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Zinc and Lead Ores Mining in Poland

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Report prepared under Jerzy Kicki, Ph.D. Eng., direction by a team of the Division of Mineral Resources Acquisition.

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The report contains data illustrating the legal situation comprising issues related to obtaining a concession to carry out mining activity, presents the resource base of zinc and lead ores mines acc. to Polish classification, the state of deposits extraction technology and engineering as well as geological and mining conditions of its performance, natural hazards occurrence, and also economic results of zinc and lead ores mining as well as prospects for this area of mining activities in Poland. A part of presented data is referred to the mining activity in the world.

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Reservation

The report uses publicly available statistical data analysed especially for the needs of this report.

Contents

Report Goals

Report goals

- Report as a method to provide the society with information on the zinc and lead mining activity, integrating with the term of open access to knowledge, which is to be the main attribute of the 21st century society,

- Report as a source of information about the zinc and lead ores mining situation in Poland in the period of its downturn activity carried out in the Olkusz area deposits and further prospects for the ZGH “Bolesław” (Mining and Metallurgical Plant) SA - the main zinc and lead producer in Poland, operating since 2012 in the structures of Stalprodukt SA Capital Group with registered office in Bochnia,

- Report as a source of reliable information established in its readers conscience and a set of facts deciding about results of zinc and lead ores mining activity.

Zinc and Lead Ores Mining in Poland

Yesterday and Today

History of zinc and lead ores mining in Poland

- Deposits of zinc and lead ores in the Silesian-Krakow region have been being mined since at least 12th century, when the Olkusz miners were extracting galena - a lead and silver containing ore.

- The first historical mention about mining activities in the area of Olkusz dates back to 1257, when the prince Bolesław Wstydliwy, while moving the monastery of the Order of (Franciscan) Poor Clares from Zawichost to Skała, undertook to pay for its upkeep two units of gold annually from the income on Olkusz lead. Olkusz was receiving numerous mining privileges and rights, being among the first in Poland - not without reason in the city coat of arms, which oldest image dates from 1386, a miner's mattock is situated between two towers of the city gate.

The MEERI PAS study based on: Włodarz B., 2006*: Zabytkowa kopalnia górnictwa kruszcowego w Olkuszu – perspektywy uruchomienia,* Górnictwo i Geoinżynieria, Year 30, Vol. 4, p. 131-141 and Paulo A., Wnuk R., 2015: *Kopalnia rud cynku i ołowiu Pomorzany skończyła 40 lat – jak długo jeszcze wystarczy jej zasobów?*. Przegląd Geologiczny, vol. 63, no. 12/2, p. 1483 – 1490

History of zinc and lead ores mining in Poland

- After World War II in Poland ten mines were operating, of which:
  - 4 in the Bytom area - closed in the years 1977 – 1989,
  - 3 in the Chrzanów area - closed in the years 1958 – 2009,
  - 3 in the Olkusz area - 2 of 3 closed - in 1996 exploitation was finished in the 'Bolesław' mine, and in 2001 in the 'Olkusz' mine.

- The ore extraction on a massive scale started in 1953, when through exploratory drilling from the surface and underground mining operations rich 'Bolesław' and 'Olkusz' deposits were discovered.

- The only zinc and lead ores mine in Poland, named 'Olkusz-Pomorzany', is operating now in the Olkusz area. It belongs the company Zakłady Górniczo-Hutnicze 'Bolesław' SA (Mining and Metallurgical Plant) in Bukowno (Stalprodukt SA Capital Group).

The MEERI PAS study based on: Włodarz B., 2006*: Zabytkowa kopalnia górnictwa kruszcowego w Olkuszu – perspektywy uruchomienia,* Górnictwo i Geoinżynieria, Year 30, Vol. 4, p. 131-141 and Paulo A., Wnuk R., 2015: *Kopalnia rud cynku i ołowiu Pomorzany skończyła 40 lat – jak długo jeszcze wystarczy jej zasobów?*. Przegląd Geologiczny, vol. 63, no. 12/2, p. 1483 – 1490

Current situation

- The depleting deposit resources of the only operating 'Olkusz-Pomorzany' zinc and lead ores mine force the mining companies to take an interest both in unmanaged deposits in Poland and deposits and mines extracting similar ore types in Europe, as well as in atypical methods of zinc and lead extraction.

- ZGH 'Bolesław' SA for a few years is the owner of the Gradir Montenegro company, mining the 'Suplija Stijena' deposit in Montenegro, being now the origin of a part of charge for the metallurgical process in the form of zinc and lead concentrates.

- ZGH 'Bolesław' SA is now a global leader in the field of recycling technologies utilisation for the needs of metals production.

- The new, announced in 2016, production strategy anticipates *inter alia*:
  - extension of the 'Pomorzany' mine operation due to obtaining a concession for the 'Klucze I' deposit mining at favourable metal price conditions,
  - the extraction of flotation tailings dumping site, the effect of a few decades of the mining operations in the Bolesław-Olkusz area, which is to become the source of 20,000 tonnes of concentrate per year.

Formal And Legal Conditions of Carrying Out Mining And Geological Activities – Certain Aspects

Validity dates of concessions for zinc and lead ores mining

ZGH „Bolesław" SA

Concession number	Concession name	Date of granting	Validity date
172/93	Pomorzany	20/07/1993	31/12/2023
8/2003	Olkusz	15/10/2003	31/12/2028
1/2009	Klucze I	02/02/2009	31/12/2026

Validity dates of concessions for zinc and lead ores prospecting and exploring

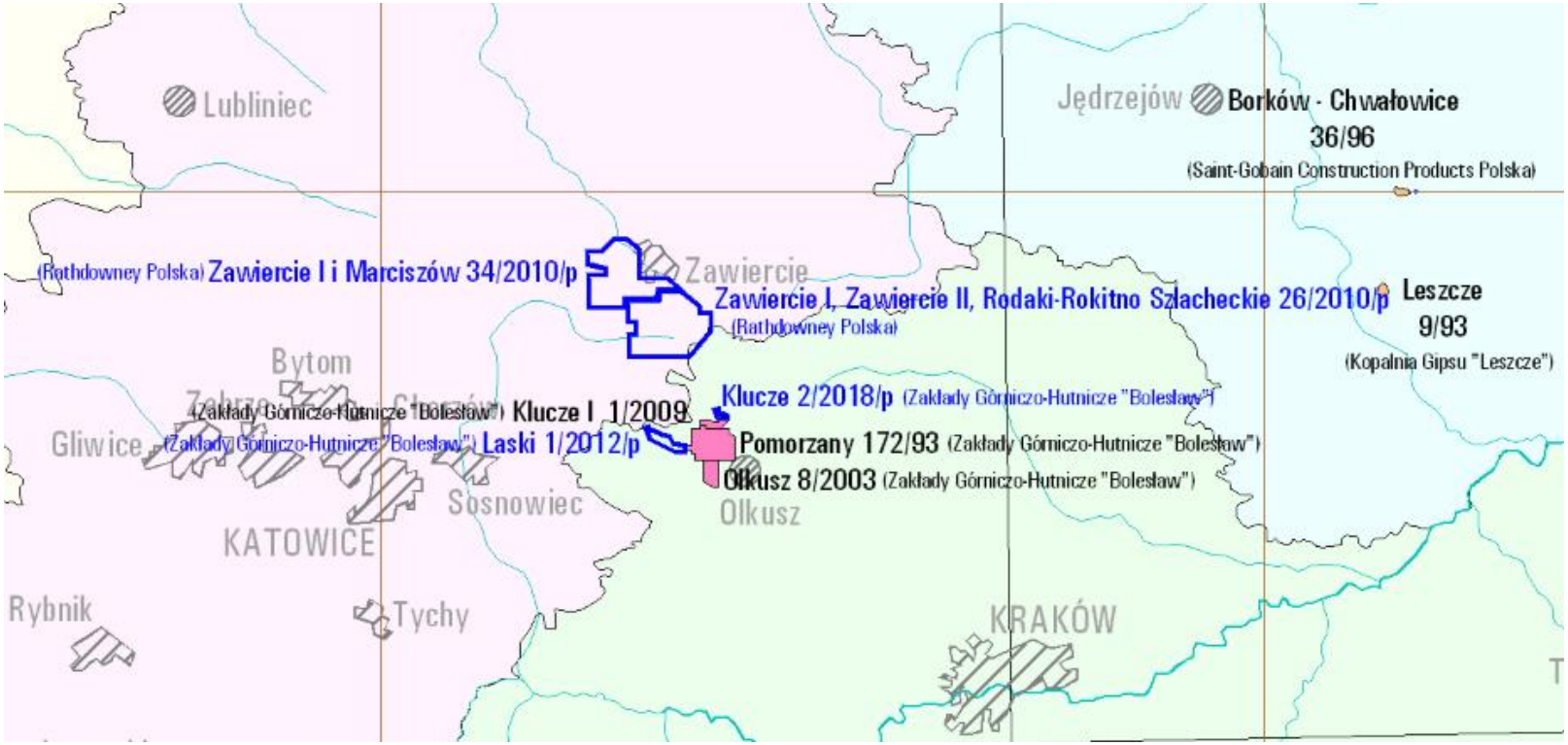
Rathdowney Polska Sp. z o.o.

Concession number	Concession name	Date of granting	Validity date
26/2010/p	Zawiercie I, Zawiercie II, Rodaki – Rokitno Szlacheckie	12/05/2010	12/05/2020
34/2010/p	Zawiercie I, Marciszów	02/07/2010	02/07/2020
27/2012/p	Chechło	20/09/2012	20/09/2022

ZGH „Bolesław" SA

Concession number	Concession name	Date of granting	Validity date
1/2012/p	Laski	18/01/2012	18/01/2020
2/2018/p	Klucze	14/03/2018	28/03/2020

Arrangement of areas covered by concessions in the Olkusz and Zawiercie area



Source:
MS: Map of concessions for prospecting, exploring, and mining deposits of chemical, rock, and metal minerals as of 28 February 2019

Zinc and Lead Ores Resources in Poland

Geology and mineralogy of Silesian-Krakow Zn-Pb deposits (1)

- Zinc and lead deposits in Poland exist in the area of more than 1200 km^2, comprising a part of the Upper-Silesian Coal Basin (Bytom, Tarnowskie Góry, and Chrzanów area) and its northern-eastern edges (Olkusz, Siewierz, and Zawiercie area).
- A balance mineralisation of zinc and lead deposits occurs mainly in Triassic carbonate formations, which corresponds to a stratigraphic interval from Rhaetian to middle coquina. The overburden of the deposits series consists of diplopore dolomites, Jurassic limestones, and clay Keuper formations.
- The Zn-Pb mineralisation of multi-stage nature was related to the development of a complex set of dolomitisation, breccia formation, and dissolution. An important role in forming the ore bodies was played by Karst processes and tectonic evolution of the boundary zone of the Upper-Silesian massif and of the Lesser Poland block, which had a significant impact on the geological structure of the region.

Source: Cabała J., 2009: Metale ciężkie w środowisku glebowym olkuskiego rejonu eksploatacji rud Zn-Pb, Prace Naukowe Uniwersytetu Śląskiego w Katowicach No 2729, p.11

Geology and mineralogy of Silesian-Krakow Zn-Pb deposits (2)

- The main ore minerals are polymorphs of zinc, lead and iron sulphides:
  - zinc sulphides are developed in the form of colour-morphous and crystalline forms of sphalerite, wurtzite, seldom brunckite;
  - lead sulphides exist primarily in the form of crystalline galena and seldom encountered boleslavit;
  - iron sulphides developed in the form of colloidal and crystalline forms of marcasite, pyrite, and cryptocrystalline melnikovit.

Source: Cabała J., 2009: Metale ciężkie w środowisku glebowym olkuskiego rejonu eksploatacji rud Zn-Pb, Prace Naukowe Uniwersytetu Śląskiego w Katowicach No 2729, p.11

Geology and mineralogy of Silesian-Krakow Zn-Pb deposits (3)

Sphalerite (polished)
Pomorzany mine

Calcite with marcasite
Pomorzany mine

Sphalerite - Galena
Trzebionka mine

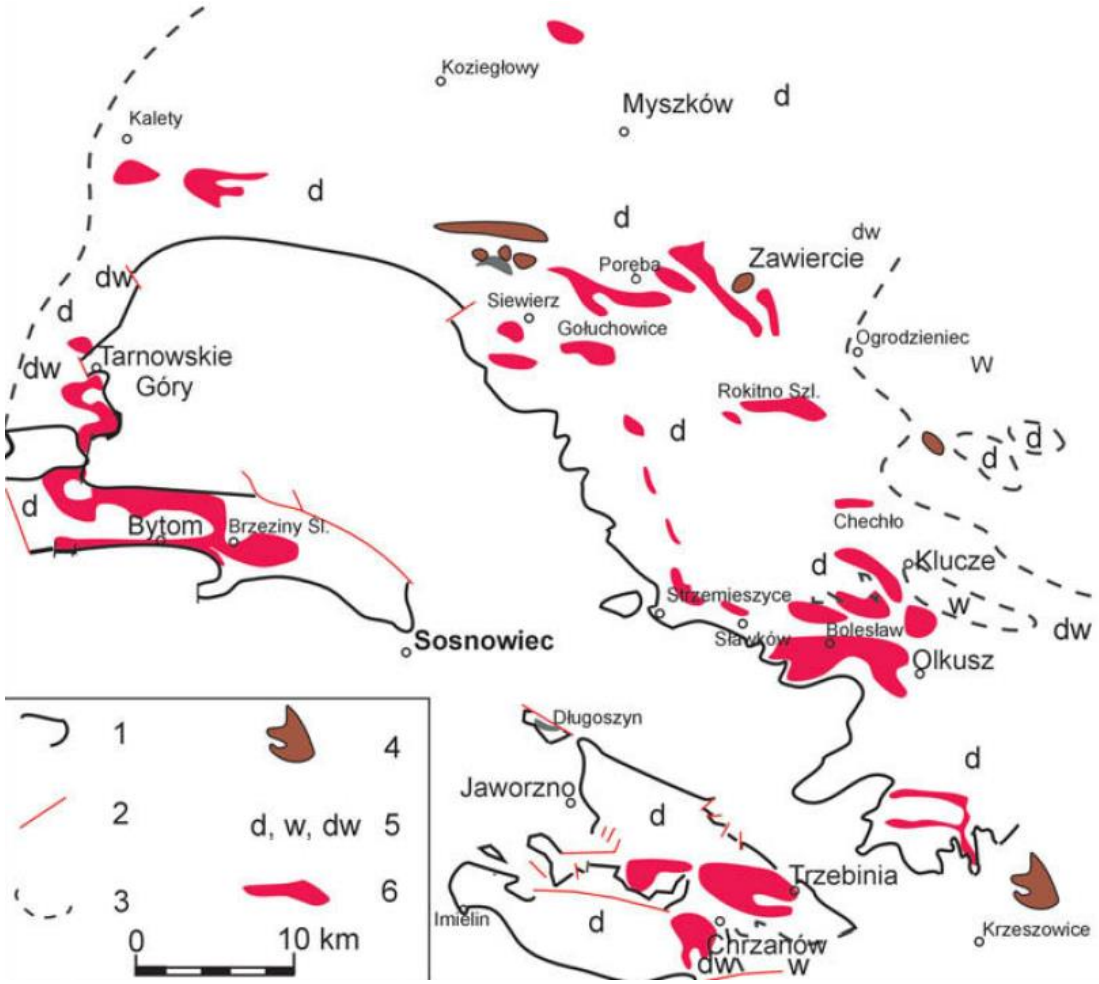
Marcasite
Pomorzany mine

Source: virtual Lesser Poland Museums website, Geological Museum of WGGiOŚ AGH

Resource base of zinc and lead ores deposits

- The existence of zinc and lead ores deposits is related to the carbonate rocks formation of the Silesian-Krakow region, considered the largest worldwide area of Zn-Pb deposits occurrence of so-called Mississippi Valley Type (MVT).
- Ores related to so-called ore-bearing dolomites of Middle Triassic, existing in the form of pseudo-beds, horizontal lenses, or bunches are of industrial importance.
- The following areas are distinguished in the Silesian-Krakow region:
  - Olkusz,
  - Chrzanów,
  - Bytom,
  - Zawiercie,
  - Tarnowskie Góry.
- The mining is carried out only in the Olkusz area from deposits: 'Klucze I', 'Olkusz', and 'Pomorzany'.
- The Bytom area of Zn-Pb ores deposits is of historical importance, as the mining was carried out here from medieval times. Only non-balanced reserves remained now in deposits.
- Deposits of the Zawiercie region were not mined yet. Prospecting and documenting work is carried out now in concession areas.

Areas of Zn-Pb mineralisation occurrence in the Silesian-Krakow region

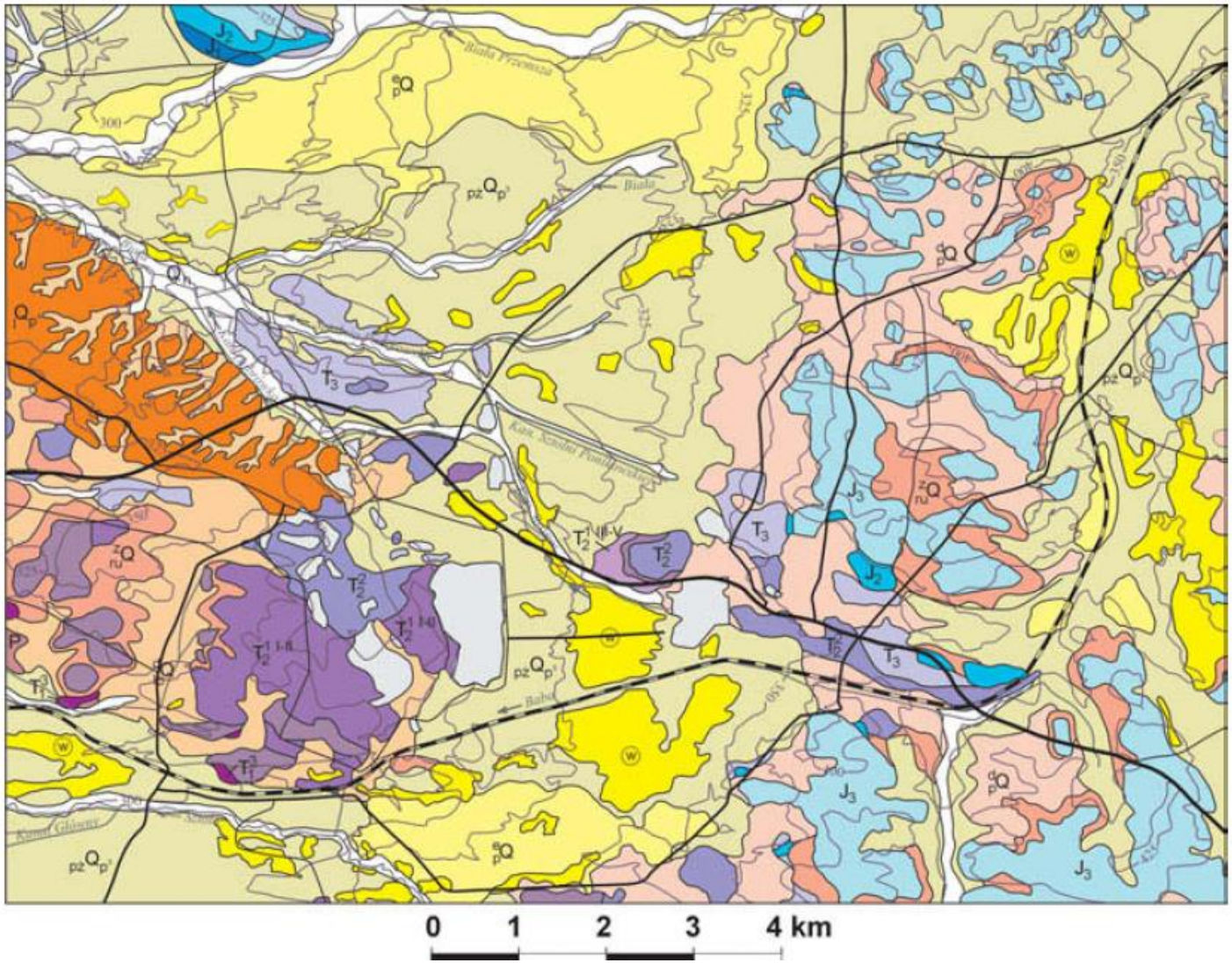


Explanations:

1. erosion edge
2. fault
3. boundary of dolomitised formations and limestones
4. uplifted Devonian formations
5. dolomites, calcareous dolomites, limestones
6. zones mineralised with Zn-Pb ores

Source: Cabała J., 2009: Metale ciężkie w środowisku glebowym olkuskiego rejonu eksploatacji rud Zn-Pb, Prace Naukowe Uniwersytetu Śląskiego w Katowicach No 2729, p.11

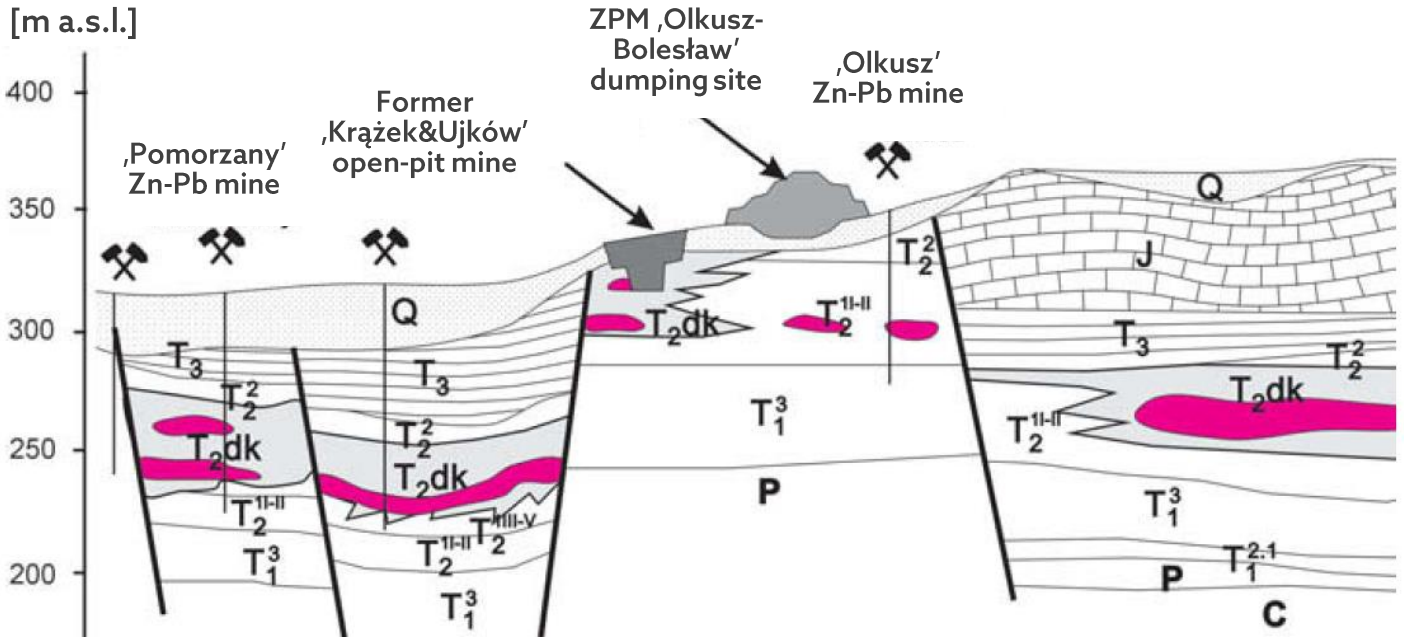
Geological map of the Olkusz area



- embankments, heaps
- Holocene
- aeolian sands, aeolian sands in dunes
- sands and clays with with local rock chips
- rock wastes
- sandy loesses, deluvial
- loesses
- fluvioglacial sands and gravels
- Upper Jurassic
- Middle Jurassic
- Lower Jurassic
- Keuper
- diplopore dolomites
- ore-bearing dolomites
- Karchowice, terebratula beds
- Gogolin beds
- Rhaetian
- Permian

Source: Cabała J., 2009: Metale ciężkie w środowisku glebowym olkuskiego rejonu eksploatacji rud Zn-Pb, Prace Naukowe Uniwersytetu Śląskiego w Katowicach No 2729, p.13

Schematic geological cross-section in the area of Olkusz-Bolesław fault ridge and Pomorzany trough

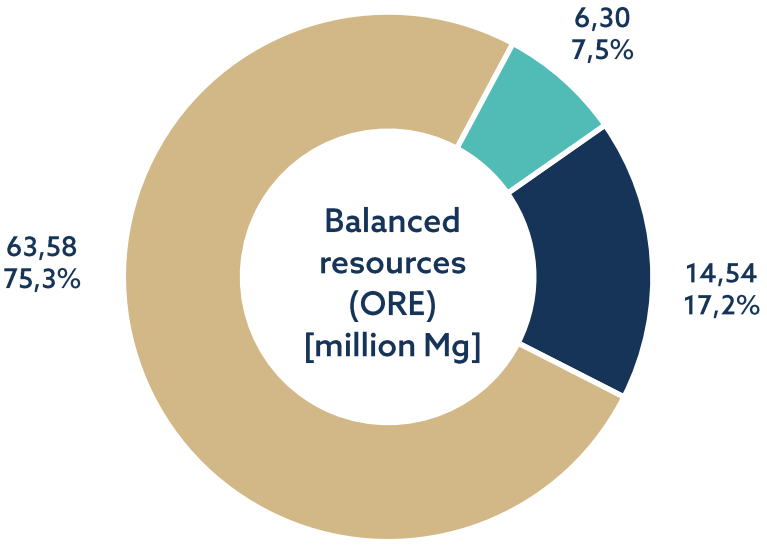


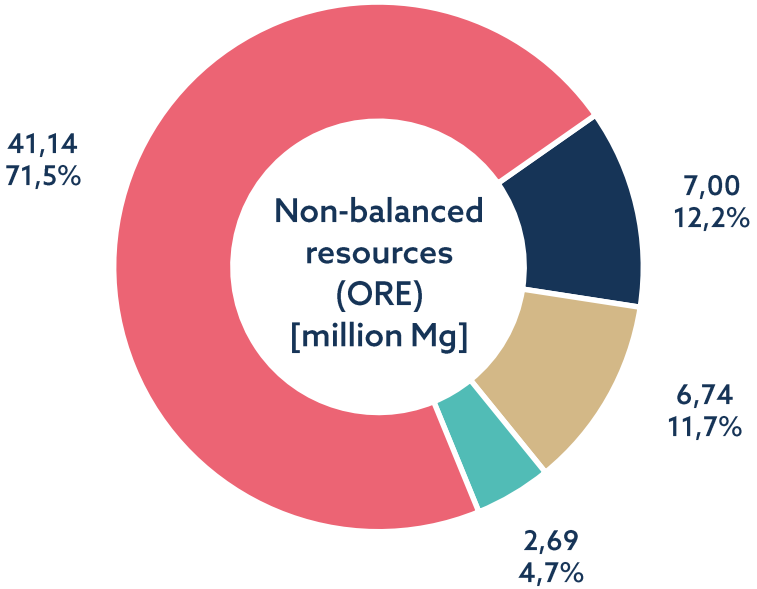
Explanations:

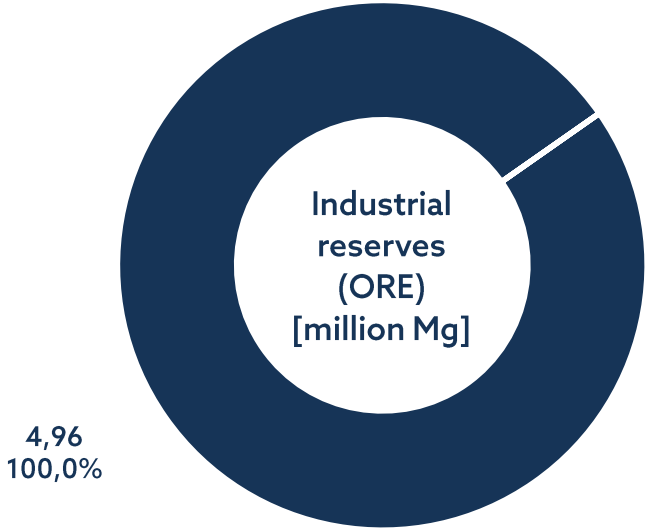
- ore-bearing horizons are marked in purple
- geological formations marked as in slide 22.

Source: Cabała J., 2009: Metale ciężkie w środowisku glebowym olkuskiego rejonu eksploatacji rud Zn-Pb, Prace Naukowe Uniwersytetu Śląskiego w Katowicach No 2729, p.12

Structure of zinc and lead ores resources in managed and unmanaged beds (1)

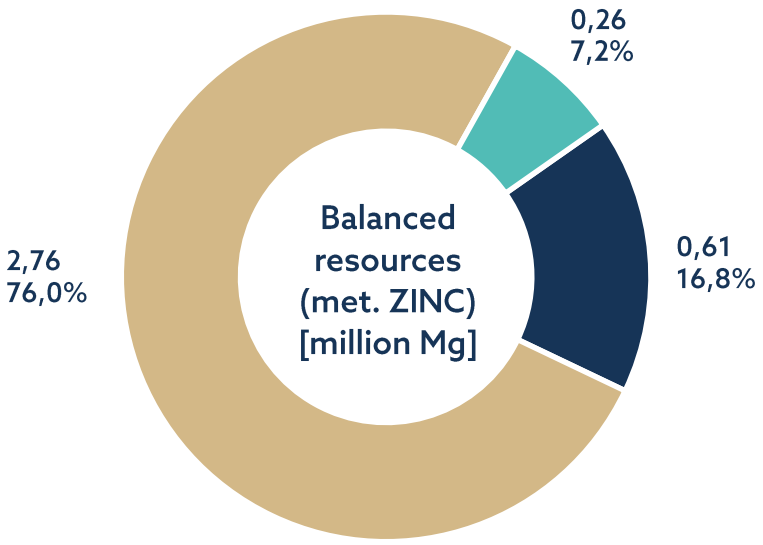


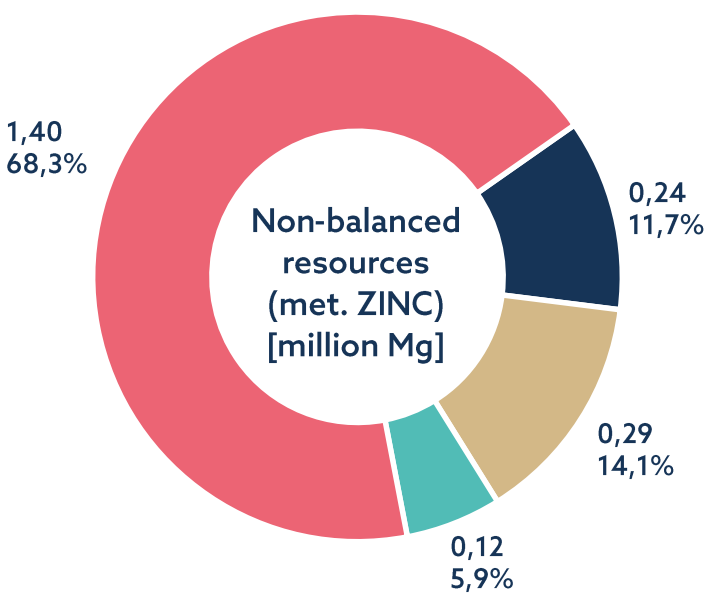


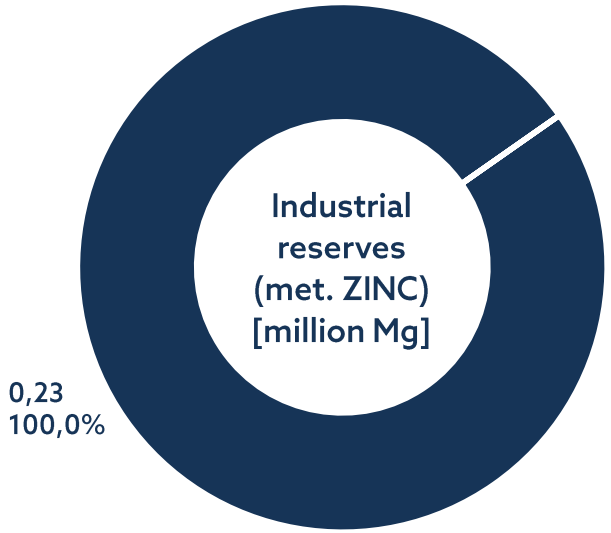


- Resources of managed beds - operating plants beds
- Resources of unmanaged beds - explored in detail
- Resources of unmanaged beds - preliminary explored
- Beds, which mining was abandoned

Structure of zinc and lead ores resources in managed and unmanaged beds (2)

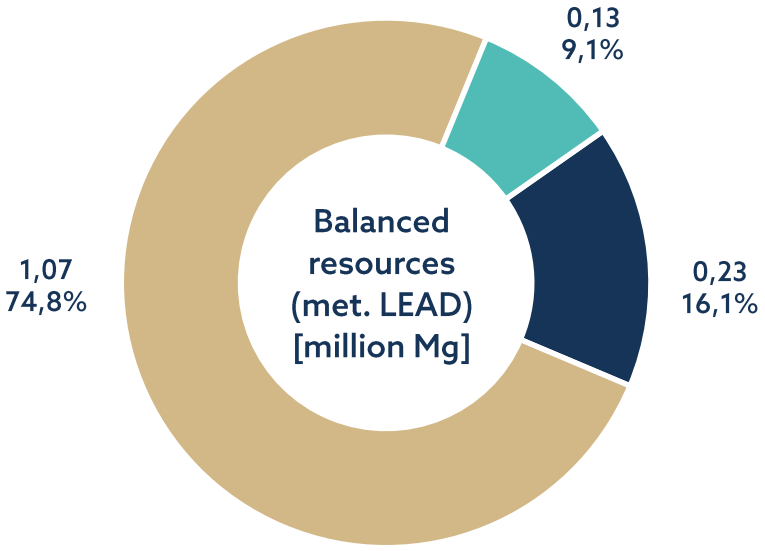


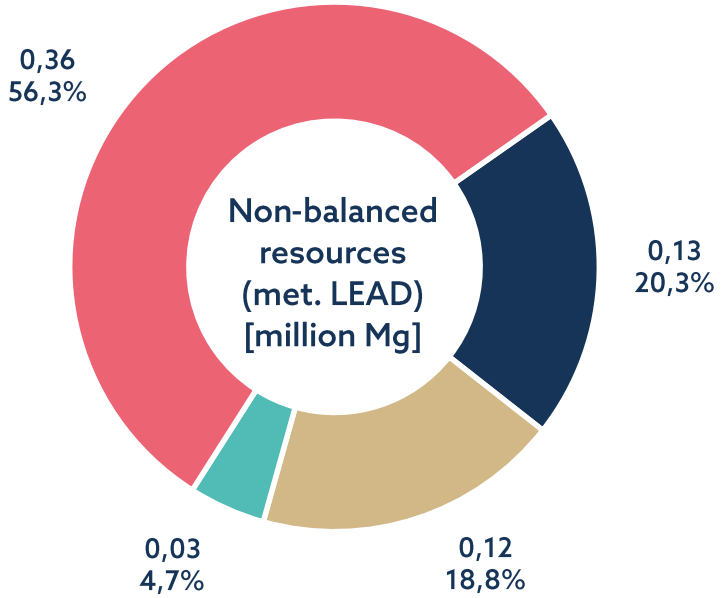


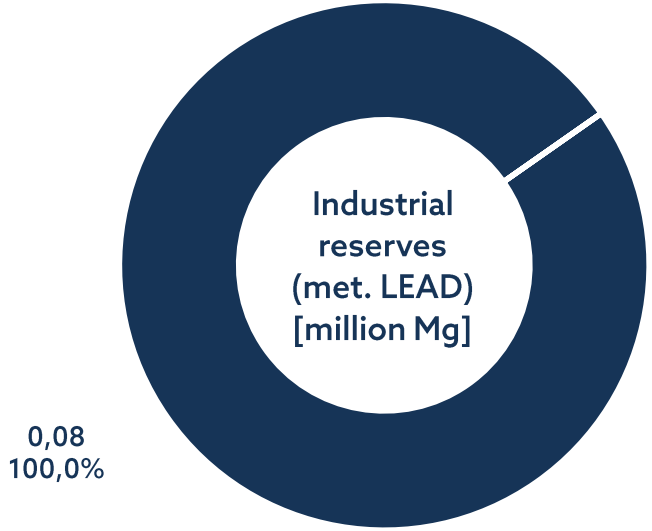


- Resources of managed beds - operating plants beds
- Resources of unmanaged beds - explored in detail
- Resources of unmanaged beds - preliminary explored
- Beds, which mining was abandoned

Structure of zinc and lead ores resources in managed and unmanaged beds (3)







- Resources of managed beds - operating plants beds
- Resources of unmanaged beds - explored in detail
- Resources of unmanaged beds - preliminary explored
- Beds, which mining was abandoned

Documented resources of zinc and lead ores in Poland (as of 31/12/2017)

Area	Balanced resources ['000 Mg]		Industrial reserves ['000 Mg]	
	of which – resources of managed deposits	of which – resources of unmanaged deposits	of which – reserves of managed deposits	of which – reserves of unmanaged deposits
Bytom				
Ore	-	-	-	-
metallic zinc	-	-	-	-
metallic lead	-	-	-	-
Chrzanów				
Ore	-	-	-	-
metallic zinc	-	-	-	-
metallic lead	-	-	-	-
Olkusz				
Ore	14 537	15 901	4 961	-
metallic zinc	609	675	232	-
metallic lead	230	383	84	-
Zawiercie				
Ore	-	53 982	-	-
metallic zinc	-	2 344	-	-
metallic lead	-	813	-	-
Total				
Ore	84 420	-	4 961	-
metallic zinc	3 628	-	232	-
metallic lead	1 426	-	84	-

Percentage metal content in zinc and lead ores in industrial reserves

Deposit	Percentage metal content in zinc and lead ores in industrial reserves	
	Zinc	Lead
Klucze I	5,8%	1,5%
Pomorzany	3,6%	0,7%
Olkusz	4,1%	2,3%

Technology and Engineering of Zinc and Lead Ore Deposits Mining

Extraction systems used now in the zinc and lead ores mining in Poland (1)

- Polish deposits of zinc and lead ores feature the existence of numerous bunches or other irregular ore clusters.
- The deposit exploration by boreholes from the surface, based on which geological documentation is prepared, is frequently insufficient to design the mining.
- In irregular, structurally complicated deposits, such as in the zinc and lead ores mining, further deposit exploration is carried out by means of underground workings and underground test boreholes. To this end prospecting roadways are driven in the deposit acc. to a specified grid 100 x 100 m or 200 x 200 m, from which test boreholes are drilled every 50, 25 or even 12.5 m. This provides the basis for detailed exploration and documentation of the deposit.
- Panels separated by prospecting roadways become mining panels, and the prospecting roadways - development roadways.

The MEERI PAS report based on: Cała M. et al., 2017: Merytoryczna ocena opracowania pt. Analiza wpływu potencjalnej budowy kopalni cynku i ołowiu w okolicach Zawiercia na otoczenie

Extraction systems used now in the zinc and lead ores mining in Poland (2)

- Variability of geological-mining parameters of the deposit, i.e. the bed thickness and strength parameters of roof rocks and of the ore-bearing series, has a decisive influence on the choice of mining system, which should feature flexibility with respect to the varying height of the mining and should ensure a possibility to secure the workings stability.

- In the case of making erroneous decisions, not preceded with detailed exploration and analysis, the hazards intensity can increase, therefore it is extremely important to choose appropriate technologies and thereby to reduce those hazards impact on the environment and on the health of people.

The MEERI PAS report based on: Cała M. et al., 2017: Merytoryczna ocena opracowania pt. Analiza wpływu potencjalnej budowy kopalni cynku i ołowiu w okolicach Zawiercia na otoczenie

Extraction systems used now in the zinc and lead ores mining in Poland (3)

- Based on many years of experience, the mining systems used now are the room-and-pillar and face with hydraulic filling with the use of self-propelled mining machines and roof bolting.
- These systems perfectly work under conditions of a varying bed thickness, ensuring at the same time a high level of safety for the staff and minimisation of the mining impact on the ground surface by the use of hydraulic filling - a mixture of sand and water - to fill voids (goafs) after the deposit extraction.
- These systems, due to changing deposit conditions, can be subject to modifications such as changing face, room or pillar dimensions or the type, spacing or length of roof bolts depending on the rock strength parameters.
- However, such changes do not have a major impact on the mining technology, on the possibility to keep the discipline of safe mining or to limit the mining impact on the ground surface.

The MEERI PAS report based on: Cała M. et al., 2017: Merytoryczna ocena opracowania pt. Analiza wpływu potencjalnej budowy kopalni cynku i ołowiu w okolicach Zawiercia na otoczenie

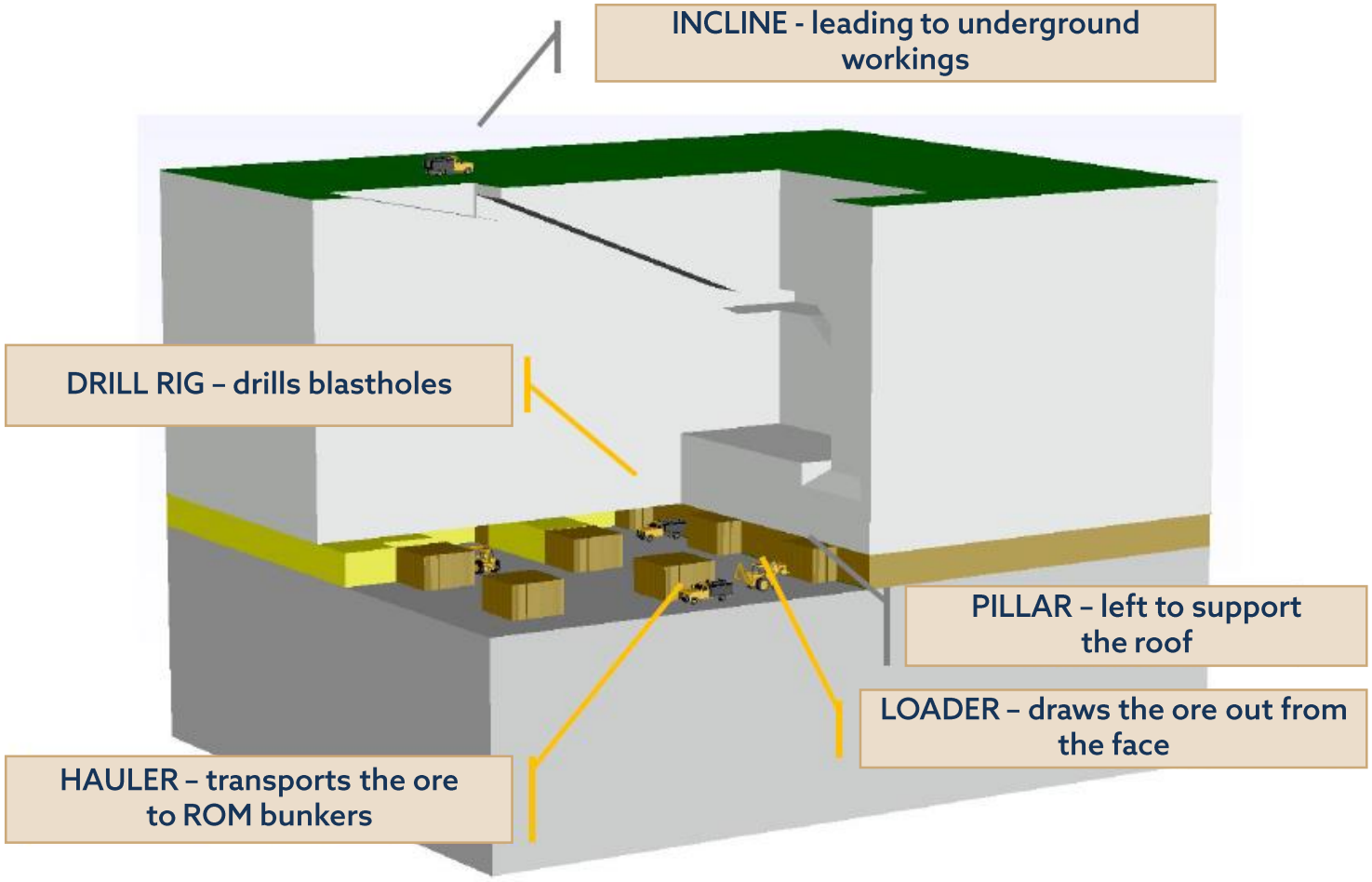
Extraction systems used now in the zinc and lead ores mining in Poland (4)

Room-and-pillar system with hydraulic filling (1)

- Under the deposit development for mining in the room-and-pillar system with hydraulic filling development roadways are driven in a 100 x 100 m grid, in this way forming panels of 1 ha area.
- Panels are divided by roadways, so-called haulage rooms, into mining pillars 12.5 to 25 m wide. Pillars separated in such a way are extracted by mining rooms 5 to 6 m wide, driven parallel to the line of front, leaving so-called inter-rooms pillars 3 to 4 m wide.
- In the second phase of mining continuous pillars are mined partially with extraction cuts driven towards goafs, leaving ultimately pillars of minimum support area of 12.5 m^2.
- The mining is carried out in so-called 'stowing increment'.
- The rock is mined by means of blasting technique - with explosives (most often dynamite). Blast holes are drilled using self-propelled drilling cars and the run-of-mine is transported by self-propelled loaders-haulers. The run-of-mine is transported to ROM bunkers situated in the area of carried out mining.

Extraction systems used now in the zinc and lead ores mining in Poland (5)

Room-and-pillar system with hydraulic filling (2)



Source: Cała M. et al., 2017: Merytoryczna ocena opracowania pt. Analiza wpływu potencjalnej budowy kopalni cynku i ołowiu w okolicach Zawiercia na otoczenie

Extraction systems used now in the zinc and lead ores mining in Poland (6)

Room-and-pillar system with hydraulic filling (3)

- After extraction of continuous pillars the extraction void (goaf) is backfilled, comprising a number of pillars and mining rooms.
- To this end on the line of penultimate pillar row timber dams or plugs from the rock acquired from stone workings are constructed .
- A filling pipeline is passed by one of dams, shortened with goafs filling, while stowing water is drained through so-called windows left in one or two dams.

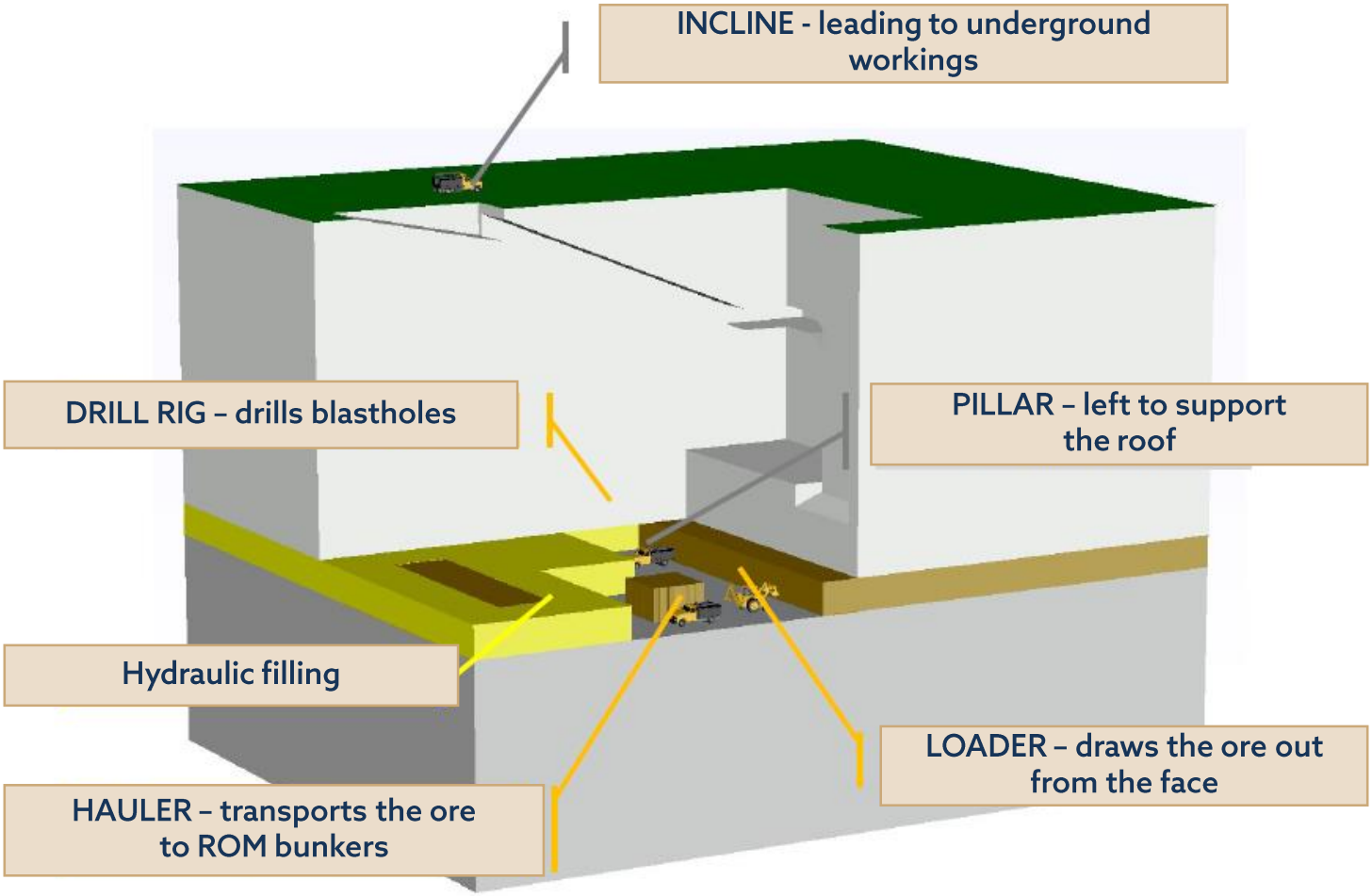
Extraction systems used now in the zinc and lead ores mining in Poland (7)

Face system with hydraulic filling (1)

- In the face system with hydraulic filling the panels are divided by roadways (raises) into mining pillars 35 to 70 m wide and 100 m long.
- From a pillar roadway (raise) the deposit is mined by one- or two-wing faces, i.e. workings with narrow faces, 5 to 6 m wide, and the height equal to the deposit thickness or separated layer, not exceeding 6 m. One-wing mining is carried out in narrow pillars (the face length is equal to the pillar width up to 35 m), while two-wing mining (deposit mined from two sides) - in wider pillars. So-called support pillar, approx. 5 m wide, is left at the haulage roadway.
- The deposit mining by face proceeds in the direction perpendicular to a longer pillar or panel edge (it does not have a front nature), and the goafs are liquidated after mining the deposit part covered by the face.

Extraction systems used now in the zinc and lead ores mining in Poland (5)

Face system with hydraulic filling



Source: Cała M. et al., 2017: Merytoryczna ocena opracowania pt. Analiza wpływu potencjalnej budowy kopalni cynku i ołowiu w okolicach Zawiercia na otoczenie

Natural hazards in the Zinc and Lead Ores Mining in Poland

Natural hazards in the zinc and lead ores mining in Poland

- Natural hazards affecting the zinc and lead ores mining safety in the Olkusz area comprise:
  - water hazard,
  - hazards related to rocks breaking away from the roof and walls,
  - methane hazard.
- Gas and rock bumps hazards do not occur.

Natural hazards in the zinc and lead ores mining in Poland

Water hazard (1)

- The water hazard is the leading hazard in zinc and lead ores mines in Poland. The hazard intensification to a large extent is related to shallow deposition of ore bodies.
- Hydrogeological conditions in the Olkusz area are typical of such deposits.
- The source of the hazards are undrained parts of the rock mass, mainly sandy Quaternary formations and a Triassic complex of porous, fissured and cavernous dolomite-limestone rocks.
- The amount and variability of water inflows to mines depend on natural factors, i.e.
  - geographical - the amount of precipitation,
  - geological - hydrogeological properties of surrounding rocks, geological discontinuities,
  - anthropogenic - phase of mine development, depth of mining.

The MEERI PAS report based on: Motyka J. et al., 2016: Dopływy wody do olkuskich kopalń rud cynku i ołowiu w ujęciu historycznym, Przegląd Górniczy, SITG, Vol. 72, No 6, p. 49-58

Natural hazards in the zinc and lead ores mining in Poland

Water hazard (2)

- The amount of water inflow to mines in the Olkusz area depends strongly on:
  - depth of carried out deposit mining below the primary groundwater level. The amount of inflow in the case of mine:
    - 'Bolesław' was approx. 40 m^3/min at a depth of drainage workings of approx. 65 m
    - 'Olkusz' reached 80 m^3/min at a depth of drainage workings of approx. 95 m
    - 'Pomorzany' was 270 m^3/min at a depth of drainage workings of approx. 140 m,
  - the amount of precipitation, in particular, when extreme phenomena occur,
  - phase of mine development, where a sudden increase in the inflow amounts in the development phase is especially visible, followed by stabilisation towards a downward trend at a mature phase, i.e. progressing mining.

The MEERI PAS report based on: Motyka J. et al., 2016: Dopływy wody do olkuskich kopalń rud cynku i ołowiu w ujęciu historycznym, Przegląd Górniczy, SITG, Vol. 72, No 6, p. 49-58

Natural hazards in the zinc and lead ores mining in Poland

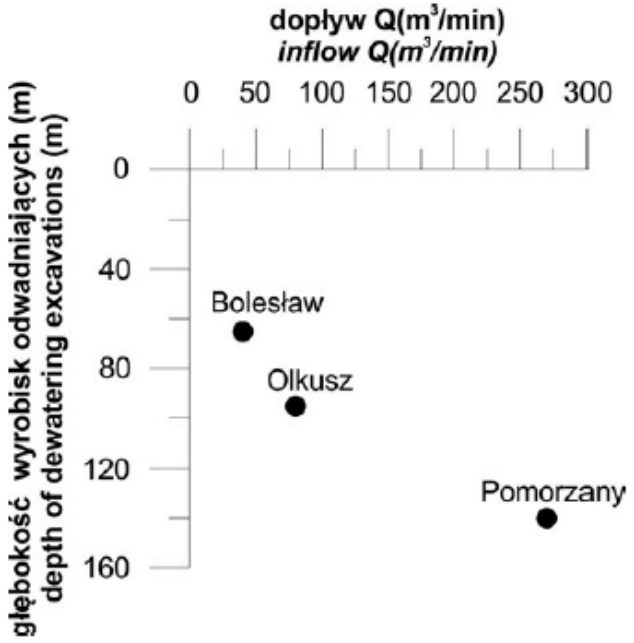
The amount of water inflow in the Pomorzany mine

Source: Motyka J. et al., 2016: Dopływy wody do olkuskich kopalń rud cynku i ołowiu w ujęciu historycznym, Przegląd Górniczy, SITG, Vol. 72, No 6, p. 49-58

Natural hazards in the zinc and lead ores mining in Poland

Water outflows from workings in the Olkusz area mines

Water outflow from a roadway in the 'Olkusz-Pomorzany' mine (2001)



Source: Motyka J. et al., 2016: Dopływy wody do olkuskich kopalń rud cynku i ołowiu w ujęciu historycznym, Przegląd Górniczy, SITG, Vol. 72, No 6, p. 49-58 and PIG-PIB, 2010: Zdrowa woda z głębi Zlemi

Natural hazards in the zinc and lead ores mining in Poland

Methane hazard - history and the current situation (1)

In the area of Olkusz zinc and lead deposits no methane hazard was found, but there is a possibility of its occurrence due to the presence of waters polluted with lignosulphonates, inflowing to the northern workings made in the 'Pomorzany' deposit.

Processes of chemical and biochemical changes of lignosulphonate compounds condition the formation of *i.a.* methane at amounts causing the methane hazard occurrence in mine workings.

The pollution with lignosulphonates is related to the activity of the Paper and Cellulose Factory in Klucze, where in the years 1930-1979 cellulose was produced by means of sulphite process. Liquid waste originating in the production process, so-called spent sulphite liquor, which most durable and most arduous component are lignosulphonate compounds, was discharged into the Błędowska Desert, close to the Biała Przemsza river. Approx. 450,000 tonnes of waste were dumped during the paper factory operations.

The MEERI PAS report based on: Nowak-Lenartowska A., 2007: Raport o oddziaływaniu na środowisko przedsięwzięcia polegającego na eksploatacji rud cynku i ołowiu ze złoża Klucze I and Adamczyk F. A., Chawiński S., 1982: Skażenie wód dołowych kopalni Pomorzany związkami lignosulfonianowymi, Akademia Górniczo-Hutnicza, ZGH Bolesław

Natural hazards in the zinc and lead ores mining in Poland

Methane hazard - history and the current situation (2)

Gravitational movements of liquid waste to the Quaternary aquifer resulted in those waters contamination. Movements of contaminated Quaternary waters towards the south, to the region where the Keuper formations cover is discontinuous (erosional windows), enabling contacts between Quaternary and Triassic level waters, meant a danger of waters contamination also in Triassic formations.

Intensive drainage of the Triassic aquifer started, when the 'Pomorzany' mine workings passed the Pomorzany fault at the end of 1973. Under the effect of hydraulic gradient created artificially by the 'Pomorzany' mine dewatering system the contaminated waters started moving in fissure-Karst aquifer towards its workings and in 1976 they appeared in certain mine leaks and outflows.

The MEERI PAS report based on: Adamczyk F. A., Chawiński S., 1982: Skażenie wód dołowych kopalni Pomorzany związkami lignosulfonianowymi, Akademia Górniczo-Hutnicza, ZGH Bolesław

Natural hazards in the zinc and lead ores mining in Poland

Methane hazard - history and the current situation (3)

In October 1977 in the ‚Pomorzany' mine an unprecedented in the history of the world zinc and lead ores mining event occurred, i.e. methane ignition and explosion, resulting in a death of 1 miner. The investigation has shown that the reason for dangerous methane accumulation were chemical changes of lignosulphonate compounds in the rocks surrounding the deposit series.

Underground mining of a shallow deposited ore deposit was designed without taking into account a possibility of methane hazard occurrence, including the use of self-propelled mining machines with normal bodies, not explosion-proof.

‚Pomorzany' mine was classified as a methane mine. The mining supervision authorities implemented a number of safe mining rigours. Numerous studies were carried out in order to recognise the hazard and recommendations were made to perform inspections of the methane hazard in the existing and planned workings on a current basis. Now - from 1995 - based on the decision of OUG Sosnowiec, the 'Olkusz-Pomorzany' mine is a non-methane mine.

Natural hazards in the zinc and lead ores mining in Poland

Hazard related to rocks breaking away from the roof and walls

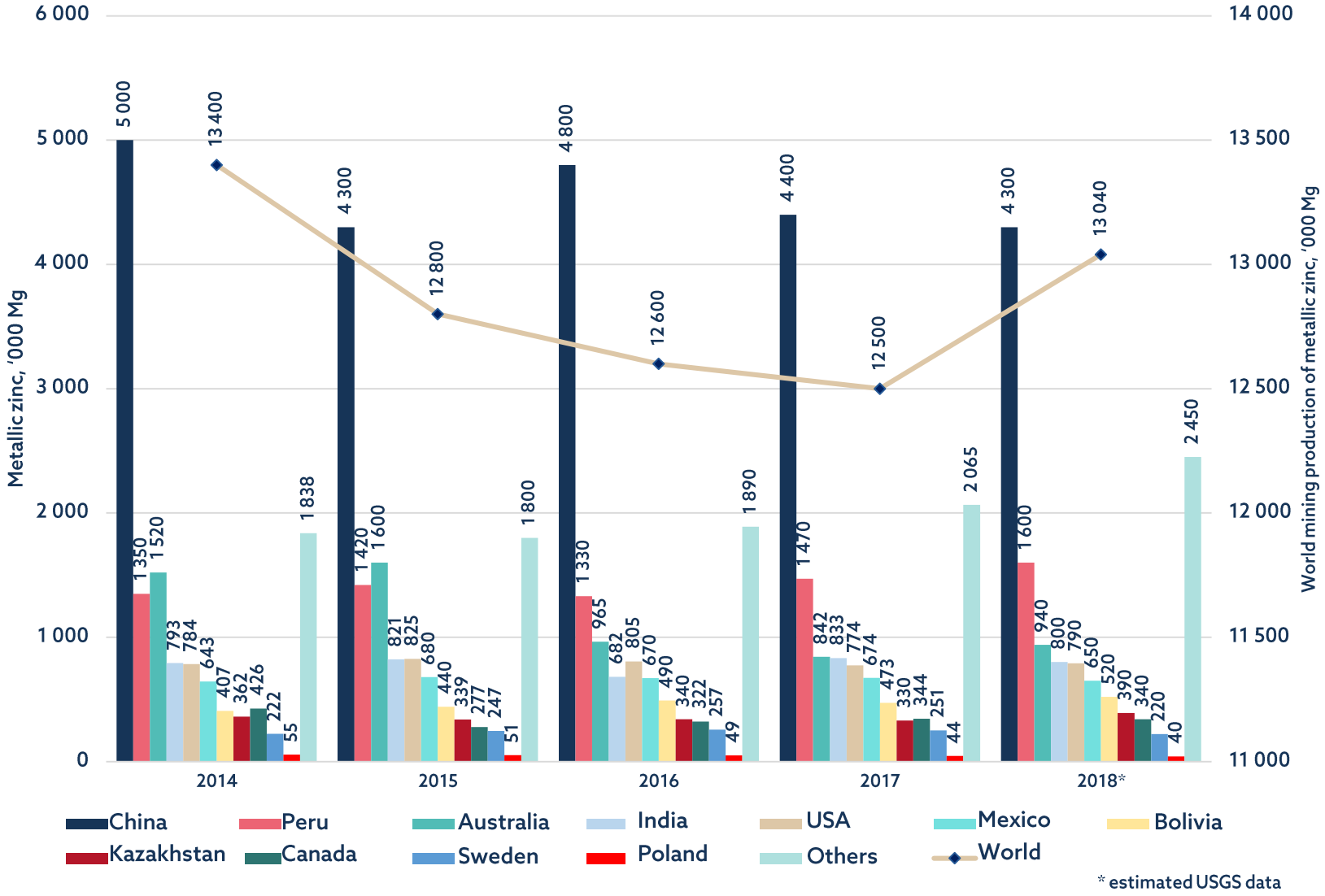
The hazard related to rocks breaking away from the roof and walls is primarily connected to weathering processes and the presence of zones with lowered geomechanical parameters, such as:

- **tectonic zones,**
- **zones of fissures and fractures,**
- **areas of increased oxidation,**
- **sites of rich, breccia type, mineralisation,**
- **hydrothermal Karst zones.**
- **erosional windows in the cover of Keuper formations,**
- **performance of blasting operations.**

The method of protecting against the hazard consists primarily in a proper choice of the support adapted to geological and mining conditions, performance of roof scaling and stability inspections on a current basis.

Market Conditions of Zinc and Lead Ores Mining - the World, Poland

Mining production of metallic zinc worldwide in the years 2014 - 2018* (1)



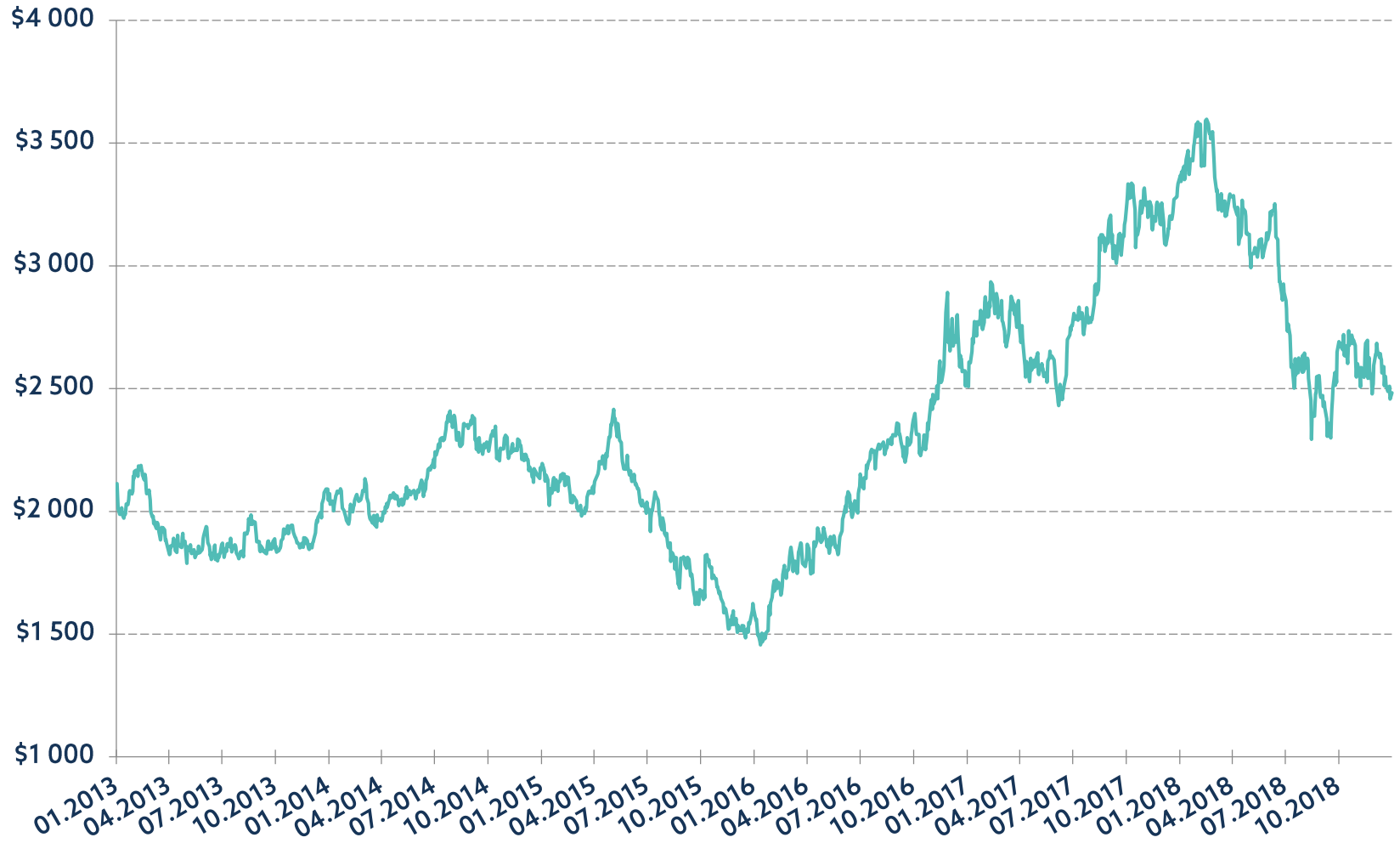
The MEERI PAS report based on USGS Mineral Commodity Summaries for the years 2015 – 2019 and USGS: Minerals Yearbook Europe and Central Eurasia 2014

Mining production of metallic zinc worldwide in the years 2014 – 2018 (2)

- The world mining production of zinc in recent 5 years has been showing a downward trend, although a small recovery was recorded in 2018, mainly due to the increase in the mining production in Australia, where at the end of 2017 the Dugald River Mine started the operations.
- 2018 witnessed continuation of metallic zinc deficit on the market, started in 2017. According to the *International Lead and Zinc Study Group*, the global consumption of refined zinc (13.74 million Mg) exceeded the production value (13.42 million Mg) by 332,000 Mg.
- In the years 2014-2018 the biggest decrease of zinc mining production occurred in Australia, where this amount was reduced by nearly 50% due to the closure of Century Mine - one of the biggest zinc mines worldwide, producing almost 500,000 Mg of zinc concentrates and 50,000 Mg of lead. In August 2018 an Australian company New Century Resources started the production of zinc concentrates from the accumulated flotation tailings containing approx. 2.2 million Mg of zinc.
- LME cash prices for zinc peaked in Q1, 2018, and then they went down to values close to the average in the years 2014-2018.

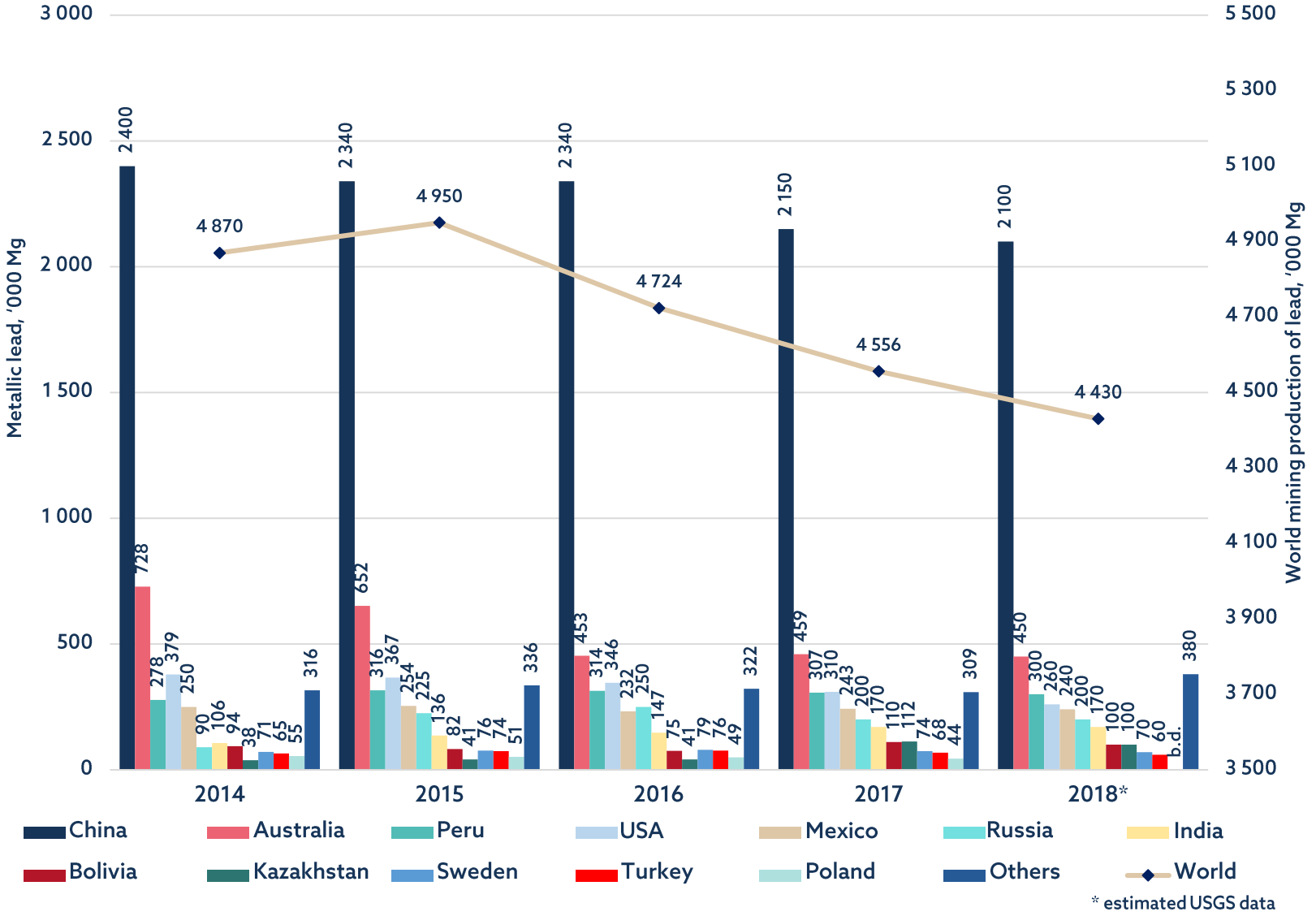
The MEERI PAS report based on USGS 2019 Mineral Commodity Summaries and a press release of MMG Limited dated 01/08/2015 displayed on the www.mmg.com website – access on 11/03/2019.

Zinc quotations on the LME (USD/tonne) in the period 01/01/2013 - 31/12/2018



The MEERI PAS report based on the Investing.com data - Zinc futures - (MZNc1)

Mining production of metallic lead worldwide in the years 2014 - 2018* (1)

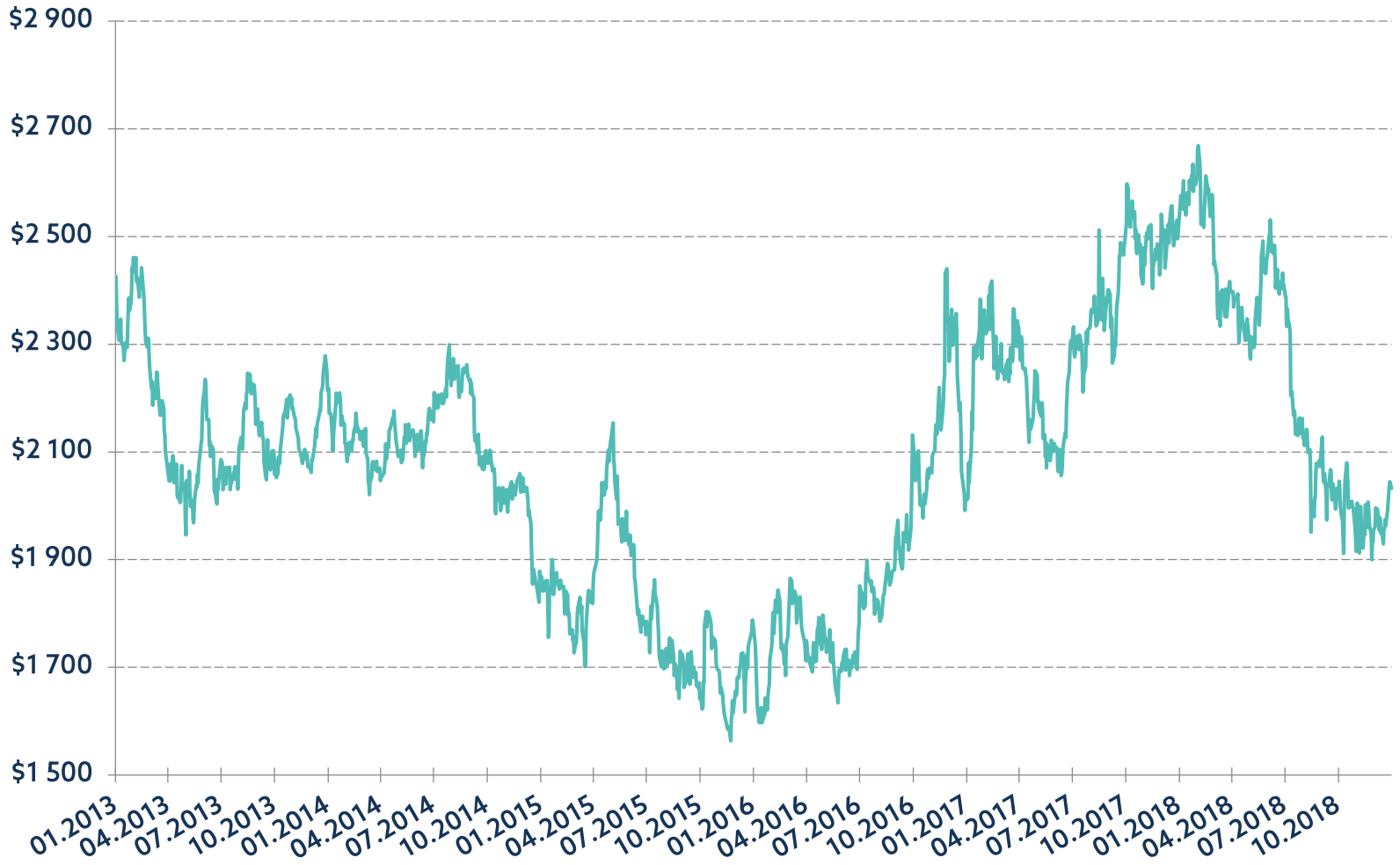


The MEERI PAS report based on USGS Mineral Commodity Summaries for the years 2015 – 2019

Mining production of metallic lead worldwide in the years 2014 – 2018 (2)

- The world mining production of lead in recent 5 years has been showing a downward trend, which is especially visible from 2015. This is primarily related to the amount of lead production in Australia (stopped mining at the Century Mine) and in the USA (reduction of mining due to growing operating costs and a fall in metal prices).
- In the second half of 2017 the LME cash prices for lead reached a 6 year high, due to insufficient supply as against increased demand for refined lead.
- According to the *International Lead and Zinc Study Group*, the global production of refined lead in 2018 was 11.59 million Mg (an increase by 0.4% as against the previous year), at the consumption of approx. 11.71 million Mg (an increase by 0.2% as against the previous year), which means a deficit on the refined lead market of 120,000 Mg.
- During 10 months of 2018 prices went down by 23%, lowering the year's average. Global stocks of lead in LME approved warehouses in mid-December were 106,950 Mg, i.e. by 25% less than at the end of 2017.

Lead quotations on the LME (USD/tonne) in the period 01/01/2013 - 31/12/2018



The MEERI PAS report based on the Investing.com data - Lead futures - (LEADc1)

Economic Results of Zinc and Lead Ores Mining in Poland

Economic results of zinc and lead ores mining in Poland

Economic results of Stalprodukt SA CG (1)

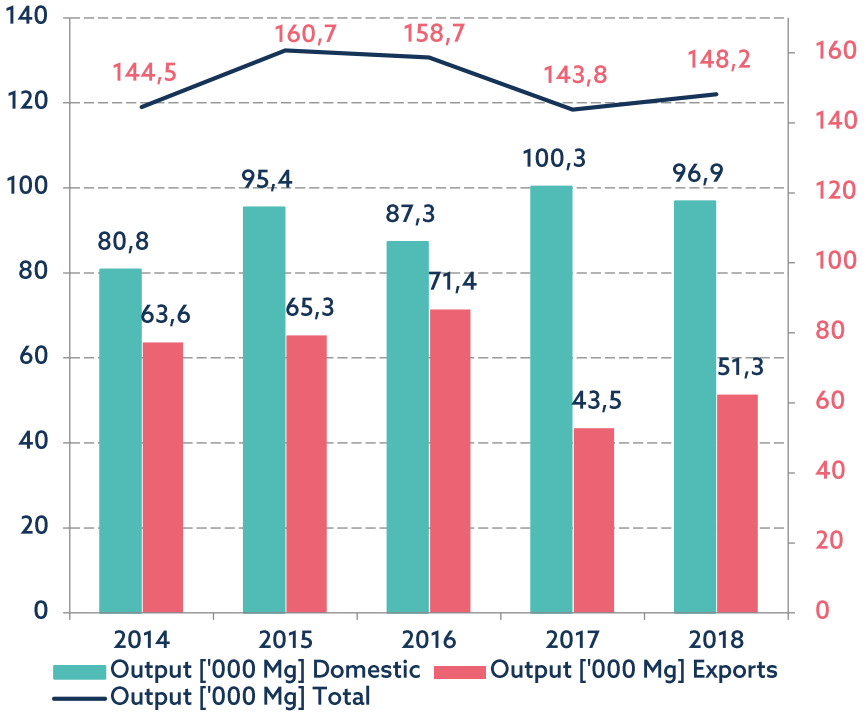
- Stalprodukt SA Capital Group is the owner of ZGH „Bolesław" SA, the only entity carrying out zinc and lead ores mining in Poland.
- Every year an Annual Report is published, presenting specifications of sales results for individual operational segments of the Stalprodukt SA Capital Group.
- To present the current economic situation of ZGH "Bolesław" SA the data originating from the Annual Report *'Management Board Report on the Activities of the Stalprodukt SA Capital Group in the period from 01/01/2018 to 31/12/2018'* were used.
- The 'Zinc Segment' comprises the activity of ZGH „Bolesław" SA together with subsidiaries, i.e. Zinc-lead ores mining and the production of zinc and lead, as well as related business.

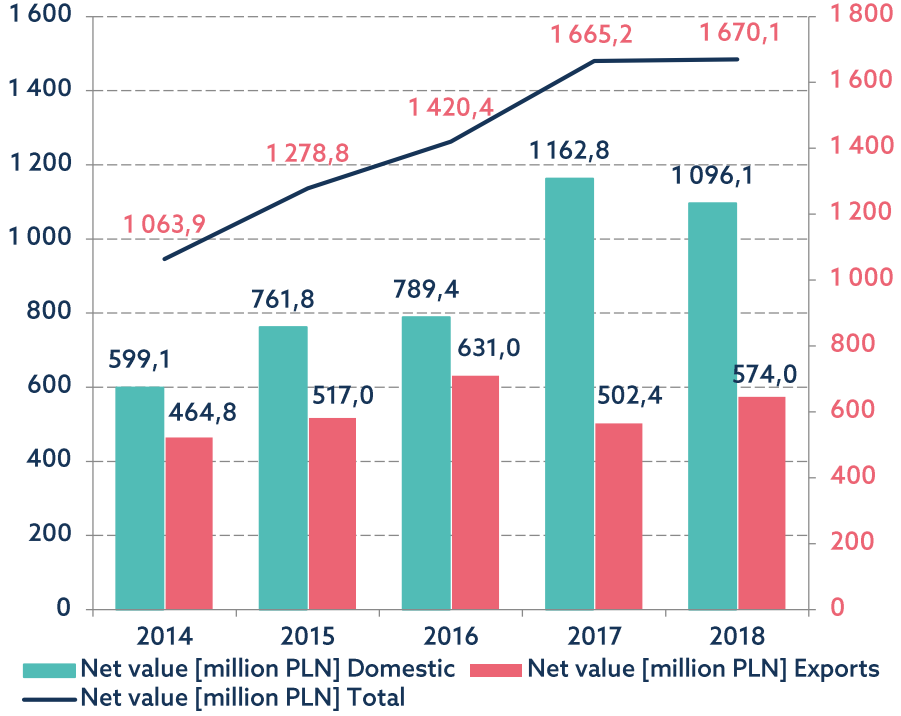
Economic results of zinc and lead ores mining in Poland

Economic results of Stalprodukt SA CG (2)

- Zinc is used mainly as the corrosion protection (hot and cold galvanising), while zinc alloys, used in high-pressure continuous casting lines, are applied e.g. in the automotive industry.
- Refined lead is used mainly to produce batteries and automotive batteries and to produce lead oxides, used in paints production.
- Flotation galena (lead concentrate) is produced at the ZGH „Bolesław" SA (77% of Zinc Segment output) and at 'Gradir Montenegro' in Montenegro (23% of the output) in the form of concentrate containing approx. 60% of lead. Despite systematically decreasing volume of 'Olkusz-Pomorzany' mine output due to the ore resources depletion, the year of 2018 witnessed an increase in the ZGH 'Bolesław' output volume in relation to improved Pb content in the ore. The concentrates production at 'Grandir Montenegro' has been systematically growing.
- Doré bars are a high-value useful waste, originating during the lead refining, fit only for further processing. As an alloy of high silver content it is a relatively significant part of the Zinc Segment revenue. The amount of doré bars production depends on the volume and content of metals in charges delivered to the 'Miasteczko Śląskie' Zinc Smelter, which at a downward trend of the lead concentrate can mean a further shift of the weight in the Segment revenue structure towards zinc and zinc products.

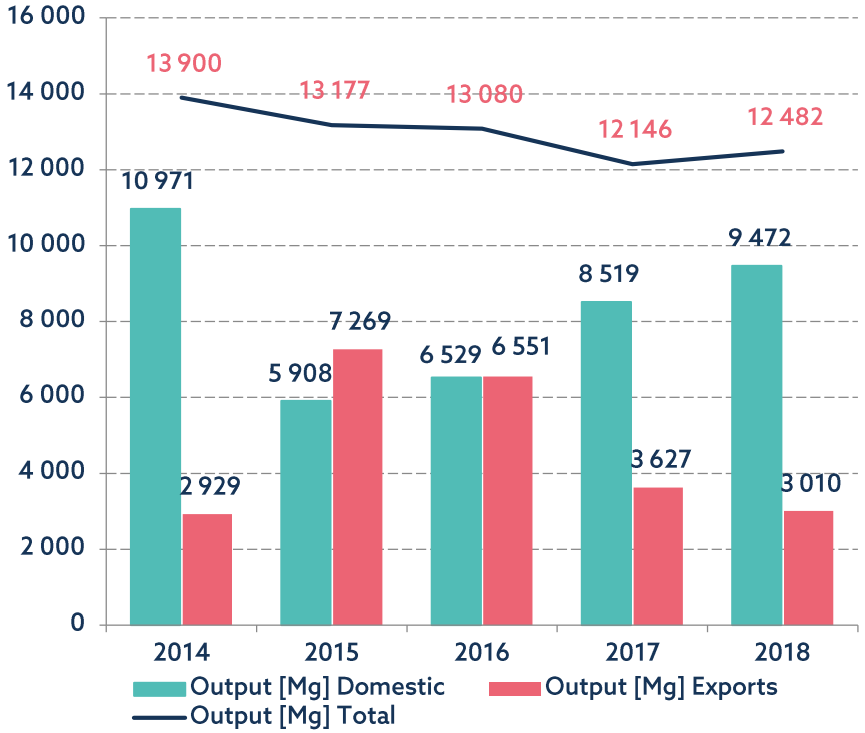
Zinc Segment
Output and net value in the years 2014-2018
Zinc and zinc alloys

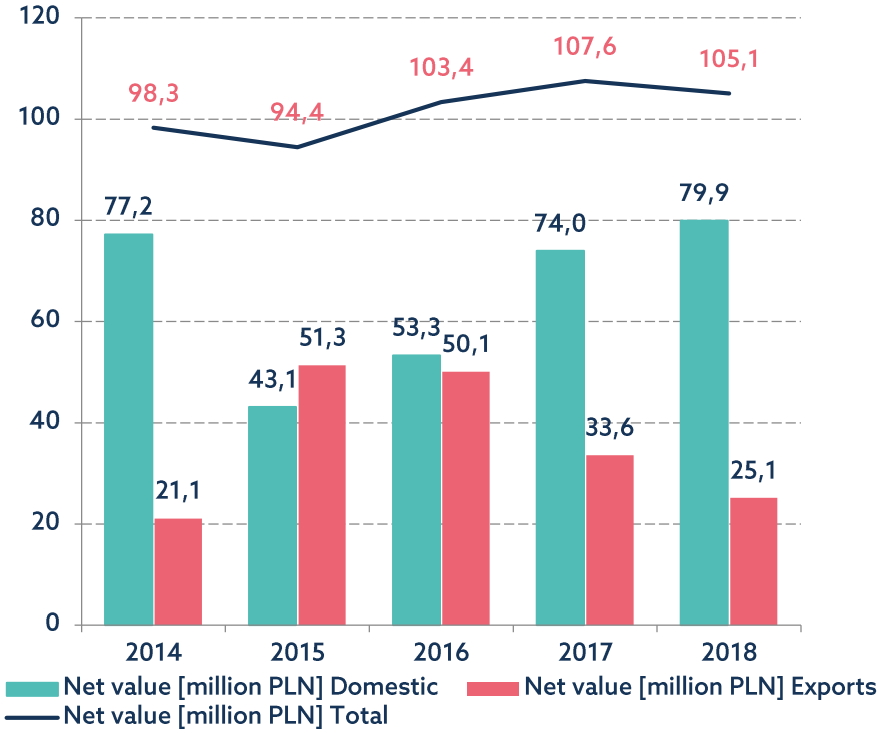




- A small increase (3%) in zinc and zinc products sales volume was recorded in 2018, where the export sales volume went up by 17.9%, parallel to domestic sales going down by 3.5% as against the previous year.
- The revenue from sales of zinc and zinc products in 2018 remained on the 2017 level due to a stopped trend of growing zinc prices occuring in previous years.
- The share of zinc in the Zinc Segment product sales revenue in 2018 was more than 88%.

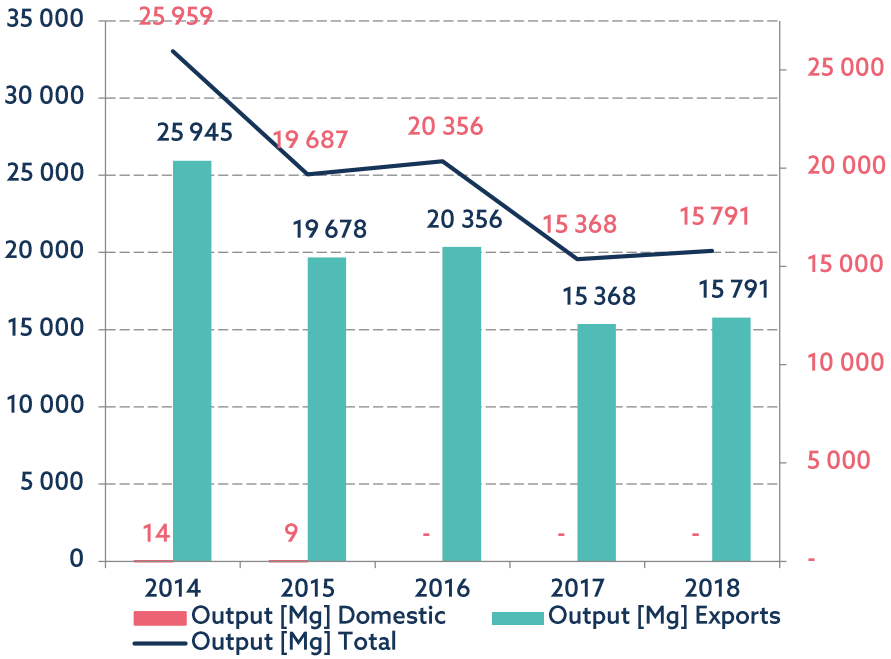
Zinc Segment
Output and net value in the years 2014-2018
Refined lead

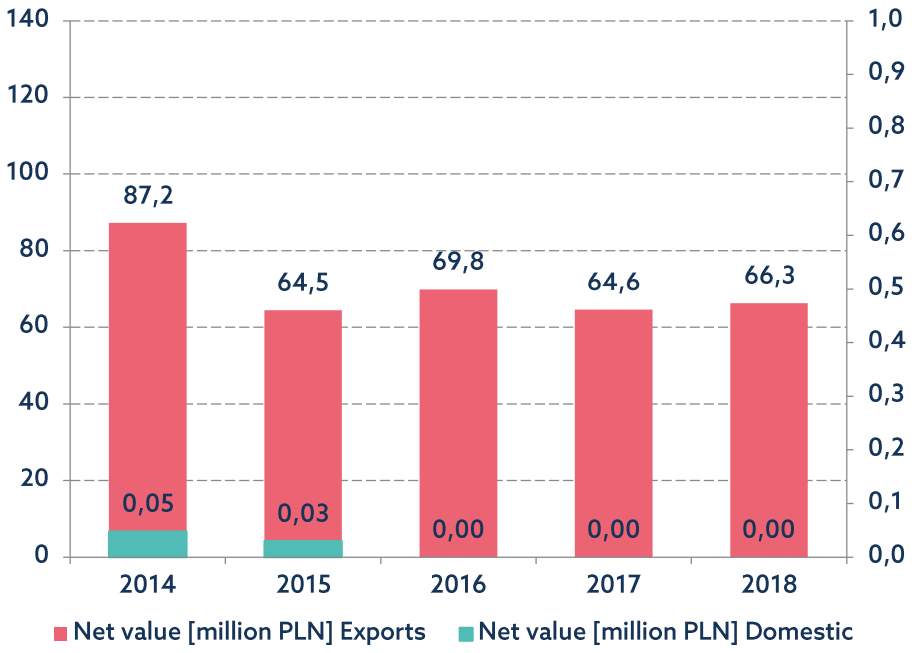




- The volume of refined lead sales increased by 2.8% in 2018 as against the previous year level, where the domestic sales grew by 11.2% and export sales fell by 17.0%.
- Despite the increase in the refined lead sales volume the revenue in 2018 was 2.3% lower than in the previous year due to a fall in lead prices by 7.7%.

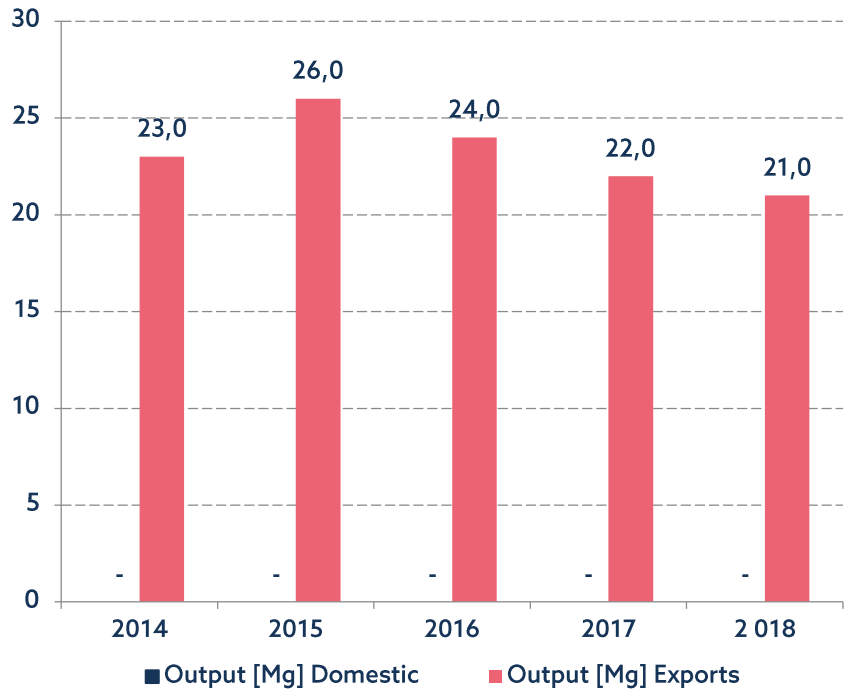
Zinc Segment
Output and net value in the years 2014-2018
Flotation galena

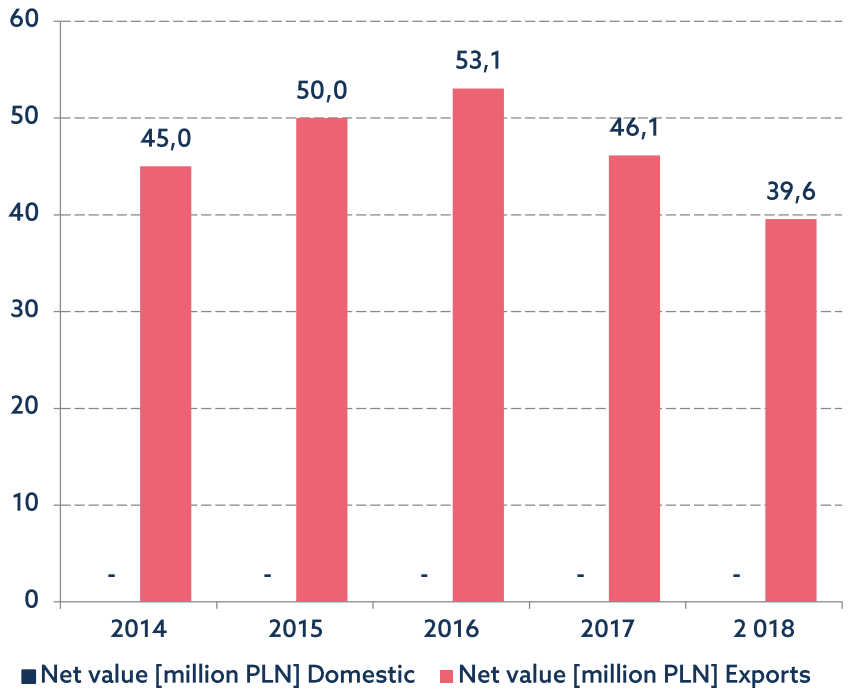




- Despite the fact that the flotation galena output volume at ZGH „Bolesław" SA has been systematically decreasing, in 2018 a small increase (2.7%) in the sales volume was recorded, where like in 2017 all the volume was exported.
- The increased output volume entirely offset the price fall, due to which the revenue from concentrate sales was 2.7% higher than in the previous year.
- The share of lead (refined and galena concentrates) in the Zinc Segment product sales in 2018 was slightly more than 9%.

Zinc Segment
Output and net value in the years 2014-2018
Doré bars





- In 2018 the doré bars sales volume went down by 3% as against 2017.
- Due to simultaneous fall in silver prices of approx. 8.8%, the revenue from sales was by 14.3% lower than in the previous year.
- The share of silver in the Zinc Segment product sales in 2018 was slightly higher than 2%.

Development Prospects for Zinc and Lead Ores Mining in Poland

Current production strategy of ZGH „Bolesław" SA - the use of recycled raw materials (1)

The current production strategy of ZGH „Bolesław" SA adopted in 2016 assumes:

- carrying out the mining of 'Klucze I' deposit and extending the period of 'Olkusz-Pomorzany' mine operation till 2022,
- introducing technology of concentrate production from a part of flotation tailings, accumulated during 60 years of mining operations in the Olkusz area at the amount of approx. 60 million tonnes on a dumping site with an area of approx. 110 ha.

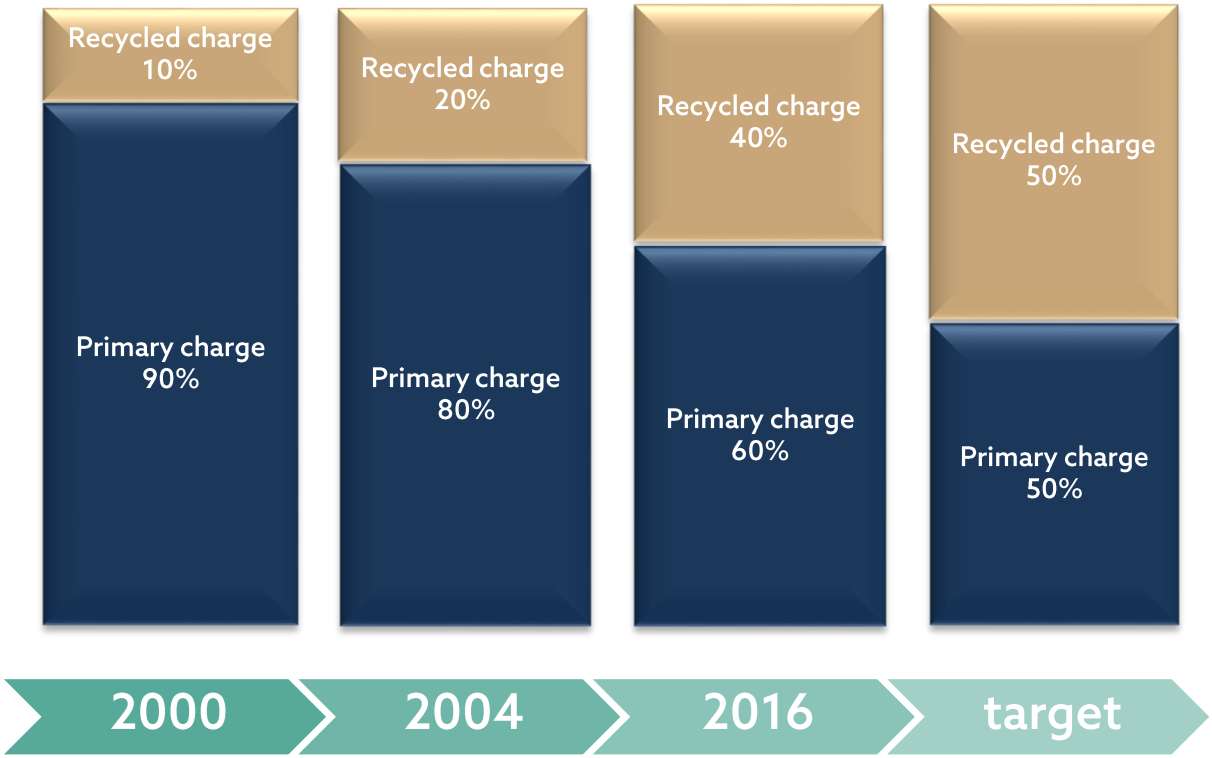
The waste in the oldest part of the site contains approx. 1.5% of zinc. In accordance with the developed technology this amount of waste should allow to obtain approx. 20,000 Mg of concentrate per year, containing approx. 45% of zinc and 10% of lead during a period of 15 years, with prospects for the increase in zinc amount in the concentrate to 50%.

ZGH „Bolesław" SA has been increasing the percentage share of recovered material in the chargé for years. This share is now approx. 35% of only zinc oxides acquired from EAF dusts, making the ZGH „Bolesław" SA the first plant worldwide utilising recycled materials on such a scale.

Source: Ochab B., 2018: Strategia i kierunki rozwoju Grupy Cynkowej ZGH Bolesław SA

Current production strategy of ZGH „Bolesław" SA - the use of recycled raw materials (2)

Structure of charges in Smelters of ZGH „Bolesław" SA CG



Current production strategy of ZGH „Bolesław" SA - the use of recycled raw materials (3)

Olkusz-Pomorzany mine

1,8 million tonnes of ore
Zn 2,9%
Pb 0,8%

100%

Ore Enrichment Plant

40% → Stone

55% → Waste

5%

Zn and Pb concentrates

Zinc smelters ZGH „Bolesław" SA CG

2,0 milion tonnes of waste

100%

Waste Enrichment Plant

99% → Waste

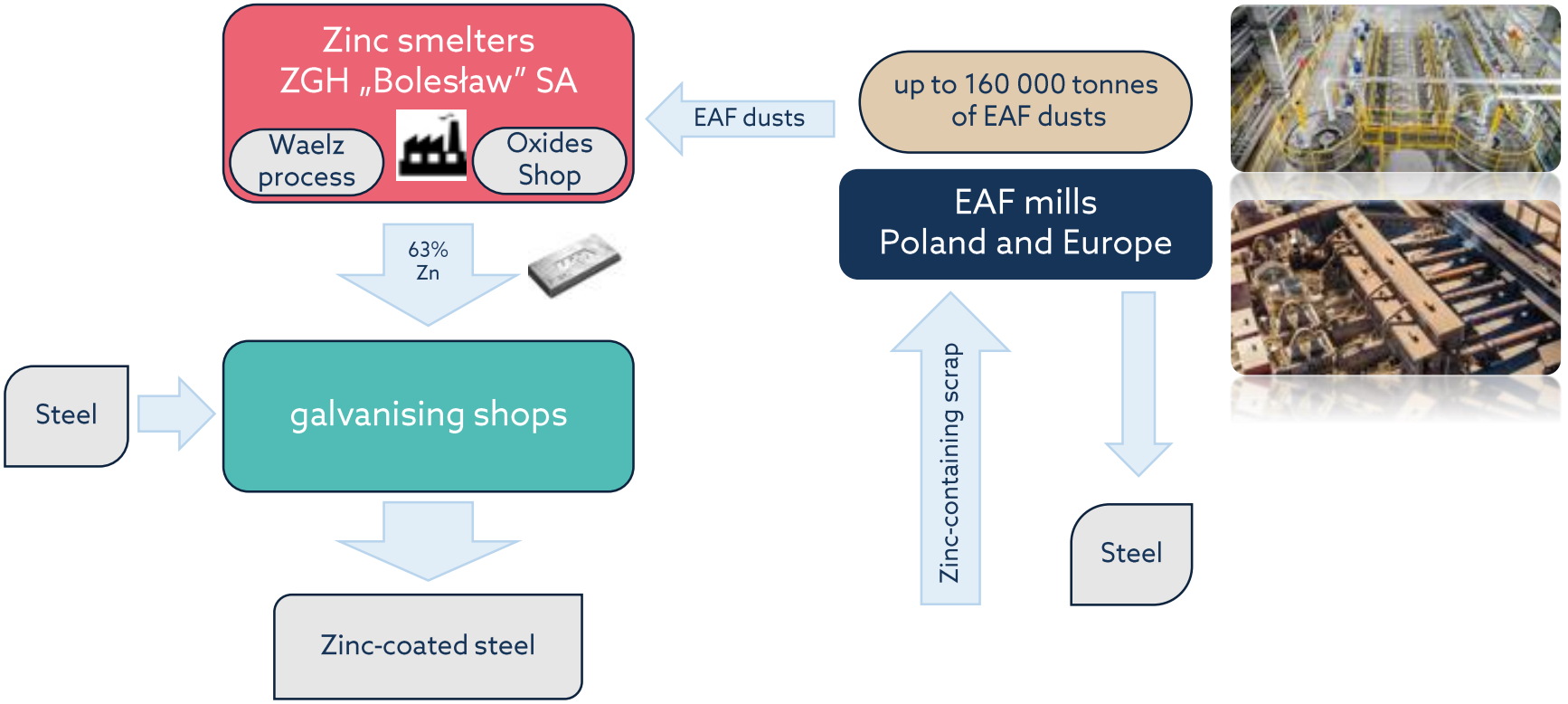
1%

ZnPbS concentrate

to zinc smelters

Source: Ochab B., 2018: Strategia i kierunki rozwoju Grupy Cynkowej ZGH Bolesław SA

Current production strategy of ZGH „Bolesław" SA - the use of recycled raw materials (4)



Source: Ochab B., 2018: Strategia i kierunki rozwoju Grupy Cynkowej ZGH Bolesław SA

Technological diagram of flotation tailings enrichment to recover zinc in the form of qualified concentrates

At the Institute of Non-Ferrous Metals in Gliwice an innovative technological diagram was developed for the recovery of sulphide zinc and lead minerals after the process of mechanical enrichment of lean waste raw material of Zn-Pb ores dumped in settling ponds, which enables profitable production of collective Zn-Pb sulphide concentrate containing 48-50% Zn and 7-8% Pb.

Based on the developed diagram an enrichment plant design was produced for the waste from ZGH „Bolesław" SA settling ponds of processing capacity of approx. 2 million tonnes per year.

Advantages of the solution:

- enrichment diagram simplicity enabling construction of the plant in the immediate vicinity of the settling pond,
- low unit cost of waste processing,
- high economic efficiency of the process,
- lesser environmental impact as a result of dumping a waste product of lower Zn-Pb contents.

Source: Instytut Metali Nieżelaznych Gliwice, Technologiczny schemat wzbogacania odpadów flotacyjnych dla odzysku cynku w postaci kwalifikowanych koncentratów, Nowe technologie oraz nowe konstrukcje maszyn i urządzeń do wzbogacania i metalurgicznego przerobu surowców mineralnych

Design of a mobile plant for waste processing from the Bytom area heaps after the process of mechanical enrichment of Zn-Pb ores - Gekon 2015

The goal of the project carried out by a consortium consisting of ZGH „Bolesław" SA, Institute of Non-Ferrous Metals, and Faculty of Mining and Geoengineering of the AGH:

- *development of specification for technical documentation of a mobile plant for waste processing from the Bytom area heaps after the process of mechanical enrichment of Zn-Pb ores.*

Project effects:

- heaps identification and determination of resources
- determination of optimum conditions for flotation of materials accumulated in heaps
- development of waste enrichment diagram
- determination of profitability and environmental impact assessment.

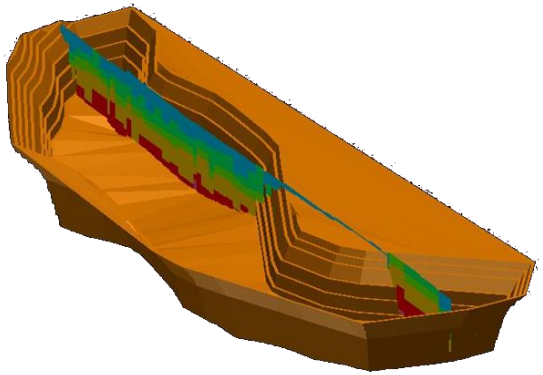
Source: Tora B., 2015: Bezodpadowe technologie przeróbki rud metali nieżelaznych, Polityka surowcowa w perspektywie nowych inicjatyw i programów, KGHM Cuprum, Wrocław

Prospects for new zinc and lead ores deposits management

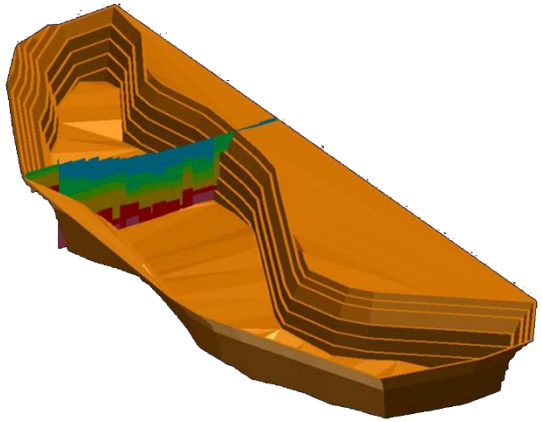
'Laski' deposit

- For a longer period the zinc and lead ores mining is in a period of downturn activity and because of that actions and analyses related to management of documented deposits are being started, which is possible only with respect to deposits of the Olkusz and Zawiercie area.
- The Zawiercie area deposits, known as the 'Olza' project, remain available to the Rathdowney company.
- In the Olkusz area the ZGH Bolesław is interested in the 'Laski', 'Sikorka', and 'Klucze 2' deposits. They could be used in the future.
- One of them, i.e. the 'Laski' deposit is the subject of interest and analyses. Like other deposits it features discontinuities in the horizontal plane and in the vertical profile as well as a variable thickness.
- Although the management only from the side of Olkusz-Pomorzany mine is considered now, in the past also options were considered to start an independent mine:
  - surface,
  - underground opened by means of inclines.

However, they turned out to be burdened with numerous environmental issues and of little economic attractiveness.



'Laski' deposit
longitudinal section

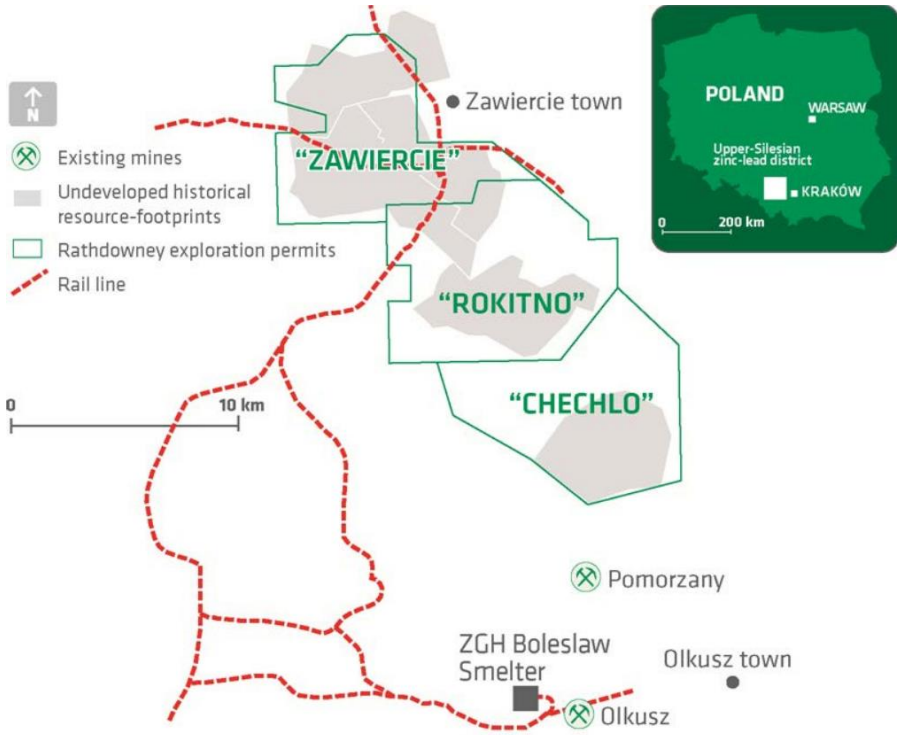


'Laski' deposit
transverse section

Development prospects for new deposits of zinc and lead ores

'Olza' Project - location

- The 'Olza' project is an initiative of Rathdowney Polska Sp. o.o.. - a division of a Canadian mining company Rathdowney Resources Ltd.. Its aim is to access proven reserves of lead and zinc ores located in the south-western part of the Zawiercie district through the construction of a modern underground mine.
- The 'Olza' project includes 3 concessions for zinc and lead ores prospecting and exploring.
- The work carried out by Rathdowney in the area of 150 km^2 since 2010 has confirmed the presence of significant deposits of zinc and lead ore.
- According to the inwestor, within the 'Olza' there are opportunities to build a modern underground mine - a significant producer of metals in Europe - which in the long term will contribute to the prosperity of the region's municipalities



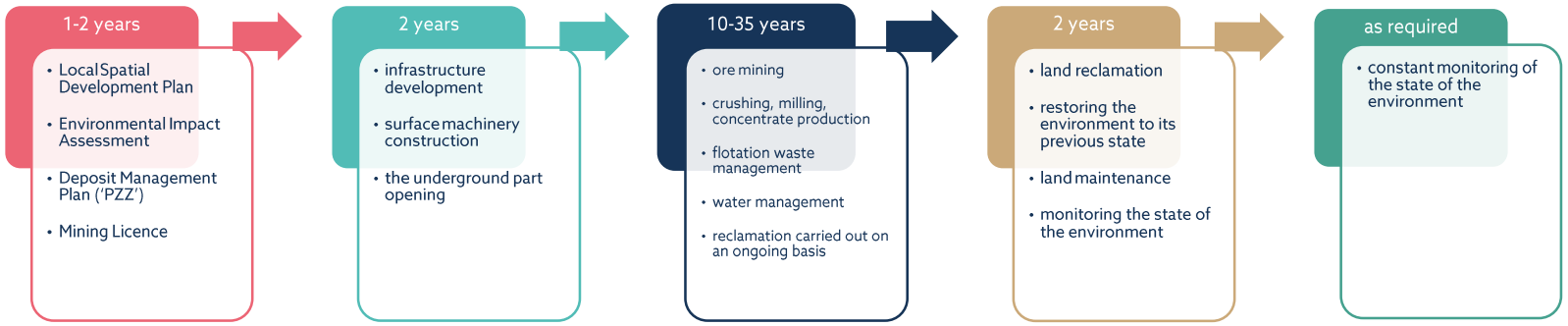
Areas covered by concessions in the 'Olza' Project location

Source: CAM, 2012: NI 43-101 Technical Report Olza Zinc-Lead Project, Zawiercie, Rokitno, Chechlo Exploaration Permits, Poland

Development prospects for new deposits of zinc and lead ores

'Olza' Project – functioning timeframe

- According to the investor, the modern mine project, if implemented, will make a significant contribution to the development of local municipalities and economy of the Zawiercie district. These benefits can be realized through:
  - foreign direct investment,
  - budget revenues
  - workplaces, whose numbers depend on the stage of development of the Project – shall be set at:
    - 250 - 400 direct jobs during the construction phase of the mine (2 years)
    - 450 direct jobs during the exploitation phase (10-35 years),
    - 3 300 direct, indirect and related jobs in the Zawiercie district.



Timeframe of 'Olza' Project

Source: http://www.projektolza.com/i/maps/2018-10-10-timeline.jpg

Development prospects for new deposits of zinc and lead ores

'Olza' Project – deposits' characterisation

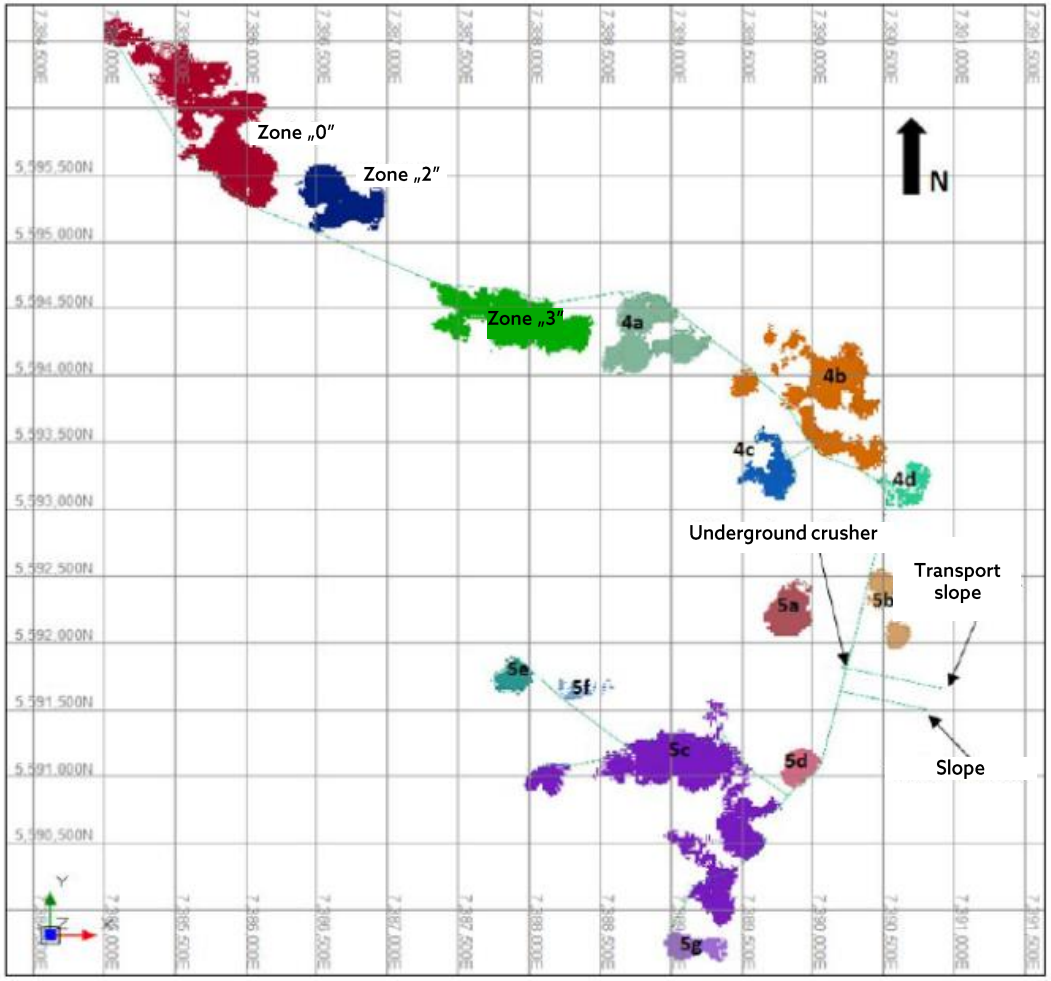
- The 'Olza' project covers the exploitation of the MVT (Mississippi Valley Type) zinc and lead ore deposits.
- The drilling program carried out by Rathdowney includes 225 core boreholes with a total length of 28,813 m. The predefined area of mineralization in 'Rokitno' and 'Zawiercie' concession has the shape of a curve. Zn-Pb concentrations occur within a corridor about 10 km long and up to 1 km wide, basically within an almost horizontally located series of ore-bearing dolomites at a depth of 70-220 m.
- Zn-Pb ore deposits occur mainly in the form of pseudo-seams and nests. The thickness of the deposits varies – in thickest zones they have up to 10 m. Similarly variable is the extent of the deposit, having usually about a few hundred meters. Mineralization in the form of breccia chimneys and veins occurs rarely.
- The main minerals found in deposit bodies are: sphalerite, galena and marcasite.

Drilling core with mineralization of zinc and lead minerals

Source: http://www.projektolza.com/s/CharakterystykaZloz.asp

Development prospects for new deposits of zinc and lead ores

'Olza' Project – the resources base



Source: Raport techniczny opracowany zgodnie z wymaganiami instrumentu krajowego 43-101 dotyczący wstępnej oceny techniczno-ekonomicznej Projektu Olza (złoża Zn-Pb) w Polsce

- The volume of resources in the "Inferred" category at the limit content of Zn equal to 2% in the 'Olza' Project, as for April 16, 2014 (metal content determined assuming 100% recovery) amounts to:
  - tonnage: 24.4 million Mg
  - % Zn content: 5.53%
  - % Pb content: 1.49%
  - % Zn + Pb content: 7.02%
  - Zn content: 1.349 million Mg
  - Pb content: 0.363 million Mg
- The projected life of the mine for the resources defined at the 2% Zn content limit in the "0", "2", "3", "4" and "5" Zones is 8 years, with a two-year period preceding mining activity.

Development prospects for new deposits of zinc and lead ores

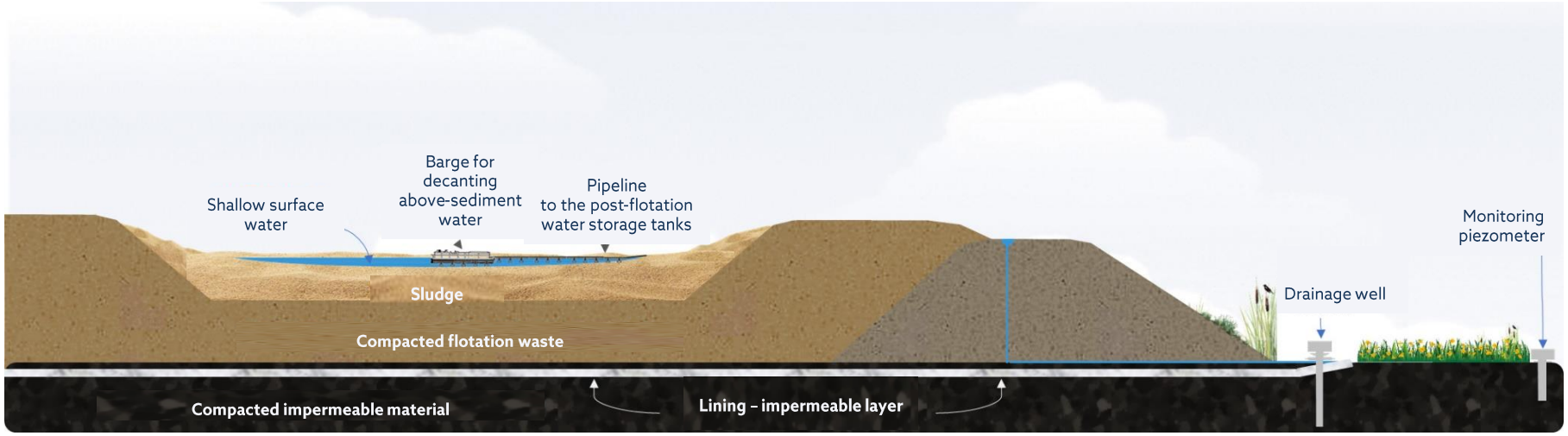
'Olza' Project - technology and engineering

- Initial Technical and Economic Assessment assumes the exploitation of Zn-Pb ore deposits, at the target production capacity of 6000 Mg per day with hydraulic filling and various variants of the room and pillar system, depending on the thickness and dip. In order to develop deposit quickly, two slopes will be cut:
  - the first one, 5.0 m wide and 4.0 m high, will be driven from the site of the enrichment plant and equipped with a 1250 mm conveyor, similar to the one used in the Chelopech mine (Bulgaria). It will act as an ore transport road from an underground crusher (such solution will reduce noise and dust of the plant's ground environment) to the surface,
  - the second one will be driven near the main part of a currently defined deposit. It will serve as a transport route for workers and materials.
- The minimum operating height was set at 2 m due to working height of the mining equipment. According to the deposit model, mining excavations will be on average from 3.5 to 5 m high, although in some areas they can reach up to 10 m.
- Extraction will be carried out based on the 4 brigade system operating in the three-shift system, with the working time of maximum 40 hours a week. It is assumed, that exploitation volume can reach the level of 2.16 million Mg per year.

Development prospects for new deposits of zinc and lead ores

'Olza' Project – ore preparation

- Metallurgical research shows that the 'Olza' Project will produce high quality zinc and lead concentrates. It was determined that a mechanical ore processing process called froth flotation would be used.
- According to the assumptions of the 'Olza' Project, the settling basin will be a 'zero discharge' facility, i.e. all water entering the facility (in the form of waste or with flotation tailings) will be retained for reuse in the processing plant and/or purified before being discharged into the environment.
- The entire settling basin will be lined with an impermeable membrane to reduce water leakage. Over time, an impermeable layer (> 20 m) resulting from the sedimentation of solid processing waste will be accumulated at the bottom of the settling pond.



Source: http://www.projektolza.com/s/CharakterystykaZloz.asp

Summary

1. The zinc and lead ores mining as one of the oldest fields of mining activity in Poland slowly goes down in history. At increasingly shrinking resources of 'Olkusz-Pomorzany' mine (5.2 million Mg of recoverable reserves at the end of 2018) the mining is predicted now to end in 2022.
2. Because of systematically declining output and zinc and lead content in the ore a new strategy of ZGH „Bolesław" SA has been being developed for years, based on charges originating still from the own Olkusz-Pomorzany mine, from recycling (based on EAF dusts and flotation tailings), on concentrates supplies from the Gradir Montenegro mine and concentrate purchases on the market. Also the management of 'Laski' deposit is considered, which resource base - at favourable economic conditions - can be mined.
3. On a further time horizon, beyond 2022, the ZGH „Bolesław" SA will increase the purchase of concentrates on international minerals commodity markets.
4. The 'Olza' project is an initiative taken by the Canadian company Rathdowney. It aims to access documented deposits of zinc and lead ore in the 'Zawiercie' region. Works carried out by the investor since 2010 within 3 concessions for prospecting and exploring confirmed the presence of appreciable resources with significant economic potential.

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