types – the Lower Silesian Coal Basin (LSCB). Exploitation of coal continues in the first two of them (USCB and LCB). The third (LSCB) now only has historical value.

The USCB is the major coal basin in Poland. This is the area where nowadays operate all but one of Polish coal mines. The total area of the Polish part of the

USCB is estimated at about 5,600 km^2. At present, anticipated economic resources of USCB account for about 78.9% of domestic resources of Poland.

In the LCB the Bogdanka coal mine is the only one that conducts exploitation. Documented deposits within the LCB cover an area of 1,200 km^2 and perspective resources – an area of 9,100 km^2. The Bogdanka mine exploits two deposits – Bogdanka and LCB – obszar K-3, which cover an area of 92 km^2 (accounting for 0.9% of the total LCB area).

Mining operations were phased out in the LSCB in 2000, along with closing of the last mining operations in the Słupiec deposit, the Nowa Ruda mine. Coal production ceased in LSCB due to difficult geological-mining conditions causing excessive exploitation costs. Anticipated economic resources left in the abandoned LSCB mining fields were reclassified as anticipated sub-economic. The abandoned anticipated sub-economic coal resources in the LSCB were estimated at about 369 Mt. In 2011, at the order of the Ministry of the Environment, verification of resources remaining in abandoned deposits was elaborated. Resources were recalculated according to new "deposit criteria" (balance criteria). Calculations also applied to seven LSCB deposits and new anticipated economic resources are now 423.05 Mt.

In the USCB, all technological types of hard coal occur. There is steam (thermal) coal, coking coal and sometimes anthracite. Mean ash content varies from 4.2 to 62.0% and mean sulfur content – from 0.4 to 3.5%. In the LCB, mainly steam coal and coking coal occur. Mean ash content is 6.2–18.1% and sulfur content ranges from 1.4 to 3.1%. In the LSCB, mean ash content amounts fall within the range of 10.1–38.8% and sulfur content is 0.7–1.6%.

Hard coal prognostic resources in Poland amounted to 20,041.7 Mt and perspective resources were 31,652.7 Mt as of 31 XII 2009 (Jureczka *et al.*, 2011). In the USCB, prognostic resources totalled 9,193.4 Mt (including 1,081.2 Mt of steam coals and 8,112.2 Mt of coking coals) and perspective resources totalled 25,533.0 Mt (19,156.8 Mt of steam coals and 6,376.2 Mt of coking coals). In the LCB, these resources amounted to 10,847.7 and 5,887.6 Mt, respectively. LSCB prognostic resources are 0.4 Mt (resources of Heddi deposit that was deleted from "The balance...") and perspective resources amounted to 232.0 Mt (Wałbrzych and Nowa Ruda area).

Total hard coal resources and the current state of their exploration and development in Poland are presented in Tab. 1.4.1. Anticipated economic resources as of 31 XII 2015 totalled 56,220 Mt. Steam coals represent 71.6% of resources, coking coals 27.0%, whereas other types of coals 1.4%. Resources of exploited coal deposits were 21,107 Mt, accounting for 37.5% of total anticipated economic resources. Anticipated economic resources covered by detailed exploration (categories A, B, C_1 of the Polish classification of resources) totalled 24,933.62 Mt, accounting for 44.3% of total anticipated economic resources. Anticipated sub-economic resources are divided into two groups: A – proper anticipated sub-economic resources and B – those meeting limit values of parameters that define a deposit, but classified as sub-economic due to difficult geological conditions. Anticipated sub-economic resources of group B were approved until 2001. Economic resources of exploited deposits as shown in approved mineral deposit development plans were 3,573.69 Mt, decreasing by 189.93 Mt in relation to 2014 due to exploitation, losses and new mineral deposit development plans. These resources are currently calculated with reference to duration of concession for exploitation; thus, their real volume in some deposits may be much greater. According to production data supplied by operators of individual hard coal mines, total hard coal output was 65,070 kt in 2015.

Fig. 1.4.1 shows changes in the magnitude of resources and output in 1989–2015. Polish coal mines have been subjected to restructuring and rationalization since the start 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 a much larger scale, verification and reclassification of resources following adjustments of the mining sector to requirements of a free-market economy. These factors resulted in a decrease of coal resources from 65.8 Mt in 1989 to 42.0 Mt in 2006 (the lowest level in the presented period). Resources remained in the range of 43–44 Mt during the next four years and then began to increase again. In 2011, this was mainly the result of a verification of resources remaining in abandoned deposits (38 new documentations for already proven deposits elaborated) and, therefore, reclassification of resources from anticipated sub-economic to anticipated economic. Resources slightly decreased in 2012 and since 2013 have been growing again due to:

- the documentation of new deposits (with total resources of 7,562.42 Mt): five in 2013 (Anna 1, Brzezinka 1, Dąb, Oświęcim-Polanka 1 and Śmiłowice), five in 2014 (Barbara-Chorzów 2, Brzezinka 3, Bzie-Dębina 2, Jan Kanty 2 and Nowa Ruda Pole Piast Rejon Wacław-Lech) and six in 2015 (Jan Kanty-Szczakowa, Lublin, Powstańców Śląskich 1, Siersza 2, Studzienice 1

Table 1.4.1. Hard coal resources [Mt]

	Number of deposits	Geological resources in place					Economic resources in place as part of anticipated economic resources
		Anticipated economic				Anticipated sub-economic group A group B	
		Total	A+B	C_1	C_2+D		
TOTAL RESOURCES	**156**	**56,220.48**	**6,076.12**	**18,857.50**	**31,286.87**	**14,987.63 1,345.67**	**3,573.69**
Steam coal		40,234.82	4,063.69	12,294.92	23,876.21	11,363.63 1,040.43	2,109.30
Coking coal		15,198.47	2,004.59	6,517.27	6,676.61	3,587.44 305.24	1,464.39
Other coals		787.19	7.83	45.31	734.04	36.56 –	–
Including resources of exploited deposits							
TOTAL	51	21,107.05	4,627.16	9,363.54	7,116.35	5,763.59 1,099.26	3,561.47
Steam coal		12,077.37	2,802.81	5,440.24	3,834.32	3,874.57 918.20	2,097.08
Coking coal		9,023.04	1,824.35	3,922.07	3,276.62	1,889.03 181.05	1,464.39
Other coals		6.64	–	1.23	5.41	–	–
1. DEPOSITS OF OPERATING MINES	47	19,816.75	4,549.94	8,735.65	6,531.16	5,342.51 1,099.26	3,301.93
Steam coal		12,029.53	2,802.81	5,421.90	3,804.83	3,870.80 918.20	2,097.08
Coking coal		7,782.68	1,747.13	3,312.52	2,723.02	1,471.71 181.05	1,204.85
Other coals		4.54	–	1.23	3.30	–	–
2. DEPOSITS EXPLOITED TEMPORARILY	2	173.53	2.83	88.15	82.55	–	8.30
Steam coal		41.63	–	14.33	27.31	–	–
Coking coal		131.89	2.83	73.82	55.24	–	8.30
3. MINES DURING PREPARATION PROCESS	2	1,116.78	74.39	539.74	502.65	421.08 –	251.24
Steam coal		6.20	–	4.01	2.19	3.77 –	–
Coking coal		1,108.47	74.39	535.73	498.35	417.31 –	251.24
Other coals		2.11	–	–	2.11	–	–
Including resources of non-exploited deposits							
TOTAL	58	31,199.31	344.86	7,926.65	22,927.79	8,689.02 246.41	–
Steam coal		25,095.92	318.31	5,518.54	19,259.07	7,230.08 122.23	–

Table 1.4.1. Cont.

	Number of deposits	Geological resources in place					Economic resources in place as part of anticipated economic resources
		Anticipated economic				Anticipated sub-economic group A / group B	
		Total	A+B	C_1	C_2+D		
Coking coal		5,464.34	26.27	2,402.41	3,035.67	1,458.95 / 124.18	–
Other coals		639.04	0.29	5.70	633.05	–	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	40	15,467.30	344.86	7,926.65	7,195.78	1,563.35 / 246.41	–
Steam coal		11,267.83	318.31	5,518.54	5,430.98	1,035.61 / 122.23	–
Coking coal		4,191.33	26.27	2,402.41	1,762.65	527.75 / 124.18	–
Other coals		8.14	0.29	5.70	2.15	–	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	18	15,732.01	–	–	15,732.01	7,125.67 / –	–
Steam coal		13,828.10	–	–	13,828.10	6,194.47 / –	–
Coking coal		1,273.01	–	–	1,273.01	931.20 / –	–
Other coals		630.90	–	–	630.90	–	–
Including abandoned deposits							
TOTAL	47	3,914.13	1,104.09	1,567.31	1,242.73	535.01 / –	12.22
Steam coal		3,061.53	942.57	1,336.14	782.82	258.99 / –	12.22
Coking coal		711.09	153.98	192.79	364.33	239.47 / –	–
Other coals		141.50	7.54	38.38	95.58	36.56 / –	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 31

and Żory-Suszec 1) – with the Lublin deposit having the largest resources (2,277.85 Mt) and the only one documented beyond the USCB (in the LCB area);

- new documentations with larger recalculated resources for 18 deposits (with total resource change of 3,328.36 Mt), including the Borynia deposit with the largest change (+ 635.66 Mt).

There were also 9 deposits deleted from "The balance..." in 2013–2015, new documentations with lesser resources recalculated for 17 deposits and the exploitation and losses from exploited deposits. These factors significantly reduced potential three-year resource growth and resources ultimately amounted to 56.22 Mt in 2015 (10.8% more than in 2014).

Restructuring and nationalization were also main factors affecting the hard coal output level that decreased from over 170 to about 96 Mt in 1989–2003 and 67.6 Mt at the end of 2011 (Fig. 1.4.1). In 2012, output exceeded the level of 71 Mt as a result of more intensive exploitation from 17 deposits. In the last three years it has decreased systematically to about 65 Mt in 2015.

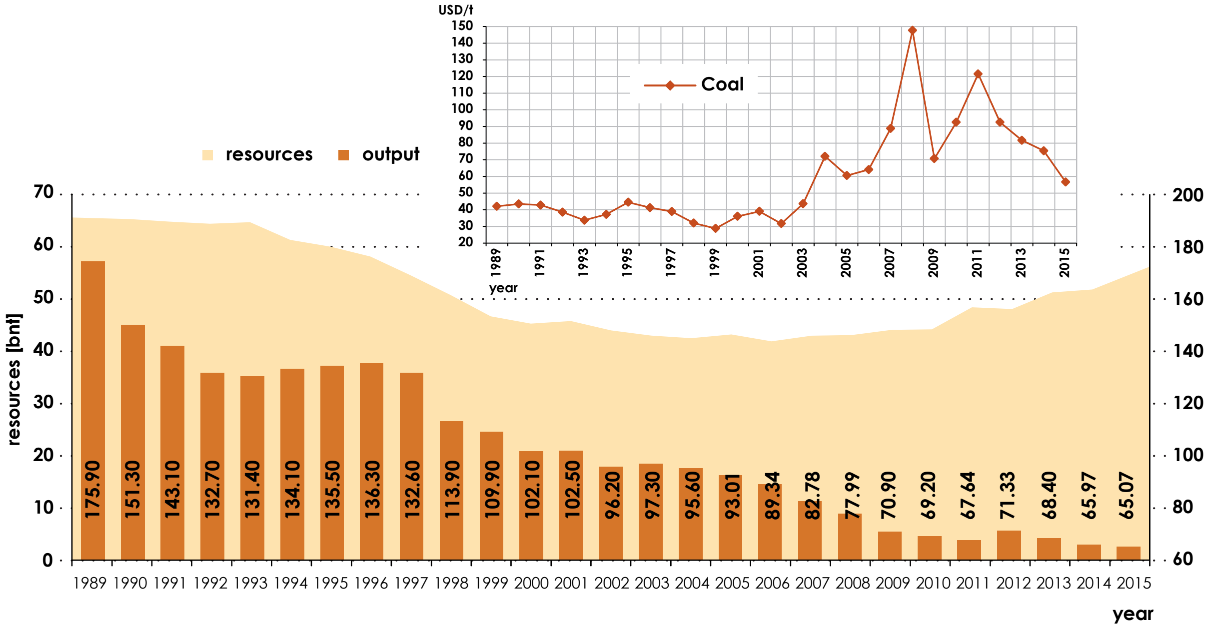


Fig. 1.4.1. Hard coal anticipated economic resources, output and annual prices in 1989–2015 (steam coal, northwest Europe marker price)

Resources and output according to: "The balance of mineral resources deposits and groundwater resources in Poland" (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al*., 2007, 2008; Wołkowicz *et al*., 2009–2010; Szuflicki *et al*., 2011); "The balance of mineral resources deposits in Poland" (in Polish; Szuflicki *et al*., 2012–2015)
Prices according to BP Statistical Review of world Energy, June 2016 – source: McCloskey Coal Information Service – prices for 1989–2000 are the average of the monthly marker, 2001–2015 the average of weekly prices

Figure 1.4.1 also presents changes in hard coal prices at the example of steam coal imported to Europe (on the basis of the McCloskey Northwest Europe marker price) in 1989–2015. The price varied between 20 and 45 USD/t in 1989–2003 to increase rapidly in the next two years. After one-year drop the prices grew to 147 USD/t in 2008 – the highest level in the analyzed period. This growth was caused by weather disturbances in Australia, Indonesia and China obstructing exploitation and transport as well as growing demand, supply difficulties in South Africa and Russia, increasing crude oil and gas prices and a weak position US dollar in relation to other currencies. Hard coal prices fell significantly in 2009 (due to the global economic crisis) followed by two-year growth (mainly due to greater demand in China). Since 2012, prices have been decreasing regularly and have reached a value below 66 USD/t in 2015. The main reasons were: decreasing demand in Europe and China and, therefore, oversupply on the international market, the significant changes in the United States energy sector with shale gas playing a more important role and leaving the US with surplus hard coal that is directed to the international market and declining crude oil prices that generate lower transport costs.

1.5. Helium

D. Brzeziński

Helium is found in numerous natural gas fields in the Polish Lowland. Its content varies from 0.02% to 0.45%. Resources of that gas were documented in 16 natural gas fields with helium content from 0.22% to 0.42% (Tab. 1.5.1). These gas fields are situated in the Zielona Góra-Rawicz-Odolanów area (southern part of the Fore-Sudetic Monocline) and relate to the Rotliegend, Zechstein Limestone and Main Dolomite formations of the Permian. Raw material is recovered from gas fields where average helium content exceeds 0.27%.

Table 1.5.1. Helium resources [Mm³]

	Number of deposits	Exploitable resources			
		Anticipated economic			Anticipated sub-economic
		Total	A+B	C	
TOTAL RESOURCES	**16**	**25.90**	**25.54**	**0.36**	–
Including:					
exploited deposits	11	22.82	22.82	0.00	
non-exploited deposits	5	3.08	2.72	0.36	–

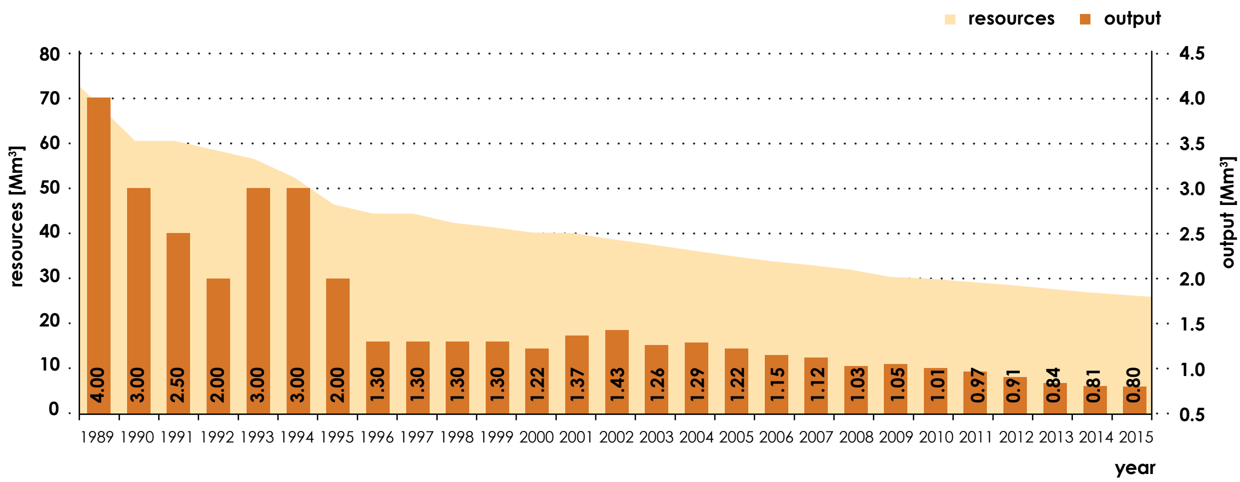


Fig. 1.5.1. Helium anticipated economic resources and output in 1989–2015

According to: "The balance of mineral resources deposits and groundwater resources in Poland" (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); "The balance of mineral resources deposits in Poland" (in Polish; Szuflicki *et al.*, 2012–2015)

"The balance..." presents only fields where helium resources are documented. Given production does not take into account the amount of helium recovered from natural gas with anticipated sub-economic helium additives (Smakowski *et al.*, 2015) i.e. below 0.08% of helium.

In 2015, anticipated economic resources amounted to 25.90 Mm³ and total helium recovery in the process of gas de-nitrogenation was 0.80 Mm³.

Resources and output changes are presented in Figure 1.5.1. They resulted from changes in the Bogdaj-Uciechów field, which is the largest field documented in Poland. Its resources account for 47% of total domestic resources. They decreased from 37.28 Mm³ in 1989 to 13.56 Mm³ in 2011 and finally to 12.25 Mm³ in 2015. The resource drop is the effect of output and reclassification of resources in 1990. In 1990–2015, helium recovery from the Bogdaj-Uciechów field totalled 15.52 Mm³. Resources and output have been declining since 1996 on an annual average of 2% and 2.4%, respectively.

1.6. High nitrogenous natural gas (HNNG)

D. Brzeziński

Until now, two high nitrogenous natural gas (HNNG) fields have been documented in Poland (Tab. 1.6.1). These are the Cychry and Sulęcin fields situated in the Polish Lowlands and characterized by nitrogen content exceeding 90% (Plate 1). HNNG is a good quality raw material for production of liquid nitrogen, but it is more often used to adjust nitrogen content in natural gas pipelines of a domestic distribution network. Its utility for the latter purpose involves gas from fields with nitrogen content exceeding 70%, which are not differentiated as a separate group of HNNG fields.

Cychry and Sulęcin HNNG fields occur in the Zechstein Main Dolomite. At present, exploitation of that gas is limited to Cychry field only. In 2015, HNNG production was about 15.46 Mm^3.

Table 1.6.1. High nitrogenous natural gas resources [Mm^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	**2**	**14,806.75**	**3,300.00**	**11,506.75**	**–**	**920.65**
Including resources of exploited deposits						
POLISH LOWLANDS (CYCHRY FIELD)	1	11,506.75	–	11,506.75	–	920.65
Including resources of non-exploited deposits						
POLISH LOWLANDS (SULĘCIN FIELD)	1	3,300.00	3,300.00	–	–	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 31

1.7. Natural gas

D. Brzeziński

In Poland, major gas fields were discovered in the area of the Polish Lowlands. Large gas fields are also known from the Carpathian Foredeep, smaller ones – from the Carpathians and the Polish economic zone of the Baltic Sea (Plate 1). About 75% of gas resources occur in Miocene and Rotliegend formations and remaining resources – in the Cambrian, Devonian, Carboniferous, Zechstein, Jurassic and Cretaceous formations.

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

In the Carpathian Foredeep, natural gas fields relate to plays involving the Jurassic, Cretaceous and Miocene formations. The fields usually contain high methane natural gas with low nitrogen content. Exceptions are several natural gas fields containing high nitrogen concentrations. In this region, gas occurs in structural-lithological multi-layer traps or, at times, massive-type reservoirs with a gas drive mechanism.

In the Carpathians, natural gas occurs in gas, oil-gas and oil-gas-condensate fields related to plays in the Cretaceous and Paleogene formations. Produced gas is characterised by high methane content (usually over 85%) whereas average nitrogen content is several percent on average.

There are two gas fields in the Polish exclusive economic zone of the Baltic Sea (B 4 and B 6) and two oil-gas fields (B 3 and B 8).

At present, the Polish Lowlands region accounts for 68.5% of exploitable domestic resources of natural gas and the Carpathian Foredeep – for 26.5% of those resources. Resources of the Polish economic zone of the Baltic Sea and the Carpathians are subordinate constituting 4.0% and 1.0% of exploitable domestic resources, respectively.

Table 1.7.1 shows exploitable resources of natural gas from gas, oil-gas and oil-gas-condensate fields with the degree of exploration and development in separate parts of the country. Data in this table refer to resources of natural gas of various methane content and are not converted to those of high methane gas (high methane gas = extracted reserves x combustion heat from real gas/ combustion heat from high methane gas, that is about 34 MJ/m^3).

In 2015, exploitable resources of natural gas were 125.04 bnm^3 (anticipated economic and anticipated sub-economic resources). Resources of exploited fields were estimated at 102.34 bnm^3, which accounts for 82% of the total amount of exploitable resources. In 2015, economic resources of natural gas were estimated at 54.91 bnm^3.

The above total domestic resources also include those gas fields that are planned to be converted for use as underground natural gas storage facilities. Production from these gas fields has been halted in order to use remaining gas as a cushion (base gas) during operation of the storage sites. Seven gas

Table 1.7.1. Natural gas resources [Mm^3]

total
from oil and condensate fields
from gas fields
from PMG fields

	Number of deposits	Exploitable resources				Economic resources in place as part of anticipated economic resources
		Anticipated economic			Anticipated sub-economic	
		Total	A+B	C		
TOTAL RESOURCES	**292**	**122,820.02 27,168.97 88,929.48 6,721.57**	**75,746.96 10,480.93 58,544.46 6,721.57**	**47,073.06 16,688.04 30,385.02 –**	**2,220.70 654.52 1,566.18 –**	**54,913.68 10,642.95 43,691.34 579.39**
Including resources of exploited fields						
TOTAL	207	101,679.10 14,695.13 80,262.40 6,721.57	69,965.50 6,259.36 56,984.57 6,721.57	31,713.60 8,435.77 23,277.83 –	663.04 651.04 12.00 –	51,006.78 6,821.06 43,606.33 579.39
BALTIC SEA	2	542.26 542.26 – –	109.46 109.46 – –	432.80 432.80 – –	–	525.81 525.81 – –
CARPATHIANS	28	1,115.84 115.25 879.09 121.50	682.56 96.83 464.23 121.50	433.28 18.42 414.86 –	10.77 1.04 9.73 –	386.72 3.73 261.49 121.50
POLISH LOWLAND	94	68,444.57 12,485.17 49,874.93 6,084.47	50,381.47 4,558.05 39,738.95 6,084.47	18,063.10 7,927.12 10,135.98 –	650.00 650.00 – –	41,460.02 5,404.08 36,055.94 –
CARPATHIAN FOREDEEP	83	31,576.43 1,552.45 29,508.38 515.60	18,792.01 1,495.02 16,781.39 515.60	12,784.42 57.43 12,726.99 –	2.27 – 2.27 –	8,634.23 887.44 7,288.90 457.89

Table 1.7.1. Cont.

	Number of deposits	Exploitable resources				Economic resources in place as part of anticipated economic resources
		Anticipated economic			Anticipated sub-economic	
		Total	A+B	C		
Including resources of non-exploited fields						
TOTAL	53	20,775.83 12,371.96 8,403.87 –	5,755.85 4,221.57 1,534.28 –	15,019.98 8,150.39 6,869.59 –	1,421.68 1.93 1,419.75 –	3,889.11 3,820.87 68.24 –
BALTIC SEA	2	4,479.45 4,479.45 – –	–	4,479.45 4,479.45 – –	–	3,765.25 3,765.25 – –
CARPATHIANS	3	240.00 – 240.00 –	240.00 – 240.00 –	–	74.93 1.93 73.00 –	–
POLISH LOWLAND	37	14,820.88 7,892.51 6,928.37 –	5,388.85 4,221.57 1,167.28 –	9,432.03 3,670.94 5,761.09 –	1,346.75 – 1,346.75 –	55.62 55.62 – –
CARPATHIAN FOREDEEP	11	1,235.50 – 1,235.50 –	127.00 – 127.00 –	1,108.50 – 1,108.50 –	–	68.24 – 68.24 –
Including abandoned fields						
TOTAL	32	365.09 101.88 263.21 –	25.61 – 25.61 –	339.48 101.88 237.60 –	135.98 1.55 134.43 –	17.79 1.02 16.77 –
CARPATHIANS	5	80.00 80.00 – –	–	80.00 80.00 – –	92.44 0.56 91.88 –	–
POLISH LOWLAND	19	197.91 21.88 176.03 –	–	197.91 21.88 176.03 –	0.99 0.99 – –	1.02 1.02 – –
CARPATHIAN FOREDEEP	8	87.18 – 87.18 –	25.61 – 25.61 –	61.57 – 61.57 –	42.55 – 42.55 –	16.77 – 16.77 –

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 31

fields have been selected for conversion to underground storage facilities thus far: Bonikowo (328.63 Mm³), Brzeźnica (45.59 Mm³), Daszewo (27.72 Mm³), Husów (372.88 Mm³), Strachocina (121.50 Mm³), Swarzów (28.80 Mm³) and Wierzchowice (5,728.12 Mm³). Total natural gas resources to be used as gas cushions are estimated at 6.65 bnm³. In 2012, the Minister of the Environment granted permission for the Henrykowice E field (crossed out from "The balance…" in 2003) to be used as an underground natural gas storage facility.

Underground hydrocarbon storage facilities are also built in salt deposits. There are three cavernous facilities – Mogilno II and Kosakowo gas storage facilities and the crude oil and Góra liquid fuels storage facility. As of the end of 2015, 11 licenses for underground natural gas, crude oil and liquid fuel storage facilities were issued.

In 2015, domestic production of natural gas from exploitable gas resources reached 5.214 bnm³ (Fig. 1.7.1).

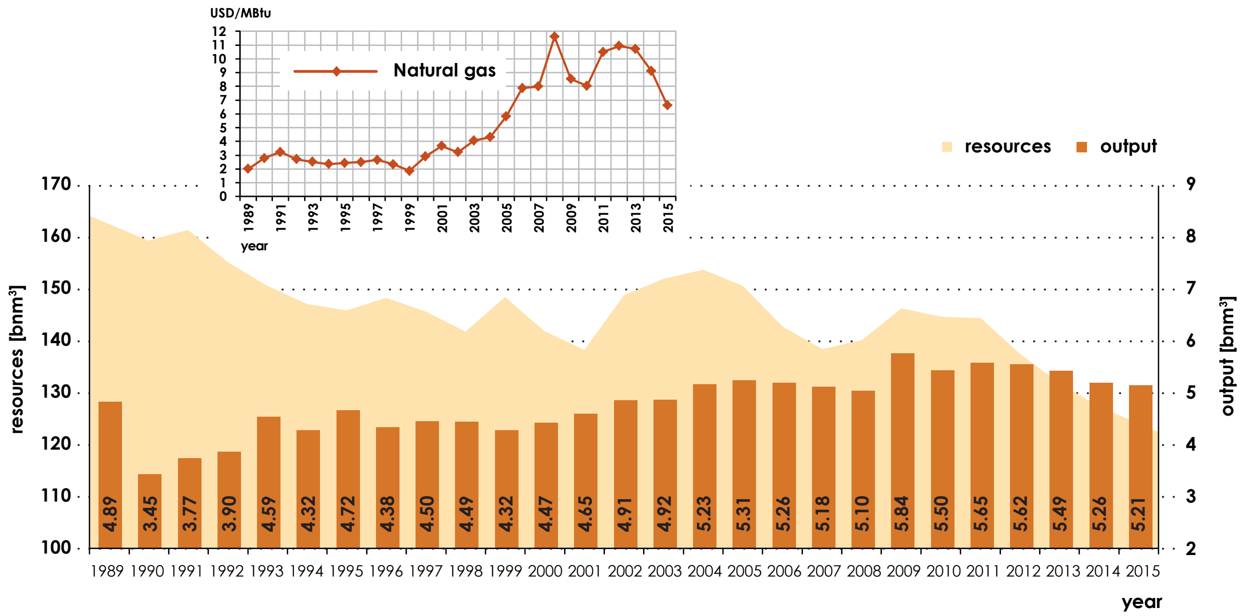


Fig. 1.7.1. **Natural gas anticipated economic resources, output and annual prices in 1989–2015 (average German Import Price)**

Resources and output according to: "The balance of mineral resources deposits and groundwater resources in Poland" (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); "The balance of mineral resources deposits in Poland" (in Polish; Szuflicki *et al.*, 2012–2015)
Prices according to BP Statistical Review of World Energy, June 2016 – source: 1989–1990 German Federal Statistical Office, 1991–2015 German Federal Office of Economics and Export Control (BAFA)

In 1989–1998, anticipated economic resources of natural gas declined and in 1999 increased significantly by 6.7 bnm³. Then, in the next two years they decreased by 10.3 bnm³ and grew once again in 2002–2004 by 15.7 bnm³ due to the documentation of new deposits – Brońsko, Międzychód, Lubiatów, B-4 and B-6. The next 11 years were characterised by a resources drop by about 19%. The most important was recorded in 2006–2007 as a result of exploitation and recalculation of Barnówko-Mostno-Buszewo (BMB) field resources. Two-year growth in 2008–2009 resulted from better exploration of already documented fields and documentation of 16 new fields with total resources of 3.1 bnm³. The highest resource increase was due to an updating of the Brońsko (8.9 bnm³) and Paproć (3.3 bnm³) field resource base. In 2015, resources decreased by 4.70 bnm³ in comparison with the previous year.

Natural gas output varied intensively in the last 11 years – from 5.305 bnm³ in 2005 to 5.839 bnm³ in 2009 and 5.214 bnm³ in 2015. The increase recorded in 2009 was the result of growing exploitation from the Polish Lowland fields. Output from onshore fields accounted for 99% of domestic output, whereas less than 1% came from the Polish exclusive economic zone of the Baltic Sea. Output in 2015 was 0.045 bnm³ lower than in 2014.

Figure 1.7.1 also presents changes in natural gas prices (the average German Import Price) in 1989–2015. There is no single uniform international market and gas prices change depending on the cost of supply to pipeline networks and sea terminals (supply and distribution costs can account for 80% of total costs). Prices varied in the 1989–2002 period in the range of 2–4 USD/MBtu and then began to increase significantly until 2008. The 2008-growth was the result of the global economic crisis. Then, prices declined in 2009 and 2010 due to a supply and demand slow-down. During the next two years average prices increased to almost 11 USD/MBtu and that growth was followed by a significant decline to a level of about 6.5 USD/MBtu in 2015. It should be emphasized that natural gas prices are strictly tied to oil prices and usually follow their trends.

1.8. Unconventional hydrocarbons

T. Podhalańska, A. Wójcicki

Shale gas as well as oil and tight gas deposits are assigned to unconventional hydrocarbon accumulations with reference to technical-economic and, on a smaller scale, geological criteria. Their exploitation is more difficult and expensive than in the case of conventional deposits. Unconventional hydrocarbon deposits are characterised by a lack of natural flow of oil and gas from surrounding rock into exploitation well tubing (production tubing). Reservoir rocks are "tight" such as in the case if shale and, as a result, oil and gas generally cannot flow through them. This impedes production in economic quantities, thus rendering it necessary to use hydraulic fracturing and other techniques of enhanced recovery to stimulate flow from the very start. Moreover, oil and gas accumulations in shale may be characterised by large extent, independently of deposit traps in geological complexes that may serve the role of reservoir and parent rock.

In Poland, the start of work on exploration and development of unconventional hydrocarbon accumulations and estimation of their potential resources in shale and sandstones took place in 2007–2008, when initial concessions for exploration of gas in shale were issued.

This chapter discusses the current state of knowledge on unconventional hydrocarbon resources of tight gas and shale gas and oil. Reserve appraisals presented here are estimates – prognoses of undiscovered and undocumented reserves. These appraisals correspond to the category of "undiscovered resources" in international classification used by oil companies (SPE-PRMS), generally comprising Gas in Place, Oil in Place and Hydrocarbons in Place and related Technically Recoverable Resources.

Tight gas

Data on tight gas originate from the latest PGI-NRI report (Wójcicki *et al.*, 2014) presenting the results of analysis of three geological complexes (hydrocarbon systems) at the most prospective and/or relatively best known regions of Poland. Estimates of geological resources were calculated by the volumetric method (Tab. 1.8.1). The complexes include: sandstones of the Rotliegend formation (Permian) in the Poznań-Kalisz area (I), Carboniferous sandstones in the Wielkopolska-Śląsk area (II) and Cambrian sandstones in the western part of the Baltic Basin (III).

Technically recoverable resources may be estimated hypothetically assuming an exploitation factor of 5–15% (10% on average) for each of these regions. This provides values somewhat higher than those for recoverable resources of conventional gas deposits (153–200 bnm^3).

Gas and oil in shales

Data on gas and oil in shales originate from the only report thus far published by the State Geological Survey (Report PGI-NRI, 2012). It was compiled on the basis of archival borehole data from the 1950–1990 period, including the results of laboratory measurements of core material to understand key properties of the reservoir. The analyses were focused on the most prospective and relatively best known Lower Paleozoic shale rocks of the Baltic-Podlasie-Lublin Basin (Tab. 1.8.2). Estimates of shale gas and oil reserves in Poland are continued by the

Table 1.8.1. Prognoses of geological resources (Gas in Place) of tight gas for selected regions of Poland (Wójcicki *et al.*, 2014)

Geological complex	Depth [mbsl]	Prognostic resources (P50) [bnm^3]
I – PERMIAN (ROTLIEGENDES) SANDSTONES	5,500–6,000 or 5,100–6,000	**345 or 812**
II – CARBONIFEROUS SANDSTONES	1,800–3,500	**1,145**
III – CAMBRIAN SANDSTONES	2,800–3,100	**38**
TOTAL	**–**	**1,528–1,995**

Table 1.8.2. Prognoses of Technically Recoverable Resources of hydrocarbons in Lower Paleozoic shale in the Baltic-Podlasie-Lublin basin (PGI-NRI Report, 2012)

Area	Gas [bnm^3]	Oil [Mt]
ONSHORE AREA	230.5–619.4	166.6
OFFSHORE AREA	115.6–148.4	48.8–101.1

PGI-NRI as a task of the state geological survey. These new appraisals will be based on archival data as well as latest information from the growing number of wells, as disclosed by exploratory companies operating in Poland (unpublished reports: Wójcicki *et al.*, 2015, 2016).

In addition to Lower Paleozoic rocks in the western part of the East European Platform, formations potentially perspective from the standpoint of shale gas and/or oil accumulations may include Miocene clay-siltstone rocks in the Carpathian Foredeep, Menillite Shale of the Outer Carpathians, shale series of the uppermost Jurassic – lowermost Cretaceous shale, shale successions of the Lower and Middle Jurassic, Rhaetian shale and Zechstein copper-bearing shale in the Polish Basin, Anthracosia Shale and Walchia Shale in the Mid-Sudetic Basin Depression, Upper Carboniferous shale in the Lublin Basin, Lower Carboniferous Culm shale in the Fore-Sudetic Monocline (area of distribution of a hybrid zone that comprises shale and sandstones prospective from the standpoint of present tight gas accumulations) and a shale series of the uppermost Devonian and lowermost Carboniferous in western Pomerania.

The most prospective shale series of the Lower Paleozoic in the Baltic-Podlasie-Lublin Basin include, depending on region, rocks of the lower part of the Pasłęk formation (especially those of the Jantar member – the lowermost Llandovery), the Sasin formation (Caradoc and locally also the uppermost Llandvirn) and Piaśnica formation (mainly in an offshore area, Upper Cambrian and sometimes the lowermost Tremadoc). Reservoir parameters were found to be poorer in the case of shale rocks of the Pelplin formation (Wenlock, especially its lower part) occurring in the Lublin region and the onshore part of the Baltic Basin (see e.g. Poprawa, 2010; Więcław *et al.*, 2010; Kosakowski *et al.*, 2016; Podhalańska, 2016; Podhalańska *et al.*, 2016).

The most probable estimates of technically recoverable resources in Lower Paleozoic rocks are given below in the PGI-NRI Report, 2012 (Tab. 1.8.2). This report was compiled using the Estimated Ultimate Recovery (EUR) production method elaborated and used by the USGS. Approximations of the total quantity of hydrocarbons that are potentially recoverable from a reserve or well were accepted following data from oil basins in the United States characterised by similar geological-deposit conditions as the Baltic-Podlasie-Lublin Basin. Lower limits of intervals for resources (Tab. 1.8.2) refer to minimum extents of areas of the distribution of shale rocks with most perspective from the standpoint of shale gas and oil deposits occurrence and the upper – maximum extent of these areas. Work is continued within the framework of state geological survey tasks (see unpublished reports: Wójcicki *et al.*, 2015, 2016).

As production of shale gas and oil has not commenced in Poland, estimates of technically recoverable resources based on approximations of the quantity of hydrocarbons recovered from a reserve or well still remain highly hypothetical.

2. Metallic raw materials

2.1. Arsenic

S.Z. Mikulski

Arsenic ore resources are related to occurrences of As minerals such as loellingite ($FeAs_2$) and arsenopyrite (FeAsS), hosted in hydrothermal veins or metasomatic intrusive metal ore types in Poland. Arsenic ores have been reported at a major deposit at Złoty Stok and from numerous ore-bearing veins at Czarnów and Miedzianka near Kamienna Góra and other sites (Radzimowice, Klecza-Radomice) in the Sudety Mts. (Plate 3). Arsenic ores were exploited at Złoty Stok from the 16th to the 20th century. In addition to As, gold was also extracted from rich ore with As content up to 40% also being a high grade Au ore containing up to 40 g/t Au. After the World War II, the Złoty Stok deposit was exploited in 1954–1960 and abandoned thereafter due to very limited demand and high toxicity of arsenic. According to mining records, in total, approximately 16 t of Au was extracted from this deposit. The amount remaining after previous extraction is estimated at 536,500 t of As ore yielding, 19,600 t of arsenic and 1,500 kg of gold. Another abandoned arsenic deposit is from Czarnów in the Sudety Mts. According to results of a general exploration conducted in 1955, resources of that deposit are relatively small. Inferred resources were estimated at about 20,500 t of arsenopyrite ore with mean content of arsenic of approximately 10.15%. Sulfide ores are accompanied by gold with maximum content of several grams per tonne.

2.2. Copper and silver ores

A. Malon, S. Oszczepalski, M. Tymiński

Copper ore deposits occur in several countries of the world and in various geological conditions. The most important are porphyric copper deposits as well as sediment-hosted stratabound copper deposits and sedimentary ones (SEDEX and massive pyrite ores). Moreover, there are other igneous copper ores of various types, generally characterized by smaller resources but sometimes with high economic value.

Polish copper and silver ores belong to the stratabound type. The deposits are situated in areas of the Fore-Sudetic Monocline and the North Sudetic Basin in the Lower Silesia (Plate 3) and related to the Zechstein Kupferschiefer formation. Minerals containing copper and other metals are mainly concentrated in copper-bearing schists as well as underlying sandstones and overlying dolomites. Deposits of the largest economic importance are those from the vicinities of Lubin in the Fore-Sudetic Monocline.

The copper-bearing series comprises three separate lithological layers: sandstones at the base, clay-marly or dolomitic schists and dolomitic limestones in the upper part. The strongest copper mineralization occurs in the black clay schists which, therefore, are named the copper-bearing schists. The major Cu minerals of the ores include: chalcocite (Cu_2S), bornite (Cu_5FeS_4) and chalcopyrite ($CuFeS_2$). They are accompanied by numerous other minerals of Cu, Ag (including native silver), Pb, Zn, Co and Ni.

The copper deposits area extends in a belt that is 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.*, 2011). This is actually a single deposit area in which copper and silver ores are currently exploited in the Lubin, Polkowice-Sieroszowice and Rudna mines.

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

In 2015, anticipated economic resources of copper and silver ores amounted to 1,976.04 Mt, whereby metallic copper amounted to 35.57 Mt and silver amounted to 107.46 kt (Tab. 2.2.1). Anticipated economic resources of copper ores in exploited deposits in the area of the Fore-Sudetic Monocline are 1,389.12 Mt (27.18 Mt of metallic copper and 81.95 kt of silver) – this accounts for about 70% of total anticipated economic resources. Economic resources of these deposits amounted to 1,162.24 Mt.

The figures 2.2.1–2.2.3 show resources and production of Cu and Ag ores and changes in resources and output of metallic copper and metallic silver in Poland in 1989–2015. There are also prices of metallic copper and silver presented (Fig. 2.2.2 and 2.2.3).

Tendencies for ores and metals (copper and silver) are very similar. Anticipated economic resources of copper ores decreased in 1989–2015 from 3.38 bnt to 1.98 bnt, mainly due to changes in criteria for evaluating anticipated economic resources. Copper ore resources occurring below a depth of 1,250 m were excluded from the Polish mineral resources balance in 1995. The resource drop also took place because of exploitation and losses. A significant increase was recorded in 1998 when a new Cu ore deposit (Głogów Głęboki) was documented. Anticipated economic resources of copper and silver ore decreased systematically in 2012–2014 because of exploitation to increase again in 2015 by 239.16 Mt in comparison to the previous year in result of documentation of a new deposit – Radwanice-Gaworzyce (in place of the earlier documented deposits: Gaworzyce, Radwanice-Wschód, Radwanice-Zachód).

Copper prices increased significantly in 2004–2007 and again in 2010–2011 reaching the level of almost 9,000 USD/t. This was the result of a supply shortfall, investments fund activities and lingering high Chinese import. The rapid drop in 2012–2015 was caused by declining demand from the Chinese market, a high level of international stocks, the policy of the US central bank and a pull-out of investors from commodity markets. The price of silver has been systematically increasing in 2002–2011 due to growing demand in the electronic industry sector, declining national reserves and increasing investment demand. Reduced investment supply and maintaining industrial demand were the main reasons for the price drop in 2012–2015.

Output of copper and silver ores, metallic copper and silver has been fluctuating in the 1989–2015. Generally, it systematically increased in 1992–2001 for ores and in 1992–2004 for metallic copper. As for metallic silver, substantial fluctuations took place in

Table 2.2.1. Copper and silver ores resources

ore [Mt]
copper [Mt]
silver [kt]

	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**	**1,976.04** ***35.57*** ***107.46***	**1,897.56** ***34.45*** ***102.87***	**78.48** ***1.12*** ***4.59***	**802.07** ***13.11*** ***41.84***	**1,169.90** ***22.91*** ***69.36***
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	5	1,389.12 *27.18* *81.95*	1,389.12 *27.18* *81.95*	–	1.81 *0.02* *0.06*	1,162.24 *22.77* *69.15*
Including resources of non-exploited deposits						
DEPOSITS COVERED BY DETAILED EXPLORATION	5	563.15 *8.14* *24.42*	492.44 *7.08* *20.16*	70.71 *1.06* *4.27*	782.18 *12.96* *41.10*	7.66 *0.14* *0.22*
Including abandoned deposits						
ABANDONED DEPOSITS	5	23.77 *0.26* *1.08*	16.00 *0.19* *0.76*	7.77 *0.06* *0.32*	18.08 *0.13* *0.68*	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 31

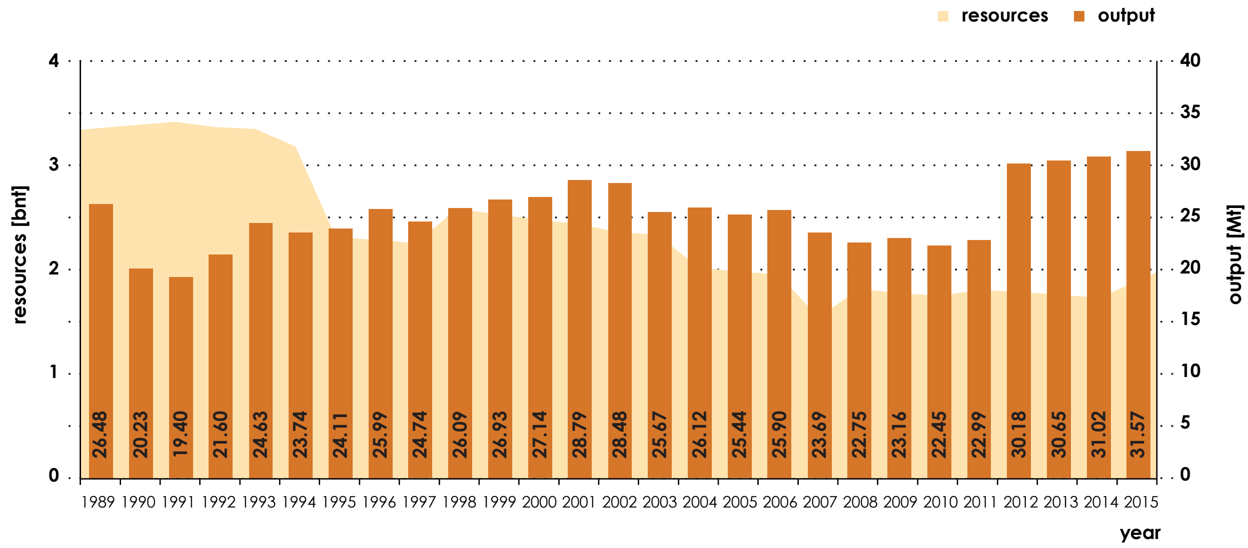


Fig. 2.2.1. Copper ores anticipated economic resources and output in 1989-2015

According to: "The balance of mineral resources deposits and groundwater resources in Poland" (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al*., 2007, 2008; Wołkowicz *et al*., 2009–2010; Szuflicki *et al*., 2011); "The balance of mineral resources deposits in Poland" (in Polish; Szuflicki *et al*., 2012–2015)

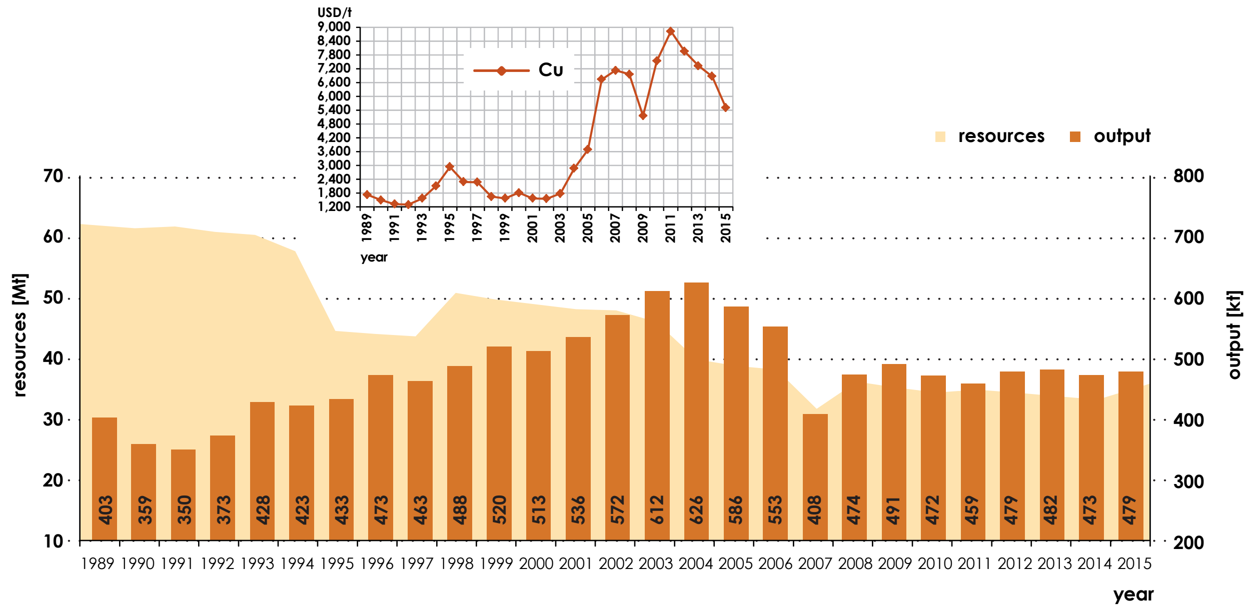


Fig. 2.2.2. Copper anticipated economic resources, output and annual prices in 1989–2015 (London Metal Exchange)

Resources and output according to: "The balance of mineral resources deposits and groundwater resources in Poland" (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al*., 2007, 2008; Wołkowicz *et al*., 2009–2010; Szuflicki *et al*., 2011); "The balance of mineral resources deposits in Poland" (in Polish; Szuflicki *et al*., 2012–2015)
Prices according to World Metal Statistics Yearbook (1989–2015)

1989–1996 and then resources increased until 2002. Thereafter, periods of nine-year, three-year and five-year drops were recorded. In 2011–2015, ore output has been increasing whereas metallic copper after significant growth in 2008 (from three deposits: Lubin-Małomice, Rudna and Sieroszowice) stayed at the same level. Silver output grew until 2011 by 75% – especially from Lubin-Małomice in 2008 and from Sieroszowice in 2011 – and after an evident drop in 2012 has not changed for the last three years. The highest increase of copper ores output in all of the five exploited deposits took place in 2012, when ex-

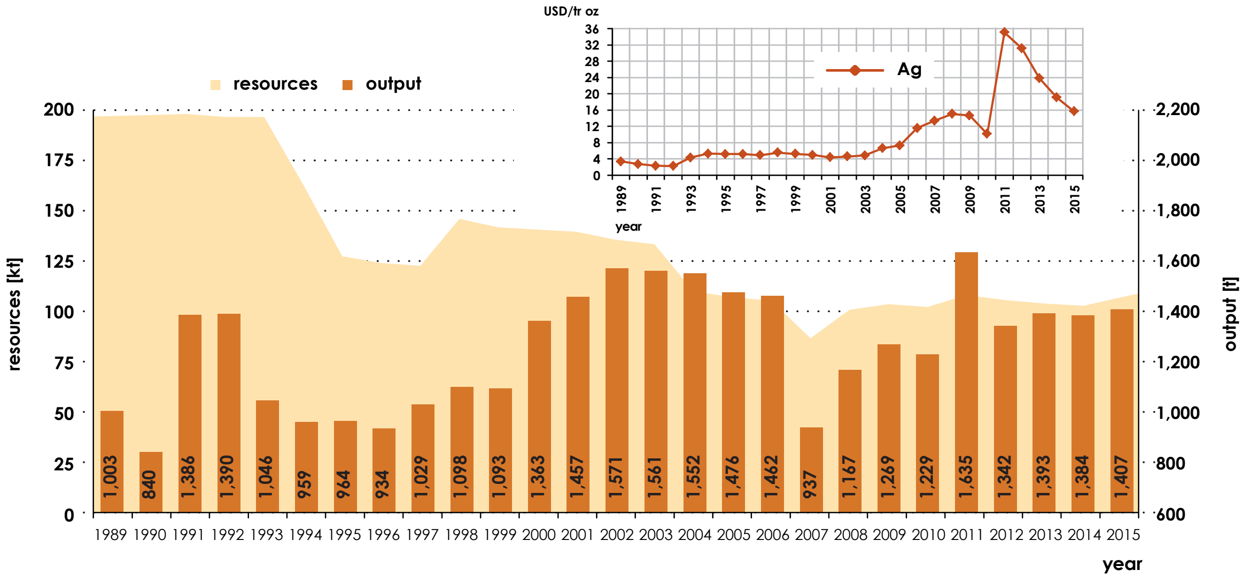


Fig. 2.2.3. Silver anticipated economic resources, output and annual prices in 1989–2015 (London Metal Exchange)

Resources and output according to: "The balance of mineral resources deposits and groundwater resources in Poland" (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); "The balance of mineral resources deposits in Poland" (in Polish; Szuflicki *et al.*, 2012–2015)
Prices according to World Metal Statistics Yearbook (1989–2015)

ploitation increased by about 30% in comparison to the previous year. In the next three years, output stayed at a quite stable level. In 2015, copper mining produced 31,568 kt of copper and silver ore yielding 479 kt of copper and 1,407 t of silver. In comparison to 2014, production of copper ore slightly increased (by 1.8%), with recovery of silver and production of metallic copper increasing by 1.7% and 1.3%, respectively.

In 2015, the KGHM Polish Copper Combine S.A. produced 574.3 kt of electrolytic copper, including 420.5 kt from own concentrates and 153.8 kt from imported concentrates. Moreover, 2,703 kg of gold and 9.17 t of rhenium – both from own and imported concentrates – was produced.

Other metals recovered from copper ores include Ag, Au, Ni, Pb, Pt-Pd, Se, Re and also sulfuric acid as a by-product. Recovery of silver has the largest economic importance. According to data provided by the KGHM Polish Copper Combine S.A., the copper processing in 2015 was accompanied by recovery of 1,283 t of silver, 431 kg of gold, 29 kt of lead, 2.97 kt of nickel sulfate, 86.98 t of selenium, 137 kg of Pt-Pd concentrate as well as sulfuric acid and copper sulfides.

2.3. Iron, titanium and vanadium ores

S.Z. Mikulski

In Poland, iron ores were exploited from the 1950s to the 1970s in several mines situated in the Częstochowa, Kielce and Łęczyca regions. The ores are hosted in sedimentary rocks in the form of accumulations of siderite nodules and iron-bearing limonitic sands. Resources of iron ores were deleted from the registry of Polish mineral raw material deposits by a decision of the Minister of the Environmental Protection, Natural Resources and Forestry in 1994 as failing to meet economic criteria. Since then, there has been no economic iron deposit documented in Poland.

Deposits of vanadium-bearing magnetite-ilmenite ores occur in anorthosite complexes of the Proterozoic Suwałki mafic massif (in north-eastern Poland) at depths from 850 m to 2,300 m. Deposits became known as a result of intense drilling exploration and an appraisal drilling program launched in the 1970s. In order to classify resources of ores, special economic criteria were elaborated and accepted in 1996. On the basis of these new criteria, ore resources of the Krzemianka and Udryń deposits were classified as sub-economic due to low content of metals, especially vanadium (from 0.26% to 0.31% V_2O_5 at the average) and occurrence at large depths.

At present, 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%, thus constituting only 1% of totally documented resources. However, large resources of shallow-seated or even exposed deposits of that type were recently discovered and proven in South Africa and several other places throughout the world. This renders any attempt to develop the ore deposits of the Suwałki area difficult to exploit in the foreseeable future. Their classification as sub-economic deposits is overly optimistic in present conditions. Moreover, any decision to start development of the Suwałki ore deposits would bring a very high risk of social and environmental conflict. Therefore, ores should be presently treated as an interesting geological object without any practical value and any greater economic importance. If this is the case, it can be stated that Poland does not have any iron ore deposits that could be the source of raw material for the steel industry.

A bog iron ore deposit in the Dębe Małe area is relatively small with resources estimated at 8,000 t. Its resources appear to lack use as raw material for the steel industry, but can easily find other industrial uses, especially as an adsorbent of H_2S, CO_2 and organic compounds of sulfur in cleaning combustion flue gases, as well as in other environmental activities.

2.4. Metals and elements coexisting in ores and other raw materials

S.Z. Mikulski

The group of mineral raw materials described in this chapter comprises different metals, which are co-occurring elements mainly in sulfide ore deposits. This is the case of Polish copper and zinc-lead deposits with fairly long records of various co-occurring elements. Elements – which often have a high market value – are already recovered or may become recoverable during the processing of these ores. Accumulations of some of these elements were covered by prospecting and exploration that often resulted in evaluations of their indicated/inferred resources. On occasion, their resources are documented.

Table 2.4.1. Elements co-occurring in ores and other mineral raw materials [kt]

Element	Copper ores	Zinc and lead ores	Total
ARSENIC (As)	–	4.80	4.80
GALLIUM (Ga)	–	0.13	0.13
GERMANIUM (Ge)	–	0.03	0.03
CADMIUM (Cd)	–	22.10	22.10
COBALT (Co)	122.36	–	122.36
MOLYBDENUM (Mo)	71.51	–	71.51
NICKEL (Ni)	71.11	–	71.11
SULFUR (S)	5,137.08	2,067.97	7,205.05
SILVER (Ag)	107.46	0.95	108.41
THALLIUM (Tl)	–	0.15	0.15
VANADIUM (V)	161.29	–	161.29

Rare earth elements and those named as dispersed elements were also found in beach sands of: Ławica Słupska (estimated resources: zirconium – 2 kt of $ZrSiO_4$; titanium – 12 kt TiO_2) and Ławica Odrzana deposit (geological resources approved in 2014: zirconium – 25.28 kt of $ZrSiO_4$, titanium – 156.78 kt of $FeTiO_3$, 20.23 kt of TiO_2), potassium-magnesium salts (boron – 6 kt; bromine – 7.2 kt) and saline waters and brines (32.16 Mm^3 of brines in the Łapczyca deposit). Data on boron, bromine, zirconium and titanium (except for the Ławica Odrzana area) originate from evaluations made in the 1960s and no new calculations have been made since then.

Table 2.4.1 shows a summary of estimations of the resources of major co-occurring elements as of 31 XII 2015.

2.5. Molybdenum-tungsten-copper ores

S.Z. Mikulski

The Myszków deposit of molybdenum-tungsten ores with copper is situated at the north-eastern margin of the Upper Silesian Coal Basin – UPCB (Plate 3) in the contact zone of the Małopolska Block and Upper Silesian Block separated by the Hamburg-Cracow Tectonic Zone. The deposit is of the Mo-W-Cu porphyry type. Its ore mineralization is of the stockwork type, forming a system of quartz veins with ore minerals, sulfides and oxides related to Variscan igneous activity. An intensive drilling program in 1975–1992 made detailed exploration of the Myszków deposit possible in an area of 0.5 km^2 and down to a depth of 1,300 m. Exploration conducted in 1993 allowed estimation of inferred resources of the Myszków in the Polish C_2 resources category (documentation prepared by the PGI). Anticipated economic resources of ores at a depth down to 1,000 m were estimated at about 380 kt, with 0.23 Mt of Mo, 0.18 Mt of W and 0.55 Mt of Cu and a mean content of Mo and W equal 0.049% and 0.041%, respectively.

In 2007, economic resources of the Myszków deposit were re-evaluated to find that they are markedly larger than previously estimated, exceeding 550 Mt of Mo-W-Cu ores. Anticipated economic resources of the deposit were estimated at about 0.295 Mt of Mo, 0.238 Mt of W and 0.8 Mt of Cu, and anticipated sub-economic resources – at 0.298 Mt of Mo, 0.212 Mt of W and 0.771 Mt of Cu. The Myszków ores have not yet been exploited. According to 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.

Molybdenum co-occurs with other metals in ores of the porphyry type mentioned above as well as in the stratabound copper deposits in the Fore-Sudetic Monocline and coal deposits in the USCB. However, nowadays applied technological processes are not aimed at separation of this metal.

Numerous occurrences of Mo-W mineralization have been found in zones of Late Carboniferous granitoid intrusions in the Sudety Mts., but no concentrations of economic importance were found thus 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).

2.6. Nickel ores

S.Z. Mikulski

Nickel ore deposits occur in the Lower Silesian region (Plate 3). These are deposits of Ni oxide ores formed as a result of weathering of serpentinized Paleozoic ultramafic rocks. Exploitation of the major Ni ore deposit at Szklary in the vicinities of Ząbkowice Śląskie was stopped in 1983 as uneconomic. Anticipated economic resources of Ni ores increased significantly in 2014 due to the documentation of a new deposit – Szklary 1. This deposit was allocated from the Szklary-Szklana Góra deposit. Therefore, anticipated economic resources (B and C_1 category) amounted to 17.21 Mt (Tab. 2.6.1) of ores with content of

Table 2.6.1. Nickel ores resources

ore [Mt]
metallic nickel [kt]

	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**	**17.21** ***0.13***	**17.21** ***0.13***	**–**	**21.32** ***0.08***	**–**
Including resources of non-exploited deposits						
1. DEPOSITS COVERED BY DETAILED EXPLORATION	1	4.37 *0.02*	4.37 *0.02*	–	–	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	1	–	–	–	13.88 *0.05*	–
Including abandoned deposits						
ABANDONED DEPOSITS	3	12.84 *0.10*	12.84 *0.10*	–	7.44 *0.03*	–

metallic Ni of 125.0 kt (limiting content of Ni in the deposit is 0.8%). Ore resources of the Grochów deposit were classified as anticipated sub-economic.

Nickel is also an accompanying metal in Cu ores of the Zechstein Kupferschiefer formation from the Fore-Sudetic Monocline. Copper deposits yield about 71.11 kt of Ni that is recovered in technological processes as nickel sulfides. This recovery has been fluctuating in the last four years (2012–2015) at about 0.6–0.8 kt of nickel. In 2015, the processing of copper sulfide ores gave 2,967 t of nickel sulfides.

Prognostic resources of Ni-layer silicate type ores in small and separate lenses in serpentinite waste around the Sowie Mts. block gneisses (Lower Silesia) are estimated at ca. 25 kt (Mikulski, 2012).

2.7. Tin ores

S.Z. Mikulski

Tin is used to produce of a wide variety of useful alloys, 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 such application decreases due to growing replacement of tin with other materials.

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

In Poland, tin ores are found in two deposits, Gierczyn and Krobica, in the Stara Kamienica Lower Paleozoic Schist Belt in the Sudety Mts. (Plate 3). Tin resources of these deposits were classified as anticipated sub-economic and were estimated at 4.6 Mt of ore with Sn content of about 0.5% at the average. Perspective resources of tin ore in the entire area of the Stara Kamienica Schist Belt were estimated at about 20 Mt, with content of metallic tin of about 100,000 t (Michniewicz, 2011).

2.8. Zinc and lead ores

A. Malon, S.Z. Mikulski, M. Tymiński

The area of northern and north-eastern margin of the Upper Silesian Coal Basin (USCB) has a long tradition of zinc and lead mining dating back to the Middle Ages. Deposits in that area are related to carbonate rock formations of the Silesian-Cracow region with Permian-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 to ore accumulations in the so-called Ore-bearing Dolomites of the Muschelkalk (Middle Triassic). 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 Zn-Pb mineralization of the so-called Mississippi Valley type (MVT).

Four areas of Zn-Pb ore deposits have been recognized in the Silesian-Cracow region: Chrzanów, Bytom, Olkusz, Zawiercie (Plate 3). Klucze I, Olkusz and Pomorzany deposits in the Olkusz area are currently under exploitation. Zinc and lead deposits of the Bytom region are of historical and scientific importance only. The deposits have been exhausted as a result of exploitation conducted since the Middle Ages, now comprise some sub-economic accumulations, mainly of Zn-oxide ores. The same situation is recorded for the Balin-Trzebionka deposit in the Chrzanów region, where a mine was closed in 2010, because reserves have been exhausted. Exploitation of deposits in the fourth region (Zawiercie) has not yet begun. Presently, exploration and documentation works are carried out within concession areas in this region.

Zinc and lead concentrations also occur in Cu and Ag ores of the Zechstein 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 data provided by KGHM Polish Copper S.A., 29.00 kt of Pb was recovered during smelter copper processing in 2015.

The highest increase of sulfide Zn-Pb ore resources can be expected in the Silesian-Cracow region. Prognostic resources in the Olkusz region were estimated at 50 Mt and 15 Mt in the Zawiercie region – at 15 Mt as of 31 XII 2009 (Mikulski *et al.*, 2011). Zinc oxide ore (galman) prognostic resources are assessed to be 60 Mt, including 51 Mt in abandoned deposits and 9 Mt in mining spoil heaps.

Estimates of Zn-Pb ores resources of the Silesian-Cracow region markedly changed during the last 50 years. These changes resulted on one hand from intense exploration of deposits and on the other from deletion of resources of zinc oxide ores (galman ores) from official records of domestic resources. These decisions to delete resources were related to high occupational and environmental hazards associated with technology used at that time in oxide ore processing. Technological problems were finally solved and, therefore, it appeared necessary to introduce special criteria for classification of zinc oxide ore resources not meeting those for sulfide ores. Such separate criteria for zinc oxide ore resources were established by a Regulation of the Minister of the Environment on classification for mineral reserves and resources dated 9 January 2007. According to the Geological and Mining Law in effect since 1 January 2012, there are separate criteria for sulfide and oxide ores deposits called as "limit values of parameters that define a deposit and its boundaries".

Anticipated economic resources of Zn-Pb ores as of 31 XII 2015 were 83.82 Mt of ore yielding 3.57 Mt of zinc and 1.42 Mt of lead (Tab. 2.8.1). These resources of Zn-Pb ores generally decreased in 1989–2015 from 343 Mt to almost 80 Mt – mainly due to changes in criteria to estimate anticipated economic resources and exclude certain resources from the Polish mineral resource balance (years: 1991, 1992, 2008; Fig. 2.8.1). That decrease of resources was due to exploitation and losses. In the last four years (2012–2015), resources decreased in 2012–2013 and 2015 due to exploitation and increased (about 12 Mt) in 2014 as a result of documentation of a new deposit – Zawiercie 3 (in place of the deposits: Zawiercie I and Zawiercie obszar Zawiercie II).

In 2015, Polish mines extracted 2,241 kt of ores yielding 65 kt of zinc and 20 kt of lead. There deposits are currently exploited: Klucze I (197 kt of ore in 2015), Olkusz (473 kt) and Pomorzany (1,571 kt). It should be noted that domestic production of ores is too small for full use of the production potential of Zn-Pb processing plants. The exploitation of Zn-Pb ores decreased in 1989–2015 from 4.22 Mt to 2.24 Mt (Fig. 2.8.1). The main exploitation drop took place in 2009 due to closure of the Balin-Trzebionka mine. In the last four years, exploitation has decreased systematically as well – from 2.33 Mt in 2012 to 2.24 in 2015. Exploitation is expected to end in the next years due to depletion of exploited deposit resource.

Table 2.8.1. Zinc and lead ores resources [Mt]

ore
metallic zinc
metallic lead

	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**	**83.82** ***3.57*** ***1.42***	**33.97** ***1.46*** ***0.62***	**49.85** ***2.10*** ***0.79***	**420.56** ***13.45*** ***3.71***	**5.53** ***0.23*** ***0.10***
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	3	13.94 *0.55* *0.22*	13.94 *0.55* *0.22*	–	7.17 *0.24* *0.13*	5.53 *0.23* *0.10*
Including resources of non-exploited deposits						
TOTAL	13	69.88 *3.02* *1.20*	20.04 *0.92* *0.40*	49.85 *2.10* *0.79*	9.43 *0.41* *0.15*	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	6	63.58 *2.76* *1.07*	20.04 *0.92* *0.40*	43.54 *1.84* *0.67*	6.74 *0.29* *0.12*	–
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						
ABANDONED DEPOSITS	4	–	–	–	403.97 *12.80* *3.43*	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 31

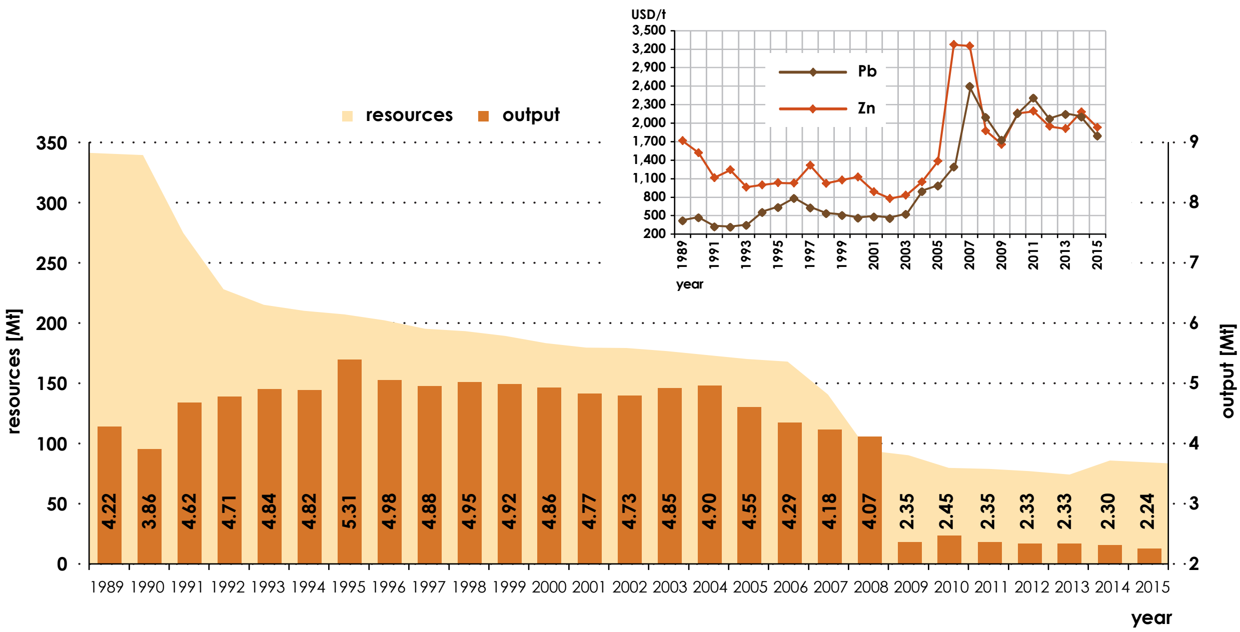


Fig. 2.8.1. Zinc and lead ores anticipated economic resources, output and annual prices in 1989–2015 (London Metal Exchange)

Resources and output according to: "The balance of mineral resources deposits and groundwater resources in Poland" (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); "The balance of mineral resources deposits in Poland" (in Polish; Szuflicki *et al.*, 2012–2015)
Prices according to World Metal Statistics Yearbook (1989–2015)

Figure 2.8.1 shows prices of zinc and lead. The prices remained at a quite stable level until 2003 and to increase significantly in 2004–2007. That was due to a decline in supply on the international market as the result of liquidation or suspended production at mining plants. Simultaneously, there was growing demand on Asian markets, especially China, whereby stocks were reduced. The next two years brought a price drop due to a supply surplus. Price growth in 2010 and 2011 was the result of growing demand, which decreased slightly in the next four years and prices declined to a level below 2,000 USD/t.

2.9. Sands with heavy minerals

K. Szamałek

Sands with placer heavy minerals are recognized and documented in the Baltic Sea – Zatoka Pomorska (Polish Exclusive Economic Zone; Tab. 2.9.1).

The share of heavy minerals in sands is variable. Heavy minerals content is varying from 1.4% to 21.7% in the sediment layer from the sea-bottom surface to a depth of 0.5 m (an average of 4.4–4.5%). The content of heavy minerals is 2.0–4.2% in the sand layer to a depth 0.5–1.0 m below the sea-bottom (an average 2.5–3.3%). As a marginal criterion for deposit determining accepted the isoline of 2.0% heavy minerals content. Recognized heavy minerals of the Ławica Odrzana deposit are: ilmenite ($FeTiO_3$), rutile (TiO_2), zircon ($ZrSiO_4$) as well as garnets $(Fe, Ca, Mg, Mn)_3(Al, Fe, Cr)_2(SiO_4)_3$. The contribution of individual minerals in the overall mass of heavy minerals is: ilmenite – 31%, zircon – 5%, leucoxene – 4%, rutile – 4%, and garnets – 32%.

Heavy minerals from the Ławica Odrzana deposit can be used for the production of pigments and coatings as well as high strength steel, in biomedical engineering, ceramics and glass, in the nuclear power industry and in the manufacture of abrasives and fibers. Silica sands remaining after the separation of heavy minerals can be used in the glass industry, in the manufacture of molding sand and also in the construction industry.

Tab 2.9.1. List of sand deposits with heavy minerals [kt]

sands
zircon
garnet
ilmenite
leucoxene
rutile

Name of deposit	The state of development	Resources		Output	County
		Anticipated economic	Economic		
TOTAL NUMBER OF DEPOSITS: 1		**13,323.20** ***25.28*** ***161.84*** ***156.78*** ***20.23*** ***20.23***	–	–	–
ŁAWICA ODRZANA	P	13,323.20 *25.28* *161.84* *156.78* *20.23* *20.23*	–	–	Bałtycki Obszar Morski

3. Chemical raw materials

3.1. Barite and fluorspar

R. Bońda

Due to its high specific gravity, barite ($BaSO_4$) is now primarily as a weighting agent in well drilling. Its use in the paper, chemical and paint industry is gradually shrinking to the advantage of chemically produced titanium white (titanium dioxide).

Fluorspar (CaF_2) is used as a flux in metallurgy (in steel production to facilitate the removal of impurities, and in production of aluminum), also in the 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 here. Economic accumulations of barite also occur in the Świętokrzyskie Mts. (Plate 4). In 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

Table 3.1.1. Barite and fluorspar resources [Mt]

	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						
ABANDONED DEPOSITS	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						
ABANDONED DEPOSITS	1	0.54	–	0.54	–	–

that of fluorite – from several to over a dozen percent. The content of fluorite generally increases with depth. The mine exploiting Boguszów deposit was completely flooded during a catastrophic flood in July 1997. It was abandoned as a result of that damage and the deposit was reclassified as only potentially economic. The following year, in 1998, mining operations at the Stanisławów deposit were also abandoned as insufficiently profitable. Some decades ago, barite was also extracted from the Strawczynek deposit in the Świętokrzyskie Mts. 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 due to low content of $BaSO_4$ (about 30%) and small resources of the deposit. Entire domestic demand for barite and fluorspar is nowadays covered by import.

Anticipated economic resources of barite are estimated at 5.66 Mt and those of fluorspar at 0.54 Mt (Tab. 3.1.1). Evaluations of resources have not changed in 2011–2015. Given increasing demand for barite there are plans to restart exploitation of its deposits (especially in Stanisławów). Prognostic resources of barite amounted to 2.5 Mt and perspective resources at 1.67 Mt as of 31 XII 2009 (Sroga, 2011a).

3.2. Clay raw materials for production of mineral paints

R. Buńda

Mineral pigments were the main material for production of mineral paints in the past. Presently, they are replaced by chemical pigments. Nevertheless, they can be also used for making oil paints, varnishes, enamels, putties etc. Chalk, barite, gypsum and burnt lime are also used as mineral fillers and weighting agents in the production of mineral paints.

The most important pigments include: ochre, umbra, terra di Siena, iron minium, browns and earth green.

In Poland, two deposits of ochre, argils and ochre claystones have been explored thus far. They are both located near Kielce – Buk and Baczyna deposits (Świętokrzyskie province – Plate 4). In these deposits, ochre forms lens accumulations in argillic measures of the Rhaetic–Liassic.

There are three types of ochre occurring in the Baczyna deposit. They are documented in the C_1 category: yellow, red and brown. This deposit has never been exploited. The Buk deposit was exploited until 1976. Presently, there are only anticipated sub-economic resources documented in this deposit. Anticipated economic resources of clay raw materials for the production of mineral paints amounted to 578.1 kt in 2015 and have not changed in the last 5 years.

3.3. Diatomaceous rock

R. Buńda

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

In the Leszczawka area (Carpathians) diatomite rocks with SiO_2 content of 72% on 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 use is in the production of light building aggregates and carriers for herbicides and fungicides. Technological tests show that appropriate processing (grinding and calcination) may improve quality of this raw material to that of proper diatomites.

Table 3.3.1. Diatomaceous rock resources [Mt]

	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**	**10.02**	**3.28**	**6.74**	**2.74**	**0.20**
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	1	0.64	0.44	0.20	–	0.20
Including abandoned deposits						
ABANDONED DEPOSITS	3	9.38	2.84	6.54	2.74	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 31

Anticipated economic resources of diatomite rocks are more than 10 Mt. Since 2000, only one deposit, Jawornik, has been exploited. In previous years, diatomite rocks were also occasionally extracted from the Kuźmina deposit, but that operation was halted in 2001. In 2015, extraction of diatomite was carried out on a small scale (0.60 kt; Tab. 3.3.1).

Further detailed exploration may markedly increase hitherto known resources of this raw material. Perspective resources of diatomaceous rock in the Leszczawka area are estimated at about 10 Mt. Chances for discovery of new large diatomite deposits appear to be the highest in the Menillite Series of the Krosno Beds in the areas of Godowa, Błażowa-Piątkowa-Harta-Bachórz and Dydynia-Krzywe (Podkarpackie province).

3.4. Potassium and magnesium salts

G. Czapowski

In Poland, distribution of potassium-magnesium salts is 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 throughout the Polish Lowlands, where they were recorded in countless drillings as well as several salt structures in central Poland and in layers in the southwestern part of the Fore-Sudetic Monocline (Plate 4).

Anticipated economic resources of the five proven potassium-magnesium salt deposits were estimated at 670 Mt and anticipated sub-economic resources at 20 Mt (Tab. 3.4.1). Sulfate (polyhalite) salt deposits of the Puck Bay form the bulk of these resources. Deposits of the Puck Bay area are of the sulfate (polyhalite) salt type with polyhalite occurring in the form of early diagenetic minerals developed in anhydrite layers that underlay, intercalate and overlay the oldest rock salt bed of the Zechstein. Polyhalite inclusions are present in the form of irregularly disseminated nests and aggregate intergrowths at depth interval from 740 m to 900 m. K_2O content ranges from 7.7% to 13.7% in that depth interval. Deposits situated along the rim of the Puck Bay rock salt deposit were covered by preliminary exploration in 1964–1971. Their indicated resources were estimated at 597 Mt assuming regular distribution of polyhalite mineralization.

Small accumulations of potassium salts (more than 72 Mt) were identified along the eastern margin of the Kłodawa salt dome, where salts of a potassium chloride type (carnalite and sylvine) occur in rocks of the Younger Potash unit, steeply inclined (at an angle of 70°), folded, locally squeezed and crumpled. Chloride salts are strongly contaminated with clay matter and sulfates. Mean content of K_2O and MgO is 8.5% and 8.1%, respectively. Potassium salt accumulations are of minor economic importance due to high variability in the thickness of strata (from several to 50 m) and problems in processing that raw material. Salts were exploited seasonally until 2000 when 1,400 t were mined. In the following years this part of the salt deposit was abandoned.

Table 3.4.1. Potassium-magnesium salt resources [Mt]

	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 were explored to a depth of 1,200 m. Two metre thickness is accepted as the minimum, providing that weighted average K_2O content in a deposit is not less than 8%. Potassium-magnesium salt resources slightly changed since 2010 (anticipated economic resources increased by 0.73 Mt and anticipated sub-economic resources – by 1.46 Mt) due to resource verification of the new established Kłodawa 1 deposit in 2010.

In 2015, predicted resources of potassium-magnesium salts in stratiform occurrences were estimated at 3,638 Mt, including prognostic resources (to a depth of 1.2 km) of 821.5 Mt and perspective ones (at a depth of 1.2–2.0 km) of up to 2,816.6 Mt (Czapowski *et al.*, 2015). Their perspective resources in the Kłodawa dome amounted to 300 Mt at a depth interval between 1–2 km (Czapowski, Bukowski, 2011).

Table 3.4.1 shows resources and the current state of exploration and development of potassium-magnesium salts. The data refer to exploitable resources (except those remaining in safety pillars).

Potassium-magnesium salts have not been exploited in Poland since 2000 (the year when 1 kt of these salts was excavated in the Kłodawa salt dome) and their anticipated economic resources have not changed significantly in the last 15 years.

3.5. Rock salt

G. Czapowski

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) as well as extending along and close to the present-day frontal overthrust of the Carpathian Mts. on their Foredeep. In the Wieliczka area, salt was produced from the Middle Ages through to the 20th century. Exploitation of these deposits ended in 1996 when salt mining was phased out at the Wieliczka mine. Proven resources of Miocene rock salt deposits are estimated to exceed 4.36 bnt, thus accounting for 5.1% of domestic resources. However, the geological structure of these deposits is very complex due to intense folding (except for the Rybnik-Żary-Orzesze deposit that is situated in a tectonic trough). Such complexity of the geological structure together 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 unfeasible. The Wieliczka mine was placed on a list of UNESCO World Heritage sites in 1978. Presently, the Wieliczka and Bochnia mines are great tourist attractions and recreation centres.

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 the country area, mainly in the Polish Lowlands (Plate 4). In the Late Permian, these areas were occupied by the evaporitic epicontinental basin that was the place of accumulation of salt sediments with total thickness of over 1,000 m. Bedded rock salt accumulations were explored down to a 1,000 m depth in the marginal parts of the basin (in areas of the Łeba Elevation and the Fore-Sudetic Monocline). Anticipated economic resources of these deposits are estimated at over 26.1 bnt, which accounts for 30.6% of domestic salt resources. In turn, the salt-bearing series are buried at depths up to 7 km in the axial part of the basin (Central Poland), locally rising almost to the surface in salt dome- and pillow-like structures. Salt structures occur in a belt stretching from Wolin Island in the northwest to the vicinities of Bełchatów in the southeast. Deposits of rock salt and potassium-magnesium salt were explored and documented in a number of the shallowest parts of these structures. Proven anticipated economic resources of deposits related to the salt structures are estimated at almost 54.9 bnt, which accounts for 64.3% of domestic salt resources. Exploitation of the Zechstein salt deposits provides 100% of the current domestic production of salt.

Large bedded rock-salt deposits were also explored in the overburden of the Sieroszowice and other copper ore deposits in the Fore-Sudetic Monocline. Since 2013, the Bądzów salt deposit was developed as a part of the Sieroszowice deposit to produce crushed road salt.

Bedded rock-salt deposits are explored down to a depth of 1,200 m providing that the deposit series (including partings) is at least 30 m thick with a minimum weighted mean of NaCl in the deposit series and partings equal at least 80%. In accordance with Polish regulations, salt deposits related to dome- and pillow-like structures are explored down to 1,400 m, providing that the distance between the top surface of salt deposits and salt mirror is not less than 150 m. Remaining requirements are the same as in the case of bedded deposits. At present, salt deposits begin to be treated as geological objects particularly advantageous for the construction of underground facilities to store oil and natural gas (the cavern gas storages Mogilno II in the Mogilno diapir and the Kosakowo gas storage in the Mechelinki stratiform deposit began to operate in 2014 and are planned to be enlarged), liquid fuel (abandoned caverns in the Góra diapir) and for safe disposals of hazardous materials.

Anticipated economic resources of rock salt (excluding those within protective pillars) in 19 deposits in 2015 were approximately 85.38 bnt, whereby anticipated sub-economic resources exceeded 40.17 bnt and economic resources in place exceeded 1.73 bnt (Tab. 3.5.1). Total salt production (prevailed brine produced by leaching mines Mogilno and Góra, subordinate volume of crushed salt is extracted from underground mines Kłodawa and Sieroszowice) from six deposits was more than 3.46 Mt. in 2015.

Table 3.5.1 shows resources and the current state of exploration and development of domestic rock salt deposits. Data refer to resources excluding those within protective pillars.

Anticipated economic resources of rock salt in Poland (excluding those within protective pillars) in the 1989–1992 period slowly increased from ca 74.64 bnt to 87.77 bnt and remained almost at the same level until 1994 (Fig. 3.5.1). Their subsequent growth in 1994 to over 121 bnt resulted from including into "The balance…" the estimated salt resources of 5 new copper deposits in the Fore-Sudetic Monocline area, in which these salts are recognized as associated raw minerals. Those resources were excluded in the following year (1995) and until 2006 the total volume of anticipated economic resources stabilized at the level of ca 80 bnt. From 2007 to 2009, resources increased to 85.4 bnt, mainly due to new assessments of Mogilno I, Mogilno II (in the Mogilno salt dome) and Mechelinki (near Puck Bay) resources. In the next three years, the resource volume remained almost constant (below 84 bnt). An increase to over 86 bnt in 2013 win the effect of activating the new Bądzów salt deposit with resources of ca 740 Mt. The following slight decrease to the present values resulted from salt production (Fig. 3.5.1).

Rock salt production changed significantly in the analyzed period. The main factor was domestic demand for brine used for calcined soda production and crushed salt. Output decreased from 4 Mt in 1989 to a critical 2.96 Mt in 1997 due to the aggregate effect of lower production in still existing mines and an end to extraction at the Wieliczka mine (Fig. 3.5.1). The next six years recorded fluctuations in output volumes (from 3.13 to 3.31 Mt), but significant growth to almost 4 Mt took place in 2004. In the 2005–2009 period, production decreased by 25% to ca 3 Mt. From 2010, a successive increasing tendency in annual salt production was observed (due to initiated construction of the Kosakowo Underground Gas Storage Facility, cavern leaching in the Mechelinki deposit and salt extraction at the new Bądzów deposit) to over 4 Mt in the 2013–2014 period. In 2015, the output decreased to less than 3.5 Mt (Fig. 3.5.1). This was the result of decreased production of solution mining Mogilno and Góra and crushed

Table 3.5.1. Rock salt resources [Mt]

	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	**19**	**85,378.49**	**45,201.97**	**40,176.52**	**22,122.99**	**1,735.79**
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	6	15,112.70	10,423.99	4,668.71	–	1,735.79
Including resources of non-exploited deposits						
TOTAL	10	70,077.82	34,698.22	35,379.60	21,937.44	–
DEPOSITS COVERED BY DETAILED EXPLORATION	3	22,533.87	20,882.81	1,651.07	9,990.28	–
DEPOSITS COVERED BY PRELIMINARY EXPLORATION	7	47,543.95	13,815.41	33,728.54	11,947.16	–
Including abandoned deposits						
TOTAL	3	187.97	79.77	108.20	185.56	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 31

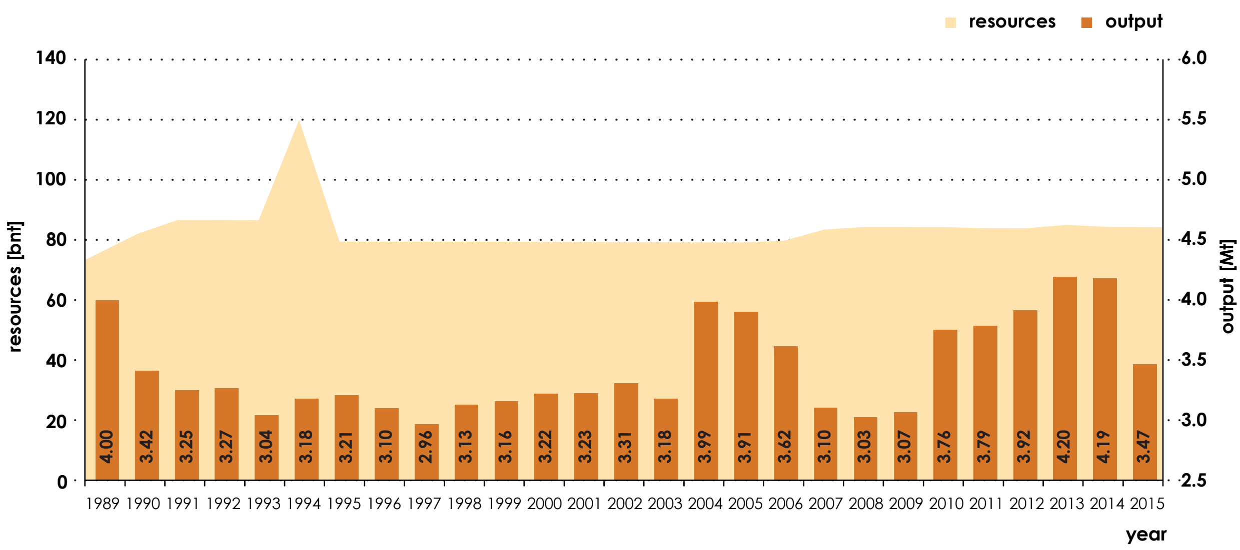


Fig. 3.5.1. Rock salt anticipated economic resources and output in 1989–2015

According to: "The balance of mineral resources deposits and groundwater resources in Poland" (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); "The balance of mineral resources deposits in Poland" (in Polish; Szuflicki *et al.*, 2012–2015)

salt mining Kłodawa and Sieroszowice in response to lower demand for road salt (warmer winters). Also, completion of construction of the first set of gas caverns at the Kosakowo Underground Gas Storage Facility led to decrease in production of brines whose entire volume was discharged into the Puck Bay.

The amounts of salt produced by the Dębieńsko Desalination Plant Ltd. from desalination of water from the Upper Silesian coal mines were rather small, fluctuating in the 2004–2015 period from 60 kt (2006–2007) to over 92 kt (in 2009). In 2015, this plant produced 81.4 kt.

In 2015, predicted resources of rock salts in both the stratiform and diapiric occurrences were estimated at ca 4,058.96 bnt including forecast resources (to a depth of 1.2–1.5 km) at ca 951.44 bnt and perspective ones (within a depth interval of 1.2–2.0 km) at up to 3,037.67 bnt (Czapowski *et al.*, 2015). The Zechstein salts with total resources of ca 4,052 bnt prevail over Miocene ones (6.9 bnt).

3.6. Siliceous earth

R. Bońda

Siliceous earth resembles diatomites in physical features and, therefore, finds similar use in industry. 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 refining and filtration and as a constituent of synthetic moulding mass. Siliceous earth differs from diatomites in the mode of origin as it is a product of decalcification of sedimentary rocks and mainly comprised of opal, a mineraloid gel.

Deposits of siliceous earth are mainly found in tectonic troughs at the margin of the Świętokrzyskie Mts. (Piotrowice and Dąbrówka deposits) and in the Lublin Upland (Lechówka deposit) in the form of sedimentary covers overlain by Oligocene rocks (Plate 4).

Table 3.6.1 shows resources and the current state of exploration and development of siliceous earth deposits in Poland. Anticipated economic resources amounted to 2,223 kt in 2015. Resources have not changed in the last several years. Presently, there is a concession for exploitation issued only for the Lechówka II deposit. It is the only siliceous earth deposit periodically exploited in Poland. Output from the Lechówka II deposit remained quite low, declining from several t in 1998–2002 to zero in 2013. The deposit has not been exploited since 2014. Exploitation of remaining deposits has been phased out in recent decades due to the unsatisfactory quality of obtained raw material, mainly usable for making insulation powder. Domestic demand for siliceous earth is fully covered by import.

Table 3.6.1. Siliceous earth [Mt]

	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**	**–**
Including abandoned deposits						
ABANDONED DEPOSITS	5	2.22	1.09	1.13	1.01	–

3.7. Native sulfur

R. Bońda

Native sulfur deposits occur in the northern part of the Carpathian Foredeep in the vicinities of Tarnobrzeg (Baranów Sandomierski-Skopanie, Grębów, Jamnica, Jeziorko-Grębów-Wydrza, Machów I and II, Osiek, Piaseczno, Rudniki, Świniary deposits), Staszów (Grzybów-Gacki, Solec, Wola Żyzna deposits) and Lubaczów near the Polish-Ukrainian border (Basznia and Basznia-1 deposits; Plate 4). Sulfur is found in the form of fillings of fissures and small cavities in chemical sediments of Miocene (Tortonian) in age, mainly post-gypsum limestones. Its origin was tied to the reduction of calcium sulfate (gypsum) by microorganisms in the presence of hydrocarbons. Sulfur content in these rocks is 25–30% (70% at the most).

Table 3.7.1. Native sulfur resources [Mt]

	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**	**504.92**	**448.50**	**56.42**	**35.76**	**19.34**
Including resources of exploited deposits						
TOTAL	1	19.34	19.34	–	0.66	19.34
Including resources of non-exploited deposits						
TOTAL	8	262.75	207.22	55.53	14.64	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	5	164.99	164.99	–	5.89	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	3	97.75	42.23	55.53	8.76	–
Including abandoned deposits						
TOTAL	6	222.83	221.94	0.89	20.46	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 31

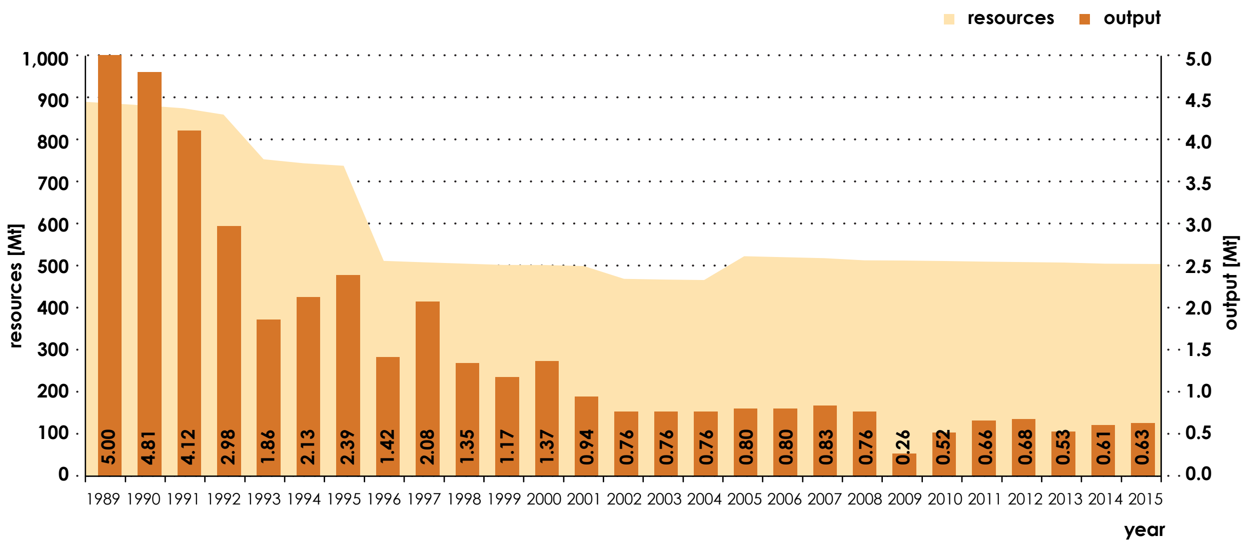


Fig. 3.7.1. Native sulfur anticipated economic resources and output in 1989–2015

According to: "The balance of mineral resources deposits and groundwater resources in Poland" (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); "The balance of mineral resources deposits in Poland" (in Polish; Szuflicki *et al.*, 2012–2015)

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

Anticipated economic resources of sulfur amounted to 505 Mt in 2015, of which 78% (395 Mt) comprise resources within Tarnobrzeg vicinities (Tab. 3.7.1). In 2015, a new deposit was documented – Basznia 1 (with resources of 6,056 kt) – it was allocated from the abandoned Basznia deposit (phased out in 1993). Resources of native sulfur have systematically declined in the last 4 years (2012–2015) due to exploitation and losses (Fig. 3.7.1). Anticipated economic resources of native sulfur amounted to almost 900 Mt in 1989. In 1992 and 1993, they decreased mainly as a result of lower estimates of resources approved for the Machów I and II, and Jamnica deposits. Until 1995, resources were presented in "The balance..."

altogether with the resources trapped in the protective pillars; since 1996 there have only been resources beyond the pillars shown. This caused a resource drop – by over 200 Mt. In 2002, resources declined due to depletion of the Jeziórko-Grębów-Wydrza deposit. A new deposit – Grębów – was documented in 2005, thus increasing resources by 57 Mt. Since 2006, anticipated economic resources have remained at level of above 500 Mt, declining slightly due to further exploitation of the Osiek deposit.

Production of native sulfur is carried out only from the Osiek deposit where sulfur is mined from the surface using the Frasch hot water method. It amounted to 627.60 kt in 2015. 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. Output from the Osiek deposit has been oscillating within the range of 500–800 kt recently. In 2009, only about 260 kt was exploited due to a rapid drop of sulfur export and declining import.

Native sulfur output was 5 Mt in 1989 and decreased eight-fold by 2015 as a result of closure of successive mines (Fig. 3.7.1). In the 1990s, there were 5 native sulfur mines in operation, whereas there is only one at present. In 1993, output dropped to 1.86 Mt mainly due to Machów I deposit phase out.

3.7.1. Sulfur as a by-product

There are 4 sulfhuric gas and oil fields in Poland. Their total resources of S were estimated at 475.36 kt (Fig. 3.7.1.1). In 1996, sulfur resources were approved in oil-gas fields: BMB (Barnówko-Mostno-Buszewo) and Zielin. In the next 2 years sulfur resources were documented in the Cychry high nitrogenous natural gas field and the Górzyca oil-gas field. Sulfur resources increased in 2006 from 586 kt to 674 kt as a result of new documentation with recalculated resources approved for the BMB field. Since 2007, resources of S co-occurring in crude oil and gas fields have been systematically decreasing due to its recovery from exploited hydrocarbons.

Sulfur recovery from sour oil and gas fields in Poland is carried out at 4 deposits and amounted to 23.82 kt in 2015 (Fig. 3.7.1.1). Sulfur has been extracted from the Zielin and BMB fields since 1997 and from the Cychry field since 1998. In 2005, temporary recovery started from the Górzyca field. Total domestic recovery from oil-gas fields in Poland has remained at a level 23–25 kt and has had rather limited importance for the domestic economy.

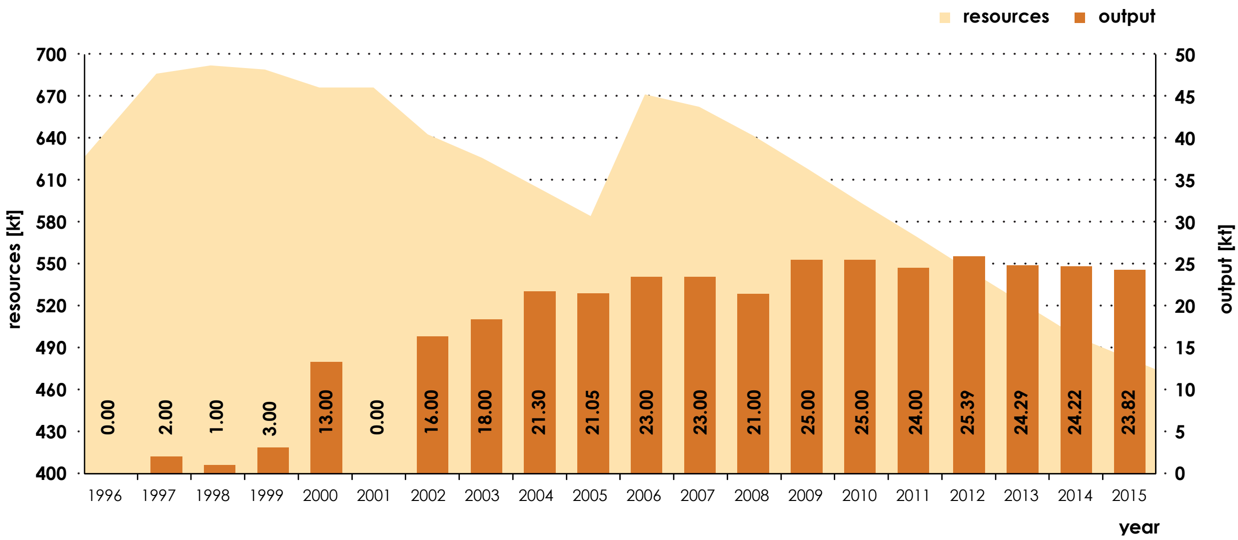


Fig. 3.7.1.1. Sulfur as a by-product anticipated economic resources and output in 1996–2015

According to: "The balance of mineral resources deposits and groundwater resources in Poland" (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al*., 2007, 2008; Wołkowicz *et al*., 2009–2010; Szuflicki *et al*., 2011); "The balance of mineral resources deposits in Poland" (in Polish; Szuflicki *et al*., 2012–2015)

4. Rock raw materials

4.1. Bentonites and bentonitic clays

D. Brzeziński

Primary bentonites are clayey rocks produced as a result of a weathering of extrusive and pyroclastic rocks (tuff or tuffite) and usually display a parent rock structure. In turn, bentonite clays originate from a redeposition of bentonite material and often yield a fairly large admixture of foreign mineral components. Bentonite clays forming a weathering mantle developed at 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, susceptibility to dispersion of water and easy absorption of cations and organic substances from water solutions. Therefore, these rocks are utilized, for example, in the foundry, chemical and ceramic industries, in engineering and hydrotechnical works, in agriculture and also serve as a component of drilling fluid.

In Poland, typical bentonites, i.e. containing more than 75% montmorillonite, are very rare. More common are bentonite clays such as those of bentonite weathering cover of basalts in Lower Silesia, bentonite clays from Upper Silesia, bentonite clays from southern fringes of the Świętokrzyskie Mts., and bentonite clays from the Carpathians (Plate 7).

In 2015, anticipated economic resources amounted to 2.88 Mt, whereas economic resources totalled 0.34 Mt (Tab. 4.1.1). There are two deposits with an approved exploitation concession – Jawor-Męcinka and Krzeniów (Dolnośląskie province). Bentonites of mantle rock (accompanying raw material) of basalt tuff are exploited only in the Krzeniów deposit. Production of bentonites was only 450 t in 2015 and domestic demand is fully met by import.

Table 4.1.1. Bentonites resources [Mt]

	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**	**2.88**	**1.16**	**1.72**	**0.25**	**0.34**
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	1	0.49	0.28	0.21	–	0.34
Including resources of non-exploited deposits						
TOTAL	5	2.33	0.87	1.45	0.25	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	3	1.40	0.87	0.53	0.25	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	2	0.92	0.00	0.92	–	–
Including abandoned deposits						
ABANDONED DEPOSITS	2	0.07	0.01	0.06	0.01	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 31

Resources and output have not changed significantly since 2012. Resources increased in 2013 due to documentation of a new deposit (Dylągówka-Zapady in the Podkarpackie province) to remain at the level of about 2.9 Mt in 2014-2015. Bentonite output is still of limited importance as after growth from 0.78 kt into 1.05 kt in 2013, it declined to 0.65 kt and 0.45 kt in 2014 and 2015, respectively.

4.2. Building ceramics raw materials

W. Szczygielski

Basic raw materials for building ceramics production include various clayey rocks which together with water form a plastic mass and moulding sands used as an admixture to the clayey raw material to improve ceramic mass properties. The formed and burnt products must meet physical and technical specifications defined by standards. Clayey and non-clayey raw materials often occur together – in a single deposit, forming beds or layers or unassisted agglomerations.

Mineral raw materials used in the building ceramics industry occur throughout the country and vary in age and origin. The most important are deposits from the Quaternary, Neogene, Jurassic and Triassic formations. The most important raw materials from the Quaternary include stagnant lake sediments such as muds and clays mainly occurring 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 from the Neogene age include clays of the so-called Poznań Series from southwestern and central Poland and those of the Krakowiec Clays from the area of the Carpathian Foredeep in southeastern Poland. The Triassic and Jurassic deposits are situated at the margin of the Świętokrzyskie Mts. and in the Częstochowa and Opole regions.

Table 4.2.1. Building ceramic raw material resources [Mm^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	**1,191**	**2,037.27**	**713.02**	**1,324.25**	**52.88**	**157.02**
Including resources of exploited deposits						
TOTAL	218	282.38	254.74	27.64	4.60	147.38
1. DEPOSITS OF OPERATING MINES	116	204.29	186.21	18.08	4.24	108.27
2. DEPOSITS EXPLOITED TEMPORARILY	102	78.09	68.53	9.55	0.36	39.11
Including resources of non-exploited deposits						
TOTAL	307	1,439.41	180.70	1,258.71	23.67	2.01
1. DEPOSITS COVERED BY DETAILED EXPLORATION	234	231.38	180.70	50.68	13.08	2.01
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	73	1,208.03	0.00	1,208.03	10.60	–
Including abandoned deposits						
ABANDONED DEPOSITS	666	315.48	277.58	37.90	24.60	7.63

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 33

Building ceramic raw material deposits in Poland are presented on a map (Plate 5).

According to the RME limit values of specifications that define a deposit (Appendix 8 – table 42) are: maximum documentation depth – to a depth of possible exploitation; minimum thickness of a deposit – 2 m; maximum overburden/thickness ratio – 0.5; maximum content of grains greater than 2 mm – 1%; maximum content of ceramic marl with grain diameter greater than 0.5 mm – 0.4%; and drying shrinkage – minimum 6%.

Anticipated economic resources amounted to 2,037.27 Mm³ in 2015 (about 4,074.54 Mt) (Tab. 4.2.1). Their quantity did not change significantly in 2012–2015.

From the total number equal 1,191 deposits: exploited deposits account for 18.3% (including 9.7% of operating mines and 8.6% of deposits exploited temporarily), non-exploited deposits for 25.8% (including 19.7% of deposits covered by detailed exploration and 6.1% of deposits covered by preliminary exploration) and abandoned deposits for 55.9%.

Output varied between 1.518–1.953 Mm³ in 2012–2015 with an annual average of 1.743 Mm³ (about 3.486 Mt). Yearly fluctuations are 20–30%. Generally speaking, output has been declining, which can be seen especially in the long term with actual output level being the lowest in decades (Fig. 4.2.1).

Traditionally, greater production is recorded in southern Poland in the area of the Świętokrzyskie, Dolnośląskie, Śląskie, Podkarpackie, Małopolskie and Opolskie provinces. Output from this area accounts for 65% of the entire domestic output. The table 4.2.2 presents the yearly average of production in particular provinces.

Table 4.2.2. Building ceramic raw material production

Province	Production [Mm³]	Percentage contribution in domestic production [%]
ŚWIĘTOKRZYSKIE	0.263	15.1
DOLNOŚLĄSKIE	0.244	14.0
ŚLĄSKIE	0.189	10.9
PODKARPACKIE	0.177	10.1
MAŁOPOLSKIE	0.152	8.8
POMORSKIE	0.135	7.8
MAZOWIECKIE	0.135	7.7
OPOLSKIE	0.112	6.4
LUBELSKIE	0.099	5.7
WIELKOPOLSKIE	0.088	5.1
ŁÓDZKIE	0.042	2.4
KUJAWSKO-POMORSKIE	0.036	2.1
PODLASKIE	0.034	1.9
LUBUSKIE	0.024	1.4
WARMIŃSKO-MAZURSKIE	0.012	0.7
ZACHODNIOPOMORSKIE	exploitation has not been conducted since 2012	

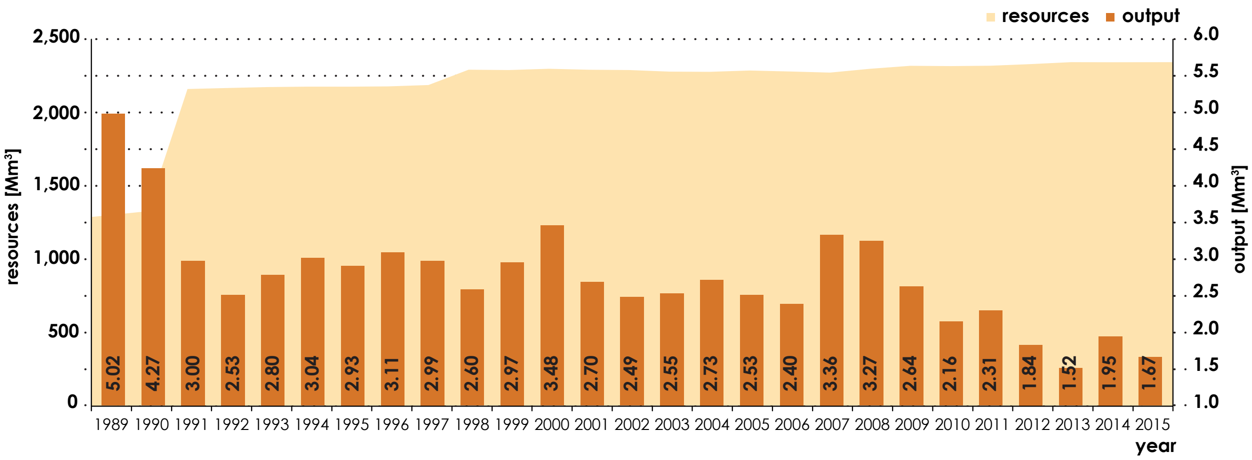


Fig. 4.2.1. Anticipated economic resources and output of building ceramic raw materials in 1989–2015

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); The balance of mineral resources deposits in Poland (in Polish; Szuflicki *et al.*, 2012–2015)

4.3. Calcite

D. Brzeziński

Calcite is used in the ceramic industry. In the past, it was used in the glass industry and as fancy stone. Veins of crystalline calcite occur in Paleozoic limestones in the Świętokrzyskie Mts. and near the city of Kraków. Anticipated economic resources documented within three deposits are estimated at 233 kt as of 31.12.2015 (Tab. 4.3.1). Calcite occurs as the main raw material only in the Radomice I deposit, whereas in others calcite is a raw material co-occurring with limestones documented for the needs of building and road industries). No calcite deposits have been exploited since 1988.

Calcite resources decreased from 287 kt in 2012 to 233 kt in 2013 due to deletion of the Korzecko deposit from "The balance...". Since then, resources have remained unchanged.

Table 4.3.1. **Calcite resources [Mt]**

	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	**3**	**0.23**	**0.23**	**–**	**–**	**–**
Including resources of non-exploited deposits						
DEPOSITS COVERED BY DETAILED EXPLORATION	3	0.23	0.23	–	–	–

4.4. Ceramic clays

M. Tymiński

Clays are raw material for the production of whiteware ceramics such as porcelain and bone china. This results from their confirmed technological suitability. From a processing standpoint, the fired products may be assigned to whiteware and stoneware. Whiteware ceramic clays, sometimes also called kaolinite clays, attaining almost 50% whiteness when fired at a temperature of 1,300°C, are used to produce porcelite and faience. In turn, stoneware products are a group of clays with very good sintering properties in the range of 1,000–1,300°C and are characterized by a very low level of water absorption after firing at 1,300°C (max. 4%) as well as high mechanical and chemical resistance after drying. They are used in the production of such stoneware goods as sewage pipes, sanitary products, chemical stoneware or pottery.

Whiteware ceramic clays occur only in the Dolnośląskie province (Plate 7). There are two types of deposits. The first are kaolinite clays in sandstones of the Upper Cretaceous represented by the Bolko II and Ocice deposits. The second are poorly coherent sandstones with cement rich in kaolinite, represented by the Janina-Zachód, Janina I and Nowe Jaroszowice deposits. A usable fraction is separated from these rocks by water-washing and obtained concentrate contains about 30% of kaolinite clay.

Stoneware ceramic clays occur mainly in the Lower Silesian region and central parts of the country (Dolnośląskie and Świętokrzyskie provinces with i.e. the Zebrzydowa Zachód, Ocice II, Baranów, Majków or Włochów deposits). Single deposits are located in the Łódzkie (Paszkowice deposit), Mazowieckie (Borkowice II and Zawada deposits) and Śląskie (Patoka II deposit) provinces.

In 2015, anticipated economic resources of whiteware ceramic clays amounted to 58.53 Mt (Tab. 4.4.1). Janina I was the only whiteware ceramic clay deposit exploited in Poland with output of 112 kt.

Anticipated economic resources of stoneware ceramic clays amounted to 76.40 Mt in 2015. Anticipated economic resources within exploited deposits amounted to 5.72 Mt (7.5% of total anticipated economic resources). Almost all of these resources were covered by detailed exploration (A, B, C_1 categories); 3 kt of resources explored in the C_2 category remains only in the Baranów deposit. Economic resources amounted to 4.48 Mt and accounted for 78.3% of anticipated economic resources of exploited deposits (Tab. 4.4.2). Output amounted to 231 kt and came from three deposits (Zebrzydowa Zachód, Borkowice II and Baranów).

Anticipated economic resources have not changed significantly since 2012 for both whiteware and stoneware ceramic clays and remained at the level of 58–59 Mt and 76–77 Mt, respectively. Slight changes in whiteware clays where caused by exploitation and better exploration of the Janina I deposit. The 0.27 Mt drop in 2015 was due to deletion of the Janina deposit from "The balance…" (0.15 Mt) as well as exploitation and a change of borders of the mining area of the Janina I deposit (0.12 Mt). Stoneware clay resources varied slightly in 2012–2015 – in the first three years due to output and exploration of the Zebrzydowa Zachód deposit. The drop by 0.34 Mt in 2015 was the result of a deletion of five deposits from "The balance…" (the Barbara Sadlno mine, Gierałtów, Kleszczowa, Nowogrodziec II and Zebrzydowa deposits with total resources of 0.64 Mt) and exploitation and losses in exploited deposits (0.21 Mt). Growth (by 0.51 Mt) in the Borkowice II deposit was caused by the approval of new documentation with recalculated resources.

Output of whiteware ceramic clays dropped in 2012 to 94 kt and then increased in the next two years to 136 kt and 143 kt, respectively. In 2015, it decreased once again to the level of 112 kt (by 21.68%). Stoneware ceramic clay output decreased significantly in 2012 when exploitation of the Paszkowice deposit was stopped to increase to a level of about 200 kt in the next two years when exploitation from the Borkowice II deposit began and to 231 kt in 2015.

Table 4.4.1. Whiteware ceramic clay resources [Mt]

	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**	**58.53**	**2.32**	**56.21**	**0.05**	**0.56**
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	1	1.67	1.35	0.32	–	0.56
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						
ABANDONED DEPOSITS	2	0.40	0.40	–	0.05	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 32

Table 4.4.2. **Stoneware ceramic clay resources [Mt]**

	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	**22**	**76.40**	**28.74**	**47.66**	**15.19**	**4.48**
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	3	5.72	5.71	0.00	5.10	4.48
Including resources of non-exploited deposits						
TOTAL	10	57.52	11.79	45.73	8.40	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	6	15.03	11.79	3.25	2.30	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	4	42.48	0.00	42.48	6.11	–
Including abandoned deposits						
ABANDONED DEPOSITS	9	13.17	11.24	1.93	1.69	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 32

4.5. Chalk

W. Szczygielski

Chalk is a weakly coherent and porous limestone sedimentary rock characterized by high calcium carbonate ($CaCO_3$) content and a fine-grained structure. It is mainly used in the manufacture of rubber, paper, chemical, and dyes, in the ceramic and cement industries, for the production of paints, lacquer, plastics, building materials, and in agriculture and animal husbandry. The natural raw material is increasingly replaced by limestone meals and by raw material obtained in the process of precipitation.

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

Proper chalk is an organogenic sediment with a white or creamy colour mainly consisting of plankton organism remains. In Poland, proper chalk occurs within the Lublin area from the Cretaceous age and in northeastern Poland where the glacial sediments are from the Quaternary age (Plate 6).

Cretaceous limestones of the chalk type used in the production of cement (the Lublin area – Chełm vicinities) are discussed in the section dealing with limestones and marls for cement and lime industries.

Proper chalk documented within glacial sediments occurs in numerous deposits in the vicinities of Kornica and Mielnik on the borderland of the Mazowieckie and Podlaskie provinces. There have been a dozen or so deposits documented in this area of which eight are still being exploited – constantly or temporarily.

Lacustrine chalk, also known as "meadow limestone" or "lacustrine limestone", is a strongly wet calcareous sediment that is white, white-yellow or gray in colour. It was formed as a result of precipitation and accumulation of carbonate sediment at the bottom of lakes.

Plants sequestering carbon dioxide from water play an important role in the precipitation process. Aside from carbonates, lacustrine chalk also contains organic matter and material from land. Lacustrine chalk must yield at least 80% of calcium carbonate ($CaCO_3$) whereas sediment containing 50–80% of $CaCO_3$ is called calcareous gyttja. Accumulations of lacustrine chalk and gyttja often occur at the base of peat.

Lacustrine chalk deposits are usually from the Quaternary age and occur in northern and northwestern Poland. There are also Tertiary accumulations occurring in central Poland that are exploited as a co-occurring raw material in lignite mines in the vicinities of Bełchatów (Łódzkie province).

According to the RME limit values of parameters that define a deposit (Appendix 8) are:

- lacustrine chalk and calcareous gyttja (table 38) are documented with minimum deposit thickness of 1 m, a maximum ratio of overburden to deposit thickness of 0.3 and minimum alkalinity (CaO) of 40% (71.2% $CaCO_3$);
- proper ("writing") chalk (table 39) is documented to a depth of 70 m with maximum overburden of 15 m, a maximum ratio of overburden to deposit thickness of 0.2 and minimum alkalinity (CaO) of 44.8% (80% $CaCO_3$).

Table 4.5.1 shows resources and the current state of chalk exploration and development.

Anticipated economic resources of chalk calcareous gyttja in 2015 were 199.99 Mt (Fig. 4.5.1). Most are lacustrine chalk and gyttja resources – 160.85 Mt (81.9%), whereas proper chalk resources account for only 18.1% (36.23 kt).

In 2012–2015, 11 deposits were exploited, including eight deposits of proper chalk and three deposits of lacustrine chalk. Annual output in this period was 157 kt and generally has been increasing from 147 kt to 172 kt.

Table 4.5.1. Chalk resources [Mt]

	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	**191**	**199.99**	**106.21**	**93.78**	**12.93**	**4.35**
Including resources of exploited deposits						
TOTAL	12	6.26	5.78	0.48	–	4.35
1. DEPOSITS OF OPERATING MINES	9	4.16	3.68	0.48	–	3.21
2. DEPOSITS EXPLOITED TEMPORARILY	3	2.11	2.11	–	–	1.14
Including resources of non-exploited deposits						
TOTAL	88	131.38	58.51	72.86	0.70	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	57	73.58	58.51	15.06	0.40	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	31	57.80	0.00	57.80	0.31	–
Including abandoned deposits						
ABANDONED DEPOSITS	91	62.35	41.91	20.44	12.23	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 32

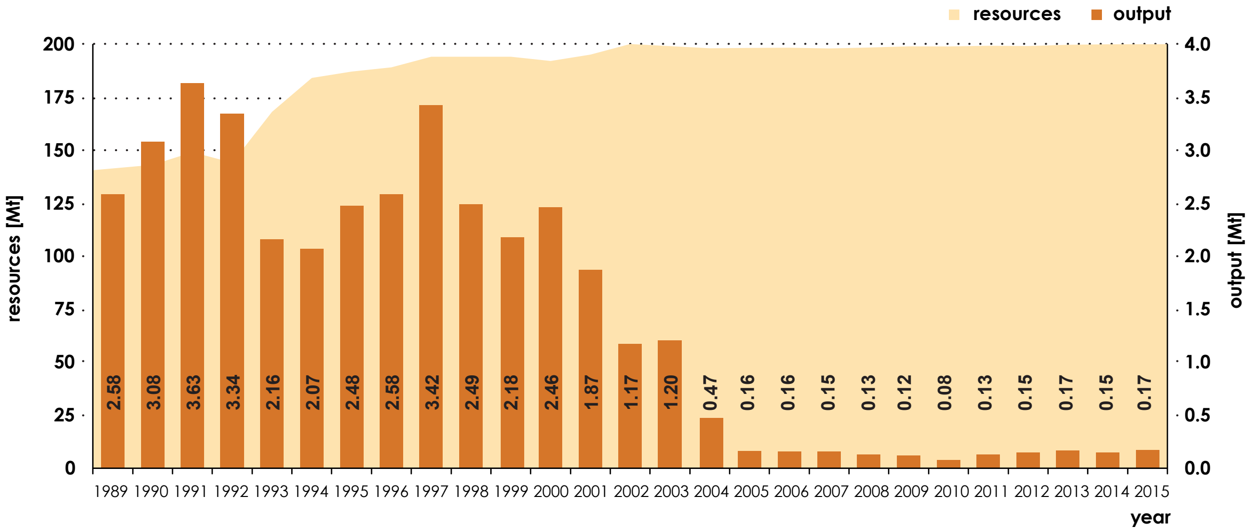


Fig. 4.5.1. Chalk anticipated economic resources and output in 1989–2015

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); The balance of mineral resources deposits in Poland (in Polish; Szuflicki *et al.*, 2012–2015)

Proper chalk accounts for 80–90% of total output and has been increasing by 4.4% per annum. Output rose to 132 kt in 2012, 137 kt in 2013 and 155 kt in 2015 and decreased to the level of 127 kt in 2014 only.

Lacustrine chalk output remained at a very low level – at 15 kt, 28 kt, 18 kt and 18 kt in the 2012–2015 period. Its exploitation mainly took place in the Lubiatowo mine (Zachodniopomorskie province) until it closed in 2015. A further decline of exploitation is expected in connection with decreasing demand for that raw material. Lacustrine chalk is temporarily exploited from an overburden of lignite deposit mined the vicinities of Bełchatów (Łódzkie province).

4.6. Clay raw materials for cement production

W. Szczygielski

Clay raw materials (loams, clays, clayey schists, loesses and others) are used as a supplement to provide alumina and silica to charge for a cement kiln. Basic raw materials are limestones and marls. 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.

Mineral supplements for cement production used on a large-scale are industrial wastes i.e.: dust, ash, metallurgical slags and others that substitute natural raw materials.

There are only several mines of these raw materials operating at the moment. In the eastern part of Poland (Lubelskie province) there are loams and loesses exploited and used by the Chełm cement factory. Output in 2012–2015 varied at the range of 94–126 kt with an annual average of 105 kt (including the Buśno deposit documented as building ceramics raw material). In contrast, there are quartz sands in the Kujawsko-Pomorskie province from the Barcin-Piechcin-Pakość deposit (documented as quartz sands for production of cellular concrete and lime-sand brick) exploited for needs of the Kujawy cement factory. Output of these sands varied in 2012–2015 between 31 kt and 128 kt (with an annual average of 95 kt).

Anticipated economic resources of clay raw material deposits for the cement industry were reported to be 276.53 Mt, whereby the resource level is stable (Tab. 4.6.1).

Table 4.6.1. Resources of clay raw materials for cement production [Mt]

	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	**28**	**276.53**	**166.45**	**110.08**	**45.63**	**0.41**
Including resources of exploited deposits						
DEPOSITS EXPLOITED TEMPORARILY	3	0.43	0.43	–	–	–
Including resources of non-exploited deposits						
TOTAL	15	201.39	91.73	109.65	2.25	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	13	95.11	91.73	3.37	2.25	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	2	106.28	0.00	106.28	–	–
Including abandoned deposits						
ABANDONED DEPOSITS	10	74.71	74.54	0.17	43.39	0.41

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 33

4.7. Clay raw materials for lightweight aggregate production

W. Szczygielski

Clay raw materials for the production of light-weight aggregates that are exploited in Poland can be assigned into two major types in relation to their utility: raw materials suitable for the production of keramsite (light-weight bloated clay aggregates) and raw materials suitable for the production of agloporite (called "glinoporyt" in Poland).

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

Keramsite is mainly used in the building industry, road construction, horticulture and agriculture.

Resources of clays suitable for the production of keramsite were documented in eight deposits, two of which are exploited. Pliocene clays are exploited at Budy Mszczonowskie in Mazowieckie province and Quaternary stagnant-lake clays at Gniew II in Pomorskie province. Until, 1995 keramsite was also produced from Oligocene clays exploited in the Bukowo (Szczecin-Płonia) deposit in the Szczecin area. Remaining deposits – Gołaszyn (Lubelskie province), Nawra (Warmińsko-Mazurskie province), Ruda (Podkarpackie province), Uniejów (Łódzkie province), Wierzchocin (Wielkopolskie province) have not yet been exploited.

Usually, raw material for keramsite production can also be used for building ceramics products: bricks, ceramic concrete blocks etc., but its thermal treatment is carried out at a lower temperature than in keramsite production – below the temperature of its swelling coefficient.

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

Agloporite clay raw materials are fairly common throughout the entire country. Quality requirements that these raw materials should meet are generally low and even lower than those for raw materials to make simple thick-walled ceramics for the building industry. Most proven resources of agloporite raw materials comprise Quaternary glacial tills and loesses (loess loams) and remaining ones are Neogene Krakowiec clays and Poznań clay and Quaternary stagnant lake clays.

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

Anticipated economic resources as of 31.12.2015 were 168.66 Mm^3 (337.32 Mt) from which resources for keramsite were 40.54 Mm^3 (81.08 Mt) – 24.0% of total resources. Resources have not changed significantly for the last several years – there are no new exploration works carried out and output remains quite low.

Output was varying between 0.097 Mm^3 and 0.104 Mm^3 in 2012–2015 with an annual average about 0.100 Mm^3.

Table 4.7.1 shows the current state of exploration and development of these deposits.

Table 4.7.1. Resources of clay raw materials for lightweight aggregate production resources [Mm^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**	**168.66**	**40.96**	**127.69**	**4.60**	**2.65**
Including resources of exploited deposits						
TOTAL	2	16.33	16.33	–	1.28	2.65
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	0.00	122.66	3.26	–
Including abandoned deposits						
ABANDONED DEPOSITS	2	2.77	2.77	–	–	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 33

4.8. Dimension and crushed stones

D. Brzeziński

The group of mineral raw minerals assigned in "The balance..." to dimension and crushed stones (in other words: road and building stones) comprises 33 lithological varieties of igneous, sedimentary and metamorphic rocks displaying properties making them useful in the domestic economy. Stones meeting a relevant requirement are used to produce crushed aggregate – a high-grade raw material for building, 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).

Igneous and metamorphic rocks explored as dimension and crushed stones mainly occur in southern Poland within the area of Dolnośląskie (basalts, granites, granodiorites, gabbros, syenites, diabases, melaphyres, porphyres, porphyric tuffs, amphibolites, serpentinites, greenstones, gneisses, migmatites, crystalline schists, marbles), Opolskie (basalts, granites, gneisses, marbles) and Małopolskie (diabases, melaphyres, porphyres and porphyric tuffs) provinces. Sedimentary rocks matching requirements for that use are much more common. Limestones and dolomites form numerous deposits in Dolnośląskie, Łódzkie, Małopolskie, Śląskie and Świętokrzyskie provinces, sandstones in Dolnośląskie, Łódzkie, Małopolskie, Podkarpackie, Śląskie and Świętokrzyskie provinces, whereas limestones, opokas and marbles in south-eastern Poland (Lubelskie and Podkarpackie provinces) (Fig. 4.8.1, Plate 6).

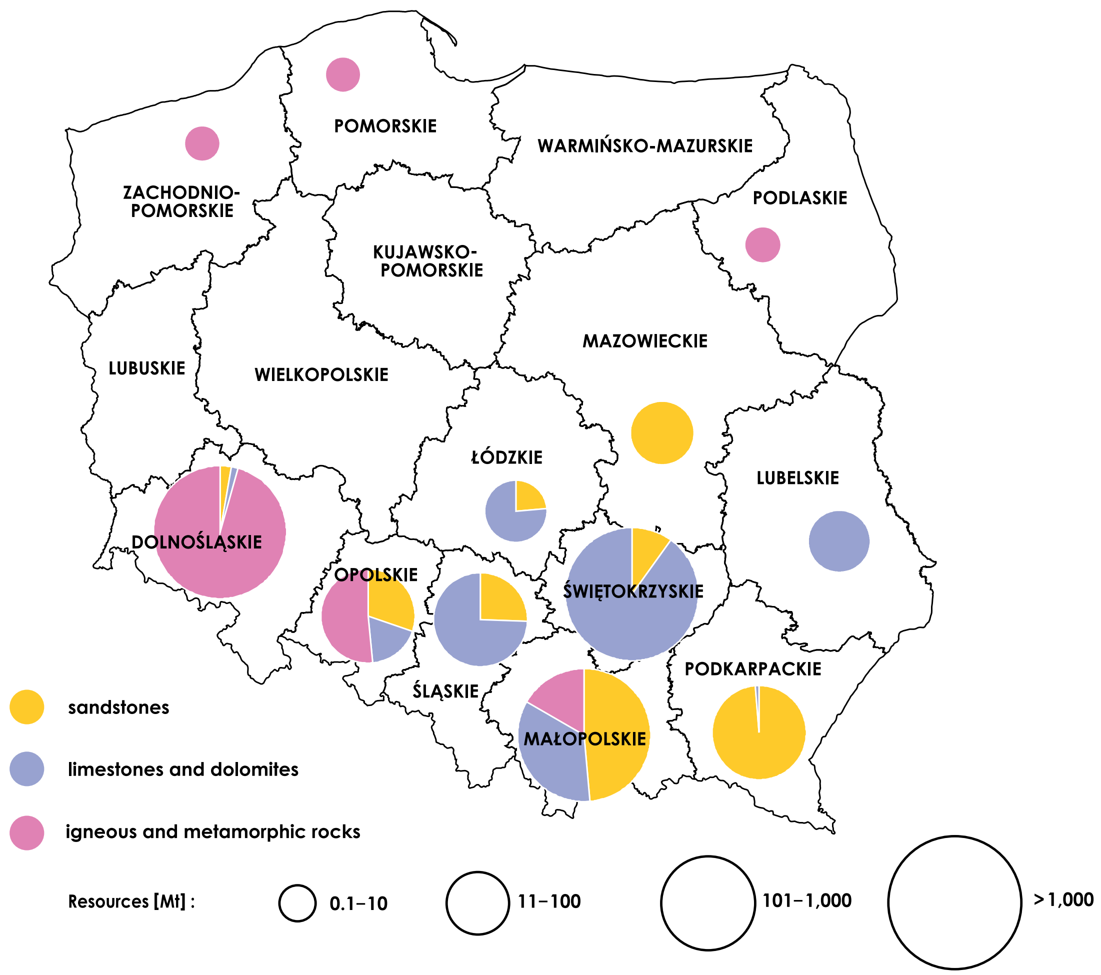


Fig. 4.8.1. Distribution of resources and principal lithological types of dimension and crushed stones in 2015

Table 4.8.1. Dimension and crushed stones resources [Mt]

	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	**746**	**10,800.98**	**7,434.98**	**3,365.99**	**531.11**	**3,382.09**
Including resources of exploited deposits						
TOTAL	331	5,526.97	4,416.55	1,110.42	109.56	3,209.51
1. DEPOSITS OF OPERATING MINES	257	4,959.00	3,873.22	1,085.77	100.02	2,857.86
2. DEPOSITS EXPLOITED TEMPORARILY	74	567.97	543.33	24.65	9.53	351.65
Including resources of non-exploited deposits						
TOTAL	246	4,406.16	2,255.07	2,151.09	391.06	172.58
1. DEPOSITS COVERED BY DETAILED EXPLORATION	199	2,619.18	2,255.07	364.11	133.91	172.58
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	47	1,786.98	0.00	1,786.98	257.15	–
Including abandoned deposits						
ABANDONED DEPOSITS	169	867.85	763.36	104.49	30.50	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 32

According to limit values of parameters that define a deposit and its boundaries, dimension and crushed stones are documented down to depth capabilities governed by equipment and method limitations for an opencast exploitation system. Additional requirements for dimension stones are: the minimum overburden to the deposit thickness ratio of 1.0, minimum divisibility for particular lithological types of: 5% for marbles and serpentinites; 10% for syenites, gabbros, granodiorites and limestones and dolomites taking polish and 20% for granites, tuffs, sandstones and limestones and dolomites not-taking polish. For non-dimension building and road stones the overburden may be up to 15 m, the maximum overburden to a deposit thickness ratio of 0.3, the maximum contribution of rocks not meeting quality requirements in the entire vertical section of a given deposit of 20% and maximum $CaCO_3$ content in limestones of 90%.

Anticipated economic resources amounted to 10,800.98 Mt (Tab. 4.8.1). About 51.2% of resources (5,526.97 Mt) are within 331 exploited deposits. There are also 199 non-exploited deposits covered by detailed exploration (A, B, C_1 categories) with resources of 2,619.18 Mt (24.2% of total resources) and 47 non-exploited deposits covered by preliminary exploration (C_2, D categories) with resources of 1,786.98 Mt (16.5% of total resources). Resources of 169 abandoned deposits account for 8.0% of total resources and are 867.85 Mt. Sedimentary rocks represent 46.6% of anticipated economic resources of dimension and crushed stones (5,029.00 Mt), igneous rocks 39.7% of resources (4,293.37 Mt) and metamorphic rocks 13.7% (1,478.61 Mt) (Tab. 4.8.2). The share of sedimentary rocks is systematically increasing – by 0.84% in comparison to the previous year, mainly due to growth of limestones and dolomites resources (by 13.5%). The most numerous is a sedimentary rock group of deposits – 533 deposits that account for 68.6% of the total number of deposits in Poland. Igneous rocks deposits account for 23.2% (180 deposits), whereas metamorphic rocks deposits constitute 8.2% (64 deposits). Relatively small deposits – with resources below 1 Mt – account for 35% of the total number of deposits and the largest ones – with resources exceeding 100 Mt – for about 2% (but their resources account for 26% for the total resource magnitude).

Economic resources of dimension and crushed stones amounted to 3,382.09 Mt decreasing in comparison to 2014 by 262.38 Mt (7.2%).

The production of dimension and crushed stones in 2015 amounted to 64.18 Mt. The most important are sedimentary rocks – limestones, dolomites and sandstones. As for igneous rocks, the highest output is recorded for granite, basalt and melaphyre. Metamorphic rocks are of least importance, but have become more substantial lately. Output is concentrated within an area of two provinces: Dolnośląskie and Świętokrzyskie with the share in Polish output of dimension and crushed stones of 42.2% (within 272 deposits and 53.1% of domestic resources) and 34.9% (within 137 deposits and 21.9% of domestic resources) respectively. Małopolska province accounts for 12.1% of domestic production (105 deposits and 11.8% of domestic resources). In the structure of output magnitude the most important are scopes below 10 kt – characteristic for about 35% of total registered deposits, but accounting for only 0.5% of total output volume. Deposits with output above 1 Mt account for about 6% of the total deposit number and contain about 50% of domestic resources and about 40% of total output volume. Dimension and crushed stones are also exploited during lignite exploitation. In 2015, there were 1.15 kt of erratic boulder, 72.40 kt of limestone and 37.21 kt of quartzite extracted from the Bełchatów and Szczerców fields (KWB Bełchatów SA mine).

Table 4.8.2 shows the current state of exploration and development and production with a breakdown of individual lithological types of rocks used in road and building construction.

Figure 4.8.2 shows changes in resources and output of the dimension and crushed stones in Poland in 1989–2015. The resource base of dimension and crushed stones has been increasing for the last 27 years, despite intensive exploitation (Plate 6). Until 1992, resources grew at an annual average of 0.3%. More significant growth began in 2006 – from a level of 2.2% yearly to about 6.3% in 2009. Since 2010, the growth rate has been systematically decreasing – from 4% to 0.5% in 2015. In 2015, anticipated economic resources increased by 61.84 Mt (0.58%) in comparison to the previous year. Until 2006, the resource structure was quite stable, whereby the important change started in following years: the most intensive growth rate was recorded for metamorphic rocks with a similar tendency – but with less intensity – for igneous and sedimentary rocks. Since 2010, the growth rate of igneous and metamorphic rocks has been declining, whereas sedimentary rock resources maintained or slightly increased their growth rate. Since 1996, the growth pace of the deposit number varied in the range of 0.5–2.0% yearly with a visible increasing tendency. In 2006–2009, the number of deposits grew at a rate of 4–7% yearly. The rate has been slowing in the last six years. The number of deposits in 2015 decreased from 750 to 746, whereby 10 new deposits were documented and 14 deposits deleted from "The balance…".

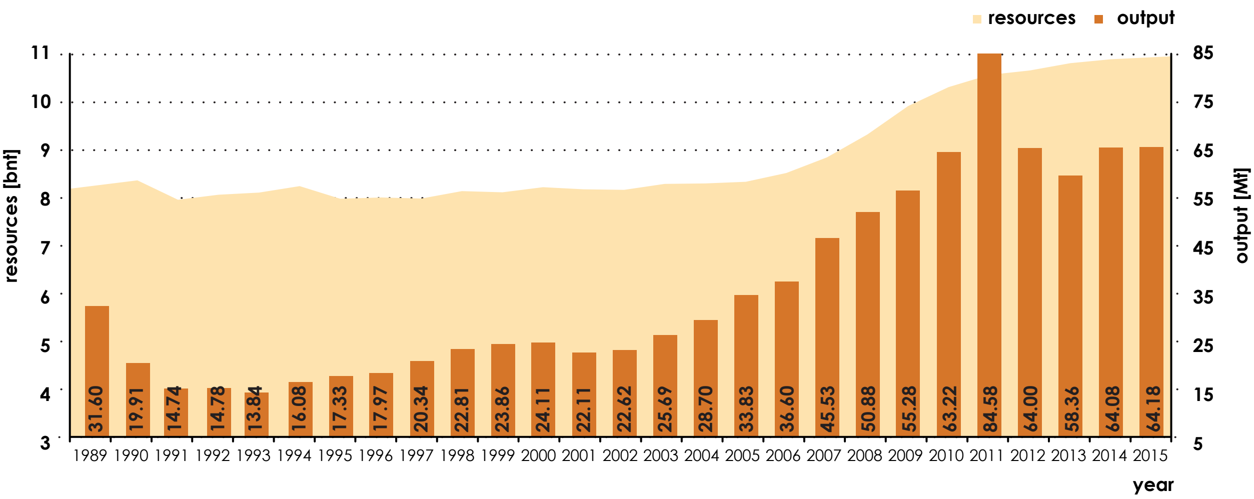


Fig. 4.8.2. Dimension and crushed stones anticipated economic resources and output in 1989–2015

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); The balance of mineral resources deposits in Poland (in Polish; Szuflicki *et al.*, 2012–2015)

Table 4.8.2 **Resources and production of lithological types of rocks used as road and building stones [kt]**

Lithological types of rocks	Resources	Production	No of deposits
TOTAL RESOURCES	**10,800,976**	**64,178**	**746***
IGNEOUS ROCKS	4,293,366	25,115	180
Basalt	582,516	6,661	44
Diabase	20,571	197	2
Gabbro	509,397	1,979	5
Erratic boulders	603	–	4
Granite	1,679,777	9,726	77
Granodiorite	151,531	331	10
Melaphyre	472,338	3,907	17
Porphyry	769,395	1,600	13
Syenite	77,312	713	6
Porphyric tuff	29,925	–	2
METAMORPHIC ROCKS	1,478,610	4,540	64
Amphibolite	182,708	1,214	11
Gneiss	491,262	765	17
Hornfels	2,922	–	3
Cristalline schist	1,808	–	2
Marble	247,446	24	15
Dolomitic marble	228,887	614	8
Migmatite	211,807	1,208	2
Serpentinite	73,956	715	4
Greenstone	37,815	–	2
SEDIMENTARY ROCKS	5,029,001	34,522	533
Chalcedonite	30,749	92	3
Dolomite	1,120,016	11,326	49
Schist	590	–	1
Menillite schist	1,029	4	5
Marl	1,877	–	2
Opoka	5,519	5	10
Sandstone	1,533,014	5,779	302
Quartzitic sandstone	218,586	1,548	7
Graywacke	89,551	243	5
Travertine	1,885	–	1
Limestone	1,797,541	11,747	137
Dolomitic limestone	13,869	471	1
Limestone and dolomite	190,663	3,309	7
Conglomerate	22,099	–	2

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

Dimension and crushed stones output rapidly increased between 1993 and 2011 and reached 84.6 Mt – the highest level in the last 20 years. This was the result of growing demand in the building sector after financial means from ISPA tools and pre-accession European Union programmes commenced. Polish accession to the EU in 2004 and execution of large financial means caused increasing demand for crushed aggregates and building stones – especially in the public road and railways sectors. An additional factor enhancing the demand for stone materials was infrastructural investments for organization of the 2012 UEFA European Championship by Poland and Ukraine. Therefore, output dropped significantly in 2012 (as soon as demand decreased) – by 20.6 Mt (24%) – in comparison to the previous year. The following year brought another drop – by 9%. Output increased in the last two years and reached a level slightly above that recorded in 2010. In 2015, it increased in comparison to 2014 by 95 kt (0.15%).

4.9. Dolomites

M. Tymiński

Polish dolomites are generally divided into two groups: industrial dolomites and dolomites for crushed stone production. Dolomites from the first group are widely used as a flux for smelting iron and steel, in production of refractory raw materials, in agriculture as raw material for production of calcium-magnesium mineral fertilizers and in the ceramic industry. The estimated structure of dolomite consumption in Poland in 2013 was as follows: aggregates and fertilizers – 91%, flux for steelworks – 5%, glass and ceramics – 3% and, refractories – <1% (Smakowski *et al.*, 2014). The second group is used in the construction industry and road construction as building and crushed stone. This use is discussed in the section on dimension and crushed stones.

Dolomite deposits occur in southern Poland in Śląskie, Dolnośląskie and Małopolskie provinces (Plate 6). Raw materials characterized by the best quality and matching the economic criteria of a flux for smelting occur within the Śląsk-Kraków area. These deposits are of the stratified type and Devonian or Triassic in age. Deposits of dolomites usable as a raw material for the ceramic industry and building and crushed stone occur in the Lower Silesian region. Dolomites form lenses in metamorphic schists. The best known of these dolomite deposits is situated at Rędziny in the vicinities of Jelenia Góra. The largest deposit of this type (Ołdrzychowice-Romanowo) is located in the area of the Kłodzko Basin and described in the section on dimension and crushed stones.

Anticipated economic resources amounted to 531.69 Mt in 2015 (Tab. 4.9.1). Anticipated economic resources of exploited deposits were 237.59 Mt in 2015 and accounted for 44.7% of total anticipated economic resources. Resources covered by detailed exploration were 373.68 Mt (70.3% of total anticipated economic resources). Such resources within exploited deposits accounted for 98.4% of anticipated economic resources (233.81 Mt). Economic resources of dolomites decreased by 2.79 Mt and were 125.49 Mt. These resources accounted for only 23.6% of total anticipated economic resources. Production of dolomite was 2,943 kt in 2015.

Table 4.9.1. Dolomite resources [Mt]

	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**	**531.69**	**373.68**	**158.01**	**7.08**	**125.49**
Including resources of exploited deposits						
TOTAL	5	237.59	233.81	3.79	6.53	125.49
Including resources of non-exploited deposits						
TOTAL	5	260.21	105.99	154.23	0.55	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	3	209.74	105.99	103.76	0.55	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	2	50.47	0.00	50.47	–	–
Including abandoned deposits						
ABANDONED DEPOSITS	2	33.89	33.89	–	–	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 32

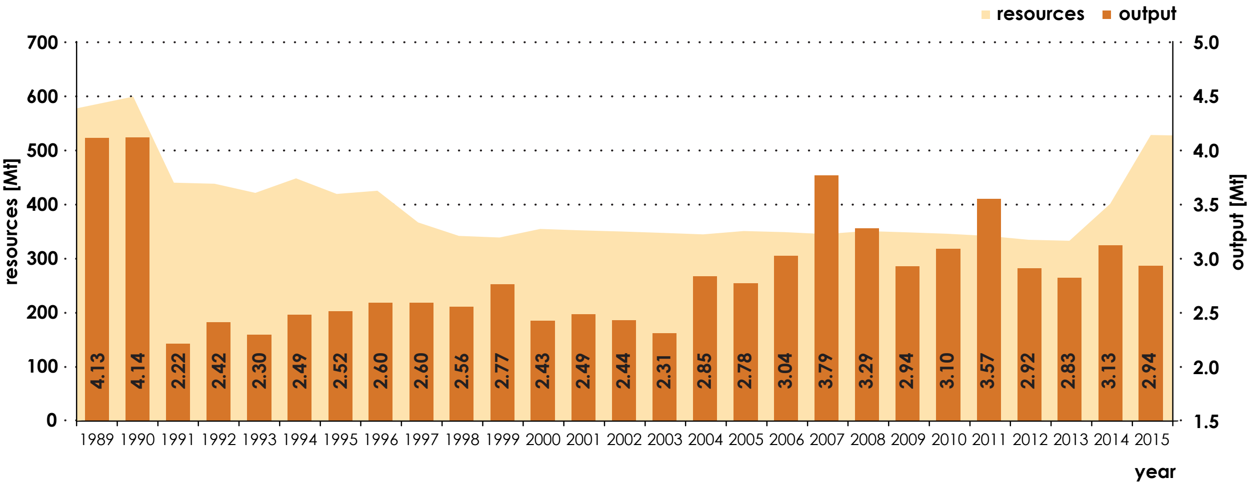


Fig. 4.9.1. Dolomite anticipated economic resources and output in 1989–2015

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al*., 2007, 2008; Wołkowicz *et al*., 2009–2010; Szuflicki *et al*., 2011); The balance of mineral resources deposits in Poland (in Polish; Szuflicki *et al*., 2012–2015)

The graph presents the size of resources and output in 1989–2015. Resources decreased significantly in 1991 due to new documentation approved for the Chruszczobród deposit (with smaller recalculated resources) and in 1997 due to the conclusion of exploitation of Bobrowniki-Blachówka and Gródek deposits. Output dropped in 1991 and after a long period of stabilization increased again in 2004–2007 and 2010–2011. The last four years were characterized by varying output and increasing resources. Resource growth in 2014–2015 (by 197 Mt) was due to new calculations elaborated for the Brudzowice (52.61 Mt), Rędziny (18.11 Mt), Chruszczobród (126.77 Mt) and Ząbkowice Będzińskie I (3.23 Mt) deposits. Significant production growth in 2014 was caused by Brudzowice (by 301.8 kt) and Rędziny (38.8 kt) deposits, whereas the output drop in 2015 was caused by Żelatowa (93.27 kt) and Brudzowice (264.20 kt) deposits (Fig. 4.9.1).

4.10. Feldspar raw materials

A. Malon

Deposits of feldspar raw material represent natural accumulations of various kinds of feldspar and feldspar-quartz rocks rich in Na_2O and K_2O (equal at least 6.5%) and Al_2O_3 (minimum 12%) and also with low content of Fe_2O_3 and TiO_2 (maximum 1.5%). They are mainly documented in the Lower Silesia (Sudety Mts. and Fore-Sudetic Region) and one deposit is located near Kraków (Plate 6). Rocks include leucogranites occurring in the vicinities of Strzeblów (Pagórki Wschodnie deposit) and Izerskie Mts. (Kopaniec deposit) and other parts of the Lower Silesian region. Other feldspar raw materials are represented by feldspars of porphyry varieties in the Karkonosze granites from the vicinities of Karpniki, Maciejowa and Góra Sośnia in the Jelenia Góra Basin (Sudety Mts.) and potassium trachyte from Siedlec and Kwaczała arcose from Wygiełzowa in the Silesian-Cracow region.

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

Anticipated economic resources amounted to 137.31 Mt in 2015 but only 10% of them are in the three exploited deposits (Karpniki, Pagórki Wschodnie and Stary Łom) (Tab. 4.10.1). Anticipated economic resources increased by 0.45 Mt in 2012 due to new documented resources of the Pagórki Wschodnie deposit (Fig. 4.10.1). Then, the resources began to decrease systematically in 2013–2015 by

Table 4.10.1. Feldspar raw materials resources [Mt]

	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**	**137.31**	**65.04**	**72.27**	**13.18**	**5.49**
Including resources of exploited deposits						
TOTAL	3	14.43	11.66	2.77	–	5.49
1. DEPOSITS OF OPERATING MINES	2	4.05	4.05	–	–	2.90
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	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 34

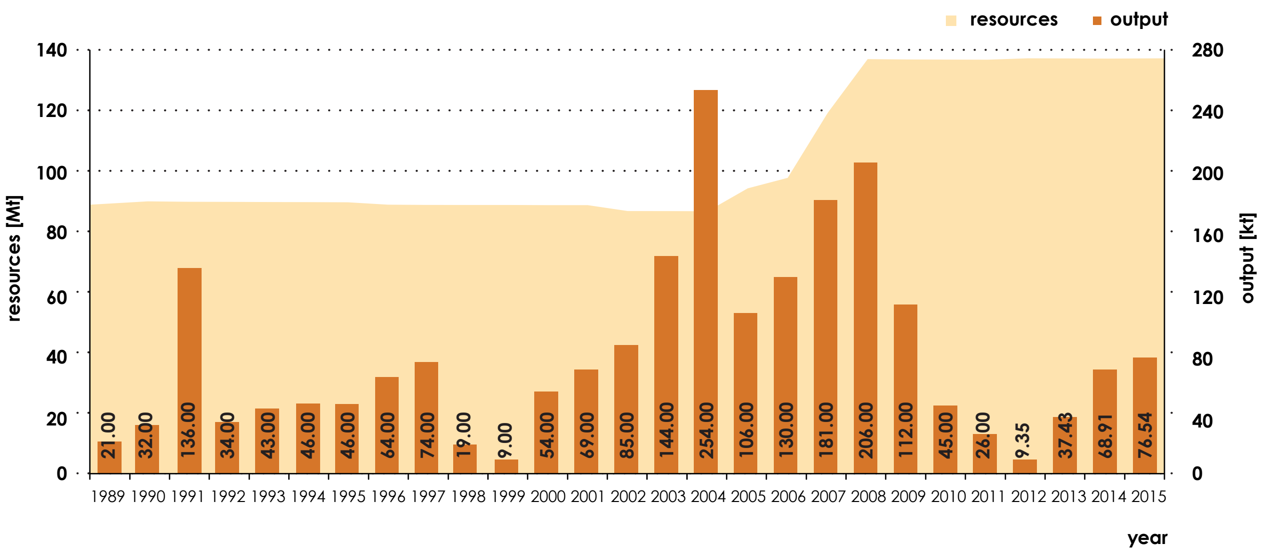


Fig. 4.10.1. Feldspar raw material anticipated economic resources and output in 1989–2015

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); The balance of mineral resources deposits in Poland (in Polish; Szuflicki *et al.*, 2012–2015)

0.18 Mt due to output and losses. The substantial increase of anticipated economic resources of feldspar in the period 1989–2011 took place in 2005–2008 when they increased by 50%. Four new deposits were recognized in this period. Economic resources of developed deposits were estimated at 5.49 Mt.

Production of feldspar raw materials was 76.54 kt in 2015, mostly (99%) from the Stary Łom deposit. Stary Łom has been exploited since 2011 and its output increased from 1.44 in 2011 to 75.91 kt in 2015. The exploitation of Pagórki Wschodnie was halted in 2012 and recommenced in 2013, but with much smaller output. Karpniki deposit was not exploited in the last five years, but still there is an active concession for its exploitation. Output was the greatest in 2003–2008. The growth of resources and high production was tied to demand from the ceramic and glass industries.

Demand for feldspar raw materials remains high in Poland. Domestic production of feldspar is mainly used in manufacturing ceramic tiles.

4.11. Filling sands

A. Malon

Filling sands are used to make hydraulically placed fill – a mixture of sand and water to fill voids created by underground mining. Deposits of these sands should be documented in an area located less than 50 km from mines in which that raw material is to be used due to high transportation costs and relatively low unit price. In Poland, filling sand deposits are exploited mainly in areas of intensive underground mining, especially mining of hard coal in the USCB, copper in the Legnica-Głogów Copper District and zinc and lead in Olkusz region (Plate 8).

The filling sand deposits are exploited mainly in areas around the USCB. About 80% of anticipated economic resources were approved and 75% of output takes place in this region. There are nine exploited deposits in USCB. Currently exploited filling sand deposits with the largest resources include Pustynia Błędowska – blok IV, Kotlarnia pole północne, Siersza-Misiury, Obora and the Szczakowa pole I deposits.

Anticipated economic resources are relatively large given decreasing demand from the mine coal industry and were 2,567.08 Mm^3 (or about 4,364 Mt – as recalculated using a weight-to-volume ratio 1.7 t/m^3) in 2015 (Tab. 4.11.1). Resources of exploited deposits amounted to about 20% of total anticipated economic resources. Anticipated economic resources generally decreased in 1989–2015 due to exploitation and losses (Fig. 4.11.1). A significant drop took place in 1999 and 2000 due to deletion of three deposits from the "The balance…" and redocumentation of the remaining three. In 2013, the Ochojec deposit was deleted from "The balance…", so total anticipated economic resources decreased by 161 Mm^3. Resources increased by 38 Mm^3 in 2014 due to new documentation of the Chróstnik deposit and by 59 Mm^3 in 2015 due to documentation of a new deposit – Marklowice 1, which was allocated from the northern part of the Marklowice deposit. All resources within the Marklowice deposit are classified as anticipated sub-economic. Economic resources increased by 6.41 Mm^3 in comparison to 2014 due to new deposit management plans approved for the Obora deposit. Most resources were reclassified and transferred from non-economic to economic.

In 2015, production of backfilling sands totalled 3.55 Mm^3 (6.03 Mt) being 0.26 Mm^3 lower than in the previous year. Production dropped in six deposits out of seven under exploitation. The most significant decline (for more than 0.07 Mm^3) occurred in the Obora, Kotlarnia pole północne and Bór (Zachód) deposits. Exploitation from the Bór (Wschód), Szczakowa pole II and Kuźnica Warężyńska deposits is on hold. In 1989–2015, output of filling sands generally decreased due to drop in the hard coal production in this period and the fact that substitutes such as power plant coal ash have mainly been used on a larger scale.

Table 4.11.1. **Filling sand resources [Mm³]**

	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	**33**	**2,567.08**	**2,026.53**	**540.55**	**614.63**	**82.99**
Including resources of exploited deposits						
TOTAL	10	527.43	474.23	53.20	168.76	82.99
1. DEPOSITS OF OPERATING MINES	7	425.85	372.66	53.20	88.79	67.89
2. DEPOSITS EXPLOITED TEMPORARILY	3	101.58	101.58	–	79.97	15.10
Including resources of non-exploited deposits						
TOTAL	16	1,741.16	1,309.16	431.99	188.14	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	12	1,358.37	1,306.35	52.02	111.96	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	4	382.79	2.82	379.97	76.18	–
Including abandoned deposits						
ABANDONED DEPOSITS	7	298.49	243.13	55.36	257.72	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 33

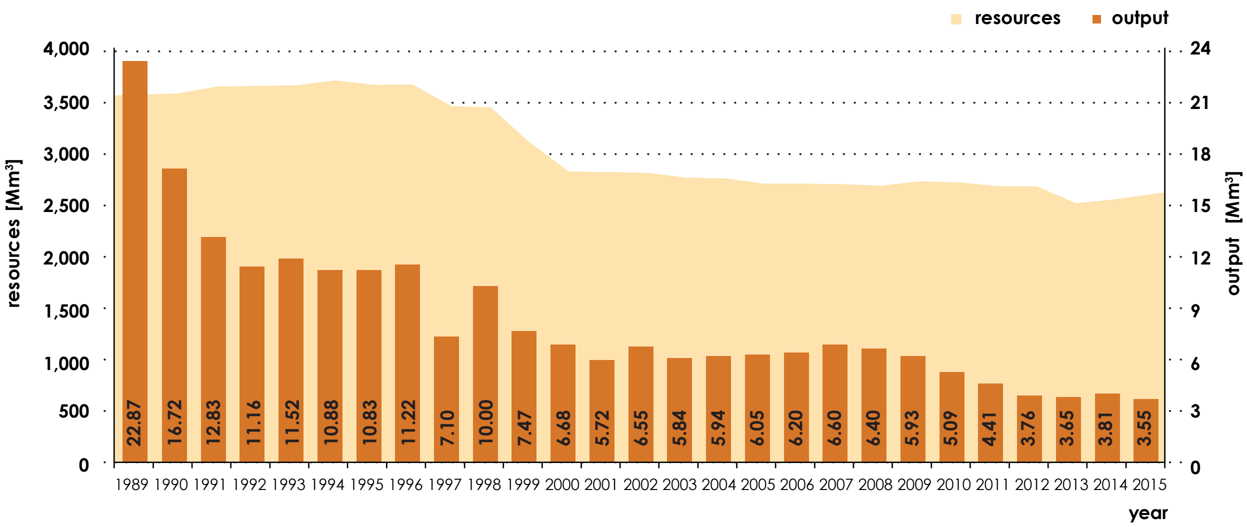


Fig. 4.11.1. **Filling sand anticipated economic resources and output in 1989–2015**

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); The balance of mineral resources deposits in Poland (in Polish; Szuflicki *et al.*, 2012–2015)

4.12. Flintstones

D. Brzeziński

Flintstones are silica concretion balls of spherical to irregular shape. They usually occur as nodules or banks among carbonate rocks of the Jurassic or Cretaceous age. Their main component is chalcedony. One of their important features is high resistance to weathering, which results in their occurrence in secondary accumulations as a component of loose clastic sediments. Flintstones are mainly used in the glass and ceramic industry. They are also used for production of facings, millstones for rolling mills and flint abrasives. Banded flintstones are used to make jewellery and stone fancy products. The most famous accumulation is found at Krzemionki Opatowskie near Ostrowiec Świętokrzyski, where flintstones were extracted in the period 3,500–1,600 BC.

There are only two documented deposits of flintstones (Bocheniec and Tokarnia) near Kielce (Świętokrzyskie province). In Tokarnia, banded flintstones are found. Both deposits have not yet been exploited, whereas their anticipated economic resources amount to 27.70 kt.

Table 4.12.1. **Flintstones resources [Mt]**

	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	**2**	**0.03**	**0.03**	**–**	**–**	**–**
Including resources of non-exploited deposits						
DEPOSITS COVERED BY DETAILED EXPLORATION	2	0.03	0.03	–	–	–

4.13. Foundry sands

A. Malon

Foundry sands are a basic raw material for making moulds and cores used in metal casting. These are quartz fine sands (about 96–98% of SiO_2). They have to be characterized by high sintering temperature as the 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 types of foundry sands are differentiated on the basis of cement and carbonate content: pure quartz sands and natural foundry sands. Deposits of foundry sands are mainly situated in the central (near Piotrków Trybunalski) and southern (between Częstochowa and Zawiercie) parts of Poland and usually have the form of sand sheet deposits (Plate 7). Sand deposits range in age from the Quaternary and Miocene to Cretaceous and even Jurassic and Triassic.

Raw material from some deposits of foundry sands can also find other uses. Pure quartz sands are also used in the glass industry and at times in the construction and road building sector.

Anticipated economic resources decreased by 4.06 Mt in comparison to the previous year and amounted to 288.79 Mt in 2015 (Tab. 4.13.1). The resource drop was due to resource correction by deletion of the Zaborze deposit from "The balance…" (–2.92 Mt), exploitation (–1.10 Mt) and losses. A small resource decrease took place in 2014 due to output. Anticipated economic resources drops were also recorded in 2012 and 2013. Three deposits were deleted from "The balance…": Unewel-Zachód (–18.67 Mt), Biała Góra I-Wschód (–4.23 Mt) and Biała Góra II-Wschód (–1.12 Mt) in 2012.

Table 4.13.1. Foundry sand resources [Mt]

	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	**73**	**288.79**	**137.55**	**151.25**	**6.04**	**22.37**
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	5	36.55	36.55	–	0.43	22.37
Including resources of non-exploited deposits						
TOTAL	37	195.40	45.00	150.40	2.79	0.97
1. DEPOSITS COVERED BY DETAILED EXPLORATION	17	52.50	45.00	7.50	2.65	0.97
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	20	142.90	0.00	142.90	0.13	–
Including abandoned deposits						
ABANDONED DEPOSITS	31	59.60	55.82	3.77	2.82	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 32

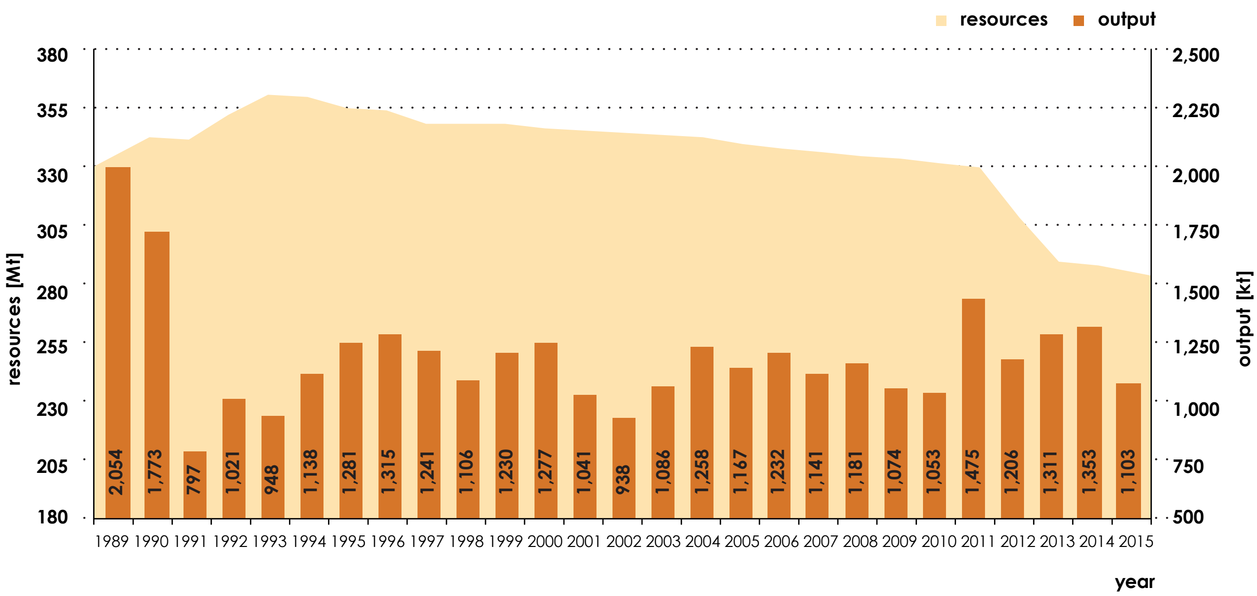


Fig. 4.13.1. Foundry sands anticipated economic resources and output in 1989–2015

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); The balance of mineral resources deposits in Poland (in Polish; Szuflicki *et al.*, 2012–2015)

These deposits are reclassified as glass and foundry sands and presented in the "Glass sands and sandstones" chapter. There was one deposit deleted from "The balance…" – Sulechowo (with resources of 4.45 Mt) in 2013. In 2013, raw material from the Czerwona Woda deposit was also reclassified as sands and is presented in the "Sand and gravel" chapter.

Anticipated economic resources of developed deposits are 36.55 Mt and decreased by 58% since in 2011 (88.15 Mt).

In 2015, production of foundry sands was 1.103 Mt, decreasing by 250 kt (18%) in comparison to the previous year (Fig. 4.13.1). Exploitation dropped in the Grudzeń-Las (by 254 kt) and Ludwików – Pole B (by 38 kt) deposits. Output from the Zawisna II deposit stopped during the year and only 40 t of raw material was extracted. Exploitation fluctuated near the level of 1 Mt in 1989–2015. There was an increase of output in 2013–2014, almost in all exploited deposits as well as a decrease in 2012 – also in the most of them.

4.14. Glass sands and sandstones

A. Malon

Quartz sand is a main raw material for commercial glass production. In that process, sands pass through preparation and mixing in a glass batch to be transported to a furnace and melted. Glass sand comes from deposits of quartz sands and weakly cemented quartz sandstone rich in silica (SiO_2), and with appropriate granulation (uniformly grained) and negligible content of colouring oxides.

In Poland, deposits of glass sands and sandstones occur in 10 provinces, primarily Cretaceous sands and sandstones in the Łódzkie province – in central Poland (east of Piotrków Trybunalski – Biała Góra and Unewel deposits) and in the Dolnośląskie province – in south-western Poland (west of Lubin – vicinities of Bolesławiec) (Plate 8). Resources within the Łódzkie province have the largest share in domestic resources (80%). In turn, sands from the vicinities of Bolesławiec (Osiecznica deposit) best match quality requirements (high chemical purity and stable grain distribution) of raw material for production of the high-quality glass (class 1–3). They also have a unique white colour.

Miocene and Quaternary glass sand deposits from other provinces are less important for the raw material base. These sands are suitable for production of a low-quality glass only (class 3–6).

Anticipated economic resources decreased by 7.89 Mt in comparison to 2011 and were 625.47 Mt in 2015 (Tab. 4.14.1). In the last four years (2012–2015) resources have fluctuated due to exploitation and approved documentation of new deposits as well as already documented ones. There were six new deposits documented in 2012–2015: Unewel-Zachód-Nowy (83.07 Mt) and Parowa 1 – Pole II,IV (21.55 Mt) in 2012, Krzeszówek I (3.13 Mt) and Sulechowo 1 (10.78 Mt) in 2013 and also Unewel Zachód-Las (29.74 Mt) and Mirosław AG (4.93 Mt) in 2014. In the same period, two deposits were deleted from the "The balance…": Unewel-Zachód (–84.53 Mt) in 2012 and Sulechowo (–6.43 Mt) in 2013. Anticipated economic resources of exploited deposits are 142.31 Mt, accounting for 23% of total anticipated economic resources.

In 2015, glass sand production increased by 379 kt in comparison to 2011 and was 2,669 kt. Most output (75%) came from three deposits in the Łódzkie province. There was a slight decrease of output in 2012–2014. Exploitation was abandoned in three deposits: Wyszków-Skuszew (since 2012) and Biała Góra I – Wschód and Ujście Noteckie II (both since 2013).

Table 4.14.1. Glass sands and sandstones resources [Mt]

	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	**35**	**625.47**	**379.35**	**246.13**	**124.52**	**54.54**
Including resources of exploited deposits						
TOTAL	7	142.31	139.30	3.01	23.92	54.54
1. DEPOSITS OF OPERATING MINES	5	122.72	119.70	3.01	23.92	48.82
2. DEPOSITS EXPLOITED TEMPORARILY	2	19.59	19.59	–	–	5.72
Including resources of non-exploited deposits						
TOTAL	22	444.61	202.92	241.69	100.58	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	14	247.91	202.92	44.99	62.92	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	8	196.70	0.00	196.70	37.67	–
Including abandoned deposits						
ABANDONED DEPOSITS	6	38.56	37.13	1.42	0.02	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 34

4.15. Gypsum and anhydrite

G. Czapowski

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

Calcined gypsum is one of the most common and ancient mortars used in building construction. At present, it is widely used in the production of various building materials and prefabricates. It is also used to produce moulds for the 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, especially in pure varieties – in surgery and dental clinics. Clear colourless gypsum crystals (selenite) are used to make optical instruments. Anhydrite is currently added to Portland cement and in the production of self-levelling floors.

In Poland, deposits of calcium sulfates (gypsum and anhydrite) are associated with the saline (halite and potassium-magnesium salts) series of evaporate formations of the Miocene and Zechstein. Their total anticipated economic resources in 15 major deposits were estimated in 2015 at over 258.6 Mt and resources of five exploited deposits at almost 126.8 Mt (Tab. 4.15.1). The exploited deposits have anticipated sub-economic resources of 0.82 Mt and economic resources in place are 109.2 Mt. Sulfate production at five operating mines in 2015 exceeded 1 Mt.

Table 4.15.1. Gypsum and anhydrite resources [Mt]

	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**	**258.64**	**190.25**	**68.38**	**20.00**	**109.22**
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	5	126.84	99.08	27.76	0.82	109.22
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	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 32

Miocene gypsum deposits of economic importance are mainly situated along the northern margin of the Carpathian Foredeep, especially in the Nida Basin (Plate 6). In these areas, gypsum forms a thick, extensive bed that is gently inclined and slightly disturbed tectonically. The gypsum bed crops out at the surface or is covered with a sedimentary blanket several to more than a dozen metres thick. The deposit series is 3 m to 46 m thick and is characterized by fairly uniform quality 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 the result of gypsification of anhydrite in zones of aggressive groundwater infiltration. Three deposits have been exploited in that region: Lubichów (closed in 2015), Nowy Ląd and Nowy Ląd-Pole Radłówka. The deposits occur at depths of 25 m to 400 m, their thickness changes from 1.7 m to 50.3 m and content of $CaSO_4 \cdot H_2O$ ranges from 56% to 95.3%. Moreover, resources of shallow-seated parts of non-exploited gypsum and anhydrite deposits that 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 bnt.

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

In 1989–1991, anticipated economic resources of sulfates (gypsum and anhydrite) in 13 deposits decreased slowly from 302 Mt to 300 Mt due to production, but their rapid increase to almost 342 Mt in 1992 resulted from resource revaluation of the Lubichów deposit and new resources in cape rock of the Wapno salt diapir (Fig. 4.15.1). A successive volume drop to almost 328 Mt in 1993 was mainly the effect of resource revaluation for two deposits (Winiary and Borków Chwałowice) and this amount became constant until 1997, when it decreased distinctly to almost 257 Mt due to depletion of resources of the abandoned Dzierżysław deposit. A subsequent increase in 1998 to more than 271 Mt resulted

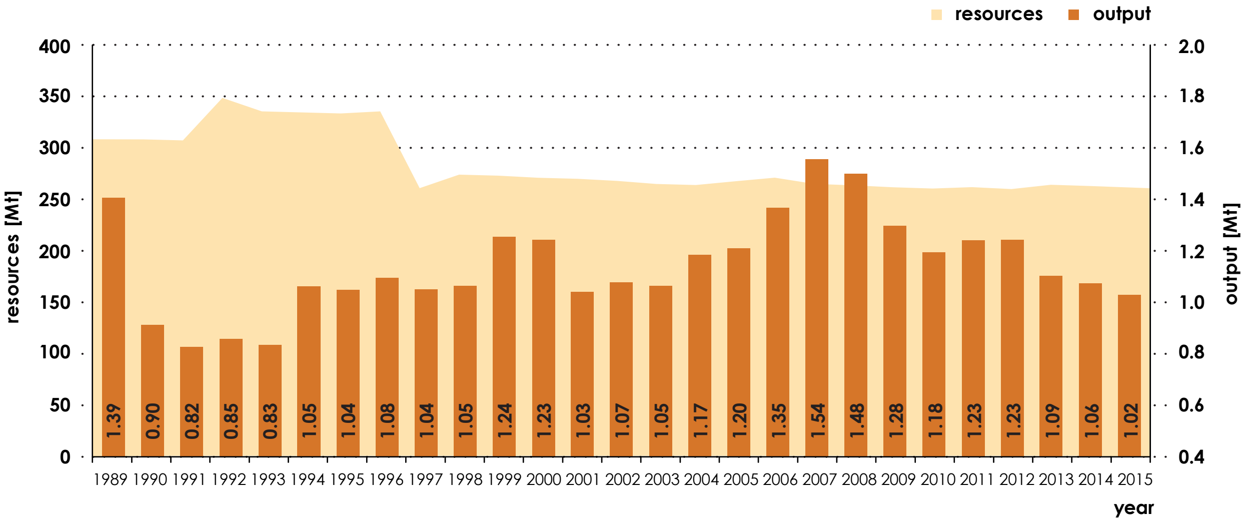


Fig. 4.15.1. Gypsum and anhydrite anticipated economic resources and output in 1989–2015

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); The balance of mineral resources deposits in Poland (in Polish; Szuflicki *et al.*, 2012–2015)

from resource revaluation of three deposits from the Fore-Sudetic area (Nawojów Śląski, Nowy Ląd-Pole Radłowka and Lubichów). In the 1998–2003 period, anticipated economic resources decreased to almost 262 Mt due to production. Significant growth was recorded in 2005–2006 (to 268 Mt) due to new estimations of Leszcze and Nowy Ląd deposit resources. From that time until 2015, the total volume of anticipated economic resources stabilised at the level of 260–262 Mt to a recent decrease to the actual amount of over 258 Mt. All registered losses mainly resulted from production and resource revaluation for active mines.

In 2015, the predicted resources of sulfates (gypsum and anhydrite) in Poland were estimated at about 575.7 bnt, including forecast resources of 483.96 bnt and perspective ones of 91.74 bnt (Sztromwasser *et al.*, 2015).

In 1989–1991, production of sulftates dropped rapidly from 1.93 Mt to 0.82 Mt (Fig. 4.15.1) due to the economical transformations. Further fluctuations ensued in that production: a slow increase to 1.23–1.24 Mt per year in 1999–2000, the following decrease to 1.03–1.07 Mt in 2001–2003 and the next rise to 1.54–1.48 Mt in 2007–2008 reflected the changing demand in the building construction sector. The observed successive decrease of annual production in 2009–2015 period to the actual volume of over 1 Mt was in response to a continuation of that trend in the national economy.

4.16. Kaolin

A. Malon

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

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

Anticipated economic resources of kaolin decreased in the last four years (2012–2015) due to exploitation and amounted to 212.08 Mt in 2015 (Tab. 4.16.1). Resources of two exploited deposits (Maria III and Dunino) amounted to 79.41 Mt (37% of anticipated economic resources). Output of kaolin raw materials dropped by 36 kt to 249 kt in 2012. Then, exploitation increased by 38 kt and was 287 kt in 2015. Most kaolin is extracted from the Maria III deposit. Exploitation of this deposit gave 285.30 kt and only 1,350 t of raw material came from the Dunino deposit in 2015.

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

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

Table 4.16.1. **Kaolin resources [Mt]**

	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**	**212.08**	**138.53**	**73.55**	**46.05**	**71.36**
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	2	79.41	79.41	–	–	71.36
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						
ABANDONED DEPOSITS	2	9.20	9.20	-	4.38	-

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 33

4.17. Limestones and marls for the cement and lime industry

D. Brzeziński

This section deals with deposits of limestones and marls exploited for use in the lime and cement manufacturing industry. Compact varieties of limestone used in production of dimension and crushed stones are discussed in a separate section, similarly as lacustrine limestone (lacustrine chalk) and proper chalk raw material used in industries other than cement and lime. Marly limestones and marls are raw materials useful only for the cement industry.

Limestone used as raw material in the lime industry are pure limestones with high content of $CaCO_3$ (>90%). Some types of limestones – meeting additional (mainly chemical) criteria – are also used in the chemical, metallurgical and sugar industries, for production of calcareous flour, including sorbents for exhaust gas desulphurization. When used in the manufacture of cement clinker, they should be supplemented with clay raw materials. Some soft types of limestones and waste from quarries are used for production of pulverized calcium carbonate in order to reduce soil acidity in agriculture.

Raw materials for the cement and lime industries are quite common in various geological formations, mainly in southern and central Poland. Most resources occur in four regions: Świętokrzyskie Mts., Kraków-Częstochowa-Wieluń, Lublin and Opole. In northern Poland, Jurassic limestones were documented within the Barcin-Piechcin area near Inowrocław (Plate 6). Both types of the raw material occur in several deposits (Bratkowszczyzna, Bukowa, Gliniany-Stróża, Górażdże, Kodrąb-Dmenin, Krasocin, Strzelce Opolskie I and Tarnów Opolski-Wschód).

Table 4.17.1. Limestones and marls for cement industry resources [Mt]

	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	**70**	**12,832.87**	**7,178.72**	**5,654.15**	**953.30**	**1,720.37**
Including resources of exploited deposits						
TOTAL	19	4,331.10	3,351.77	979.33	73.59	1,720.37
1. DEPOSITS OF OPERATING MINES	18	4,322.46	3,343.13	979.33	73.59	1,712.19
2. DEPOSITS EXPLOITED TEMPORARILY	1	8.63	8.63	–	–	8.18
Including resources of non-exploited deposits						
TOTAL	49	8,494.78	3,821.56	4,673.22	877.88	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	34	4,537.19	3,821.56	715.63	105.21	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	15	3,957.59	0.00	3,957.59	772.66	–
Including abandoned deposits						
ABANDONED DEPOSITS	2	7.00	5.39	1.60	1.84	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 34

Limestone and marl deposits are explored and documented down to depth capabilities of the equipment and technological limitations in open cast mining. According to economic criteria and limit values of parameters that define a deposit, the overburden may be up to 15 m thick at the most whereas the maximum proportion of overburden to deposit thickness cannot exceed 0.3. An additional requirement for marly limestones and marls for the lime industry refers to mean content of $CaCO_3$ which should be over 90% in the entire vertical section of a given deposit.

Anticipated economic resources of limestones and marls in 2015 amounted to 18,397.70 Mt, including 12,832.87 Mt (69.8%) within 70 deposits for the cement industry and 5,564.83 Mt (30.2%) within 118 deposits for the lime industry (Tab. 4.17.1 and 4.17.2).

Anticipated economic resources of exploited deposits (deposits of operating mines and deposits exploited temporarily) represent 33.8% of total resources for the cement industry and 33.5% of total resources for the lime industry.

Production of both raw materials amounted to 43.10 Mt in 2015 – 24.45 Mt of raw materials for the cement industry and 18.66 Mt for the lime industry.

Figure 4.17.1 shows changes in resources and output of raw materials for the cement and lime industry in Poland in 1989–2015.

Anticipated economic resources did not changed significantly in the last 27 years, vary in the range of 16.67–18.44 bnt. Resources have been systematically growing since 1991 by 0.34% at the yearly average. This was despite intensive exploitation and mainly due to documentation of new deposits (Patoki – 6.65 Mt, Anna 2 – 6.29 Mt, Płazów I – 4.56 Mt, Dobrut and Dobrut 1 – 1.75 Mt) and an updating of resources in already documented deposits (Krasocin – 244.75 Mt, Tarnów Opolski-Wschód – 97.35 Mt, Chełm – 26.90 Mt, Kowala – 24.31 Mt, Bukowa – 19.56 Mt, Działoszyn Trębaczew – 19.35 Mt, Leśnica Małogoszcz – 12.43 Mt, Niwiska Górne Grądy – 5.73 Mt, Rudniki-Jaskrów – 4.51 Mt). In 2015, anticipated economic resources of limestones and marls for the cement industry decreased by 0.60 Mt in

Table 4.17.2. Limestones for lime industry resources [Mt]

	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	**118**	**5,564.83**	**3,194.55**	**2,370.28**	**1,107.13**	**960.83**
Including resources of exploited deposits						
TOTAL	23	1,873.31	1,700.84	172.47	16.90	960.61
1. DEPOSITS OF OPERATING MINES	18	1,710.25	1,539.42	170.83	1.96	850.23
2. DEPOSITS EXPLOITED TEMPORARILY	5	163.06	161.41	1.64	14.95	110.37
Including resources of non-exploited deposits						
TOTAL	60	3,462.10	1,276.70	2,185.41	1,043.93	0.22
1. DEPOSITS COVERED BY DETAILED EXPLORATION	42	1,547.88	1,213.90	333.97	630.08	0.22
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	18	1,914.23	62.79	1,851.44	413.85	–
Including abandoned deposits						
ABANDONED DEPOSITS	35	229.41	217.02	12.39	46.29	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 34

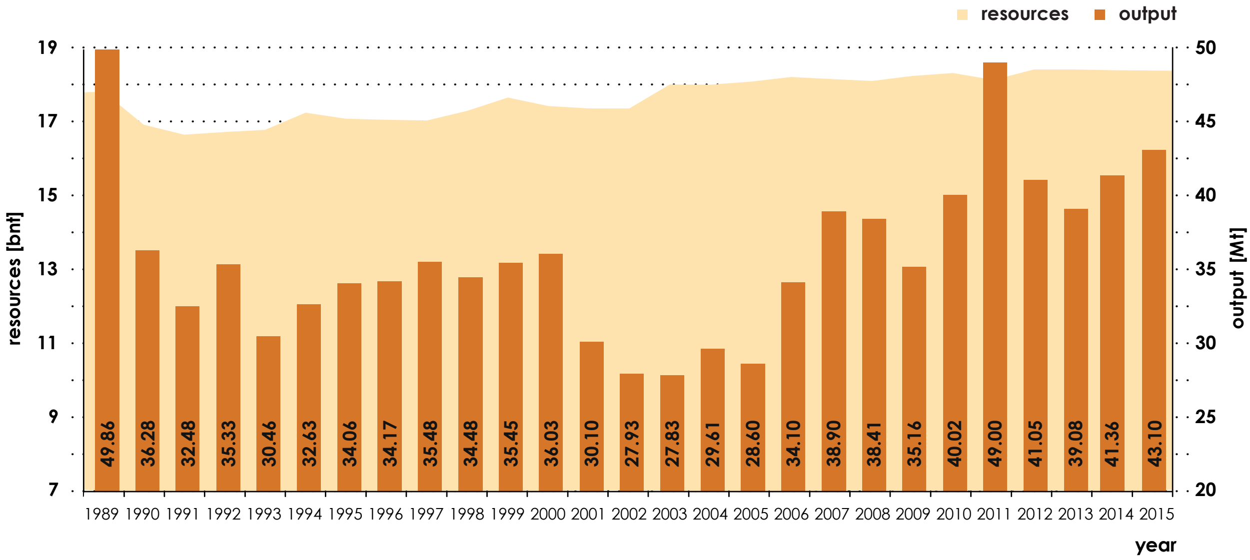


Fig. 4.17.1. **Limestones and marls for the cement and lime industry anticipated economic resources and output in 1989–2015**

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); The balance of mineral resources deposits in Poland (in Polish; Szuflicki *et al.*, 2012–2015)

comparison to the previous year, whereas resources of limestone for the lime industry decreased by 26.00 Mt.

Output was characterized by cyclical fluctuations tied to the economic situation in the building sector. The highest output volumes were recorded in 1989 and 2011 – 49.86 Mt and 49.01 Mt, respectively. In 2001–2005, output remained at its lowest level – below 30 Mt, as a result of modernization of the cement industry sector. Since 2006, production increased to 34.10 Mt in 2006, 49.01 Mt in 2011 and 43.10 Mt in 2015. This was caused by growing demand in the housing road building sectors during preparations for the EURO 2012 championships. Most funds came from the European Union. Production of both raw materials increased in 2015 by 1.74 Mt (4.2%) in comparison to the previous year.

4.18. Magnesites

A. Malon

Magnesite (magnesium carbonate – $MgCO_3$) originates from decay of magnesium-rich igneous rocks under hydrothermal conditions and occurs in the form of 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 a vein type with individual veins attaining up to 3 m in thickness and characterized by complex geological structure and high variability in the quality of raw material. Magnesite is currently exploited in an open strip mine at Braszowice only. Perspective resources are assessed to be 3.25 Mt (Sroga, 2011b).

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

Anticipated economic resources at the end of 2015 were estimated at 14.00 Mt and decreased due to exploitation by 0.11 Mt in comparison to the previ-

Table 4.18.1. **Magnesites resources [Mt]**

	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**	**14.00**	**4.25**	**9.75**	**2.18**	**3.97**
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	1	3.97	3.97	–	–	3.97
Including resources of non-exploited deposits						
DEPOSITS COVERED BY PRELIMINARY EXPLORATION	4	5.92	–	5.92	2.18	–
Including abandoned deposits						
ABANDONED DEPOSITS	1	4.11	0.28	3.83	–	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 32

ous year. In the last four years (2012–2015), anticipated economic resources decreased by 0.57 Mt mainly due to output and new resource recalculation for the Szklary deposit – as a new nickel ores deposit (Szklary 1) was documented within the area of the Szklary deposit.

In 2015, domestic production of magnesite from the only Polish deposit under exploitation was 96 kt, only slightly decreasing in comparison to 2014. It was the fourth successive year with output remaining at a similar level of about 80–90 kt.

4.19. Mineral raw materials for engineering works

W. Szczygielski

Mineral raw materials for engineering works are mainly comprise clayey-sandy and clayey rocks, but also others – sandstones and limestones that do not meet criteria necessary for dimension and crushed stones. These raw materials are utilized in the road industry for road embankment construction. Clayey rocks can be also used for packaging and reclamation of waste disposals hydro-building and other purposes.

Usually (in about 70%), resources of mineral raw materials for engineering works are documented as accompanying raw material. These are parts of deposits that do not meet balancing criteria of a main raw material, i.e. parts of sand and gravel deposits with overly high ash content or parts of dimension and crushed stone deposits with insufficient strength.

Anticipated economic resources amounted to 9.20 Mm^3 in 2015 (Tab. 4.19.1). In 2011–2015, 21 deposits were exploited. Output has been declining from a level of about 500 km^3 to 34 km^3 in 2015. Initial growth and a subsequent drop were strictly related to the process of building and modernizing the road sector in Poland. Most investments have been completed and new investments processes have slowed down.

The table given below shows the current state of identification and management of mineral raw materials for engineering work resources in Poland.

Table 4.19.1. Mineral raw materials for engineering work resources [Mm^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	**39**	**9.20**	**8.83**	**0.38**	**0.50**	**4.41**
Including resources of exploited deposits						
TOTAL	14	3.98	3.64	0.34	0.50	3.68
1. DEPOSITS OF OPERATING MINES	7	3.34	3.01	0.34	–	2.85
2. DEPOSITS EXPLOITED TEMPORARILY	7	0.64	0.64	–	0.50	0.82
Including resources of non-exploited deposits						
DEPOSITS COVERED BY DETAILED EXPLORATION	20	5.15	5.15	–	–	0.73
Including abandoned deposits						
ABANDONED DEPOSITS	5	0.07	0.03	0.04	–	–

4.20. Peat

W. Szczygielski

Peat is an organic matter of the late Quaternary age, most often Holocene. It is an accumulation of partially decayed vegetation. The process of peat forming requires a high groundwater level and acidic and anaerobic conditions that inhibit decay of plant material. According to genetic features, there are three distinguished types of peat: low, high and medium. The richest in food ingredients is low peat accumulating in river valleys and lake edges. High peat is nutrient-poor and occurs at watershed locations. Medium peat is characterized by features of both previous types.

More than 50% of peatlands are found in the northern part of Poland. They cover an area of about 1.2 Mha (around 4.2% of the country area) and their volume is estimated at over 17 bnm^3. Until now, almost 50,000 peatlands have been catalogued by the Institute for Land Reclamation and Grassland Farming. According to these records, about 36% of catalogued peatlands form a potential resource basis for peat harvesting. Only a small part of these peatlands has been explored and can be assessed as deposits according to the GML.

According to the RME limit values of parameters defining a deposit are (Appendix 8):

- peat deposit: minimum deposit thickness – 1 m, maximum ratio of overburden thickness to mineral deposit – 0.5, maximum ash content – 30%;
- therapeutic peat (mud) deposits: minimum deposit thickness – 1 m, maximum ratio of overburden thickness to mineral deposit – 0.5, maximum organic matter content in dry mass – 25%, minimum grade of decomposition – 30% (H3), bacteriological valuation (coli titer) ≥1.0, coli titer perfringens ≥1.0;
- mud silt deposits: minimum deposit thickness – 1 m, maximum ratio of overburden thickness to mineral deposit – 0.5, maximum organic matter content in dry mass – 80%, minimum grade of decomposition – 30% (H3), bacteriological valuation (coli titer) ≥1.0, coli titer perfringens ≥1.0.

Table 4.20.1. Peat resources [Mm³]

	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	**286**	**93.32**	**80.57**	**12.75**	**6.89**	**34.80**
Including resources of exploited deposits						
TOTAL	84	47.63	47.61	0.03	4.74	34.19
1. DEPOSITS OF OPERATING MINES	70	46.50	46.47	0.03	4.74	33.76
2. DEPOSITS EXPLOITED TEMPORARILY	14	1.14	1.14	–	–	0.44
Including resources of non-exploited deposits						
TOTAL	126	38.65	26.15	12.49	1.11	0.33
1. DEPOSITS COVERED BY DETAILED EXPLORATION	106	26.17	26.15	0.01	0.94	0.33
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	20	12.48	0.00	12.48	0.17	–
Including abandoned deposits						
ABANDONED DEPOSITS	76	7.04	6.81	0.23	1.04	0.27

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 34

In 2015, anticipated economic resources of peat within 286 deposits were estimated at 93.32 Mm³ (Tab. 4.20.1). The total area covered by the deposits is 4.5 kha.

Peat is used in agriculture, gardening, fruit-growing and soil reclamation. It can improve the physical properties of soil. Peat is a base for production of gardening peat, peat substrates, peat mixtures and agriculture peat. In the past, peat was also used as fuel, raw material for chemical industry and for cardboard and cardboard production and as a sorbent.

Peats in medicine are therapeutic muds at health resorts for baths and compresses and are used in the production of therapeutic and cosmetic products.

There are 36 deposits of therapeutic muds documented in Poland with total resources of 10.34 Mm³. Exploitation is carried out at ten locations in Poland and has totaled 6.7 km³ and 10.1 km³ lately. Mud treatments are offered by about 30 out of 45 Polish health resorts of which 13 have mud deposits in their area (8 of which are currently exploited).

Peats as therapeutic muds can be used according to a Polish law (dated 28 July 2005, Journal of Laws, 2005 no. 1399) regulating spa activity.

Therapeutic properties of peat must be confirmed by authorities authorized by the Minister for Health on the basis of tests confirming these properties and excluding negative effects on the human body.

The raw material usable for therapeutic purposes is peat from a non-dehydrated deposit with documented resources and a humification degree of organic matter above 30%. It must also meet physiochemical and microbiological requirements as defined in a Regulation of the Minister of Health dated 13 April 2006 (Journal of Laws, 2006 no. 80 pos. 565).

Appendix 2 – the scope of tests necessary to determine therapeutic properties of peloids;

Appendix 4 – criteria for assessing therapeutic properties of water and gas, peloids and climate and their usefulness for therapeutic purposes. II. Criteria for assessing therapeutic properties of peloids.

The list of authorities entitled to carryout tests and issue certificates confirming the therapeutic properties can be found on the Ministry of Health website (http://www2.mz.gov.pl).

4.21. Phyllite, quartz and micaceous schists

M. Tymiński

Metamorphic phyllite, quartz and micaceous schists are used in building construction as a major component of fine gravel cover of roll tar paper (phyllite and micaceous schists), in agriculture as an inert dust carrier for pesticides, and in the manufacture of refractory materials as a major component of refractory cement (crystalline schists).

Three deposits of phyllite schists from the Opolskie province (Plate 7) are the only deposits of that raw material hitherto proven in Poland: Chomiąża, Dewon-Pokrzywna and Dewon-Pokrzywna 2. Anticipated economic resources of this raw material in Poland were estimated in 2015 at approximately 17,127.12 kt and production (from Dewon-Pokrzywna deposit) at 135.01 kt. Two other deposits are not being exploited – Dewon-Pokrzywna 2 is only covered by preliminary exploration, whereas the Chomiąża deposit has been abandoned since 1989 and remaining resources are estimated at 0.31 Mt.

Quartz schists occur only within the Strzelin granite massif at Jegłowa in the Lower Silesian region (Dolnośląskie province). The Jegłowa deposit is still the only temporarily exploited deposit of that raw material documented in Poland. Its anticipated resources were estimated in 2015 at 8,697.03 kt and economic resources – at 2,765.76 kt. The Jegłowa deposit is widely known for occurrences of beautiful quartz crystals, especially clear and colourless rock crystals (described in part 6.5.2).

Micaceous schists occur in the Orłowice deposit located near Lwówek Śląski and in the Jawornica deposit in Kłodzko county. Total anticipated economic resources of that mineral raw material as of 31.12.2015 were estimated at 6,661.31 kt and economic resources at 4,399.56 kt. Resources from the Orłowice deposit account for 85.6% of anticipated economic resources and 88.2% of economic resources. Exploitation is being carried out from both of these deposits.

Anticipated economic resources of phyllite schists decreased in the 2012–2015 by 757.54 kt due to exploitation of the Dewon-Pokrzywna deposit. In 2015, output dropped from a level of about 190 kt to 135 kt by 34.79 kt (20.5%) in comparison to 2014. Quartz schists resources increased by almost 50% due to the approval of a new management plan for the Jegłowa deposit with reclassified resources in 2013 and reached a level of 8,697 kt. Resources have not changed in 2014 and 2015, as there was no exploitation from this deposit. Resources of micaceous schists slightly decreased since 2012 – from 6,671 kt to 6,661 kt in 2015 due to exploitation and losses. In 2015, production from the Orłowice deposit increased by 11.7% and reached 2.95 kt and from the Jawornica deposit decreased to 0.50 kt (schists from this deposit are used as crushed stones).

4.22. Quartz sands for production of cellular concrete and lime-sand brick

A. Malon

Sands are widely used in the production of cellular concrete and bricks and sand lime blocks in the entire area of Poland. Raw material suitable for that production has to be sufficiently pure, fine-grained and well sorted. These requirements are met by Quaternary sands of glacial and fluvioglacial origin as well as river and aeolian sands. Sands most suitable for these purposes mainly include fluvioglacial and aeolian sands characterized by high silica content, good grain segregation (content of 0.05–

0.5 mm grains should exceed 65%), a high degree of grain roundness and low content of extraneous matter.

According to the RME, exploitable quartz sand deposits require a minimum content of quartz grains of 90%, maximum content of silts of 5%, thickness not smaller than 2 m and a ratio of cover to deposit series not higher than 0.5.

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

Anticipated economic resources of quartz sands for production of cellular concrete amounted to 143.27 Mm^3 (257.89 Mt – recalculated according to 1.8 factor), decreased by 0.56 Mm^3 in comparison to the previous year (Tab. 4.22.1). The reasons for this drop were exploitation, losses (0.36 Mm^3) and deletion of the Wola Suchożebrska deposit from "The balance…" (0.20 Mm^3). Economic resources within exploited deposits amounted to 17.99 Mm^3 (58.03% of total anticipated economic resources).

Exploitation of quartz sands for production of cellular concrete increased in comparison to the previous year by 42.55 km^3 and totalled 361.43 km^3 (650.57 kt). The Niegocin II deposit located in the Warmińsko-Mazurskie province was abandoned whereas exploitation from Przygody deposit in the Mazowieckie province is still on hold.

Anticipated economic resources of sands for production of lime-sand bricks decreased by 0.66 Mm^3 due to exploitation and losses and amounted to 271.26 Mm^3 (488.27 Mt) in 2015 (Tab. 4.22.2). There are 42.51 Mm^3 within exploited deposits that account

Table 4.22.1. Quartz sands for production of cellular concrete resources [Mm^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**	**143.27**	**53.98**	**89.29**	**1.62**	**17.99**
Including resources of exploited deposits						
TOTAL	11	30.19	25.55	4.64	0.27	17.52
1. DEPOSITS OF OPERATING MINES	9	28.66	24.02	4.64	0.27	16.00
2. DEPOSITS EXPLOITED TEMPORARILY	2	1.53	1.53	–	–	1.51
Including resources of non-exploited deposits						
TOTAL	37	103.33	18.68	84.65	0.82	0.47
1. DEPOSITS COVERED BY DETAILED EXPLORATION	13	24.58	18.68	5.90	0.34	0.47
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	24	78.75	0.00	78.75	0.47	–
Including abandoned deposits						
ABANDONED DEPOSITS	11	9.74	9.74	–	0.53	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 33

for 15.7% of total resources. Economic resources within exploited deposits amounted to 15.28 Mm^3 (35.94% of total anticipated economic resources). In 2015, production of these quartz sands increased by 45 km^3 and amounted to 622 km^3. The exploitation of the Jedlanka II deposit (Lubelskie province), Grabowo-Kruki and Grabowo-Kruki II deposits (Mazowieckie province) started again in 2015. In turn, exploitation from Czostków (Świętokrzyskie province) and Żytkowice 2 deposits (Mazowieckie province) was halted in 2015.

Total anticipated economic resources of quartz sands for production of cellular concrete and lime-sand bricks in 2015 amounted to 414.53 Mm^3 (746.15 Mt).

Anticipated economic resources of quartz sands for production of cellular concrete varied in 1989–2015, but generally increased from 121 Mm^3 in 1989 to 143 Mm^3 in 2015 (Fig. 4.22.1). There were few periods of growth of resources, mainly as a result of documentation of new deposits: Futymówka (9.5 Mm^3) and Gołąb 1 (0.2 Mm^3) in 1991, Brzeziny (3.1 Mm^3) and Zapłocie (1.0 Mm^3) in 1994, Postolin in 2000 (5.5 Mm^3) and Brzeziny-1 (1.1 Mm^3) in 2011. New resources were also explored within deposits already documented – the Studzienice deposit in Pomorskie province (8.5 Mm^3) in 2009. In the last four years, resources have been decreasing mainly due to the exploitation and losses.

Despite increasing resources, the production base did not grow in 1989–2015. It varied between 1.098 Mm^3 and 0.361 Mm^3 due to a crisis in the building material sector and production limitations and also due to the fact that other raw materials such as fly ash from power stations or building sands were used for cellular concrete production. Nevertheless, Poland shall remain a European leader in the production of articles made from cellular concrete.

Anticipated economic resources of quartz sands for production of lime-sand bricks have been quite steady and remained within the range of 265–

Table 4.22.2. Quartz sands for production of lime-sand bricks resources [Mm^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**	**271.26**	**142.21**	**129.05**	**6.28**	**19.34**
Including resources of exploited deposits						
TOTAL	27	42.51	40.98	1.53	0.11	15.28
1. DEPOSITS OF OPERATING MINES	23	37.78	36.25	1.53	0.11	14.02
2. DEPOSITS EXPLOITED TEMPORARILY	4	4.73	4.73	–	–	1.26
Including resources of non-exploited deposits						
TOTAL	49	193.69	70.91	122.79	2.57	4.03
1. DEPOSITS COVERED BY DETAILED EXPLORATION	26	72.34	70.91	1.43	2.57	4.03
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	23	121.35	0.00	121.35	–	–
Including abandoned deposits						
ABANDONED DEPOSITS	28	35.06	30.32	4.74	3.60	0.03

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 33

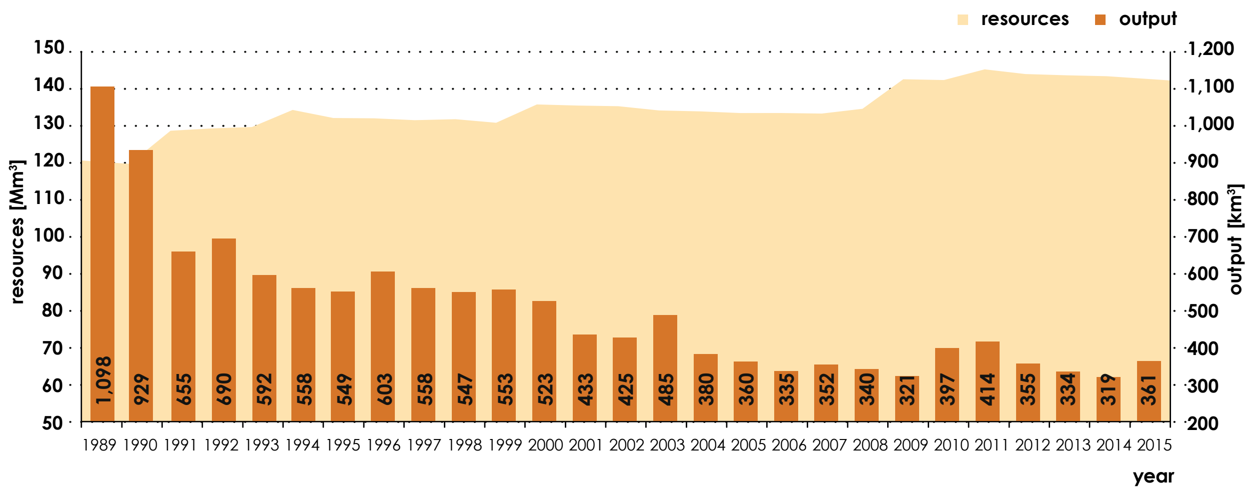


Fig. 4.22.1. Quartz sands for production of cellular concrete – anticipated economic resources and output in 1989–2015

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al*., 2007, 2008; Wołkowicz *et al*., 2009–2010; Szuflicki *et al*., 2011); The balance of mineral resources deposits in Poland (in Polish; Szuflicki *et al*., 2012–2015)

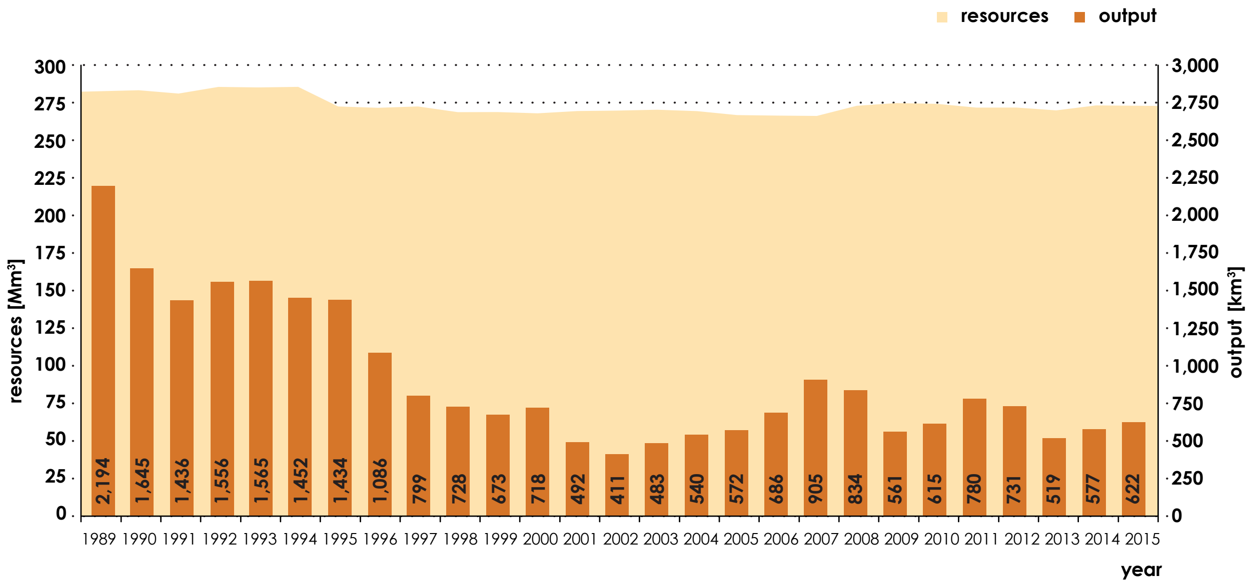


Fig. 4.22.2. Quartz sands for production of lime-sand bricks – anticipated economic resources and output in 1989–2015

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al*., 2007, 2008; Wołkowicz *et al*., 2009–2010; Szuflicki *et al*., 2011); The balance of mineral resources deposits in Poland (in Polish; Szuflicki *et al*., 2012–2015)

284 Mm^3 with a slight negative tendency (Fig. 4.22.2). An increase of the new documented resources is bridged by output. Production depends on demand for building materials. This raw material is utilized locally, in production plants located in the neighbourhood of deposits. Exploitation decreased from 2.194 Mm^3 to 0.411 Mm^3 in 1989–2002 and then varied from 0.483 Mm^3 to 0.905 Mm^3 in 2003–2015.

4.23. Refractory clays

M. Tymiński

Kaolinite clays called refractory clays are an indispensable raw material for the production of aluminosilicate fire resistant materials. They are also used for production of ceramic tiles and sanitary articles. Such clays originate from a wash down of outcropping and near-surface kaolinized rocks and redeposition of kaolinite, leading to separation of quartz grains and marked improvement of fire resistance properties of that raw material.

Refractory clays are represented by kaolinite or kaolinite-illite clays. They are characterized by high plasticity and when fired at temperatures over 1,500°C 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 the melting point of these clays. In turn, the presence of iron compounds causes the yellow to brownish and red colour of the refractory clays.

In Poland, deposits of refractory clays occur in the Lower Silesian region and in the NE part of the Świętokrzyskie Mts. (Plate 7). The only exploited deposit of refractory clays (Rusko-Jaroszów deposit) is situated in the first of these areas. Other refractory clay deposits are not exploited at present. The second largest deposit is called Kryzmanówka and is located in the Mazowieckie province.

Anticipated economic resources amounted to 54.36 Mt in 2015 (Tab. 4.23.1). Anticipated economic resources covered by the detailed exploration (in A, B, C_1 categories) were 53.68 Mt and accounted for 98.8% of total anticipated economic resources. Economic resources were 1.65 Mt (3% of total anticipated economic resources and 61.6% of anticipated economic resources within exploited deposits). In 2015, production of refractory clays was 87 kt. The exploited raw material may be used without any processing or after firing as so-called "fired clays".

The anticipated economic resources of refractory clays decreased slightly within the last four years – from 54.65 Mt in 2012 to 54.36 Mt in 2015. The main rea-

Table 4.23.1. Refractory clays resources [Mt]

	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**	**54.36**	**53.68**	**0.68**	**110.26**	**1.65**
Including resources of exploited deposits						
TOTAL	2	2.68	2.48	0.20	–	1.65
1. DEPOSITS OF OPERATING MINES	1	1.35	1.15	0.20	–	1.27
2. DEPOSIT EXPLOITED TEMPORARILY	1	1.33	1.33	–	–	0.37
Including resources of non-exploited deposits						
DEPOSITS COVERED BY DETAILED EXPLORATION	6	48.62	48.47	0.15	106.02	–
Including abandoned deposits						
ABANDONED DEPOSITS	9	3.07	2.73	0.34	4.24	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 32

son for the decline was exploitation from the Rusko-Jaroszów deposit and deletion of the Czerwona Woda deposit from "The balance…" (in 2015). Output has not changed significantly since 2012 and has remained in the range of 83–92 kt. In 2015, it increased by 4 kt (4.8%) in comparison to the previous year.

PGE Górnictwo i Energetyka Konwencjonalna SA (PGE GiEK SA) reported that exploitation of refractory and ceramic clays from non-documented deposits (so-called exploitation points) in the KWB Turów Mining Plant in 2015 amounted to 4.08 kt.

4.24. Refractory quartzites

A. Malon

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

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

In Poland, quartzite deposits occur in two regions: the Lower Silesia region and the Świętokrzyskie Mts. (Plate 7). In the Lower Silesia they are formed of irregular quartzitic layers and lenses dated at the Neogene. The majority of these sites were explored and exploited in the past, so abandoned deposits still comprise some relict resources. It should be added here that two quartzite deposits from Mików still have to be developed.

Quartzite deposits occurring in the Świętokrzyskie 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 (Bukowa Góra) is still being exploited. Raw material from that deposit has not been classified as fire-proof quartzite, but rather as quartzitic sandstone. Therefore, the Bukowa Góra deposit is discussed in the section on dimension and crushed stones (4.8).

Table 4.24.1. Refractory quartzites resources [Mt]

	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**	**6.59**	**3.57**	**3.02**	**3.96**	**–**
Including resources of non-exploited deposits						
TOTAL	6	5.93	3.21	2.72	3.84	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	5	5.23	3.21	2.02	3.84	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	1	0.70	–	0.70	–	–
Including abandoned deposits						
ABANDONED DEPOSITS	12	0.66	0.36	0.30	0.12	–

Anticipated economic resources of the refractory quartzites decreased by 0.29 Mt and were indicated as 6.59 Mt (Tab. 4.24.1). Ten abandoned and exhausted deposits were deleted from “The balance…” in 2015. In 2012–2014, resources were at the same level (6.88 Mt).

No output of refractory quartzites was registered in 2012–2015 because the Bukowa Góra deposit was the only exploited deposit in the refractory quartzites group.

4.25. Sand and gravel

D. Brzeziński, W. Miśkiewicz, J. Stawierej, A. Wałkuska

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

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

The bulk of Polish natural aggregates deposits are of the Quaternary age. The share of deposits of the Pliocene, Miocene and Liassic age is subordinate.

The quality of raw material (especially its homogeneity) largely depends on the genetic type of a deposit. Deposits of fluvial origin clearly predominate in the Carpathian-Sudetic zone (southern Poland). In the Sudety Mts., the most common deposits are those of sandy-gravel higher terraces of the Pleistocene age, mainly built 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 a predominance of material originating from disintegration of flysch rocks, except for those of the Dunajec River valley, showing a fairly high contribution of crystalline rocks from the Tatry 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 from river accumulation. Deposits from the northern part of that area represent gravel-sandy accumulations mainly comprising Scandinavian material – debris of crystalline rocks and limestone with an admixture of quartz and sandstones. In central and southern parts of this region, deposits are mainly formed from sandy sediments with significant share of debris of local rocks.

According to the RME that sets the limit values of parameters defining a deposit, a sand deposit with sand content above 75% should be characterized by thickness of at least 2 m, a ratio of overburden to deposit thickness no higher than 0.3 and content of grains of silt fraction below 10%, while sand, graveled-sand and sandy-gravel deposit with sand content below 75% should be characterized by thickness of at least 2 m, a ratio of overburden to deposit thickness no higher than 1 and content of grains of silt fraction below 15%.

Anticipated economic resources of natural aggregates as of 31.12.2015 totalled 18,639.57 Mt (Tab. 4.25.1). Sand and gravel deposits are documented within recognized four subtypes: sand, sand and gravel, gravel and loamy sand. Resources of sands with sand content above 75% amounted to 7,937.6 Mt (increased by 310 Mt in comparison to the previous year) from which 2,121.3 Mt are within exploited deposits. Resources of graveled-sands and sandy-gravel sands with sand content between 25 and 75% amounted to 9,812.6 Mt (increased by 42.1 Mt). Resources of gravel (with sand content <25%) amounted to 860.3 Mt (decreased by 77.2 Mt) and resources of loamy sands amounted to 28.8 Mt (increased by 3.6 Mt).

The identification and management structure of resources are shown in Figure 4.25.1. Provinces with the greatest resources are: Dolnośląskie (2,212 Mt), Małopolskie (1,846 Mt), Podlaskie (1,524 Mt), Opolskie (1,393 Mt), Podkarpackie (1,283 Mt) and Mazowieckie (1,235 Mt). About 0.4% of the total number are deposits with resources between 10 and 500 Mt, nonetheless their resources account for 60% of

Table 4.25.1. Sand and gravel resources [Mt]

	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	**9,704**	**18,639.57**	**10,813.38**	**7,826.18**	**391.18**	**3,680.47**
INCLUDING:						
Sand		7,937.58	5,020.26	2,917.32	83.97	1,608.55
Sand and gravel		9,812.64	5,412.95	4,399.69	283.05	1,970.34
Gravel		860.30	353.96	506.35	15.00	83.99
Loam		28.82	25.99	2.83	9.16	17.59
Including resources of exploited deposits						
TOTAL	3,870	5,470.05	4,654.62	815.43	57.78	3,129.09
INCLUDING:						
Sand		2,121.34	2,021.08	100.26	20.88	1,312.10
Sand and gravel		3,122.14	2,455.50	666.64	27.52	1,721.15
Gravel		202.89	157.19	45.70	5.94	79.36
Loam		23.63	20.80	2.83	3.44	16.47
1. DEPOSITS OF OPERATING MINES	2,595	4,353.28	3,769.19	584.09	43.88	2,489.15
INCLUDING:						
Sand		1,600.05	1,520.80	79.26	16.79	1,007.83
Sand and gravel		2,539.24	2,082.24	457.00	19.98	1,395.23
Gravel		190.63	145.63	45.00	3.67	69.84
Loam		23.36	20.53	2.83	3.44	16.26
2. DEPOSITS EXPLOITED TEMPORARILY	1,275	1,116.77	885.43	231.35	13.90	639.94
INCLUDING:						
Sand		521.28	500.28	21.00	4.09	304.28
Sand and gravel		582.91	373.27	209.64	7.54	325.92
Gravel		12.26	11.56	0.70	2.27	9.52
Loam		0.27	0.27	–	–	0.21

Table 4.25.1. **Cont.**

	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 non-exploited deposits						
TOTAL	3,573	11,740.60	5,089.75	6,650.85	241.64	514.33
INCLUDING:						
Sand		5,170.82	2,471.62	2,699.21	52.80	276.36
Sand and gravel		5,952.15	2,446.75	3,505.40	175.14	232.37
Gravel		612.78	166.54	446.24	7.99	4.49
Loam		4.75	4.75	–	5.72	1.12
1. DEPOSITS COVERED BY DETAILED EXPLORATION	3,234	5,427.11	5,056.45	370.66	136.56	510.30
INCLUDING:						
Sand		2,516.75	2,465.19	51.55	37.83	274.54
Sand and gravel		2,755.26	2,437.41	317.85	87.76	230.16
Gravel		150.26	149.00	1.26	5.26	4.49
Loam		4.75	4.75	–	5.72	1.12
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	339	6,313.49	33.30	6,280.19	105.08	4.03
INCLUDING:						
Sand		2,654.07	6.42	2,647.65	14.97	1.82
Sand and gravel		3,196.90	9.34	3,187.55	87.38	2.21
Gravel		462.52	17.54	444.98	2.73	–
Including abandoned deposits						
ABANDONED DEPOSITS	2,261	1,428.92	1,069.02	359.90	91.76	37.05
INCLUDING:						
Sand		645.41	527.56	117.85	10.29	20.08
Sand and gravel		738.34	510.70	227.65	80.39	16.83
Gravel		44.64	30.23	14.41	1.07	0.14
Loam		0.45	0.45	–	–	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 32

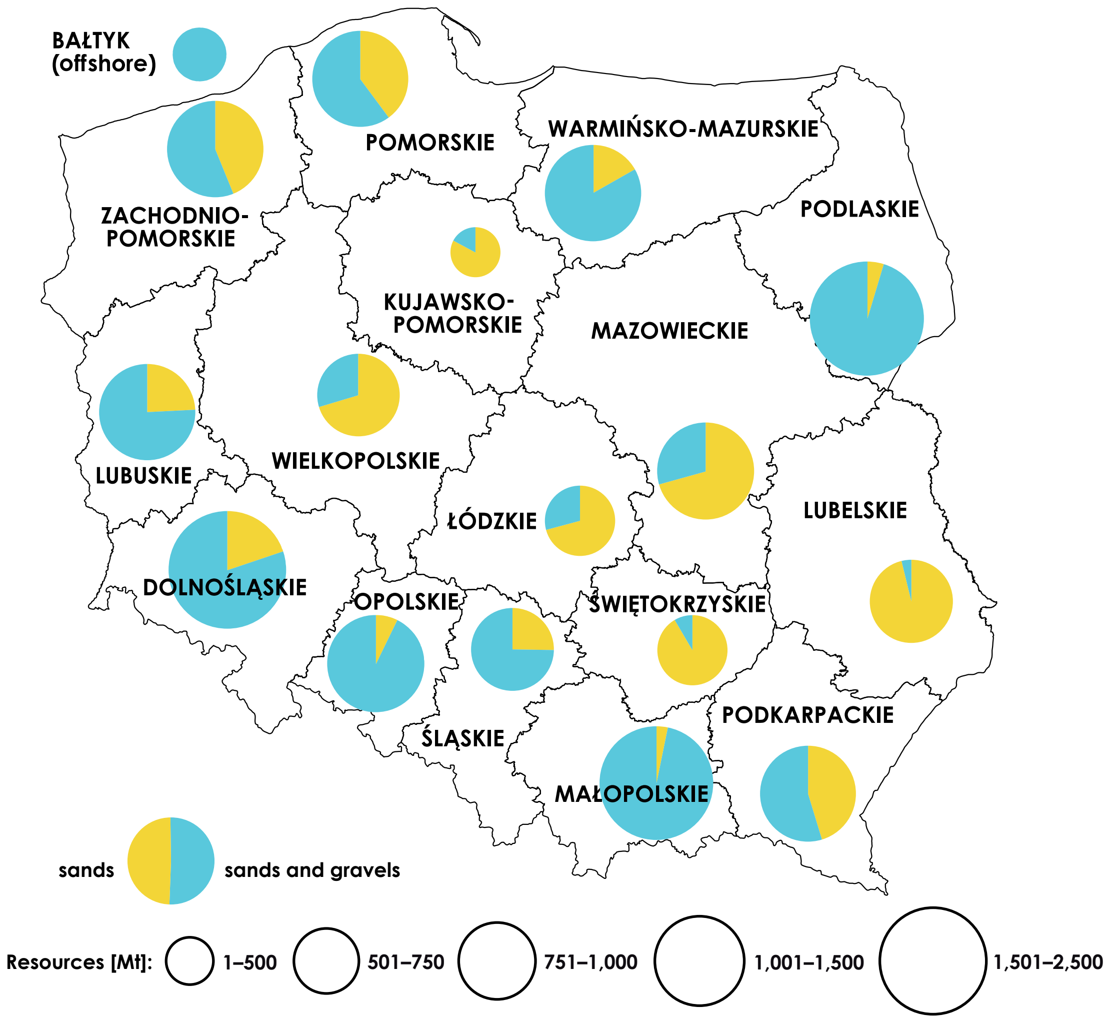


Fig. 4.25.1. Distribution of sand and gravel resources in 2015

the domestic resources base. Deposits with resources below 50 kt comprise 16.9% of the total deposit number, containing 30.9 Mt of resources (0.17% of domestic base).

The frequency of occurrence of various magnitude deposits of sand and gravel in Poland is shown in Figure 4.25.2.

In 2015, production of natural sands and gravel amounted to 167.93 Mt. More than one-half of exploited raw material (111.9 Mt – 66.7%) came from deposits with resources in the range of 0.5–20 Mt. Approximately 7.2 Mt of sands and gravel (4.3% of domestic output) were exploited from much smaller deposits. Natural sand and gravel are also obtained during lignite exploitation. In 2015, 8.6 kt of sand and sand and gravel was exploited from the Bełchatów deposit – Szczerców field.

Anticipated economic resources of sand and gravel increased significantly in the years 1989–1993 and then changed slightly by staying at the level of about 14.5 bnt until 2005. Since 2006, resources have grown by 18.6 bnt – about 20% (Fig. 4.25.3). Resources have increased visibly in the last four years, despite varying output. This was the result of growing demand for natural sand and gravel in the road construction sector. Construction of new sections of the A-2, A-4 and A-1 motorways and new motorways led to prospection and exploration of new raw material sources. In 2015, anticipated economic resources amounted to 18,639.57 Mt and increased by 278.67 Mt (1.5%) in comparison to 2014. The growth dynamic decreased compared to the previous period when it was 2.1%.

Sand and gravel output increased in 1994–2011, excluding 2001, 2002 and 2009 (Fig. 4.25.3). Exploitation changes coincided with political-economy events such as the Polish association with the EU, the access of Poland to the EU and the global economic crisis. Since 2005 (when it was 116.7 Mt) output increased by a dozen or so Mt annually and

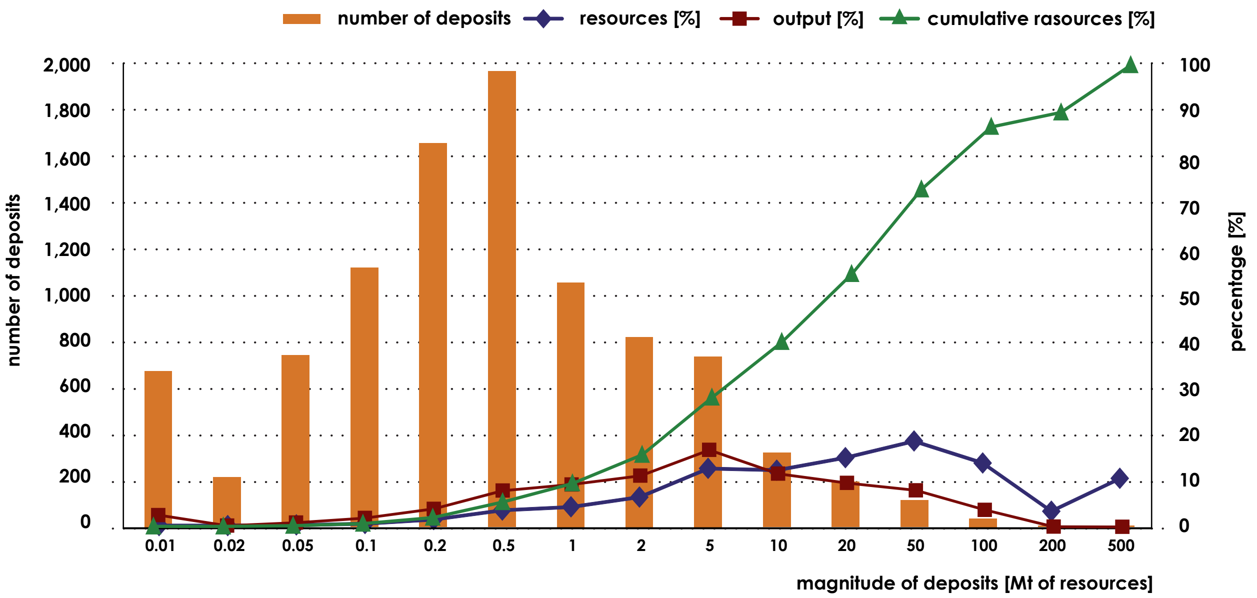


Fig. 4.25.2. **Frequency of resources magnitude in sand and gravel deposits in 2015**

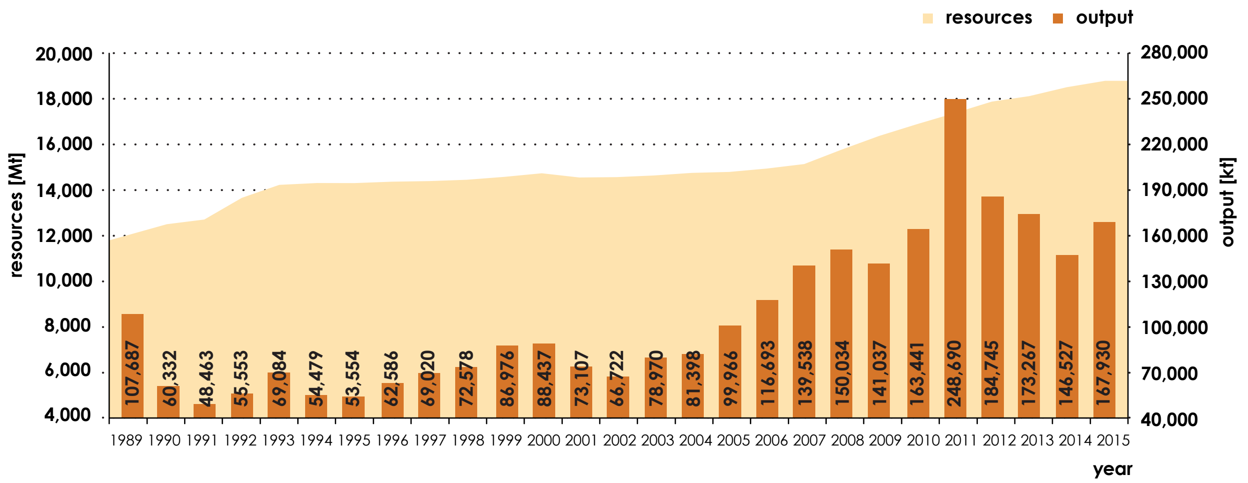


Fig. 4.25.3. **Sand and gravel anticipated economic resources and output in 1989–2015**

According to: The balance of mineral resources deposits and groundwater resources in Poland (in Polish; Przeniosło, 1989–2005; Przeniosło, Malon, 2006; Gientka *et al.*, 2007, 2008; Wołkowicz *et al.*, 2009–2010; Szuflicki *et al.*, 2011); The balance of mineral resources deposits in Poland (in Polish; Szuflicki *et al.*, 2012–2015)

amounted to 248.7 Mt in 2011. The next three years (2012–2014) brought an output drop, whereas in 2015 it returned to the level recorded in 2010. Significant growth in 2011 was strictly tied to growing demand for raw materials in the road construction sector while preparing for the 2012 UEFA European Championship. Most evident growth was in regions where motorways were built (A-2 – Łódzkie, Mazowieckie and Wielkopolskie provinces; A-1 – Kujawsko-Pomorskie province; A-4 – Podkarpackie province). In other regions, exploitation was the result of motorways and local road (i.e. beltways) construction. As soon as these investments ended, output decreased significantly. Growing tendencies returned when new tranches for road investments began in 2015. The most important of them are: S7 in the Pomorskie, Warmińsko-Mazurskie, Mazowieckie, Świętokrzyskie and Małopolskie provinces; S3 and S5 in the Wielkopolskie, Kujawsko-Pomorskie and Dolnośląskie provinces; S6 in the Zachodniopomorskie province; A1 in the Śląskie province (GDDKiA, 2016). In 2015, output increased by 21.4 Mt (14.6%) in comparison to the previous year and was 167.93 Mt. After a three-year output decrease, growth was recorded in 14 provinces with a drop in only two (Mazowieckie and Lubelskie).

4.26. Vein quartz

A. Malon

Quartz (SiO_2) is the most common mineral in igneous, metamorphic and sedimentary rocks. Under conditions favourable for crystallization such as voids in igneous or metamorphic rocks, it forms sharp-pointed hexagonal long and slender crystals that are widely used as a popular ornamental stone and also as a gemstone in jewellery. Depending on admixture of colouring oxides, several varieties of these gemstones are differentiated: clear and colourless rock crystal, yellow to orange citrine, pink to rose 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 as a result of hydrothermal activity as an infill of open fissures and fractures cutting a given rock massif. Quartz infills are characterized by high content of silica (SiO_2) and low content of colouring oxides (Fe_2O_3 and TiO_2). Quartz crystal from these occurrences, in light of its piezoelectric properties, is a basic electronic raw material. It is also widely used in optics. Its purest varieties are used in the manufacture of high-quality glass and are also the source of high-quality quartz powder and grits to production of ferrosilicon.

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

Anticipated economic resources of vein quartz amounted to 5.61 Mt in 2015 and decreased by 0.95 Mt in comparison to 2014, mainly due to deletion of

Table 4.26.1. Vein quartz resources [Mt]

	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**	**5.61**	**3.72**	**1.89**	**0.35**	**1.72**
Including resources of exploited deposits						
TOTAL	2	3.83	2.00	1.83	0.31	1.72
1. DEPOSITS OF OPERATING MINES	1	0.49	0.32	0.17	0.31	0.37
2. DEPOSITS EXPLOITED TEMPORARILY	1	3.34	1.68	1.66	–	1.35
Including resources of non-exploited deposits						
DEPOSITS COVERED BY DETAILED EXPLORATION	2	0.28	0.22	0.06	–	–
Including abandoned deposits						
ABANDONED DEPOSITS	3	1.50	1.50	–	0.05	–

The key for comparison and estimation of mineral resources from Polish mineral classification into UNFC-2009 is presented on page 32

the Sady (Białe Krowy) deposit from "The balance…" (0.94 Mt) (Tab. 4.26.1). Resources did not change in 2012 and 2013 and then amounted to 6.564 Mt. The largest anticipated economic resources hitherto discovered are 3.3 Mt in the Stanisław deposit located south-west of Jelenia Góra and 1.5 Mt in the Krasków deposit from the vicinities of Świdnica, Sudety Mts. (Plate 6).

Two out of all deposits at the Sudety Mts. are developed: Stanisław and Taczalin, but only the Taczalin deposit has been exploited since 2014. Output from the Taczalin deposit was 5.90 kt in 2014 and 4.32 kt in 2015. Production from Stanisław deposit was suspended in 2005.

5. Brines, curative and thermal water

L. Skrzypczyk, J. Sokołowski

According to the GML, groundwater is considered a mineral only on the basis of specific physical and chemical properties. Such requirement is met by brines as well as curative and thermal water.

Brine: groundwater with total content of solid dissolved minerals of at least 35 g/dm^3. Taking the purpose of exploitation into account, an Ordinance of the Council of Ministers only classified the deposit in Łapczyca in the Małopolskie province as brine. This brine, occurring in a Miocene sandstone formation, is used for therapeutic purposes and bath salt production. Groundwater with similar composition (strongly mineralised waters of Cl-Na or Cl-Na-Ca type, with a higher amount of iodine ion) is common in the area of the Polish Lowlands. It occurs in deeply seated formations at a depth of several thousand meters.

Curative water: According to the GML, curative water is groundwater with no chemical and microbiological contamination, characterized by natural diversity of physical and chemical properties and 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-silica acid content – at least 70 mg/dm^3 (silica 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).

Over 70% of known bodies of curative water occur in areas of health resorts and towns in southern Poland, the Sudety Mts. and the Carpathian region (including the Carpathian Foredeep. Remaining deposits occur in Western Pomerania and other parts of the Polish Lowlands. Curative water is mainly used for balneology (baths, inhalations, drinking treatment) and bottling (i.e. Krynica-Zdrój, Muszyna, Piwniczna-Zdrój, Wysowa, Polanica-Zdrój, Busko-Zdrój), but also in the production of salt, lye, mud and pharmaceutical preparations (i.e. Ciechocinek, Dębowiec, Iwonicz-Zdrój, Rabka-Zdrój).

Mineralized and specific types of groundwater with total content of solid dissolved minerals over 1,000 mg/dm^3, (Dowgiałło *et al.*, 2002), not considered as curative, commonly occur in Poland at various depths, usually greater than for fresh water. The variety of chemical composition of that water (Fig. 5.1) is caused by diversity of geological and hydrogeological conditions. The following types are distinguished:
- strongly mineralised chloride water, mainly the Cl-Na, (J) type;
- bicarbonate water, mainly the HCO_3-Ca-(Mg), (Fe) type;
- specific water with variable mineralisation: Fe, F, J, S, H_2SiO_3, Rn, CO_2, thermal.

Thermal water: groundwater in all geological units with a temperature of at least 20°C at the outflow, excluding drainage waters from mining areas. It occurs in Poland in the area of the Polish Lowlands within large reservoirs of regional importance, as well as in the Carpathians and Sudety Mts. (Fig. 5.2)

In the area of Polish Lowlands, thermal water from Lower Cretaceous and Lower Jurassic formations is the most prospective for use. It occurs in widespread hydrogeological basins (covered structures). In Carpathians, thermal water occurs in Cretaceous, Paleogene and Neogene formations and also in Triassic deposits of the Podhale Trough, which is characterised by a small area and strong tectonic involvement (i.e. Bańska, Biały Dunajec, Białka Tatrzańska, Bukowina Tatrzańska). In the Carpathian Forehead Foredeep thermal water occurs in Cambrian, Devonian,

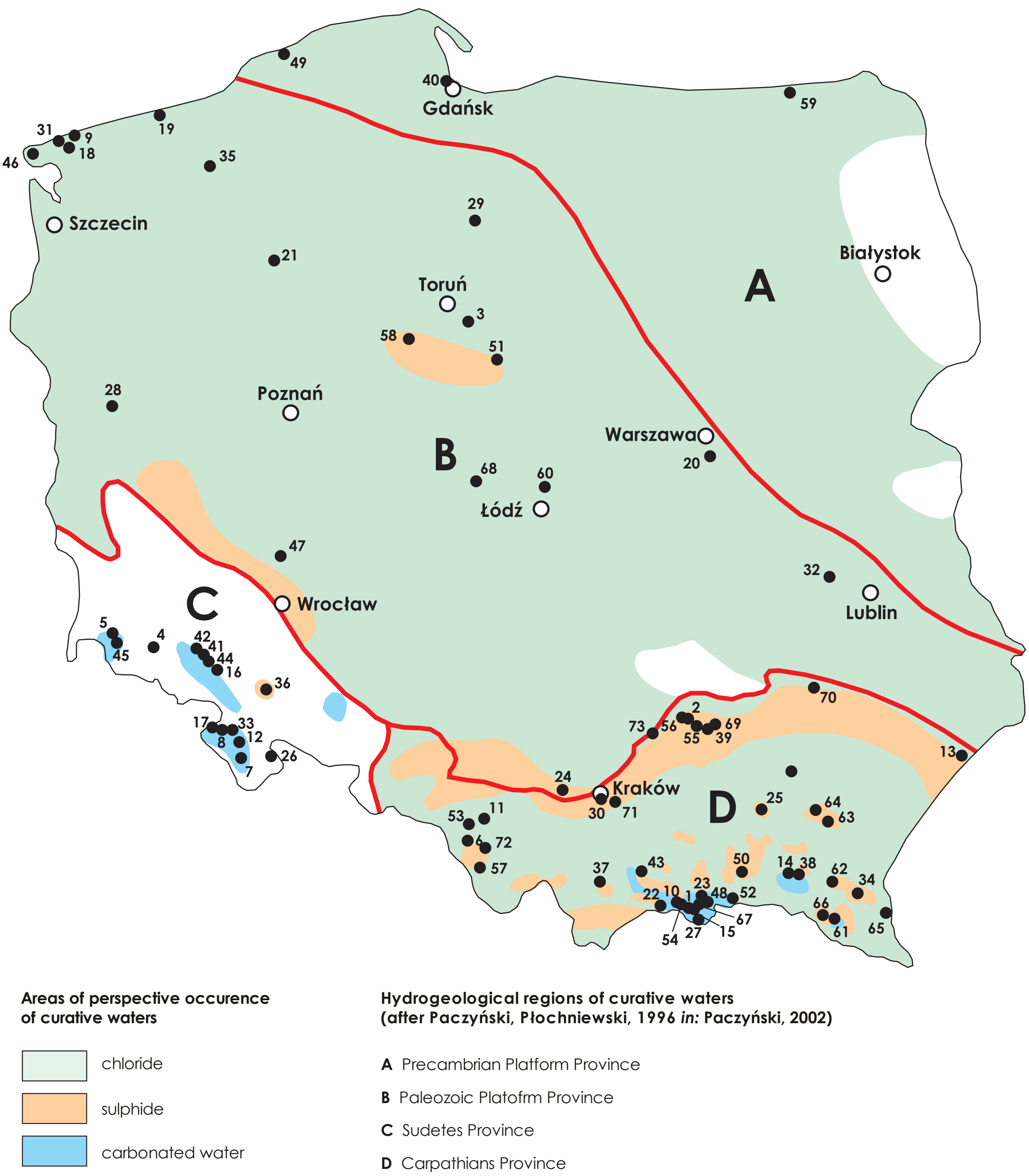


Fig. 5.1. Occurrence of particular chemical types of curative and mineralised water

Curative water deposits: 1 – Muszynianka, Muszynianka II; **2** – Busko II, Busko-Północ; **3** – Ciechocinek; **4** – Cieplice; **5** – Czerniawa-Zdrój; **6** – Dębowiec III; **7** – Długopole-Zdrój; **8** – Duszniki-Zdrój; **9** – Dziwnówek Józef; **10** – Głębokie Kinga, Łomnica-Zdrój, Piwniczna-Zdrój II, Wierchomla Wielka źródła; **11** – Goczałkowice-Zdrój I; **12** – Gorzanów, Szczawina; **13** – Horyniec; **14** – Iwonicz; **15** – Muszyna, Muszyna-INEX, Muszyna-Zdrój, Powroźnik-Krynica-Zdrój, Galicjanka, Galicjanka II, Szczawnik-Cechni, Złockie Z-7; **16** – Jedlina-Zdrój; **17** – Kudowa; **18** – Kamień Pomorski; **19** – Kołobrzeg II; **20** – Konstancin; **21** – Piła IG 1; **22** – Krościenko n. Dunajcem źródła, Szczawnica I; **23** – Krynica-Zdrój I; **24** – Krzeszowice; **25** – Latoszyn W-1; **26** – Lądek-Zdrój; **27** – Leluchów L-4; **28** – Łagów Lubelski IG 1; **29** – Marusza; **30** – Mateczny I, Swoszowice; **31** – Kamień Pomorski IG 1; **32** – Nałęczów II; **33** – Polanica-Zdrój, Stary Wielisław; **34** – Polańczyk; **35** – Połczyn; **36** – Przerzeczyn; **37** – Rabka-Zdrój; **38** – Rymanów; **39** – Solec- Zdrój, Wełnin; **40** – Sopot; **41** – Stare Bogaczowice źródła; **42** – Stare Rochowice; **43** – Szczawa; **44** – Szczawno-Zdrój; **45** – Świeradów-Zdrój; **46** – Świnoujście I; **47** – Trzebnica IG 1; **48** – Tylicz I; **49** – Ustka; **50** – Wapienne; **51** – Wieniec; **52** – Wysowa; **53** – Zabłocie-Korona, Zabłocie-Tadeusz; **54** – Zubrzyk, Żegiestów-Zdrój, Żegiestów-Cechini; **55** – Dobrowoda; **56** – Las Winiarski; **57** – Ustroń; **58** – Inowrocław I, Inowrocław II; **59** – Gołdap; **60** – Kotowice M-1; **61** – Rabe; **62** – Lesko źr. nr 1, 4; **63** – Nieborów źródła; **64** – Rzeszów S-1, S-2; 65 – Czarna Góra źr. nr 5; 66 – Komańcza źr. nr 1; **67** – Krynica Dolna, Szczawiczne II; **68** – Uniejów I; **69** – Dar Natury; **70** – Lipa-Zdrój-1; **71** – Wieliczka W-VII-16; **72** – Jaworze IG 1, IG 2; **73** – Cudzynowice GT-1

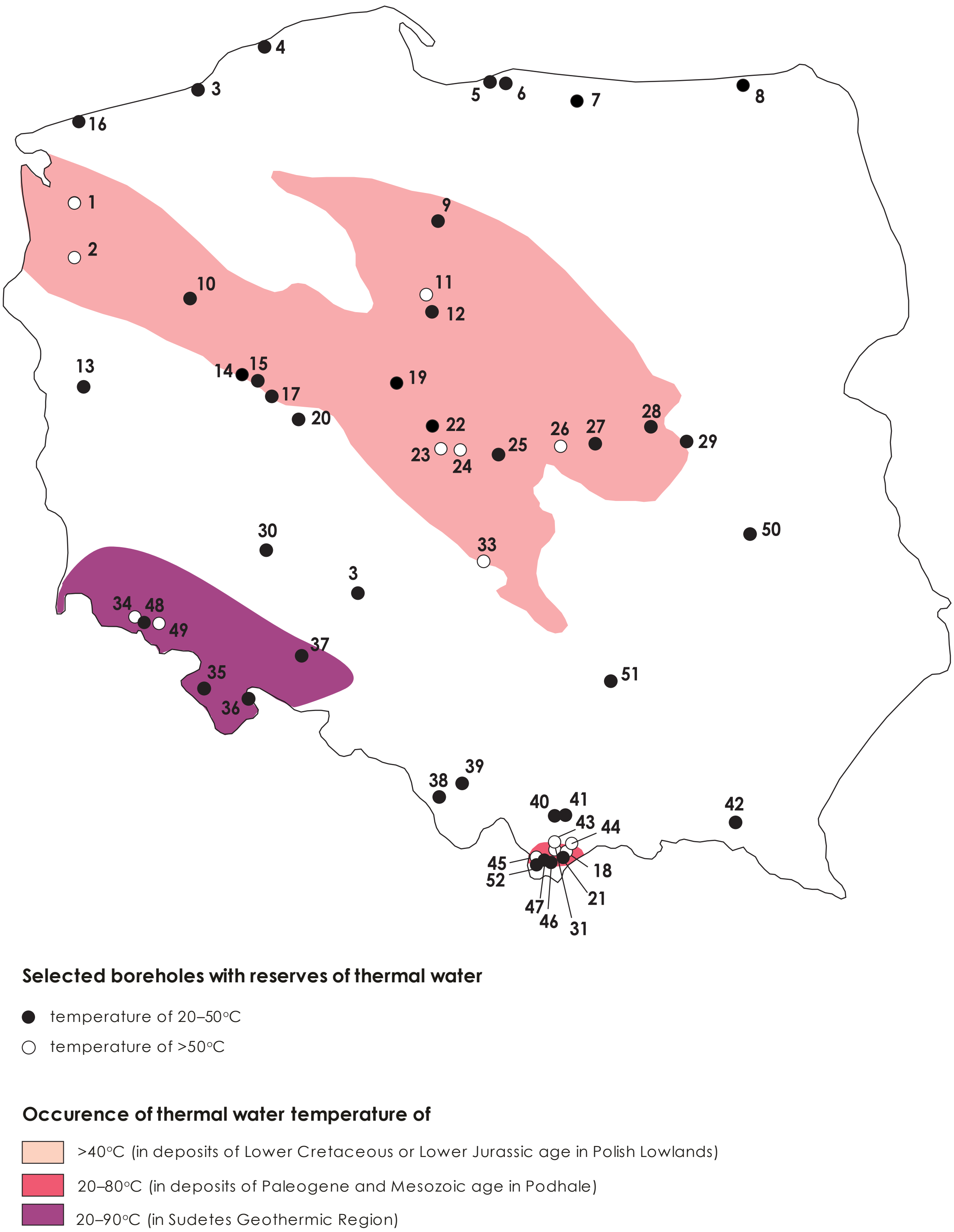


Fig. 5.2. **Occurrence of thermal water (Kapuściński *et al.*, 1997)**

1 – Stargard Szczeciński GT-2; **2** – Pyrzyce GT-1, GT-3; **3** – Jamno IG-3; **4** – Ustka IGH-1; **5** – Krynica Morska IG-1; **6** – Frombork IGH-1; **7** – Lidzbark Warmiński GT-1; **8** – Gołdap GZ-1; **9** – Grudziądz IG-1; **10** – Piła IG-1; **11** – Toruń IG-1; **12** – Ciechocinek XIV, XVI, XVIII; **13** – Łagów Lubuski IG-1; **14** – Tarnowo Podgórne GT-1; **15** – Swarzędz IGH-1; **16** – Trzęsacz GT-1; **17** – Środa IG-2; **18** – Bukowina PIG/PNiG-1; **19** – Ślesin IGH-1; **20** – Czeszewo IG-1; **21** – Zazadnia IG-1; **22** – Dobrów IGH-1; **23** – Uniejów PIG/AGH-2; **24** – Poddębice GT-2; **25** – Łódź EC-II nr 3; **26** – Skierniewice GT-1; **27** – Mszczonów IG-1; **28** – Warszawa IG-1; **29** – Wilga IG-1; **30** – Trzebnica IG-1; **31** – Furmanowa PIG-1, Poronin PAN-1; **32** – Wołczyn VII A; **33** – Kleszczów GT-1; **34** – Cieplice C-1, C-2; **35** – Duszniki GT-1; **36** – Lądek L-2; **37** – Odra-5/1; **38** – Ustroń U-3, U-5; 39 – Jaworze IG-1, IG-2; **40** – Rabka IG-2; **41** – Poręba Wielka IG-1; **42** – Lubatówka 12, 15; **43** – Bańska IG-1, PGP-2, PGP-3; **44** – Białka Tatrzańska GT-1; **45** – Chochołów PIG-1; **46** – Zakopane IG-1, IG-2; **47** – Szymoszkowa GT-1; **48** – Staniszów ST-1; **49** – Karpniki KT-1; **50** – Celejów GT-2; **51** – Cudzynowice GT-1; **52** – Siwa Woda IG-1

Carboniferous, Jurassic, Cretaceous and Miocene formations. In the Sudety Mts., the most prospective formation is the Carboniferous aquifer in the vicinity of Jelenia Góra (Cieplice Śląskie-Zdrój). Thermal water is also found at Lądek-Zdrój, Duszniki-Zdrój and Grabin in the vicinity of Niemodlin. Thermal water is also used for heating as well as recreation and balneologic purposes.

In 2015, reserves of 132 deposits of groundwater classified as mineral were estimated at 5,829.38 m^3/h. Reserves of thermal water were estimated at 4,164.80 m^3/h, those of curative water at 1,660.88 m^3/h and brines at 3.70 m^3/h. During the last five years since the previous edition was released, the geological administration has approved 59 hydrogeological documentations. As a result, resources of groundwater considered as mineral increased by about 1,604.07 m^3/h. At this time, the number of deposits increased to 132 and resources of thermal water increased by about 1,619.1 m^3/h, whereas resources of curative water decreased by about 15.03 m^3/h. No change was observed for brines. Currently, 78 deposits are exploited in Poland. In 2011, the number of active deposits was set at 62.

The volume of brine, curative and thermal water intake in 2015 was calculated at 12,189,071.19 m^3/year. In comparison to 2011, it increased by approximately 4,126,233.93 m^3.

6. Noble metals and jewellery stones

6.1. Gold

S.Z. Mikulski

Gold occurs in several geological formations in Poland. Gold deposits were intensively prospected and exploited at least since the early Middle Ages. At present, gold is extracted only from copper-silver deposits mined in the area of the Fore-Sudetic Monocline. Gold mainly occurs in sediments of oxidized facies, in rocks of the Weissliegendes Sandstone of the Rotliegend and in lower parts of the Zechstein copper-bearing shales. Gold is recovered during technological processing of sulfide ores. In 2015, 431 kg of gold was recovered from domestic sulfide Cu-Ag ores and taking into account imported inputs – 2,703 kg in total. Gold recovery from domestic deposits has been generally stable, at the level of at about 400 kg per year in 2012–2015, decreasing down to 226 kg only in 2014.

The gold and arsenic mine at Złoty Stok, closed in 1960, was the last active gold mine in the Sudety Mts. (Plate 3). Documented gold resources of the Złoty Stok skarn deposit were estimated in 1954 at 2,000 kg of anticipated economic resources of ore and 490 kg of anticipated sub-economic ones. The mean content of gold in arsenic ore is 2.8 g/t. The Złoty Stok deposit was exploited in 1954–1960, which resulted in extraction of 25% of its resources. Resources remaining in the deposit are estimated at 537,000 t of ores yielding 19,600 t of arsenic and 1,500 kg of gold. The deposit was abandoned due to very limited demand for arsenic and its high toxicity. At present, the chances of reactivating this mining operation are very low.

Gold was also extracted from hydrothermal gold-bearing quartz-sulphide veins at Radzimowice, Klecza-Radomice, Czarnów and Wądroże Wielkie. As well, in the Lower Silesia region placer gold was also extracted from Cenozoic sands and gravels. Gold-bearing sediments occur in numerous river valleys (e.g. Bóbr, Kwisa, Kaczawa, Nysa Łużycka) in the vicinities of Złotoryja, Lwówek Śląski and Bolesławiec.

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

6.2. Amber

K. Szamałek

Amber has played a very important role in Polish history, tradition and the economy. During many centuries, this mineral was a basic good exchanged between Poland and the Roman Empire. Amber occurs in numerous places in Poland, mainly in Tertiary deposits (*in situ* accumulation) as well as in Quaternary deposits (secondary accumulation). Outside the beach zone of the Baltic Sea (especially the eastern part), amber deposits are also reported in the Pomorskie and Lubelskie provinces.

Amber in Tertiary sediments (*in situ)* occurs in two regions – the northern near Chłapowo (at a depth of 60–130 m) and southern near Parczew (at a depth of 20–30 m). Quaternary glacial sediments containing amber were transported from eroded accumulation of the Chłapowo-Sambia delta sediments. Amber accumulations are also reported on Baltic beaches from Kołobrzeg to the Polish-Russian border on Mierzeja Wiślana penisula.

Table 6.2.1. **Amber resources [t]**

	Number of deposits	Geological resources in place				Economic resources in place as part of anticipated economic resources
		Anticipated economic			Anticipated sub-economic	
		Total	C_1	D		
TOTAL RESOURCES	**8**	**1,139**	**30**	**1,109**	**–**	**17**
Including resources of exploited deposits						
DEPOSITS OF OPERATING MINES	1	17	17	–	–	17
Including resources of non-exploited deposits						
TOTAL	6	1,119	10	1,109	–	–
1. DEPOSITS COVERED BY DETAILED EXPLORATION	1	10	10	–	–	–
2. DEPOSITS COVERED BY PRELIMINARY EXPLORATION	5	1,109	–	1,109	–	–
Including abandoned deposits						
TOTAL	1	3	3	–	–	–

Economic geological resources of amber are estimated at 1,139 t (Tab. 6.2.1). During licensed geological operations in Poland in 2015, extraction of amber has been reported in amount of 1,033 kg. The geopotential for amber is still huge in Poland. The most promising area for geological prospecting are the Lubelskie province (near Parczew-Lubartów), the Pomorskie province (near Słupsk) and the Zachodniopomorskie province.

It is estimated that the annual amber collecting on the Baltic beaches is around 5–6 tonnes.

6.3. Chrysoprase

W. Mizerski

Chrysoprase is a rare variety of chalcedony valued as a gemstone. It is green, semi-translucent to sometimes transparent, characterised by hardness and density somewhat smaller in comparison to other varieties. Chrysoprase owes its colour to the presence of minute inclusions of nickel compounds such as schuchardite, pimelite and garnierite. Colour intensity depends on concentrations and relative proportions of these compounds. There are several varieties of chrysoprase differing in admixtures of various mineral compounds, e.g. opal chrysoprase – prazopal, chalcedony-opal chrysoprase, chalcedony chrysoprase and quartz chrysoprase. The most precious stones are apple-green and deep emerald-green in colour and characterised by a high degree of transparency. Chrysoprase is very attractive and highly appreciated decorative and jewelry stone. It was already widely used in ancient times in the Mediterranean Sea basin to become one of the most precious gems in Europe in the 19th century. It is also used as a facing and decorative stone.

In Poland, the deposit in Szklary near Ząbkowice Śląskie in the Sudetic Foredeep (Lower Silesia) was famous for its high quality chrysoprases. It was known since ancient times and exploited in the Middle Ages to be developed in 1740. In this deposit, chrysoprase occurs in chalcedony-opal veins in serpentinites. The largest specimens extracted from that deposit were up to more than a dozen kg in weight. In the 20th century, chrysoprase was exploited there in a nickel mine that was abandoned in the 1980s. Peak production of chrysoprase in that open-strip mine was about 2 t per year. At present the deposit has been largely depleted, but, nevertheless, collectors can still find even fairly large specimens. It is possible in this region to delineate five prospective areas of chrysoprase and related semi-precious stone occurrence. Some minor occurrences of chrysoprase are also known in the serpentinite massifs at Grochowa, Braszowice and Wiry near Mt. Sobótka. Of these, the Wiry deposit seems most promising from the standpoint of potential chrysoprase resources.

6.4. Nephrite

W. Mizerski

Nephrite is a metamorphic rock formed from metasomatic processes when acid or alkaline igneous rocks burst into dolomites, dolomitic marbles or serpentinites and in conditions of directional pressures. This rock is almost monomineral and is composed of calcium-iron-magnesium amphiboles from the actinolite (tremolite or sometimes ferroactinolite) series. Nephrite shows numerous colour variations, including white (tremoline nephrite related to dolomites) through green (tremoline nephrite related to serpentinites), dark green and black (ferrites rich in ferroactinolite) and sometimes red as a result of iron oxidation. Its texture is mylonitic or aphanitic. Nephrite is mainly composed of tremolite or actinolite microfibres 0.05 mm in length and 0.002 mm in diameter on average. Fibres are felted in the form of a massive rock that is exceptionally resistant to breakage with pseudoconchoidal fracture breakage and often minor scale-like loosenings. In the ancient time, it was used for religious purposes and subsequently as a very gentle healing stone as well as for gemstones, talismans, ornamental objects, decorations and for weapons and tools.

Nephrite deposits are relatively rare throughout the world. In Poland, they are known in the vicinities of Jordanów Śląski, Strzeblów and Tąpadła in Lower Silesia only. The Jordanów Śląski deposit, which is best documented, was also regarded as the second best quality nephrite in Europe. That deposit is formed from nests and veins of nephrite in serpentinites that are variable in thickness. It was already known in Neolithic times, when that stone was used to make as heads and knives as well as weapons and tools. Nephrite blocks up to 40 cm in thickness and 2.5 m in length were still extracted in an abandoned quarry at Jordanów Śląski at the start of the 20th century. Exploitation of that deposit was phased out by the end of that century and its resources have not yet been re-evaluated due to problems created by irregular distribution of nephrite in host rock. Nevertheless, it can be stated that exploitation may resume if a new study confirms potential for development of that deposit.

6.5. Other

W. Mizerski

6.5.1. Agate

Agate is a multi-coloured banded variety of chalcedony. It is most often characterised by concentric (spherulitic) banded patterns, but specimens displaying a succession of parallel bands also occur. Individual bands may highly differ in colour (from white to gray, yellow, red, blue, green and black) depending on presence of very fine ingrowths of minerals such as chlorites, hematite or seladonite. Banding is the most characteristic visible property of agates. Several dozen varieties of agate are differentiated with reference to types and pattern bands as well as the type and style of banded structure. They mainly occur in extrusive igneous rocks such as melaphyre, porphyry or basalts, representing an infill of cavities, usually those produced by volatiles in original molten mass. Agates have formed from a deposition of layers of silica in a cavity or void from its walls to the centre.

Due to their high resistance to weathering, agates also form secondary accumulations in soil or are deposited as gravel in streams. They belong to decorative or ornamental stones exploited by humans for over 5,000 years. Agates are widely used as gemstones in jewellery as well as an exquisite ornamental stone in decorative arts and material for abrasive preparations and laboratory equipment.

In Poland, agates are most common in Lower Silesia, especially the Kaczawskie Mts. and the Kaczawa Foreland in vicinities of Nowy Kościół, Wielisław Złotoryjski, Lubiechowa, Wleń, Płóczki and Lwówek Śląski. They can also be found in smaller amounts in the vicinities of Kamienna Góra, Wałbrzych, Nowa Ruda and Kłodzko. There, agates occur as nodules several cm in diameter. Larger agate geodes, about 20 cm in diameter, are much less common, but it possible to find exceptionally large specimens, even about 1 m in diameter. Agates can also be found in the vicinities of Alwernia, Rudno and Regulice in the Kraków region. They occur in extrusive rocks from the Permian age such as melaphyre and its tuffs. Despite fairly large reserves, agates have never been mined in Poland on an industrial scale.

6.5.2. Rock crystal (clear quartz)

Rock crystal (pure quartz, traditionally also called clear quartz) is mainly known from igneous rocks and various hydrothermal deposits. It also occurs in metamorphic rocks as well as sedimentary, mainly detrital ones. Especially well-developed and large monocrystals are found in druse cavities in pegmatites and hydrothermal veins. Individual crystals are usually several centimetres long, but it is possible to find crystals several dozen cm long. Due to high purity and strong lustre, it was treated as a substitute for diamond. In ancient Greece and Rome, rock crystal was used for decoration and jewellery as well as to make cylinder and stamp seals. Rock crystals were also among gems used in decoration of the Crown of the Polish Kingdom. Rock crystal is still very attractive and highly appreciated by mineral collectors and used to make jewellery as well as ornaments and decorations.

In Poland, beautifully developed and very pure rock crystals occur in Jegłowa near Strzelin (Sudety Mts.), where its exploitation already began in the 18th century. There, it is possible to find crystal clusters up to 120 × 60 × 30 cm in size and with monocrystals up to 20 cm in length. These clusters are embedded in kaolin mass that infills caverns or forms veins in quartz schists. Exceptionally fine crystals can be also found in dolomites at Stawniowice near Głuchołazy (Paczków Foreland) and the Stanisław vein quartz mine in the Izerskie Mts. The Taczalin quartz deposit near Legnica, operating with some disruptions until 2005, can be also prospective from that standpoint.

6.5.3. Jasper

Jasper is a siliceous rock of sedimentary or sometimes volcanogenic or igneous origin. It may have a variety of colours that usually range from brown to red and cherry-red and sometimes yellow, green, blue and even black depending on the presence of admixtures of iron and manganese oxides as well as hydroxides and other minerals. Jasper varieties are single or multicoloured. The resulting picture may sometime resemble images of landscapes, ruins or flowers. Jasper is an aggregate of chalcedony and micro-granular quartz in varying proportions. It belongs to fairly common rocks known to occur in the form of veins, lenses, encrustations, nodules and secretions. It is one of most popular semi-precious gemstones in decoration and jewellery, already widely used in ancient times.

In Poland, the main occurrence of jasper is in the Świerki locality near Nowa Ruda (Sudety Mts.), where if forms beds up to almost 2 m in thickness in a Permian melaphyre series. However, a mine where it was extracted was put into liquidation in 2012 and further studies are needed to document resources in neighbouring areas. Jasper is also known from Przeździedza near Wleń and Dobromierz in the Sudety Mts. It also occurs in the area of Niedźwiedzia Góra hill near Krzeszowice, (Kraków region), where it is represented by exotic blocks in diabases. Subordinate occurrences of jasper are also known in sedimentary rocks at Lanckorona near Wadowice in the same region.

7. Mineral raw materials balance

7.1. Output of mineral raw materials

A. Malon, M. Tymiński

This chapter presents tendencies in raw material output in Poland in 1989–2015. The total number of deposits documented in Poland changed significantly in the analyzed period (Fig. 7.1.1). In 1989 and 1990, it did not exceed 5,000 but then has systematically grown – to 7,000 in 1998, 8,000 in 2002, 10,000 in 2008 and more than 13,500 in 2015. The number of documented deposits in 2015 was almost three times larger than in 1989. The amount of exploited deposits grew slightly until 1998 – not exceeding 2,600. The following years brought quite faster growth with the number of deposits above 3,000 in 2004, more than 4,000 in 2010 and exceeding 5,100 in 2014. It was the highest number of exploited deposits in the analyzed period. In 1989, exploited deposits accounted for 47.3% of total documented deposits and this share declined until 1998 (36%). By 2010, the rate did not change significantly. In the next several years, it slightly grew to 37% in 2015, but it was still much lower than in 1990s. Rock raw materials deposits account for about 90% of all documented deposits in Poland (especially sand and gravel deposits), so tendencies within this group determine the entire domestic situation. The analyzed period was characterized by a growing number of documented deposits while exploited deposits remained at a quite stable level (for all raw materials and rock groups). This was mainly because not all new documented deposits have been the subject of exploitation immediately. The growing number of deposits has not influenced resource growth. It may have been due to the size of new documented deposits – much smaller than already documented areas. The best example is sand and gravel raw material where the largest deposits (with resources between 10 and 500 Mt) account for only 0.4% of the total number, but whose resources account for 60% of the domestic resources base.

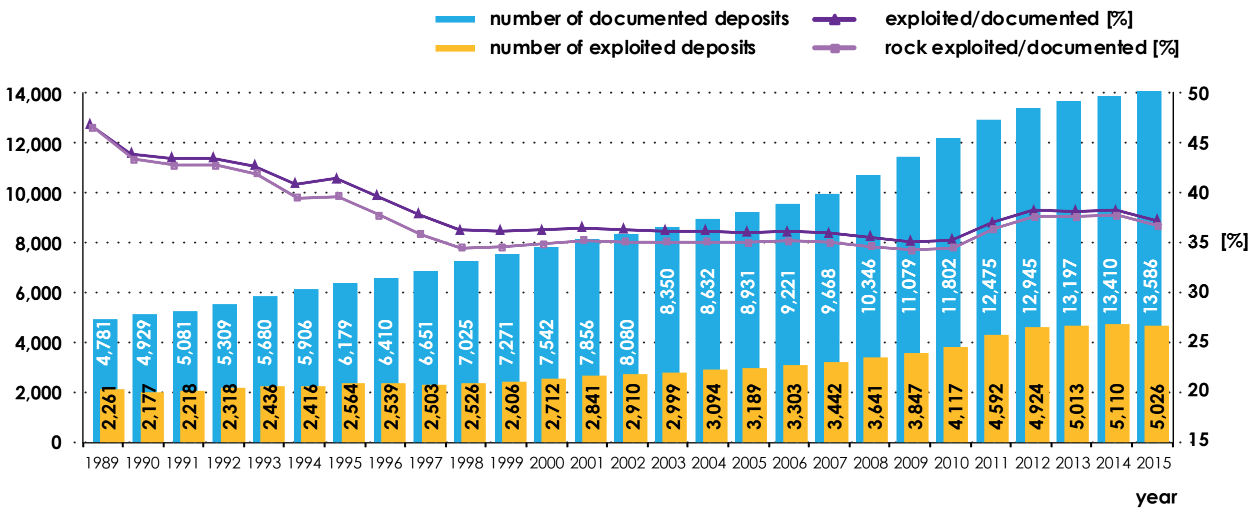


Fig. 7.1.1. Number of documented and exploited raw material deposits in 1989–2015

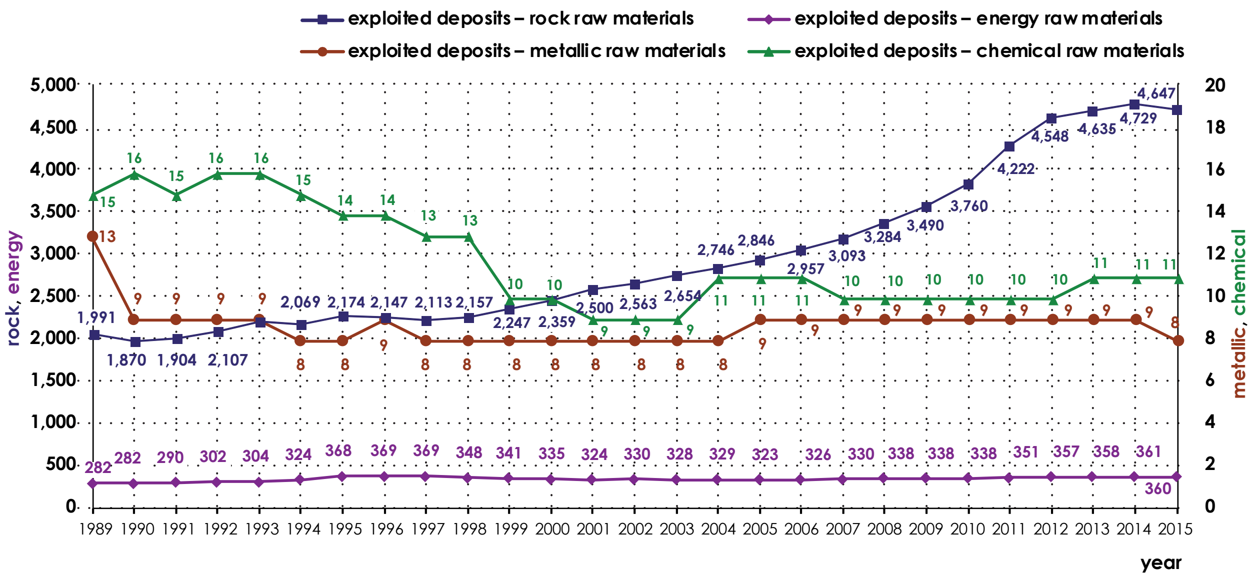


Fig. 7.1.2. Number of exploited deposits within four raw materials groups in 1989–2015

As for particular raw material groups, the most important – as regards the number of documented deposits and number of exploited ones – is the rock raw materials group (especially sand and gravel) (Fig. 7.1.2). In 2015, it accounted for 94.3% of all deposits documented in Poland and for 92.5% of deposits under exploitation. These rates did not change significantly in the analyzed period – they amounted to 87% and 86.3% in 1989, 91.1% and 87% in 2000 and to 93.8% and 91.3% in 2010. The number of exploited rock raw material deposits increased from 1,951 in 1989 to 4,647 in 2015 (almost two and a half times) with only a one-year drop in 1990 and 2015 and a two-year drop in 1996–1997. Energy raw material deposits are the second largest group with the number of documented deposits accounting for 5% of domestic deposits and with the number of exploited deposits accounting for 7.2% of the total number. Exploited deposits of this group fluctuated during the entire analyzed period within the range of 280–370 deposits. Two other groups of raw materials (chemical and metallic) are of less importance with the number of exploited deposits being 11 and 8 in 2015, respectively. Exploited chemical raw material deposits dropped in number from 16 to 10 in 1994–1999 (closure of sulfur and barite/fluorite mines due to economic conditions) and then remained without minor changes. The number of exploited metallic raw materials deposits decreased from 13 to 9 in 1990 (closure of iron, zinc and lead ores mines and end to the exploitation of copper ores in the North Sudetic Basin) and then remained at the level of 8–9.

Output of the metallic and chemical raw materials group in 1989–2015 did not change significantly (Fig. 7.1.3). It remained within the range of 24–34 Mt per year and 3–9 Mt per year, respectively. Natural gas and coal bed methane (CBM) output dropped in 1990 and then systematically grew until 2009 and exceeded 6 bnm³. It decreased to 5.5 bnm³ within the next six years. Output of other energy raw materials (excluding gas and CBM) declined in the analyzed period – from almost 250 Mt in 1989 to 129 Mt in 2015 (by 48%). Since lignite output remains at a stable level, crude oil production is of less importance (about 1 Mt per year), but is still growing. It is obvious that the main reason for this drop is hard coal output. It started at 176 Mt in 1989 then was 102 Mt in 2000, 69 Mt in 2010 and finally 65 Mt in 2015. That was because Polish coal mines have been subjected to restructuring since the start of transformation of the national economy at the end of the 1980s – to adjust the mining sector to requirements of a free-market economy.

The rock raw material group is the most important in raw material output in Poland. There are three mineral raw materials determining output magnitude – sand and gravel, dimension and crushed stones and limestones and marls for the cement and lime industries. They accounted for 56.6%, 21.6% and 14.5% of total group output in 2015, respectively. In 1989, these shares were 37%, 12.6% and 19.9%, in 2000 49%, 13.4% and 20%, whereas in 2010 they were 56.2%, 21.7% and 13.8%, respectively. Output of rock dropped in 1990–1991 to the level of 136 Mt and then increased within the next nine years to 180 Mt. In 2001, a one-year decrease was recorded, mainly due to drops in all of these three main raw materials – by 15 Mt in sand and gravel, 6 Mt in lime-

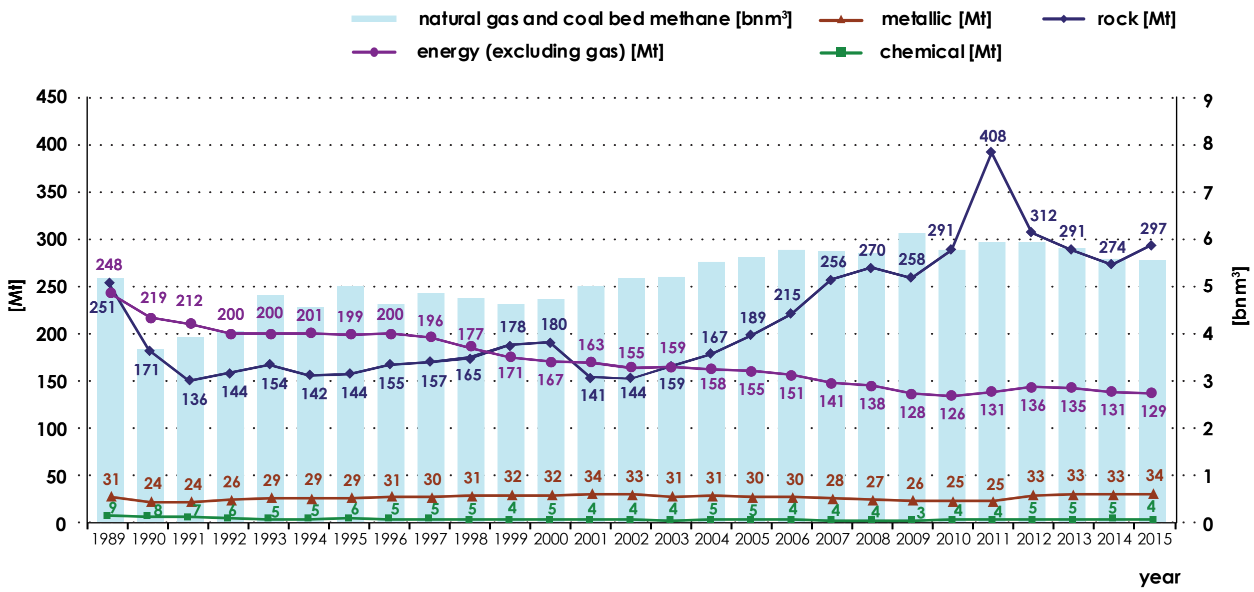


Fig. 7.1.3. Output of mineral raw materials groups and natural gas in 1989–2015

stones and marls and 2 Mt in dimension and crushed stones. In 2002–2011, exploitation grew by 267 Mt (nearly three times). It coincided with political-economic events such as the Polish association with the EU, the access of Poland to the EU and the global economic crisis. These factors caused increasing demand, especially in the building and road sectors. Significant growth in 2011 (by 117 Mt in comparison to 2010) was strictly tied to growing demand for raw materials in the road-building sector while preparing for the 2012 UEFA European Championship. Sand and gravel production grew by 85.2 Mt in 2011, whereas for dimension and crushed stones and limestones and marls it was 21.4 Mt and 9.0 Mt, respectively. The next three years (2012–2014) brought an output drop due to an investment halt, whereas a growing tendency returned in 2015 when new tranches for road investments commenced.

7.2. Exports and imports of mineral raw materials

M. Tymiński

Information on turnover in exports and imports of mineral raw materials in Poland is prepared annually on the basis of data collected by the Polish Custom Service. Such data originate from special custom statements – SAD (in the case of trade turnover by European Union countries to/from non-EU countries) and INTRASTAT (in case of export and import within the EU). Data are elaborated according to a Combined Nomenclature (CN), which is closely tied to the international classification system called Harmonized System – HS. Combined Nomenclature has applied to the Polish Customs Tariff since 1991. The Combined Nomenclature is the part of the Integrated Tariff of the European Communities (TARIC) that was established under Article 2 of Council Regulation (EEC) No 2658/87 of 23 July 1987 on tariff and statistical nomenclature and on a Common Customs Tariff Regulation (EC) No 1789/2003 of 11 October 2003 amended the Regulation mentioned above. The Regulation established in 2003 is has been obligatory in Poland since 1 May 2004.

Data on mineral raw materials turnover in 2006–2015 do not cover natural gas. Such information is not available since 2006 due to data confidentiality – according to Regulation (EC) No 638/2004 of the European Parliament and of the Council dated 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 is only in the dozens of Mm³ annually and the lack of data does not affect the

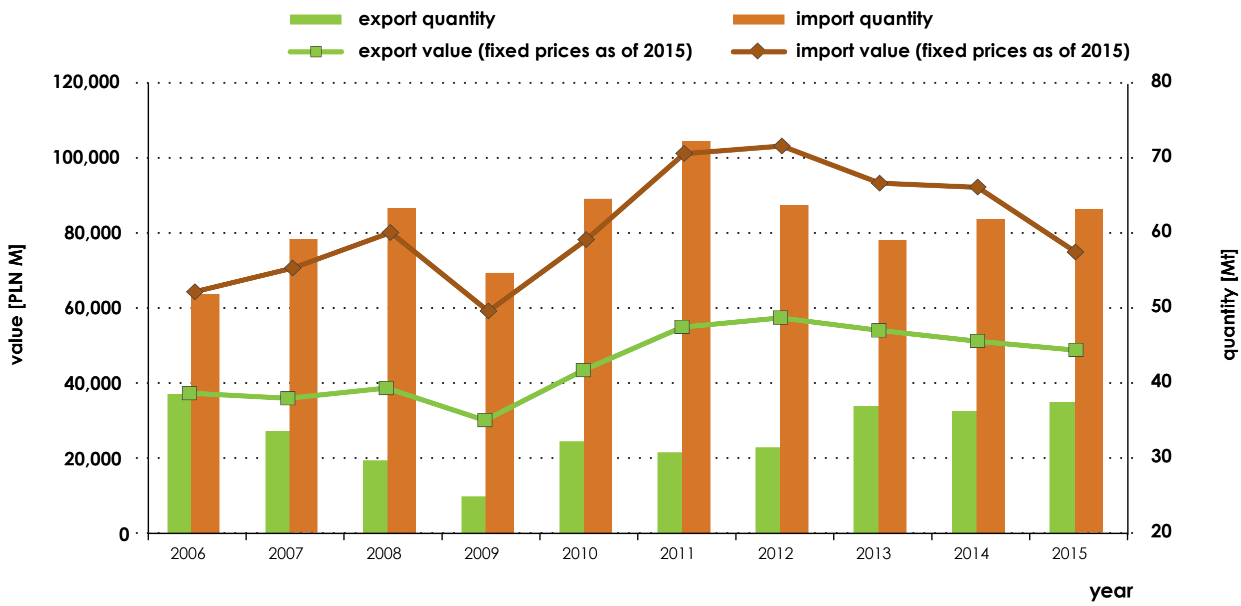


Fig. 7.2.1. Mineral raw material exports and imports in terms of value and quantity in 2006–2015 (excluding natural gas)

total balance of raw material turnover. The lack of data on natural gas import to Poland reduces the total amount and value of raw materials brought into Poland. Officially presented data by the Central Statistical Office of Poland only cover the magnitude of natural gas imported by Poland, but without publishing directions of imports. Therefore, such data are not included in this study. Nevertheless, in the analyzed period natural gas import increased from 9–10 bnm^3 in 2006–2010 to about 11.2 bnm^3 in 2014. Therefore, the balance of mineral raw materials turnover is higher than the balance with consideration of these figures.

Trade turnover in the raw materials sector in Poland increased significantly after access to the European Union. It was especially evident in statistics covering 2004 and following years both in the value and magnitude of export and import. The last ten years brought further changes in trade turnover (Fig. 7.2.1).

In 2009, global economic crisis resulted in drop of export and import down to only 25 Mt and 55 Mt, respectively. Then, within the next several years they increased to almost 40 Mt and over 60 Mt, respectively. The highest level of import was achieved in 2011. It amounted to 73 Mt, mainly due to increasing rock raw materials import for the road building sector. Export and import values, strictly tied to quantity, experienced the same changes. They decreased to their lowest levels in 2009 and then rose to more than PLN 100,000 M (import) and almost PLN 60,000 M (export) due to an increase of raw material prices on the international market. These values have dropped since 2012 due to lower prices of energy and metallic raw materials that are the main subjects of turnover in Poland.

The variation of import-export balance by value and quantity during the last 10 years is shown in Figure 7.2.2. The value balance decreased substantially in 2007–2008 and in 2010–2011. This negative tendency was reversed in 2009 and 2012. The lowest level was attained in 2011 – it amounted to PLN –48.82 bn and improved significantly in 2013 (PLN –41.56 bn) and 2015 (PLN –27.82 bn). The quantity balance declined significantly in 2007–2011 with slight growth in 2009. There was significant improvement of the balance in 2012–2013 when it amounted to –23.31 Mt. The balance dropped slightly in 2014 and 2015 to about –27 Mt. Given the magnitude of gas import provided by the Central Statistical Office of Poland (about 11 bnm^3), the balance would drop in 2015 to about –38 Mt.

Summary statistics for minerals and mineral commodities in Poland in 2015 are presented within four groups: fuels, metals, chemicals and rocks. The total magnitude and value of imports–exports of raw materials as well as particular groups of raw materials are presented in Table 7.2.1.

The total value of raw material export decreased by 5.62% in comparison to the previous year and amounted to PLN 49,158 M (11,776 MEUR) in 2015. The import value amounted to PLN 76,973 M (18,434

MEUR) and decreased by 19.41%. The export–import turnover balance improved significantly (by PLN 15,615 M) but was still negative and amounted to PLN 27,815 M (6,659 MEUR) in 2015 (excluding natural gas).

The total quantity of the raw materials import increased by 2.11% in 2015 and amounted to 64,008 kt, while the export quantity increased by 3.14% and amounted to 37,075 kt. The balance remained at the same level as in 2014 (about –27 Mt – excluding natural gas).

Fig. 7.2.2. **Balance of mineral raw materials imports and exports in terms of value and quantity in 2006–2015 (excluding natural gas)**

Table 7.2.1. **Imports and exports of mineral raw materials in 2015 (value in PLN and EUR)**

Group of mineral raw materials	Import Export					Balance		
	Quantity [kt]	%	Value [kPLN]	Value [kEUR]	%	Quantity [kt]	Value [kPLN]	Value [kEUR]
TOTAL	**64,008*** **37,075***	**100.0** **100.0**	**76,973,144*** **49,157,786***	**18,434,470*** **11,775,678***	**100.0** **100.0**	**–26,933***	**–27,815,358***	**–6,658,792***
FUELS	40,849* 25,075*	63.8* 67.6*	51,507,569* 23,246,077*	12,341,820* 5,571,714*	66.9* 47.3*	–15,774*	–28,261,492*	–6,770,106*
METALS	10,828 3,041	16.9 8.2	16,898,977 19,413,974	4,043,926 4,648,622	22.0 39.5	–7,787	+2,514,996	+604,696
CHEMICALS	5,327 4,483	8.3 12.1	6,135,075 4,307,600	1,465,927 1,030,666	8.0 8.8	–844	–1,827,475	–435,262
ROCKS	7,003 4,476	10.9 12.1	2,431,522 2,190,134	582,797 524,676	3.2 4.4	–2,527	–241,387	–58,121

* Excluding natural gas

Figures 7.2.3 and 7.2.4 show the structure of raw material export and import in Poland in 2012 and 2015, i.e. total values and shares of various types of raw materials in international turnover. Generally speaking, the main subjects of trade remained the same with crude oil, petroleum products, hard coal and copper among them. Prices of these commodities determine the final balance value.

As for the value of raw material export in 2015, most important were crude oil and petroleum products (28.16% of total export value), hard coal and coal derivatives (16.32%), raw materials and products of copper metallurgy (14.94%), aluminum (6.34%), silver (5.59%), nitrogen and multi-component fertilizers (5.71%) and iron and ferroalloys (5.57%).

The highest values of import causing a negative balance of turnover value were those of such raw materials as: crude oil (47.82% of the total import value), petroleum products (13.21%), aluminum (7.80%), iron and ferroalloys (4.75%), raw materials and products of copper metallurgy (4.30%), hard coal and coal derivatives (3.39%), nitrogen and multi-component fertilizers (2.78%), potassium raw materials (1.44%), silica (1.24%) and phosphorus (1.15%).

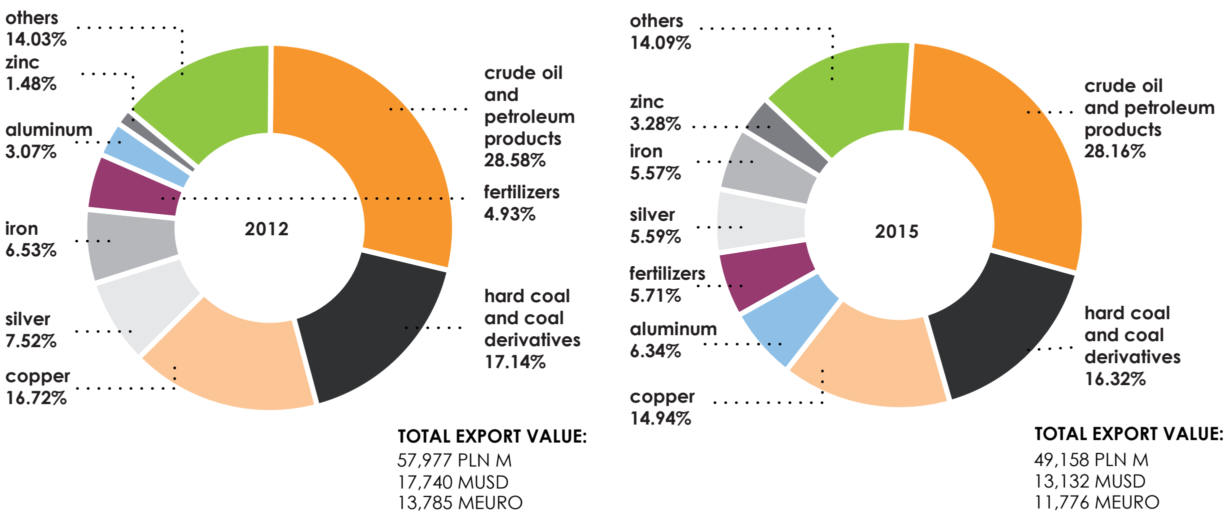


Fig. 7.2.3. The structure of mineral raw material export in 2012 and 2015

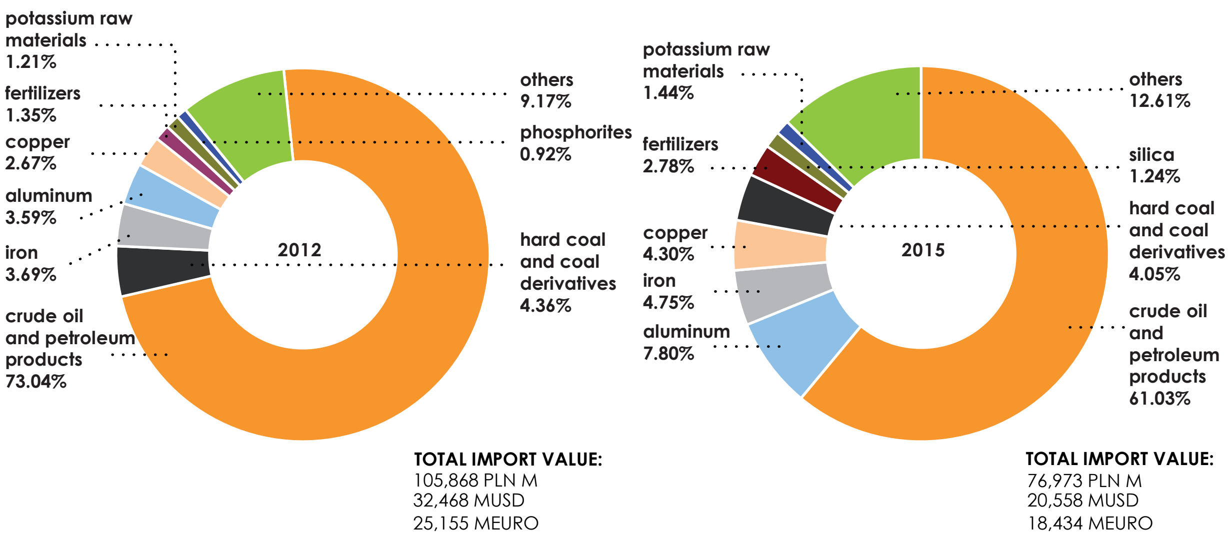


Fig. 7.2.4. The structure of mineral raw materials import in 2012 and 2015

Percentage contributions of particular groups of raw materials to the value of export and import in 2012–2015 are presented in Figures 7.2.5 and 7.2.6. Fuels (energy raw materials) are still the most important group, especially in Polish import (due to crude oil and petroleum products), but they also contribute strongly to export value (mainly due to petroleum products and hard coal).

Contributions to the export value have been oscillating significantly in three mineral groups during the last five years with rock raw materials export quite constant in the analyzed period. The highest increases of value with respect to the previous year were noted in 2013 in fuels (by 3.8%), in 2015 in chemicals (by 1.6%) and in 2014 in metals (by 1.5%). Fuels are still the most important group in Polish export value mainly due to petroleum products and hard coal exports. Nevertheless, due to minor drops in 2014–2015, their contribution remained the same as in 2012. The biggest drop, recorded in 2013 for metals (by 3.6%) was compensated in the next two years and the share of metallic raw materials returned to the level of about 40%.

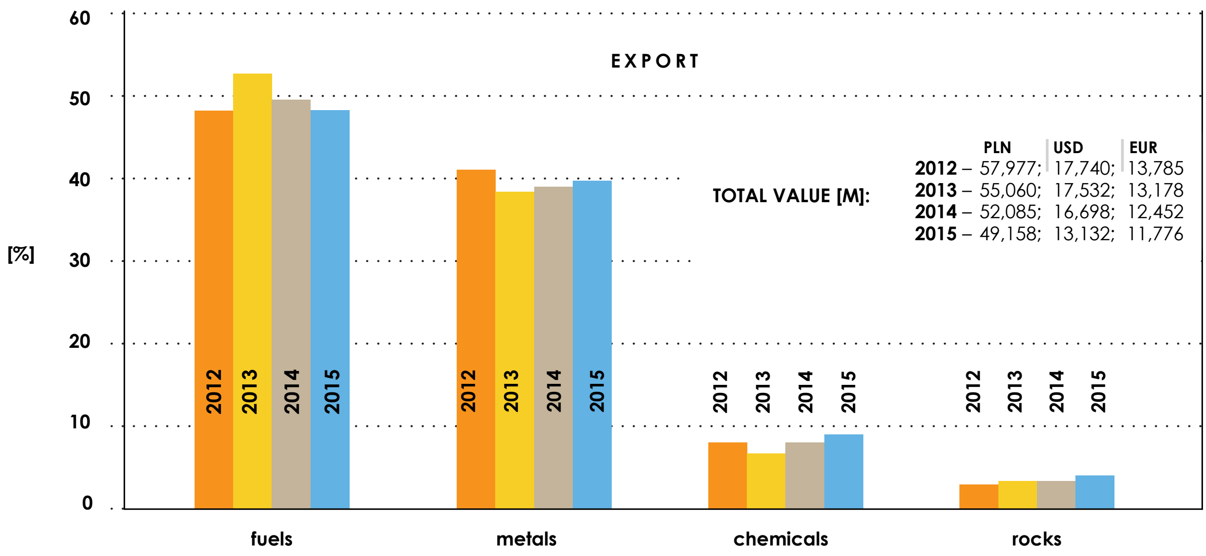


Fig. 7.2.5. Contribution of raw materials groups to the value of export in 2012–2015 (excluding natural gas)

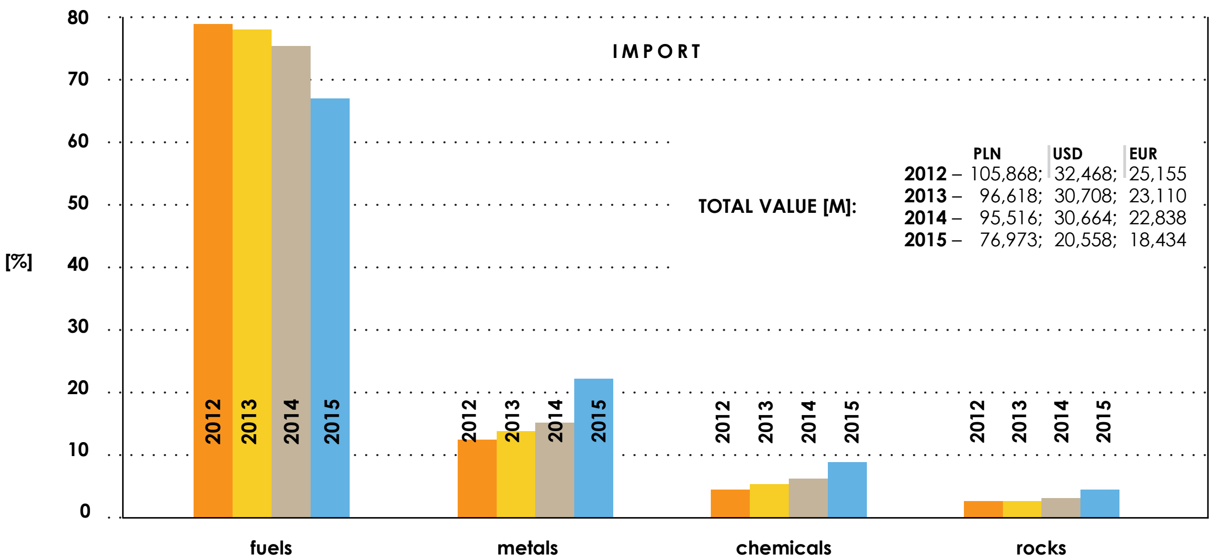


Fig. 7.2.6. Contribution of raw materials groups to the value of import in 2012–2015 (excluding natural gas)

The contribution to import value changed within two groups of raw materials. It dropped by 12.4% for fuels in the analyzed period and was equal only 66.9% in 2015. At the same time, metal import increased by 8.7% exceeding 22% in 2015. Chemical raw material contribution has risen by 3% for the last years, whereas that of rock raw materials remained at the same level.

The two graphs below present the magnitude of export and import of a particular raw material group. As shown, fuel export increased significantly by 5 Mt during 2012–2015 (due to hard coal and petroleum products) with rock raw materials growing slightly and two other groups remaining at the same level (Fig. 7.2.7).

As for the import quantity, two groups stayed at a steady level – energy and chemical raw materials. There was substantial growth of import of metals – by 1.6 Mt – mainly due to growing demand for iron ores and iron concentrates. In turn, rock import fell by 34% (3.6 Mt) as a result of declining demand for dimension and crushed stones (Fig. 7.2.8).

The tables below show a comparison of export/import values (Table 7.2.2) and quantities (Table 7.2.3) in 2014–2015.

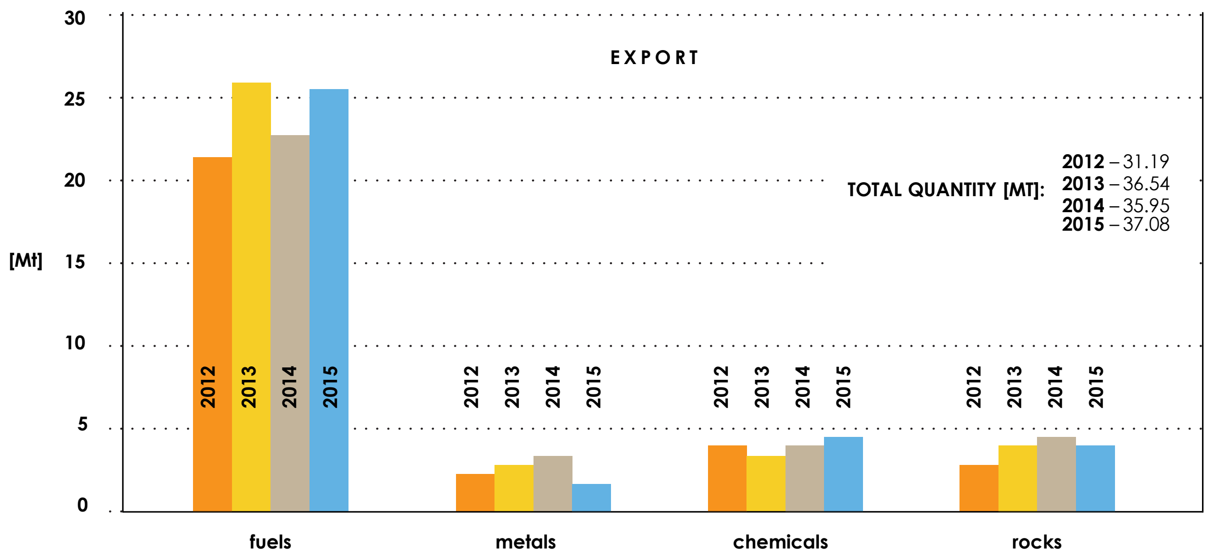


Fig. 7.2.7. **Magnitude of mineral raw materials export in 2012–2015 (excluding natural gas)**

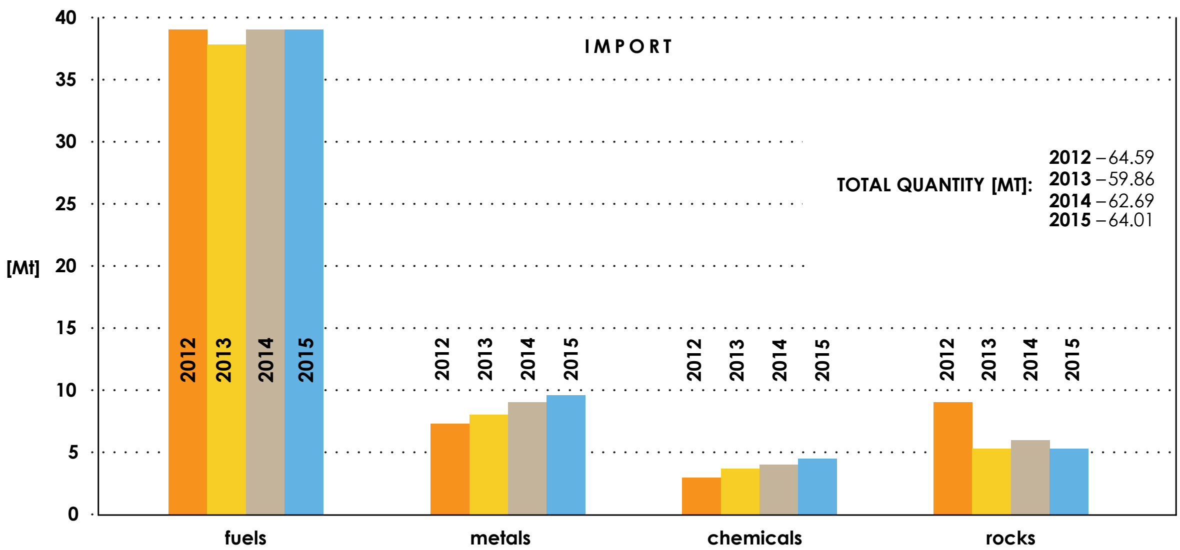


Fig. 7.2.8. **Magnitude of mineral raw materials import in 2012–2015 (excluding natural gas)**

Table 7.2.2. Comparison between export/import values in 2014–2015 (value in PLN and EUR)

import
export

Group of mineral raw materials	2014			2015			Comparison		
	Value [MPLN]	Value [MEUR]	%	Value [MPLN]	Value [MEUR]	%	Absolute value 2015–2014 [MPLN]	% of PLN value 2014 = 100	Absolute value 2015–2014 [MEUR]
TOTAL	**95,515.87***	**22,838.41***	**100.0**	**76,973.14***	**18,434.47***	**100.0**	**–18,542.73***	**80.59***	**–4,403.94***
	52,085.44*	**12,452.17***	**100.0**	**49,157.79***	**11,775.68***	**100.0**	**–2,927.65***	**94.38***	**–676.49***
FUELS	72,096.51*	17,239.54*	75.5*	51,507.57*	12,341.82*	66.9*	–20,588.94*	71.44*	–4,897.72*
	26,132.74*	6,247.93*	50.2*	23,246.08*	5,571.71*	47.3*	–2,886.66*	88.95*	–676.22*
METALS	15,354.27	3,670.04	16.1	16,898.98	4,043.93	22.0	1,544.71	110.06	373.89
	20,145.11	4,815.57	38.7	19,413.97	4,648.62	39.5	–731.14	96.37	–166.95
CHEMICALS	5,574.20	1,333.16	5.8	6,135.08	1,465.93	8.0	560.88	110.06	132.77
	3,752.83	897.29	7.2	4,307.60	1,030.67	8.8	554.77	114.78	133.38
ROCKS	2,490.89	595.68	2.6	2,431.52	582.80	3.2	–59.37	97.62	–12.88
	2,054.75	491.37	3.9	2,190.13	524.68	4.5	135.38	106.59	33.31

* Excluding natural gas

Table 7.2.3. Comparison between export/import quantities in 2014–2015 [Mt]

import
export

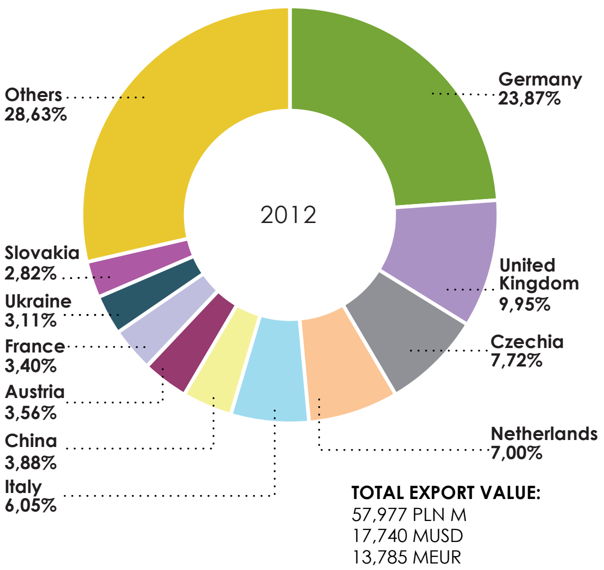
Group of mineral raw materials	2014		2015		Comparison	
	Quantity	%	Quantity	%	Absolute value 2015–2014	% 2014 = 100
TOTAL	**62.69***	**100.0**	**64.01***	**100.0**	**1.32***	**102.11***
	35.95*	**100.0**	**37.08***	**100.0**	**1.13***	**103.14***
FUELS	40.02*	63.8*	40.85*	63.8*	0.83*	102.07*
	23.33*	64.9*	25.08*	67.6*	1.75*	107.50*
METALS	10.27	16.4	10.83	16.9	0.56	105.45
	3.83	10.6	3.04	8.2	–0.79	79.37
CHEMICALS	5.17	8.3	5.33	8.3	0.16	103.09
	4.06	11.3	4.48	12.1	0.42	110.34
ROCKS	7.23	11.5	7.00	10.9	–0.23	96.82
	4.74	13.2	4.48	12.1	–0.26	94.51

* Excluding natural gas

Total import value in 2015 decreased by 19.41% and export value by 5.62% in comparison to 2014. The import value significantly increased in metal (due to aluminum import) and chemical (mainly fertilizers) groups (both by 10.06%), while drops were observed within fuels and rocks – by 28.56% (due to a much lower value of crude oil and petroleum product import) and 2.38%, respectively. The export value rose by 14.78% for chemicals (mainly fertilizers) and by 6.59% for rocks, whereas drops were noted for fuels (by 11.05%, mainly crude oil) and metals (by 3.63%).

Total import magnitude in 2015 increased by 2.11% and export by 3.14% in comparison to 2014. The import quantity increased within three groups: metallic raw materials (by 5.45% – due to aluminum import), chemicals (by 3.09%) and fuels (by 2.07%). A drop was observed in rocks – by 3.18%. The export quantity increased within two groups of mineral raw materials – by 10.34% (chemicals – mainly sulphur and sodium) and by 7.50% (fuels – petroleum products). Metal and rock export decreased by 21.63% (mainly iron) and 5.49% (mainly dimension and crushed stones), respectively.

Figures 7.2.9 and 7.2.10 show main directions of raw materials export and import in Poland in 2012 and 2015. As for export and import, main trade partners



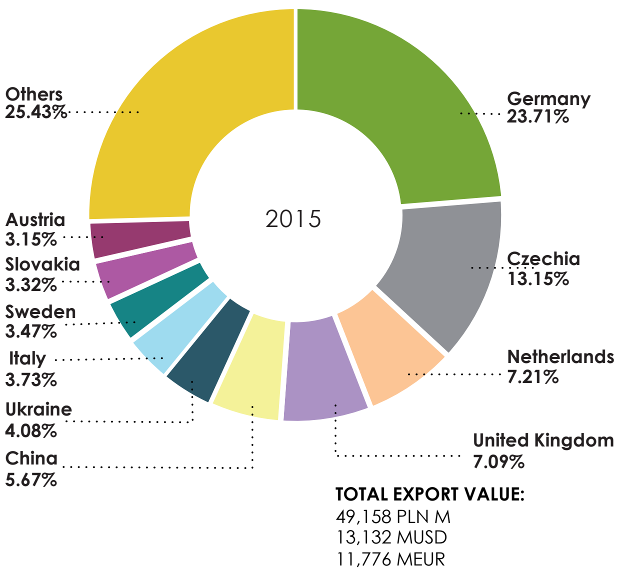
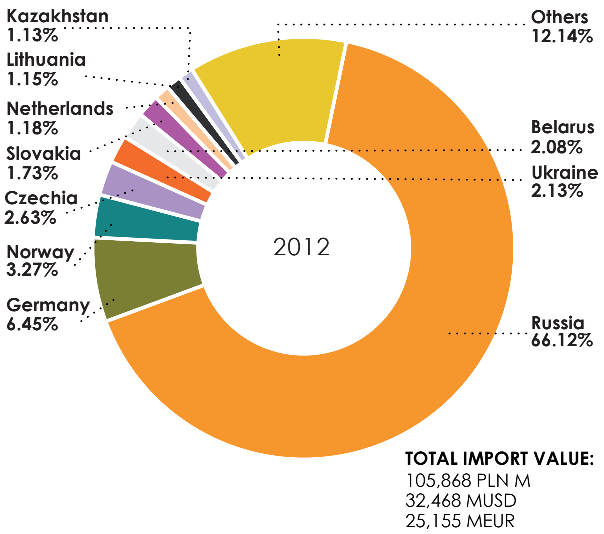


Fig. 7.2.9. **Main directions of raw materials export in 2012 and 2015**



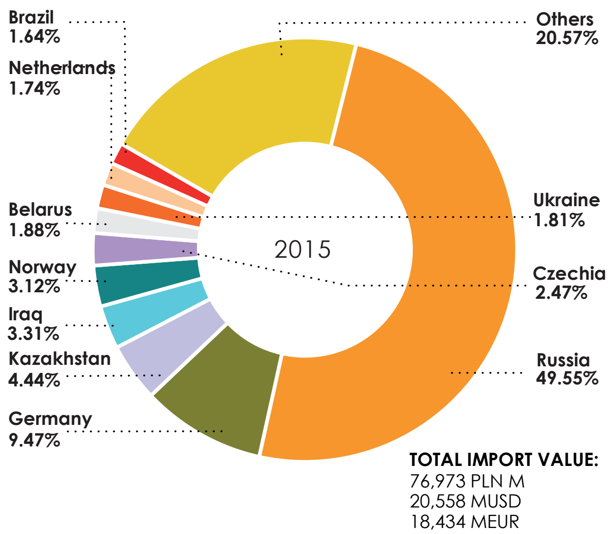


Fig. 7.2.10. **Main directions of raw materials import in 2012 and 2015**

have not changed significantly. In 2015, similarly to previous years, the highest value was attained by raw materials export to Germany. The export value to this country amounted to PLN 11,655 M, which constituted 23.71% of the total Polish raw materials export value. Other important countries with a significant contribution to the total Polish raw material export were the Czech Republic (13.15%) and the Netherlands (7.21%) (Fig. 7.2.9). The total export value to these three countries was PLN 21,666 M (44.07% of the total export value).

The major part of mineral raw materials import in 2015 came from Russia. The import value was PLN 38,145 M, which constitutes 49.56% of the total mineral raw materials import value in Poland. Other important countries were Germany (9.47%) and Kazakhstan (4.44%) (Fig. 7.2.10). The total import value from these three countries amounted to PLN 48,855 M (63.47% of the total import value).

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APPENDIX 1

Selected parts of the Geological and Mining Law

This chapter presents only essential provisions of the geological and mining law as to the scope of the law, ownership of mineral deposits and licensing policy (without hydrocarbons). This is an unauthorized translation of the Act. All questions and problems concerning the law should be addressed to the Ministry of Environment, Department of Geology and Geological Concession: Departament.Geologii.i.Koncesji.Geologicznych@mos.gov.pl.

Geological and Mining Law

Act
dated 9 June 2011

SECTION I
GENERAL PROVISIONS

Art. 1.

1. The Act defines the terms and conditions for the undertaking, execution and completion of activities within the scope of:

1) geological work;

2) mineral exploitation from deposits;

3) non-reservoir storage of substances in the subsurface;

4) storage of waste in the subsurface;

5) subsurface storage of carbon dioxide for a demonstration project of carbon dioxide capture and storage.

2. The Act also specifies:

1) requirements for the protection of mineral deposits, groundwater and other components of the environment in connection with the activities referred to in par. 1;

2) supervision and control of activities regulated by law.

Art. 2.

1. Provisions of the Act, except in Chapter III, shall apply to:

1) the construction, expansion and maintenance of drainage systems of liquidated mining plants;

2) excavation work carried out in closed underground mining plants for purposes other than those specified by law, in particular, for tourism, curative and recreational purposes;

3) underground work conducted for scientific, research, experimental and training purposes for geology and mining needs;

4) tunnelling with use of mining techniques;

5) decommissioning of entities, equipment and installations referred to in points 1–4.

2. Provisions of the Act concerning entrepreneurs shall apply mutatis mutandis to entities that have obtained decisions other than a concession constituting the basis for undertaking activities regulated by the Act.

Art. 3.

This Act shall not apply to:

1) the use of water to the extent regulated by separate regulations;

2) the digging of pits and boreholes to a depth of 30 m in order to use the Earth heat beyond mining areas;

2a) the digging of pits and drilling boreholes to a depth of 30 m in order to use underground water less than

5 m³/day beyond mining areas;

3) research and education carried out without geological operations;

4) acquisition of samples of minerals, rocks and fossils for scientific, collection and instruction purposes carried out without mining operations;

5) operations related to artificial supply of the shoreline zone with sand from sea bottom sediment in maritime areas of the Republic of Poland;

6) the exploitation of aggregates to the extent necessary to complete urgent work to prevent flooding during a state of natural disaster;

7) determination of geotechnical conditions for the foundation of buildings without geological work. (…)

Art. 5.

1. Water is not defined as a mineral with the exception of curative and thermal waters and brines.

2. Water:

1) curative water is groundwater, which is not contaminated in terms of chemical and microbiological conditions and is characterised by natural variability of physical and chemical features and contains:

a) dissolved solid minerals – at least 1,000 mg/dm³ or

b) ferrous ion – at least 10 mg/dm³ (ferruginous water), or

c) fluoride ion – at least 2 mg/dm³ (fluoride water), or

d) iodide ion – at least 1 mg/dm³ (iodide water), or

e) divalent sulfur – at least 1 mg/dm³ (sulfurous water), or

f) meta-silicic acid – at least 70 mg/dm³ (water containing silica), or

g) radon – at least 74 Bq/dm³ (radon water), or

h) unbound carbon dioxide – at least 250 mg/dm³, whereby quantities from 250 to 1,000 mg/dm³ are called carbonic acid water, and those exceeding 1,000 mg/dm³ are called "szczawa" water;

2) thermal water is an underground water, which at the intake outflow has a temperature of at least 20°C.

3. Brine is groundwater containing dissolved solid minerals of at least 35 g/dm³. (…)

Art. 6.

1. The meaning of the Act:

1) geological data – the results of direct observations and measurements obtained in the course of geological work; (…)

2) geological information – data and geological samples together with the results of their processing and interpretation, particularly that found in geological documentation and recorded on data carriers; (…)

3) excavated minerals – all minerals disconnected from deposits; (…)

5) mining area – space within which an entrepreneur is entitled to mineral exploitation, underground non-reservoir storage of substances or underground storage of waste, as well as necessary mining work to execute concessions;

6) underground landfill – part of a rock mass, including underground mining excavation, used for waste disposal by land filling; (…)

7) prospecting – geological work to identify and initially document mineral deposits or ground water;

8) geological work – design and investigation aimed to identify the geological structure of the country, in particular, prospecting and exploration of mineral and groundwater deposits, determination of geological-engineering conditions and preparation of geological maps and documentation as well as design and research for purposes of Earth heat exploitation or the use of groundwater;

9) entrepreneur – party holding a concession for activities regulated by this Act;

10) restoration to a previous state – restoration to the state existing before damage, in particular, by providing building objects, devices and installations an unimpaired state of resistance, heat absorbance, tightness and technical-functional utility;

11) geological operation – any activities within the framework of geological work below the surface, including those requiring the use of explosives, as well as the shut-down of excavations arising after such operations,

12) mining operation – performance, protection or shut-down of mining excavations in relation to the activity regulated by this Act;

13) prospecting – geological work in the area of mineral or groundwater deposits for which preliminary documentation was compiled;

14) blasting agents – explosives in terms of the Act dated 21 June 2002 on explosives earmarked for civil use (Official Journal, no. 117/1007 with further amendments);

15) mining damage zone – space subjected to the anticipated damaging effects of mining operations at a mining plant,

16) hydrocarbons – crude oil, natural gas and its natural derivatives, as well as methane in coal deposits, with the exception of methane occurring as accompanying mineral; (…)

17) mining excavation – space on land or in the subsurface created as a result of mining operations,

18) mining plant – a technically and organisationally separate set of means directly used for activities regulated by the Act relating to the exploitation of minerals from deposits and in underground mining excavation of hard coal together with remaining mineral exploitation technology for the preparation of exploited minerals for sale, underground non-reservoir storage of substances or underground storage of waste, including mining excavations, buildings, equipment and installations; (…)

19) mineral deposit – a natural accumulation of minerals, rocks and other substances that through excavation can bring economic benefits;

20) tipping of overburden – means a set of activities conducted in open pit mining excavations, inherent technically and organizationally with movement and storage of masses of soil and rocks removed from such deposits to allow exploitation of useful minerals.

Art. 7.

1. The undertaking and execution of activities defined by this law is allowed only if it does not violate any specific purpose of properties foreseen in a local urban spatial development plan and in separate regulations.

2. In the absence of a local urban spatial development plan, the undertaking and execution of activities defined by this law is permissible only if it does not violate the manner of using property foreseen in a study of conditions and directions of spatial management as well as in separate regulations.

SECTION II
MINING OWNERSHIP, MINING USUFRUCT AND OTHER MINING RIGHTS

Art. 10.

1. Mining ownership covers deposits of hydrocarbons, hard coal, methane occurring as accompanying mineral, lignite, metal ores with the exception of soddy iron ores, native metals, ores of radioactive elements, native sulfur, rock salt, potassium salt, potassium-magnesium salt, gypsum and anhydrite, gemstones, despite the place of their occurrence.

2. Mining ownership also covers deposits of curative waters, thermal waters and brines.

3. Deposits of minerals not listed in par.1 and 2 are covered by the law of real estate ownership of land.

4. Mining ownership also covers parts of rock mass located outside spatial borders of land property, in particular, within the borders of maritime areas of the Republic of Poland.

5. The State Treasury holds the right of mining ownership.

Art. 11.

The Civil Code shall apply toward matters not regulated by this Act on mining ownership and in case of disputes between the State Treasury and a land owner, as well as provisions of geodetic and cartographic law on land properties, including their demarcation.

Art. 12.

1. Within the bounds specified by law, the State Treasury, with the exclusion of other parties, can benefit from the subject of mining properties or dispose of its rights of property exclusively by establishing mining usufruct.

2. State Treasury rights arising from mining ownership with reference to activities:

1) which require a concession, are performed by competent concession authorities;

2) referred to in Art. 2 par. 1, are performed by the provincial boards of.

3. If the subject of mining ownership is located within maritime areas of the Republic of Poland, the performance of ownership rights requires agreement with the minister responsible for the maritime economy.

4. Rules governing mining usufruct do not apply to geological works that do not require a concession.

Art. 13.

1. The establishment of mining usufruct must take place through a written agreement in order to be valid..

1a. Mining usufruct shall enter into force on the date of concession issue.

3. The agreement referred to in par. 1, sets compensation for the establishment of mining usufruct and the manner of its payment.

4. Compensation for the establishment of mining usufruct constitutes State Treasury revenue. (…)

Art. 14.

1. With the exception of situations specified in par. 21 and Chapter III, Section 3, the establishment of mining usufruct may be preceded by a tender, especially if sought by more than one entity.

2. Intent to establish mining usufruct by tender shall be reported by the concession authority in each case by the way of notice.

3. Tender requirements shall be non-discriminatory and shall be based on the following criteria:

1) technical and financial capability of the bidder;

2) proposed technology of works;

3) proposed amount of remuneration for the establishment of mining usufruct.

4. The Council of Ministers shall specify by the way of an ordinance the rules of placing notices of tenders for acquisition of a mining usufruct right, data that shall be included in a notice, requirements to be satisfied by an offer, the deadline for the submission of tenders and tender-end procedure, organisation and the manner of conducting a tender, including the appointment and work of a bid commission guided by the need to present comprehensive information in an invitation notice, as well as to provide clear and non-discriminatory conditions for tender and competition protection, including a fair assessment of submitted tenders.

Art. 15.

1. Any party exploring a mineral deposit, (except a hydrocarbon deposit or complex of underground carbon dioxide storage) being the subject of mining ownership and sufficiently documented to enable preparation of a deposit development plan and who obtained a decision approving geological documentation of deposits may demand the establishment of mining usufruct for its own benefit with priority over other parties.

2. Any disputes regarding the matters specified in par. 1 shall be resolved by common courts competent for the seat of the Concession Authority representing the State Treasury.

3. The claim referred to in par. 1, shall expire five years after the date of notification of a decision approving geological documentation. (…)

Art. 18.

1. If another party's real estate or a part thereof is necessary to conduct activities regulated by the Act, an entrepreneur may demand the right to use such real estate or part thereof for the defined period with remuneration.

2. The right referred to in par. 1 cannot include rights to gain profit from the property.

3. If real estate or a part thereof cannot be used for existing targets due to restrictions of rights, the owner (perpetual usufructuary) may demand an entrepreneur to buy out the real estate.

4. In case of any disputes, a matter shall be resolved by common courts.

Art. 19.

1. An entrepreneur granted a concession for exploitation of:

1) hydrocarbons extraction; (…)

2) hard coal extraction;

3) lignite extraction,;

4) non-reservoir underground storage of hydrocarbons;

5) underground storage of carbon dioxide

– may demand a buyout of real estate or a part thereof located in a mining area to the extent necessary to conduct intended activities.

2. Any disputes shall be resolved by common courts. (…)

SECTION III
CONCESSIONS

CHAPTER 1
CONCESSION RULES

Art. 21.

1. Activities in the scope of:

1) prospecting or exploration of mineral deposits referred to in Art. 10 par. 1, with the exception of hydrocarbons deposits; (…)

2) exploitation of minerals from deposits;

2a) prospecting or exploration and extraction of hydrocarbons from deposits;

3) underground non-reservoir storage of substances,;

4) underground waste storage;

5) underground carbon dioxide storage;

– can be executed after the granting of a concession. (…)

3. Provisions of this Chapter shall apply toward licensing of activities relating to prospecting or exploration of hydrocarbons deposits and exploiting hydrocarbons from deposits, subject to the provisions of Chapter 3.

4. Concessions shall be granted for a period of at least three years and a maximum of 50 years, unless the entrepreneur submitted an application for a shorter period concession. (…)

5. A concession entitles commercial activity within an indicated space.

Art. 22.

1. A concession for:

1) prospecting or exploration of mineral deposits, as referred to in Art. 10 par. 1, with the exception of hydrocarbons deposits;

1a) prospecting or exploration of an underground complex for carbon dioxide storage;

2) exploitation of minerals from deposits;

2a) prospecting or exploration and extraction of hydrocarbons from deposits;

3) an underground non-reservoir storage of substances;

4) underground waste storage;

5) underground carbon dioxide storage

– shall be granted by the minister responsible for the environment. (..)

2. The County Head shall grant concessions to exploit minerals from deposits, upon together fulfilment of the following requirements:

1) the area of documented deposit not covered by usufruct rights does not exceed 2 ha;

2) mineral exploitation from a deposit does not exceed 20,000 m³ during a calendar year;

3) activities will be conducted with open pit method and without the use of explosives.

3. An entrepreneur granted a concession by the County Head to exploit minerals from a deposit adjacent to deposits, which are already covered by a concession granted to the same entrepreneur for the same type of activity, shall commence exploitation of deposits no earlier than the date when the decision declaring expiry of the earlier concession becomes final.

4. The Province Marshal shall grant a concession for exploitation of minerals from deposits within the scope not specified in Art. 1 and 2.

Art. 23.

1. The granting of a concession for:

1) prospecting or exploration of ores of radioactive elements and their exploitation from deposits shall require an opinion of the Chairman of the State Atomic Agency;

2) exploitation of minerals from deposits from the subsurface underneath inland waters and in areas indicated in the Water Law shall require acceptance by the authority competent for water maintenance of water recourses and an opinion of the authority competent for the granting of a Water Law permit;

3) exploitation of the minerals referred to in Art. 10 par. 1 from deposits, and underground non-reservoir storage of substances as well as carbon dioxide storage requires acceptance by the minister responsible for the economy;

4) carbon dioxide storage requires an opinion of the European Commission.

2. In relation to activities undertaken outside the boundaries of maritime areas of the Republic of Poland, the granting a concession for:

1) prospecting or exploration of a mineral deposit, with the exception of hydrocarbons deposits, and prospecting or exploration of an underground complex for carbon dioxide storage;

2) prospecting or exploration as well as extraction of hydrocarbons from deposits

– shall require an opinion of the head of a municipality or town or city mayor at the location of intended activity.

2a. In relation to activities undertaken outside the boundaries of maritime areas of the Republic of Poland:

1) the granting of a concession to exploit minerals from deposits, underground non-reservoir storage of

substances or underground storage of waste or underground carbon dioxide storage;

2) the granting of the investment decision mentioned in Art. 49z par. 1

– shall require consent of the head of a municipality or the, town or city mayor at the location of intended activity (…).

3. The granting of a concession by the County Head requires an opinion of the Province Marshal. (…)

Art. 24.

1. The following shall also be specified in an application for granting a concession, in addition to the requirements laid down in regulations on environmental protection and economic activities:

1) land owners of properties for the location of intended activity (…)

these requirements shall not apply to prospecting or exploration of hydrocarbons;

2) the applicant's rights to real estate (space) within the boundaries of which intended activities shall be performed or specification of the right that an applicant seeks to obtain;

3) the period for which a concession is to be granted, together with designation of the commenced date of activities;

4) the resources available to an applicant to ensure proper performance of intended activities;

5) areas designated as special areas of nature conservation (…)

6) manner of mitigating negative influence of intended activity on the environment. (…)

Art. 25.

1. The purpose, scope and type of geological work shall also be specified in an application for granting a concession for prospecting or exploration of mineral deposits, as well as information on work to be undertaken to achieve the intended purpose, including the type of employed technologies.

2. In the case of deliberate performance of geological work, two copies of a geological work project shall be attached to the application referred to in par. 1.

Art. 26.

1. The following shall also be specified in an application for granting a concession to exploit minerals from deposits:

1) mineral deposit or part thereof to be the subject of mining;

2) quantities and intended method of mineral extraction;

3) the degree of intended utilisation of mineral deposit resources, including accompanying minerals and useful co-occurring trace elements, as well as available resources to achieve this objective and, in the case of curative water, thermal waters and brines – exploitation of water intake resources;

4) the proposed location of a mining area and mining protective area presented in accordance with requirements established for mining maps, indicating boundaries of the country territorial division;

5) geological and hydro geological conditions of exploitation and, if necessary, conditions for injecting waters into a formation.

2. The following documents shall be attached to the application referred to in par. 1:

1) the right to use geological information to the extent necessary to perform intended activity held by the Applicant and a copy of the decision approving geological documentation;

2) the rights to an area within the boundaries in which intended open-pit mineral exploitation is to be conducted, or a proof of a promise to get such rights. This obligation does not apply to lignite.

3. A deposit development plan shall be attached to the application referred to in par. 1 specifying requirements for rational management of a mineral deposit, in particular, through comprehensive and rational use of the main mineral as well as accompanying minerals and exploitation technology ensuring a reduction of adverse environmental impact. This obligation does not apply to a concession granted by a County Head.

3a. The deposit development plan for minerals referred to in Art. 10 par. 1, with the exception of hydrocarbons deposits, requires an opinion of the mining authority. (…)

Art. 29.

1. The concession authority shall refuse to grant a concession if intended activity is detrimental to the public interest, particularly with regard to national security or environment protection, including rational management of mineral deposits, or prevents the use of real estate in accordance with purposes specified respectively by a local urban spatial development plan or separate regulations and, also if the absence of a local urban spatial development plan prevents the use of real estate as defined in a study of conditions and directions of spatial management of a municipality or in separate regulations. (…)

Art. 30.

1. A concession shall specify:

1) the type and manner of intended activity;

2) the space within which intended activity is to be performed;

3) the validity period of a concession;

4) the commencement date of activities specified by the concession and, if necessary, the conditions under which activities will commence.

2. A concession may stipulate other requirements with regard to the activities it covers, in particular, those concerning general safety and environmental protection.

3. A concession is not exempt from requirements specified in separate regulations, including the receipt of decisions it foresees.

Art. 31.

1. A concession for prospecting or exploration of mineral deposit, with the exception of hydrocarbon deposits or prospecting/exploration of an underground complex for carbon dioxide storage, shall also determine:

1) the purpose, scope and nature of intended geological work, including geological operation; in the case of a concession for prospecting/exploration of mineral deposits, with the exception of hydrocarbons deposits, the minimal class of deposit recognising;

2) the scope and schedule for transfer of geological information and samples obtained as a result of geological work execution;

3) the level of charge for activities specified in a concession.

2. The surface of the area covered by a concession for prospecting or exploration of a mineral deposit as well as prospecting/ exploration of an underground complex for carbon dioxide storage cannot exceed 1,200 km².

Art. 32.

1. A concession for exploitation of minerals from deposits, underground non-reservoir storage of substances or underground storage of waste or underground carbon dioxide storage shall also designate boundaries of the space and mining area.

2. The basis for demarcation of boundaries of a mining area is a geological documentation and a deposit development plan (…).

3. If not jeopardising proper use of a deposit, the mining area defined in concessions for exploitation of minerals from a deposit may cover part of a deposit.

4. A concession for exploitation of minerals from a deposit may also determine:

1) minimum resource utilisation and operations necessary for rational development of a deposit;

2) conditions for water injection into rock mass; in such cases the regulation on use of water and environment usage charges shall not apply. (…)

Art. 33.

If a concession is preceded by a decision adopted on environmental conditions in proceedings with public participation, provisions on the participation of social organisations shall not apply to concession proceedings.

Art. 34.

1. A concession authority can modify the concession also upon request of an investor – concession holder. (…)

Art. 36.

1. If not to the detriment of the public interest, particularly in relation to national security or environmental protection, including rational management of mineral deposits, together with consent of the entrepreneur granted a concession, the concession authority shall transfer a concession by the way of a decision to an entity that:

1) meets requirements stipulated by regulations governing business activity;

2) agrees to accept all conditions arising from a concession;

3) demonstrates to the extent necessary for performing the intended activity:

the right to land real estate, the right for mining usufruct, or a promise of obtaining such rights;

4) demonstrates the right to use geological information in to the extent necessary for performing intended activity;

5) demonstrates ability to meet requirements concerning performance of intended activity. (…)

Art. 38.

1. A concession expires:

1) when the period for which it was granted has lapsed;

2) when it has become devoid of purpose;

3) in case of death of an entrepreneur being an individual;

4) in case of liquidation of an entrepreneur other than referred to in par. 3;

5) in case of resignation of concession holder. (…)

APPENDIX 2

Unauthorized English version of selected most important documents concern mineral exploration and extraction

Date dd-mm-yy

CONCESSION No. ....

Pursuant to art. 46, sec. 1, point 1 of the Freedom of Commerce Act of 2 July 2004 (Journal of Laws, 2015, Item 584, with subsequent amendments), in connection with art. 21 sec. 1 point 2, art. 22 sec. 1 point 2, art. 30 and art. 32 sec. 1–4 of the Geological and Mining Law Act of 9 June 2011 (Journal of Laws, 2015, Item 1131, with subsequent amendments) and art. 104 of the Administrative Procedure Code Act of 14 June 1960 (Journal of Laws, 2016, Item 23, with subsequent amendments), upon review of an application submitted by (name of entrepreneur) with reference to an agreement on the establishment of mining usufruct signed on dd-mm-yy between (name of entrepreneur) and the State Treasury, represented by the Minister of Environment upon attainment of accord, as required by Geological and Mining Law provisions,

I resolve

1. to grant (name of entrepreneur) a concession for exploration and development of a (type of mineral raw material) deposit in the area (area name as defined by the entrepreneur), situated in the communes: ...., ... district, ... province; whereby

2. boundaries of the concession area are delineated at the surface by lines connecting points … to … in the "PL-1992" or "PL-2000" coordinate system.

No.	PL-1992 coordinate system	
	X	Y
1	0000000,00	0000000,00
2	0000000,00	0000000,00
3	0000000,00	0000000,00
4	0000000,00	0000000,00
5	0000000,00	0000000,00
6	0000000,00	0000000,00

3. The surface of the concession area in vertical projection is .... km².

4. Planned geological works aim to explore and develop a (type of mineral raw material) deposit. Their outcome will be presented in the form of geological documentation.

5. Activities under a concession contract may include (examples):
   - drilling (number) exploration wells with total length of (number of meters), each to a maximum depth of (number) m;
   - geophysical surveys – (for example, three profile magnetotelluric profiles at a total length of 10 km);
   - laboratory analyses;
   - documentation.

   A detailed specification of planned activity as well as location and schedule of geological works is provided in "Geological work project" in an annex to the concession application.

6. Conditions that an entrepreneur should meet under this concession are defined in an agreement on the establishment of mining usufruct signed on dd-mm-yy between (name of entrepreneur) and the State Treasury, represented by the Minister of Environment upon attainment of accord, as required by Geological and Mining Law provisions.

7. I require (name of entrepreneur) to collect and forward geological samples in accordance with art. 82 sec. 5 of the Geological and Mining Law and Regulations of the Minister of Environment – 9 June 2015 on the forwarding of information from records of ongoing geological works, except for geological samples that are subject to analyses leading to their total destruction or compromised integrity of a borehole core.

8. I require (name of entrepreneur) to issue written reports:

a) quarterly reports in the form of tables summarizing activity under the concession – results of work listed in point 5 that was completed or is in progress as well as that planned. Reports for each quarter summarise results as on 31 March, 30 June, 30 September and 31 December throughout the duration of the concession. Reports must be submitted to the licensing authority within 14 days from the end of the month closing a reporting period. This duty arises from the date when the concession became final.

b) annual reports summarizing activity under the concession presenting the results of work completed in the course of analysis of deposit parameters and that in progress. Annual reports drafted as on 31 December, must be submitted to the licensing authority by 31 January of the following year on electronic data carriers in formats matching standards for recording and presentation for relevant types of works.

9. The concession is granted for a period of .... years, counting from the date when it became final.

10. Commencement of activity under the concession shall take place within ..... months counting from the date when this concession became final. Commencement is understood as the start of drilling specified in point 5 of the concession. I obligate the entrepreneur to inform the licensing authority in writing that activity under the concession was initiated within 14 days of its start.

11. I set the fee for the activity specified in the concession at PLN .... (in writing: .... Polish zlotys) to be paid in a full single payment within 14 days from the date when this concession became final. Sixty percent of the fee for activity specified in the concession is paid to the budget of communes in which activities under the concession are to be carried out and in proportion to the concession area situated within boundaries of a given commune. The remaining 40% is revenue of the National Environment Protection and Water Management Fund.
I obligate (name of entrepreneur) to timely submit deposit slips from payments made in accordance with art. 133 of the Geological and Mining Law to the licensing authority and other public administration bodies as specified in art. 141 of that law.

12. This concession shall not infringe the rights of land property owners and does not exempt an entrepreneur from the obligation to comply with regulations in force, in particular, those imposed by the Geological and Mining Law and those concerning land use and protection of the environment, arable and forestland, nature, water and waste management.

Justification

....

Recipients:

1. (name of entrepreneur)
2. a/a.

cc:

1. Ministry of Energy
2. Marshal's Office of .... province
3. District Administrative Authority in ....
4. .... Commune Office
5. .... Regional Mining Authority
6. National Environment Protection and Water Management Fund
7. Central Mining Office
8. Register of Mining Areas, Polish Geological Institute – National Research Institute

Date dd-mm-yy

CONCESSION No. ....

Pursuant to art. 46, sec. 1, point 1 of the Freedom of Commerce Act of 2 July 2004 (Journal of Laws, 2015, Item 584, with subsequent amendments), in connection with art. 21 sec. 1 point 2, art. 22 sec. 1 point 2, art. 30 and art. 32 par. 1–4 of the Geological and Mining Law Act of 9 June 2011 (Journal of Laws, 2015, Item 1131, with subsequent amendments) and art. 104 of the Administrative Procedure Code Act of 14 June 1960 (Journal of Laws, 2016, Item 23, with subsequent amendments), upon review of an application submitted by (name of entrepreneur) with reference to an agreement on the establishment of mining usufruct signed on dd-mm-yy between (name of entrepreneur) and the State Treasury represented by the Minister of Environment upon attainment of accord, as required by Geological and Mining Law provisions,

I resolve

1. to grant (name of entrepreneur) a concession for the exploitation of (type of mineral raw material) from a deposit (name of deposit as stated in geological documentation) situated in the area of communes: ...., ... district, ... province;

2. to establish a mining area (name of area) for the ..... deposit (name of deposit as stated in geological documentation), ... km² in area and situated in the area of districts: ...., ... county, ... province, with boundaries delineated by lines connecting points from ... to ... in the "PL-1992" or "PL-2000" coordinate system.

No.	PL-1992 coordinate system	
	X	Y
1	0000000,00	0000000,00
2	0000000,00	0000000,00
3	0000000,00	0000000,00
4	0000000,00	0000000,00
5	0000000,00	0000000,00
6	0000000,00	0000000,00

Mining damage zone is established together with a mining area: ...... km² in area with boundaries delineated by lines connecting points from ... to ... in ... the "PL-1992" or "PL-2000" coordinate system.

No.	PL-1992 coordinate system	
	X	Y
1	0000000,00	0000000,00
2	0000000,00	0000000,00
3	0000000,00	0000000,00
4	0000000,00	0000000,00
5	0000000,00	0000000,00
6	0000000,00	0000000,00

The location of the mining area and mining damage zone is shown in a map at a scale of 1: 10.000 constituting an annex to this concession.

3. Exploitation of raw materials will be carried out by underground / open-pit / borehole mining.

4. Conditions that the entrepreneur should meet under this concession are defined in an agreement on the establishment of mining usufruct signed on dd-mm-yy between (name of entrepreneur) and the State Treasury, as represented by the Minister of Environment.

5. Exploitation of raw materials will be conducted in accordance with a decision of the Regional Director for Environment Protection dated dd-mm-yy, defining environmental conditions for a given undertaking.

6. The concession is granted for a period of (number) years, counting from the date when this concession became final.

7. Activity covered by this concession will commence on dd-mm-yy.

8. This concession shall not infringe the rights of land property owners and does not exempt the entrepreneur from the obligation to comply with regulations in force, in particular, those imposed by the Geological and Mining Law and those concerning land use and protection of the environment, arable and forest land, nature, water and waste management.

Justification

....

Recipients:

1. (name of entrepreneur)
2. a/a.

cc:

1. Ministry of Energy
2. Marshal's Office of .... province
3. County Administrative Authority in ....
4. The head of the municipality
5. Regional Mining Authority
6. National Environment Protection and Water Management Fund
7. State Mining Authority
8. Register of Mining Areas, Polish Geological Institute – National Research Institute

Data dd-mm-yy

AGREEMENT

on the establishment of mining usufruct for exploration and development of (type of deposit) deposit in the (name of area as given by the entrepreneur) area

signed on dd-mm-yy between:

The State Treasury – Ministry of Environment, hereafter **"State Treasury"**

and

(name of entrepreneur), represented by (authorised person), herein called as **"Holder of Mining Usufruct Rights",** in short – **"Usufructuary"**,

which stipulates as follows:

§1.

1. The State Treasury, as sole owner of the subsurface with space situated in the area of communes: ...., ... district, ... province, with boundaries delineated by lines connecting points from ... to ... in ... of the "PL-1992" or "PL-2000" coordinate system:

No.	PL-1992 coordinate system	
	X	Y
1	0000000,00	0000000,00
2	0000000,00	0000000,00
3	0000000,00	0000000,00
4	0000000,00	0000000,00
5	0000000,00	0000000,00
6	0000000,00	0000000,00

establishes mining usufruct in favour of the Usufructuary in the above mentioned space, which is limited from above by a lower land property boundary and from below – by ordinate (number) m BLS.

2. The Usufructuary is entitled in the subsurface space, as defined in sec. 1:

a) in rocks .... – to conduct all activities related to exploration and development of (type of mineral raw material) deposit in (name of area as given by the entrepreneur) area,

b) in the remaining part – to conduct all necessary work and actions related to access to rocks (as specified in Point a).

3. The surface of the concession area in vertical projection is .... km².

§2.

1. Mining usufruct is established for a period of (number) years counting from the date when the Agreement is signed with the exceptions set forth in § 8.

2. Mining usufruct expires on the date of concession revocation.

§3.

1. The mining usufruct agreement grants the Usufructuary exclusive rights to use the space as defined in § 1 to explore and develop (type of mineral raw material) in the (name of deposit as stated in geological documentation) deposit, as well as to conduct all necessary work and operations within its boundaries in accordance with applicable legal regulations, especially those enforced by the Geological and Mining Law Act of 9 June 2011 (Journal of Laws, 2016, Item 1131, with subsequent amendments), hereinafter referred to as the Geological and Mining Law, as well as administrative decisions issued with reference to these regulations. The Usufructuary may manage the studied mineral deposit only to the extent necessary for compilation of geological documentation.

2. The Usufructuary undertakes to immediately inform the State Treasury in writing of any transformations resulting in changes of the company name and its corporate structure, Industry Identification Number (REGON) and Tax Identification Number (NIP) as well as an increase or decrease of share capital, legally authorised transfer of concession to another entity, filing for bankruptcy, declaration of bankruptcy, launching of arrangement procedures or initiation of proceedings to wind up the company. The State Treasury may request the Usufructuary to provide explanations in this regard. Relevant information shall be provided within 30 days from the date when the above circumstances have arisen.

§4.

The Agreement shall not infringe the rights of third parties, especially land property owners, and does not exempt the Usufructuary from the obligation to comply with regulations in force, in particular, those governing the exploration and development of mineral raw material deposits and protection and use of environmental resources.

§5.

The State Treasury reserves the right to establish additional usufruct within the space defined in § 1 sec. 1 for activity other than that specified in the agreement in a manner not infringing specified rights of the Usufructuary.

§6.

1. As compensation for mining usufruct in the space defined in § 1 sec. 1, the Usufructuary will pay compensation fee PLN .... (in writing: .... Polish zlotys) to the State Treasury no later than ....

2. The compensation fee specified in sec. 1 will be subject to indexation with consideration of the average annual consumer price index (CPI) set for the period from Agreement signing to the year preceding payment of compensation, as published by the Chairman of the Central Statistical Office in the Official Journal of the Republic of Poland "Monitor Polski".

3. If the Usufructuary loses mining usufruct rights being the subject of the Agreement before the date set in § 2 sec. 1, it will be obligated to pay compensation for the entire calendar year during which usufruct rights were lost. However, if usufruct rights were lost due to revocation of a concession or other reasons as stated in § 8 sec. 1, 3 or 5, the Usufructuary will be obliged to pay the fixed part of compensation for the entire usufruct period, as specified in § 2 sec. 1. Compensation shall be paid within 30 days from the date of loss of usufruct rights. Such loss shall not relieve the Usufructuary from compliance with environmental protection obligations related to the subject of mining usufruct, especially those concerning the protection of mineral raw material deposits.

4. The Usufructuary shall pay compensation for mining usufruct to the bank account of the Ministry of Environment, ..., transfer title: payment for establishment of mining usufruct in connection with a granted concession for exploitation of (type of mineral raw material) in the (name of deposit as given in geological documentation) deposit. The date of payment shall be the date when the State Treasury bank account is credited with the payment amount.

5. Polish Value Added Tax (VAT) is not added to compensation defined in sec. 1 and 2. If regulations change and undertakings covered by this agreement are subject to VAT, compensation shall be increased with due tax.

6. The State Treasury will inform the Usufructuary in writing of any changes to the bank account referred to in sec. 4.

7. The Usufructuary shall submit proof of payment of fees pursuant to sec. 1, 2 and 6 of this Agreement within 30 days from the date of payment of fee for establishment of mining usufruct.

§7.

The Usufructuary may dispose of the mining usufruct established in § 1 sec. 1 of this Agreement only upon receipt of prior written consent of the State Treasury.

§8.

1. A breach of obligations arising from the agreement subject to sec. 3 and 5 by the Usufructuary authorises the State Treasury to terminate the Agreement with immediate effect and without Usufructuary rights to pecuniary claims. However, the agreement cannot be terminated if the Usufructuary breaches obligations under the Agreement due to force majeure.

2. If the Agreement is terminated due to reasons provided in sec. 1, the Usufructuary shall pay the State Treasury a contractual penalty of 25% of compensation for the entire usufruct period as specified in § 2 sec. 1, subject to indexation for the year preceding the year in which the Agreement was terminated.

3. If payment of compensation is delayed over 30 days in relation to deadlines set in § 6 sec. 1, the State Treasury shall call on the Usufructuary to make overdue payment within 30 days under the penalty of Agreement termination with immediate effect.

4. The Usufructuary may terminate the Agreement in whole or in part, subject to a 90-day notice period effective at the end of a calendar month. Agreement termination does not exempt the Usufructuary from the obligation to pay the fee for the entire year during which the rights to mining usufruct were terminated, subject to indexation in accordance with § 6 sec. 2, within 30 days of giving termination notice, nor from the obligation to comply with environmental protection regulations related to mining usufruct, especially those pertaining to the protection of mineral resources.

5. The State Treasury may terminate the Agreement in whole or in part with 30-days' notice effective at the end of a calendar month if the Usufructuary fails to inform the State Treasury of circumstances specified in § 3 sec. 2 within 30 days of their appearance.

6. Termination of this agreement shall be invalid unless drafted in writing.

7. The Parties agree that compensation for mining usufruct defined in § 6 sec. 1 and 2 is not refundable if the Usufructuary terminates the Agreement.

8. The State Treasury reserves the right to seek compensation exceeding the contractual penalty on general principles if damage suffered by the State Treasury is greater than the penalty.

§9.

In cases of *force majeure*, the Parties shall make immediately every effort to agree on measures necessary in view of the of the circumstances invoked. *Force majeure* means unforeseeable and unavoidable circumstances directly affecting the Usufructuary and preventing execution of the Agreement.

§10.

The Usufructuary may apply for extension of the agreement in whole or in part for a period previously agreed with the licensing authority. An application for extension shall be submitted at least six months prior to the date specified in § 2. The application shall be invalid unless drafted in writing.

§11.

All disputes arising in connection with the Agreement shall be exclusively resolved by a court having jurisdiction for a seat of the State Treasury.

§12.

Provisions of the Geological and Mining Law and Civil Code (in particular, those referring to lease) shall apply toward all matters not settled in this Agreement. If the Agreement is terminated, the Usufructuary is not entitled to any claims against the State Treasury for increased value of the mining usufruct subject.

§13.

The Usufructuary shall cover any costs related to the conclusion of this Agreement.

§14.

Any changes to the Agreement shall be invalid unless drafted in writing.

§15.

This Agreement shall be executed in two counterparts with one copy for each party.

State Treasury Usufructuary

MINING USUFRUCT AGREEMENT

on the **extraction of** (type of mineral raw material) from a deposit (name of deposit as given in geological documentation),

signed on dd-mm-yy between:

the State Treasury – Minister of Environment, hereafter referred to as **"State Treasury"**

and

(name of entrepreneur), represented by (details of authorised person), hereafter referred to as **"Holder of Mining Usufruct Rights"**, in short – **"Usufructuary"**,

which stipulates as follows:

§1.

1. The State Treasury, as sole owner of subsurface space situated in area of communes: …………., ………………. district, ……………. province, including a deposit (name of deposit as given in geological documentation) of (mineral raw material type), with boundaries delineated by lines connecting points from … to … in the "PL-1992" or "PL-2000" coordinate system:

No.	PL-1992 coordinate system	
	X	Y
1	0000000,00	0000000,00
2	0000000,00	0000000,00
3	0000000,00	0000000,00
4	0000000,00	0000000,00
5	0000000,00	0000000,00
6	0000000,00	0000000,00

establishes mining usufruct in favour of the Usufructuary in the above mentioned space, limited by a lower boundary of the documented deposit, on the condition that the Usufructuary obtains a concession for exploitation of (type of mineral raw material) from the (name of deposit as given in geological documentation) deposit by dd-mm-yy.
If the condition for granting the concession specified in sec. 1 is not met, contractual obligations under this agreement shall expire.

2. In the subsurface space as defined in sec. 1, the Usufructuary is entitled to conduct all activities related to the exploitation of (type of mineral raw material). The Usufructuary is authorised to engage in all actions related to the extraction of (deposit type).

§2.

1. Mining usufruct is established for a period of (number) years counting from the date when the Agreement is signed with the exceptions set forth in § 8. Mining usufruct is established on the date of agreement conclusion for a period of …….. years subject to § 8.

2. Mining usufruct expires on the date of concession revocation.

§3.

1. The mining usufruct agreement grants the Usufructuary exclusive rights to use the space as defined in § 1 to extract (type of mineral raw material) in the (name of deposit as given in geological documentation) deposit, as well as to conduct all necessary works and operations within its boundaries in accordance with applicable legal regulations, especially those enforced by the Geological and Mining Law Act of 9 June 2011 (Journal of Laws, 2016, Item 1131, with subsequent amendments), hereinafter referred to as the Geological and Mining Law, as well as administrative decisions issued with reference to these regulations.

2. The Usufructuary undertakes to immediately inform the State Treasury in writing of any transformations resulting in changes of the company name and its corporate structure, Industry Identification Number (REGON) and Tax Identification Number (NIP) as well as an increase or decrease of share capital, legally authorised transfer of concession to another entity, filing for bankruptcy, declaration of the bankruptcy, launching arrangement procedures or initiation of proceedings of winding up the company. The State Treasury may request the Usufructuary to provide explanations in this regard. Relevant information shall be provided within 30 days from the date when the above circumstances have arisen.

§4.

This agreement shall not infringe the rights of third parties, especially land property owners, and does not exempt the Usufructuary from the obligation to comply with regulations in force, in particular, those governing the exploitation of mineral raw materials and protection and use of environmental resources.

§5.

The State Treasury reserves the right to establish additional usufruct within the space defined in § 1 sec. 1 for activity other than that specified in the agreement in a manner not infringing specified rights of the Usufructuary.

§6.

1. As compensation for mining usufruct in the space defined in § 1 sec. 1, the Usufructuary will pay a fixed fee of PLN .... (in writing: .... Polish zlotys) to the State Treasury for each agreement year counted as subsequent consecutive 12-month periods.

2. Upon commenced extraction of mineral raw material from a deposit, the Usufructuary will additionally pay the State Treasury a variable part of compensation of 5% of the mining fee from the previous year as on the last day of February of the previous year. The due mining fee for the previous year is the sum of due mining fees for the first and second half of the previous year that are paid on the basis of official regulations set forth in art. 134 in connection with art. 137 of the Geological and Mining Law.

3. The compensation referred to in sec. 1 and 2 shall be paid by the end of February of each usufruct agreement year for the previous year.

4. If the licensing authority issues a decision, as noted in art. 138 of the Geological and Mining Law, specifying the level of due fee, the Usufructuary shall pay the outstanding variable part of compensation for a given year within 30 days of the date when such decision became final. The outstanding part is the difference between variable part of compensation calculated under sec. 2 and the sum of amount due for the previous year after consideration of fees resulting from a decision issued on the basis of art. 138 of the Geological and Mining Law, and the variable part of compensation paid according to calculation for the last day of February of a given calendar year. Overpayment that cannot be credited toward future liabilities will not be eligible for a refund.

5. If mining usufruct does not comprise an entire year (meant as a rolling 12-month period), the Usufructuary pays due compensation calculated with reference to sec. 1 in proportion to the number of months in a given calendar year in the given usufruct agreement year rounded up to full months.

6. If the Usufructuary loses mining usufruct rights being the subject of an agreement before the date set in § 2 sec. 1, it will be obligated to pay compensation for the entire calendar year during which usufruct rights were lost. However, if usufruct rights were lost due to revocation of a concession or other reasons as stated in § 8 sec. 1, 3 or 5, the Usufructuary will be obliged to pay the fixed part of compensation for the entire usufruct period, as specified in § 2 sec. 1. Compensation shall be paid within 30 days from the date of loss of usufruct rights. Such loss shall not relieve the Usufructuary from compliance with environmental protection obligations related to the subject of mining usufruct, especially those concerning the protection of mineral raw material deposits.

7. The Usufructuary shall pay compensation for mining usufruct to the bank account of the Ministry of Environment, ..., transfer title: payment for establishment of mining usufruct in connection with a granted concession for exploitation of (type of mineral raw material) in the (name of deposit as given in geological documentation) deposit. The date of payment shall be the date when the State Treasury bank account is credited with the payment amount.

8. Polish Value Added Tax (VAT) is not added to compensation defined in sec. 1 and 2. If regulations change and undertakings covered by this agreement are subject to VAT, compensation shall be increased with due tax.

9. The State Treasury will inform the Usufructuary in writing of any changes to the bank account referred to in sec. 7.

10. The Usufructuary shall submit proofs of payment of fees pursuant to sec. 1, 2 and 6 of this Agreement within 30 days from the date of payment of fee for establishment of mining usufruct.

§7.

The Usufructuary may dispose of the mining usufruct established in § 1 sec. 1 of this agreement only upon receipt of prior written consent of the State Treasury.

§8.

1. A breach of obligations arising from the agreement subject to sec. 3 and 5 by the Usufructuary authorises the State Treasury to terminate the Agreement with immediate effect and without Usufructuary rights to pecuniary claims. However, the agreement cannot be terminated if the Usufructuary breaches obligations under the Agreement due to force majeure.

2. If the Agreement is terminated due to reasons provided in sec. 1, the Usufructuary shall pay the State Treasury a contractual penalty of .....% of the fixed part of compensation for the year preceding that in which the Agreement was terminated, as defined in § 6 sec. 1.

3. If payment of compensation is delayed over 30 days in relation to deadlines set in § 6 sec. 3, the State Treasury shall call on the Usufructuary to make overdue payment within 30 days under the penalty of Agreement termination with immediate effect.

4. The Usufructuary may terminate the Agreement in whole or in part, subject to a 90-day notice period effective at the end of a calendar month. Agreement termination does not exempt the Usufructuary from the obligation to pay the fixed part of compensation specified in § 6 sec. 1, for the entire year during which the rights to mining usufruct were terminated and the variable part of compensation defined in § 6 sec. 2, within 30 days of giving termination notice, nor from the obligation to comply with environmental protection regulations related to mining usufruct, especially those pertaining to the protection of mineral resources.

5. The State Treasury may terminate the Agreement in whole or in part with 30-days' notice effective at the end of a calendar month if the Usufructuary fails to inform the State Treasury of circumstances specified in § 3 sec. 2 within 30 days of their appearance.

6. Termination of this agreement shall be invalid unless drafted in writing.

7. The Parties agree that compensation for mining usufruct defined in § 6 sec. 1 and 2 is not refundable if the Usufructuary terminates the Agreement.

8. The State Treasury reserves the right to seek compensation exceeding the contractual penalty on general principles if damage suffered by the State Treasury is greater than the contractual penalty.

§9.

In cases of force majeure, the parties shall make immediately every effort to agree on measures to deal with existing circumstances. Force majeure means unforeseeable and unavoidable circumstances directly affecting the Usufructuary and preventing execution of the agreement.

§10.

The Usufructuary may apply for extension of the Agreement in whole or in part for a period previously agreed with the licensing authority. An application for extension shall be submitted at least six months prior to the date specified in § 2. An application shall be invalid unless drafted in writing.

§11.

All disputes arising in connection with the Agreement shall be exclusively resolved by a court having jurisdiction for a seat of the State Treasury.

§12.

Provisions of the Geological and Mining Law and Civil Code (in particular, those referring to lease) shall apply toward all matters not settled in this Agreement. If the Agreement is terminated, the Usufructuary is not entitled to any claims against the State Treasury for increased value of the mining usufruct subject.

§13.

The Usufructuary shall cover any costs related to the conclusion of this Agreement.

§14.

Any changes to the Agreement shall be invalid unless drafted in writing.

§15.

This Agreement shall be executed in two counterparts with one copy for each party.

State Treasury Usufructuary

Plate 1

OIL AND GAS FIELDS

Resources:

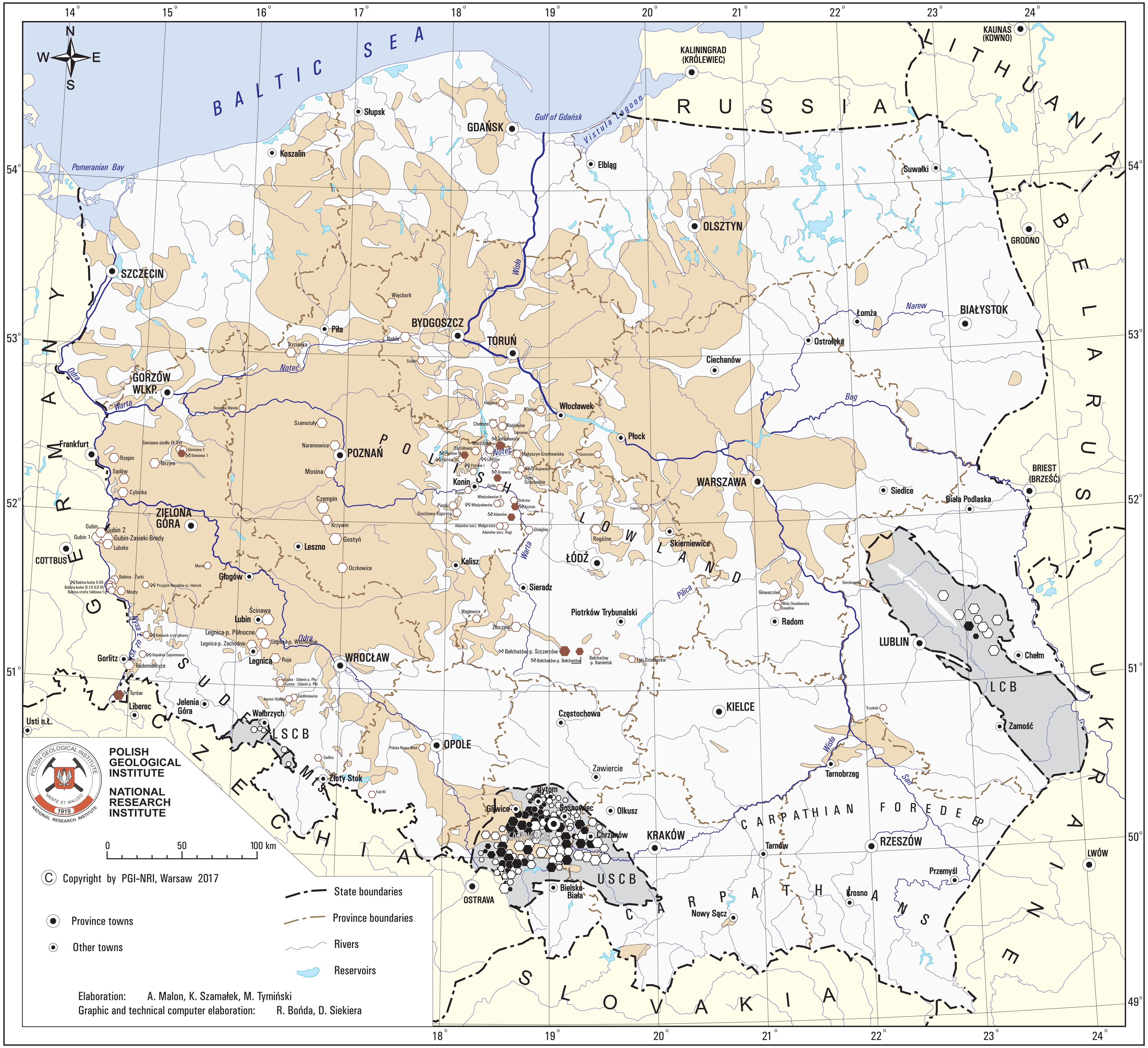
0.2 1 Mt	Oil fields
0.2 1 5 Mt	Oil and gas fields
0.2 1 5 bnm³	Gas fields
1 5 bnm³	High nitrogenous natural gas fields
0.2 1 5 bnm³	Coal bed methane (CBM) as the main raw material in a deposits
0.2 1 5 bnm³	Underground gas storage facilities
	Areas of prospects for CBM occurrence

Occurrence of oil- and gas-bearing formations:

- Oil- and gas-bearing rocks of the Carpathian Foredeep
- Oil- and gas-bearing rocks of the Carpathians area
- Permian (Zechstein) oil- and gas-bearing formations
- Carboniferous oil- and gas-bearing formations
- Pre-Carboniferous oil- and gas-bearing formations
- Boundary of Zechstein formation (after R. Wagner, 1978)

Plate 2

HARD COAL AND LIGNITE DEPOSITS



Hard coal:

L S C B	Lower Silesian Coal Basin
U S C B	Upper Silesian Coal Basin
L C B	Lublin Coal Basin

50 200 500 Mt — Deposits in exploitation

50 200 500 Mt — Deposits not exploited

Lignite:

20 200 1,000 Mt — Deposits in exploitation

20 200 1,000 Mt — Deposits not exploited

Occurrence of coal-bearing formations:

Paleogene lignite-bearing formations (E. Ciuk, M. Piwocki, 1990)

Carboniferous hard coal-bearing formations

Extent of coal-bearing Carboniferous formation

Plate 3

METALLIC RAW MATERIALS DEPOSITS

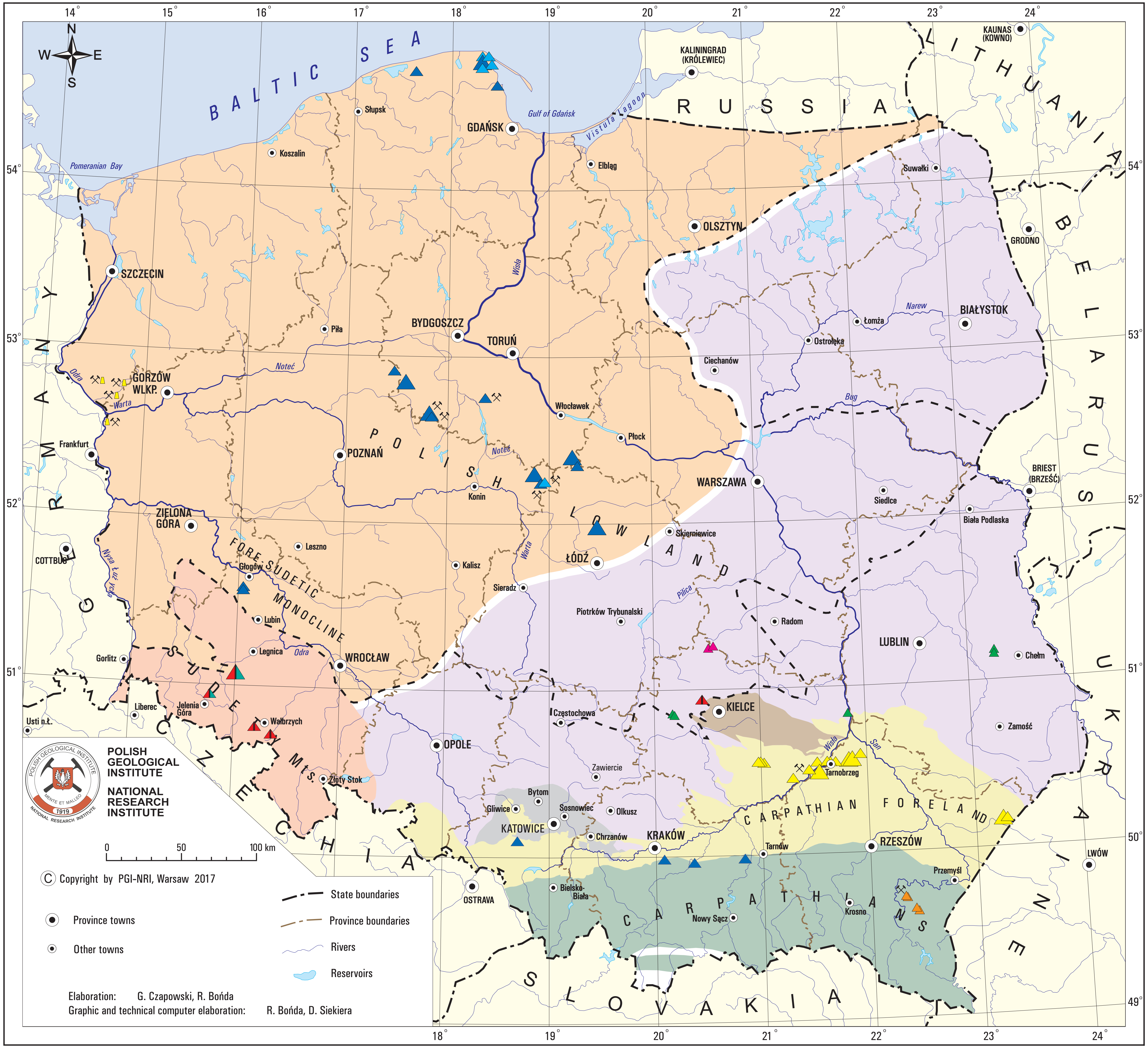
- Copper and silver ores deposits
- Zinc and lead ores deposits
- Molybdenium-tungsten-copper ores deposits
- Nickel ores deposits
- Tin ores deposits
- Arsenic and gold ores deposits
- Sands with heavy minerals
- Deposits in exploitation

Areas of deposits occurrence:

- Paleogene formations of the Carpathian Foredeep
- Carpathians area
- Triassic ore-bearing dolomites
- Other Mesozoic formations
- Permian (Zechstein) formations
- Carboniferous formations
- Paleozoic rocks of Sudety Mts. and Świętokrzyskie Mts.
- 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:

- 50 Mt — Native sulfur deposits
- Sulfur as a by-product (in natural gas fields)
- 4,000 Mt — Rock salt deposits
- 400 Mt — Potassium salt deposits
- 4 Mt — Barite deposits
- 4 Mt — 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 Foreland
- Carpathians area
- Mesozoic formations
- Permian (Zechstein) formations
- Carboniferous formations
- Paleozoic core of the Świętokrzyskie Mts.
- Crystal rocks of the Sudety Mts.
- Boundary of Zechstein formations occurrence
- Boundary of the Zechstein and Mesozoic deposits occurrence

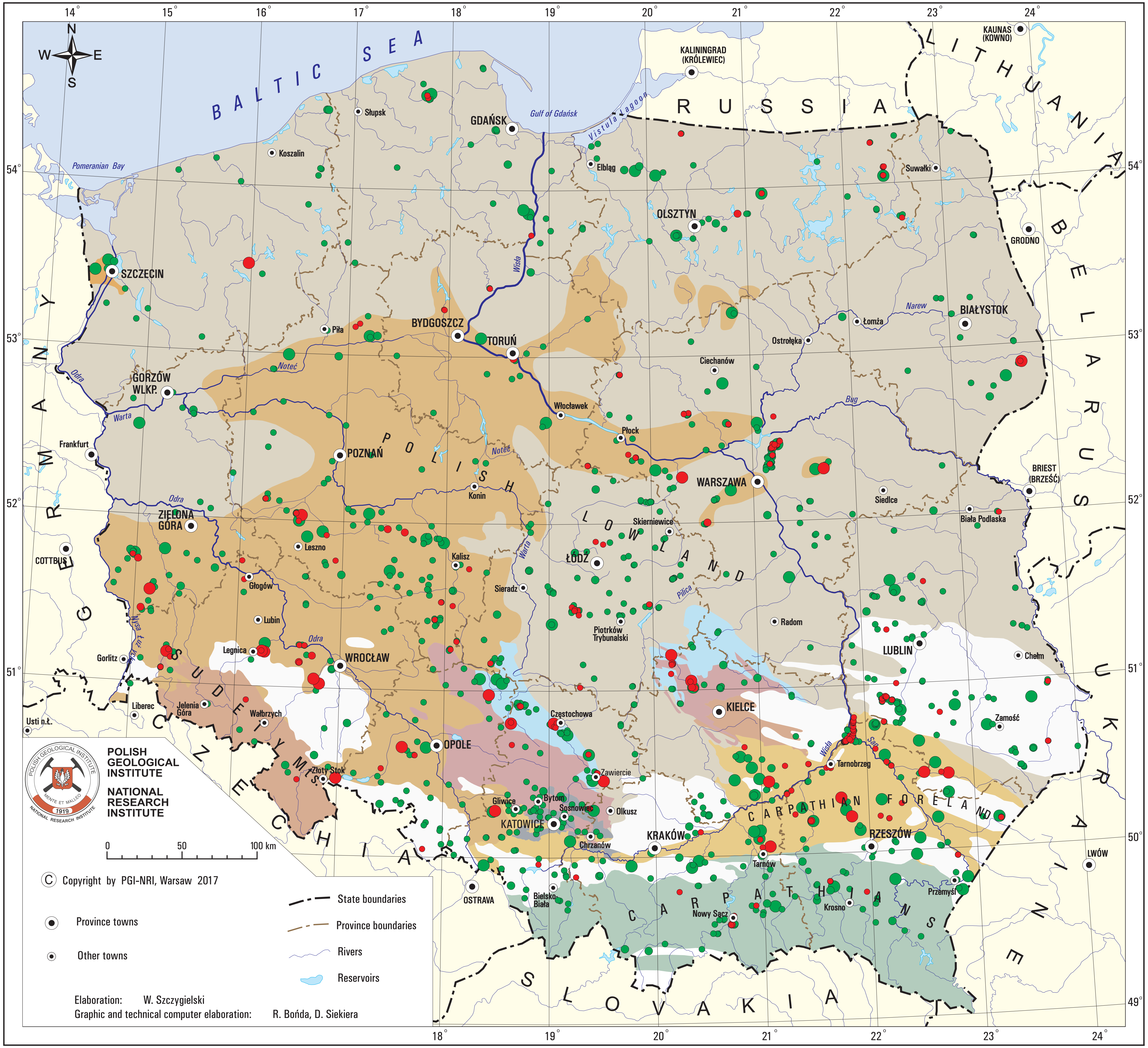


Plate 5

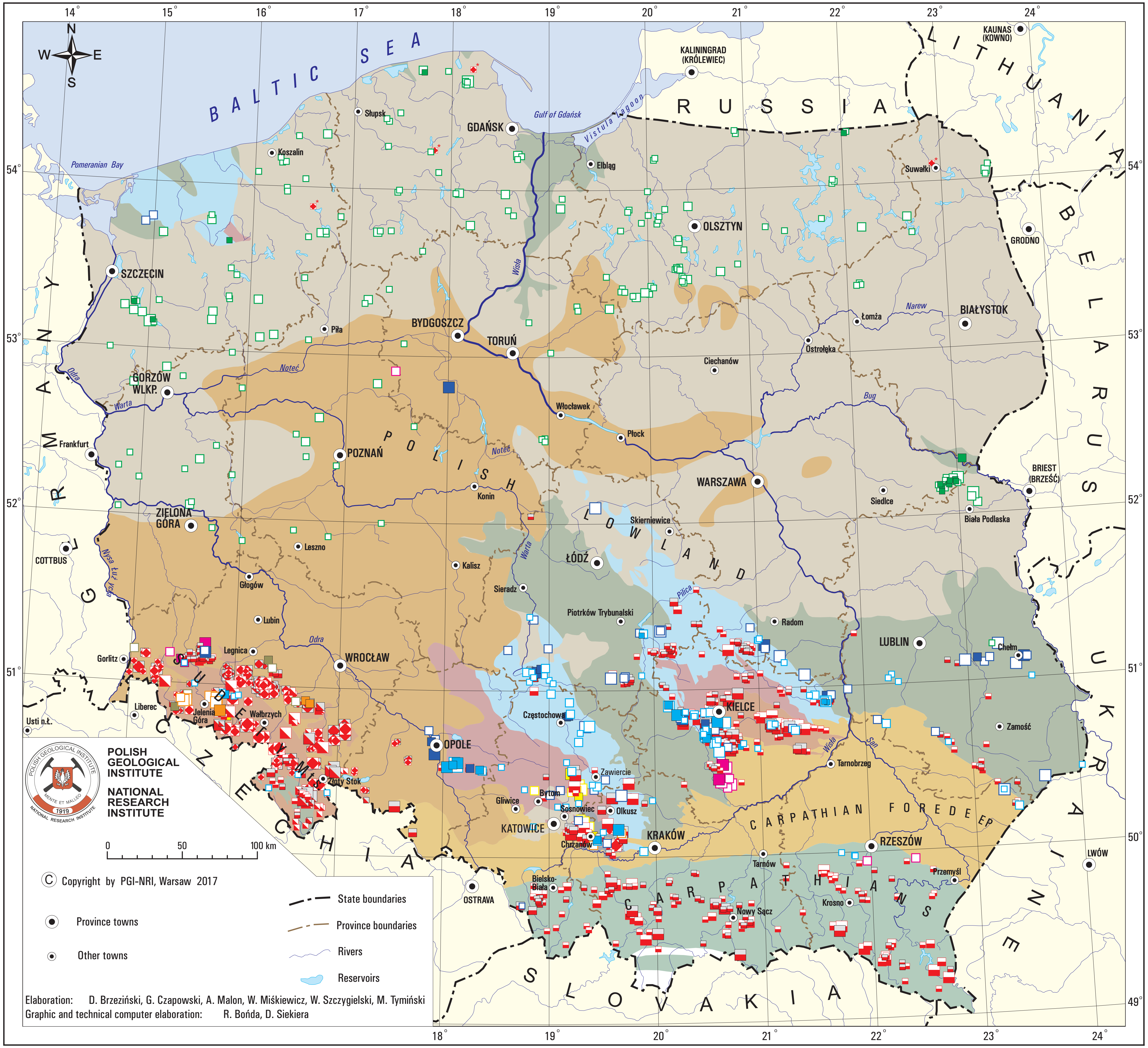
BUILDING CERAMICS RAW MATERIALS DEPOSITS

Deposits with resources:

In exploitation	Not exploited
< 1.5 Mm³	< 1.5 Mm³
1.5-3 Mm³	1.5-3 Mm³
> 3 Mm³	> 3 Mm³

Areas of deposits occurrence:

- Loesses and loessic 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 Sudety Mts. and Świętokrzyskie Mts. (claystones and residual clays)



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Graphic and technical computer elaboration: R. Bońda, D. Siekiera

Plate 6

COMPACT ROCK RAW MATERIALS DEPOSITS

Resources:

- 50 Mt — Dolomites deposits
- 20 Mt — Gypsum and anhydrite deposits
- 1 10 Mt — Chalk deposits
- Vein quartz deposits
- 10 Mt — Feldspar raw materials deposits
- 10 200 Mt — Deposits of limestones and marls for cement industry
- 10 100 Mt — Deposits of limestones for lime industry

Dimension and crushed stones deposits:

- 10 25 Mt — Sedimentary rocks
- 10 25 Mt — Metamorphic rocks
- 10 25 Mt — Igneous rocks
- Erratic boulders

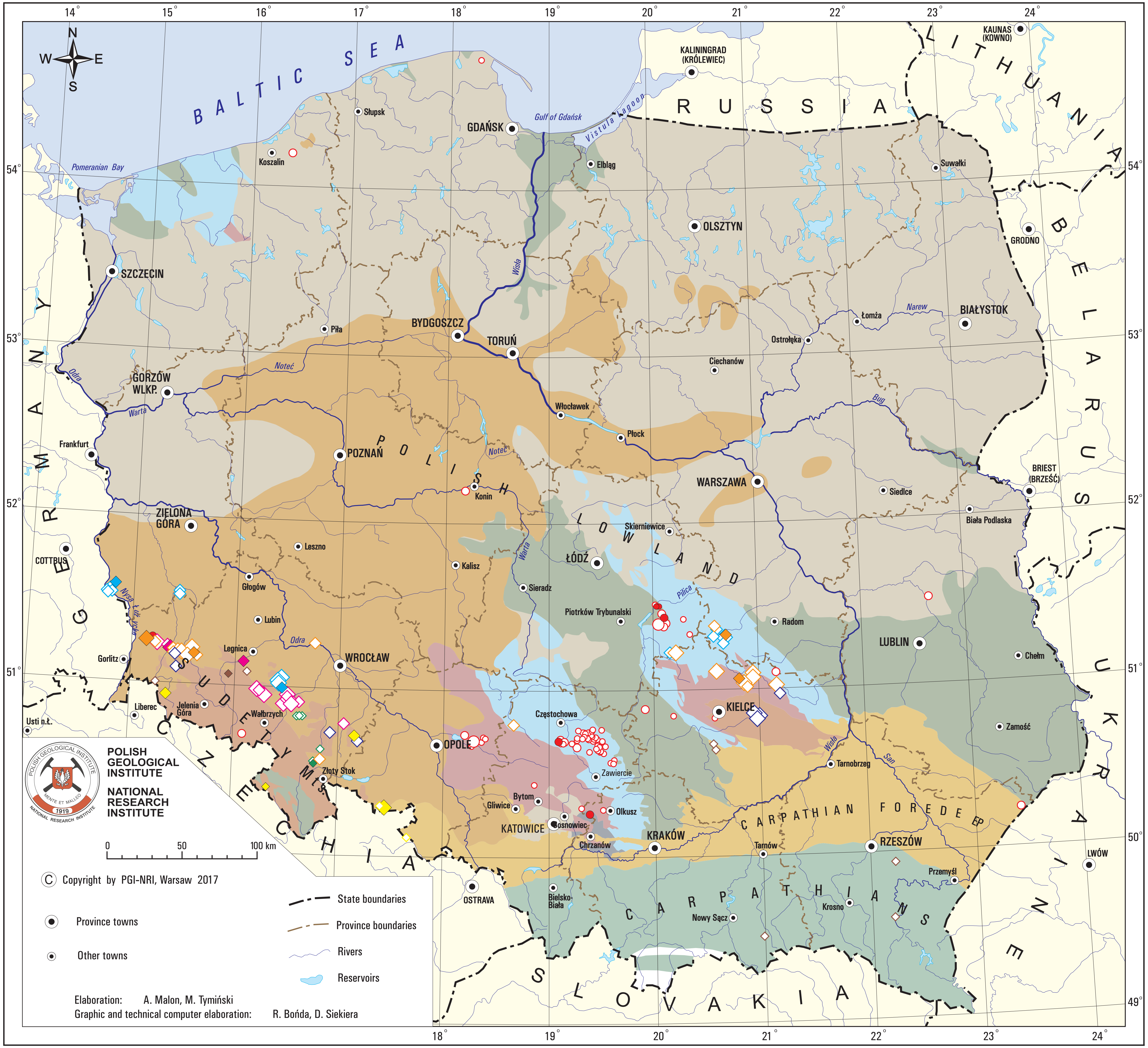
Deposits in exploitation — Deposits not exploited

Areas of deposits occurrence:

- Quaternary
- Miocene-Pliocene
- Paleogene of the Carpathian Foredeep
- Carpathian flysch
- Cretaceous
- Jurassic
- Triassic
- Upper Paleozoic
- Paleozoic rocks of Sudety Mts. and Świętokrzyskie Mts.

Plate 7

CERAMIC AND REFRACTORY RAW MATERIALS DEPOSITS



Resources:

- Bentonitic raw materials deposits
- Ceramic clays deposits (3 Mt)
- Foundry sands deposits (2 20 Mt)
- Kaolin raw materials deposits (10 Mt)
- Magnesites deposits
- Refractory clays deposits (3 Mt)
- Refractory quartzites deposits (1 Mt)
- Schists deposits (5 10 Mt)
- Deposits in exploitation
- Deposits not exploited

Areas of deposits occurrence:

- Quaternary
- Miocene-Pliocene
- Paleogen of the Carpathian Foredeep
- Carpathians flysch
- Cretaceous
- Jurassic
- Triassic
- Upper Paleozoic
- Paleozoic rocks of Sudety Mts. and Świętokrzyskie Mts.

Plate 8

CLASTIC ROCK RAW MATERIALS DEPOSITS

Resources:

- 2 20 100 Mt — Sand and gravel deposits
- 1 0 Mt — Glass sands and sandstones deposits
- 10 100 Mm³ — Filling sands deposits
- 2 Mt — Quartz sands for production of cellular concrete
- 2 Mt — Quartz sands for production of lime-sand brick
- Deposits in exploitation
- Deposits not exploited

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 Świętokrzyskie Mts. and the Kraków-Częstochowa Jurassic
- Fluvial and aeolian accumulation on Cretaceous bedrock
- Fluvial and aeolian accumulation of the Carpathian Foredeep
- Fluvial accumulation (Carpathians and Sudety Mts.)
- Boundary of the North Polish Glaciation
- Boundary of the Middle Polish Glaciation

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