GOSPODARKA SUROWCAMI MINERALNYMI

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New methodology of resources categorization and calculation for undeveloped Zn-Pb ore deposits in the Upper Silesian ore district

Introduction

The ore mining in the Upper Silesian district has a hundreds-of-years-long tradition. The well-known, historical Zn-Pb ore mining centers were: Tarnowskie Góry, Bytom, Chrzanów and Olkusz. At the early stage of these operations, which dates back to the XIIth century, only lead ore with silver admixtures was exploited. Since the XVI-th century the mining of oxidized Zn ores has started, followed by extraction of sulphide Zn ores (since 1870). According to Szuwarzyński (1996), in the second half of the XIXth century the Upper Silesian mines supplied some 40% of world Zn production and the initial reserves of developed deposits might have been around 400–500 Mt of ore grading 5–6 wt.% combined Zn+Pb.

The last stage of intensive development of the Upper Silesian Zn-Pb deposits took place in the 1960–1970-ties. Due to significant, systematic exploration effort large deposits were discovered in the Olkusz region (“Olkusz” and “Pomorzany”), and in the Chrzanów region (“Balin” and “Trzebionka”) and, after only an initial assessment, the construction of new mines has started. Moreover, the old “Bolesław” mine has been reactivated and many new prospects were explored, which resulted in discoveries of several deposits in the vicinity of Olkusz, Zawiercie and Siewierz.

Unfortunately, this long-lasting, intensive mining activity led to the exhaustion of ore resources. Since many decades both the Tarnowskie Góry and the Bytom regions have been

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of only historical and scientific importance. At the break of XXth and XXIst centuries the closure procedures of the “Bolesław”, “Olkusz” and “Trzebionka” mines have been initiated. Hence, the only full-scale operating Zn-Pb ore mine in Poland is “Olkusz-Pomorzany” where both the demonstrated and inferred resources should ensure mining operations until about 2016 (Wnuk et al. 2007).

The future of Zn-Pb ore mining in the Upper Silesian Ore District are several deposits discovered in both the Olkusz and Zawiercie regions (Fig. 1), which were explored with drillings and assessed mostly between 1970-ties and 1990-ties. The exception is the “Klucze” deposit, for which the assessment report has been successively supplemented until 2006 due to possible development of this locality using the existing infrastructure of the “Olkusz-Pomorzany” Mine. In fact, the southern portion of the “Klucze I” deposit is currently under development.

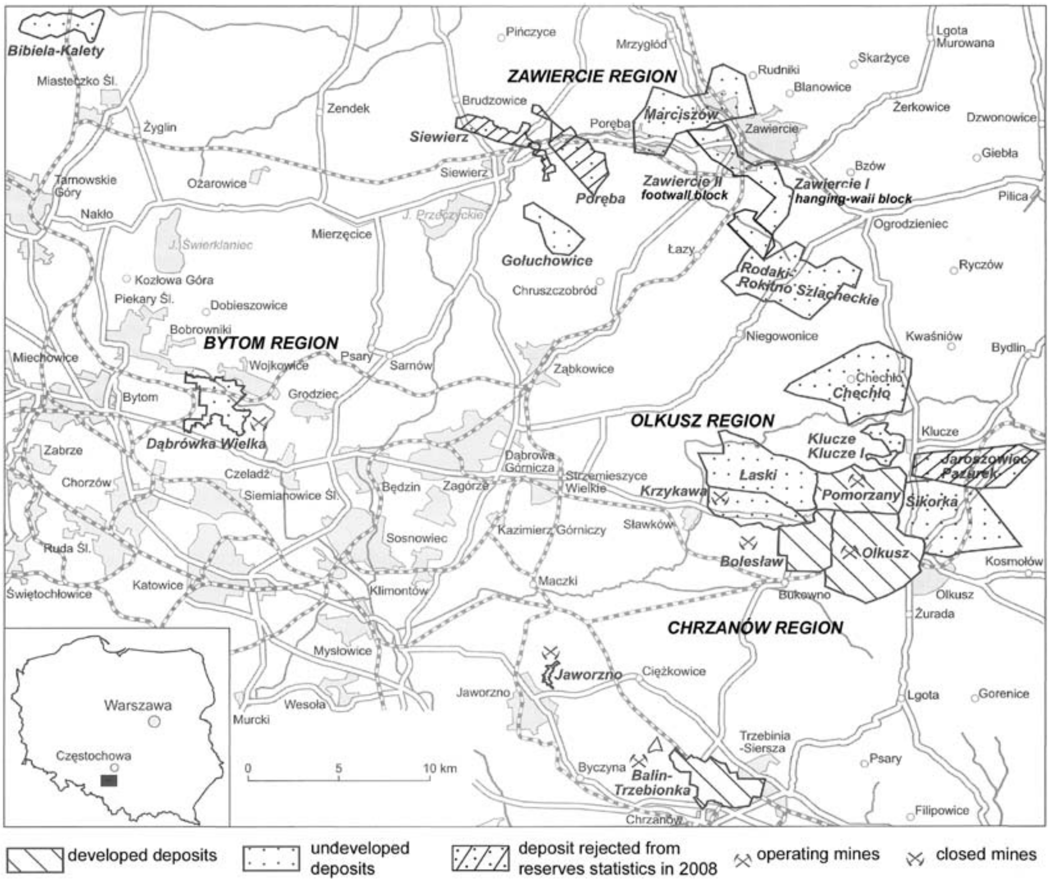

Fig. 1. Sketch-map of Zn-Pb ore deposits in the Upper Silesian district (after “Resources of mineral raw-materials and groundwaters in Poland, data for Dec. 31, 2007, supplemented for Dec. 31, 2008”)

Rys. 1. Schemat lokalizacji złóż rud Zn-Pb w obszarze górnośląskim (na podstawie „Bilansu zasobów kopalin i wód podziemnych w Polsce wg stanu na 31.12.2007 r., uzupełnionego na 31.12.2008 r.”)

1. Characteristic geological features of the Upper Silesian Zn-Pb ore deposits

The Upper Silesian Zn-Pb ores are hosted in the Ore-bearing Dolomite, which is a metasomatite, resulted from the hydrothermal replacement of Middle Triassic limestones and dolomites (Bogacz et al. 1975). In some areas Zn-Pb mineralization appears also in Lower Triassic (Roethian) dolomites and in Devonian carbonates (Fig. 2).

The epigenetic dolomitization affected almost full thickness of the Lower Muschelkalk Górażdże, Terebratula and Karchowice beds as well as some parts of the Gogolin Beds, and, locally, also Roethian dolomites, and bottom parts of the Diplopora Dolomites.

The increased contents of Zn and Pb were detected in full sequence of the Ore-bearing Dolomite. However, the economic-grade mineralization is located mostly within 20-meters-thick part of the Górażdże Beds, immediately above the contact with the underlying Gogolin Beds (Blajda 1993; Szuwarzyński 1996). Ore bodies mined from this zone are stratoidal or

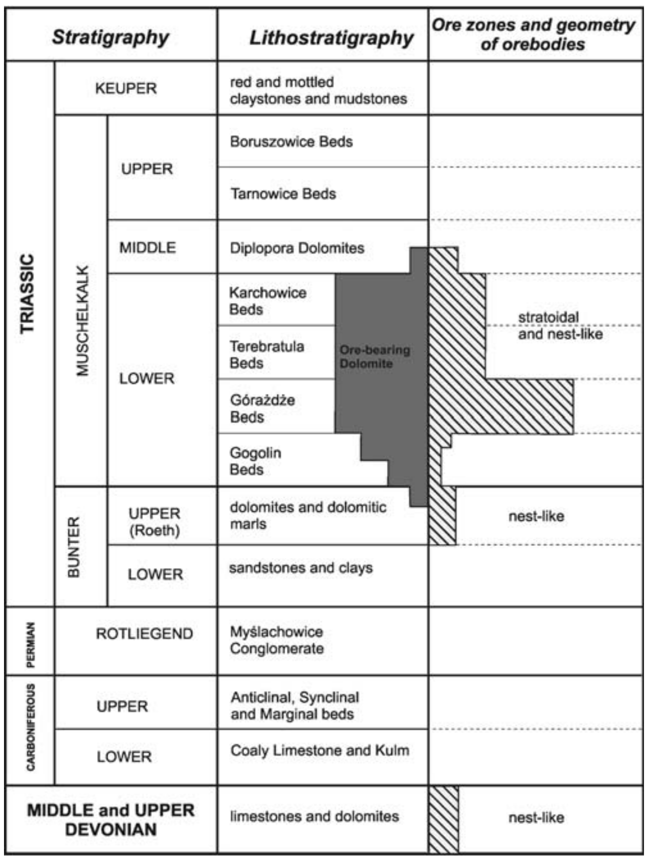

Fig. 2. Schematic lithostratigraphic column of the Upper Silesian Ore District (after Nieć 1997, simplified)

Rys. 2. Schematyczny profil litostratygraficzny utworów złożowych w górnośląskim obszarze rudonośnym (wg Niecia 1997, uproszczony) nest-like. Their horizontal extensions range up to several hundreds of meters and thickness vary from several to a dozen of meters and more. Typical stratoidal ore bodies ("ore horizons") occurred in both the Chrzanów and Bytom regions (Szuwarzyński 1996). Their origin is attributed to metasomatic replacement of dolomite by ore minerals. In the Olkusz region prevailing part of ore mineralization is hosted in karst collapse breccias (Sass-Gustkiewicz 1985).

Typical feature of the Upper Silesian Zn-Pb ore deposits is their simple mineral composition with only two industrially important minerals: crystalline or collomorph sphalerite (ZnS) and crystalline galena (PbS) accompanied by marcasite and less common pyrite. In the peripheral parts of ore bodies calcite and barite were observed. In the weathering zone sulphide ores were transformed into oxidized ones named "galman" in polish mining terminology. Field observations in operating mines revealed, that the most common are: layered (Smolarska 1968; Szuwarzyński 1996) and massive (Sass-Gustkiewicz 1985) ores dominated by sphalerite. Average Zn grade in ores extracted from the Olkusz region in 1960–1970-ties was about 5 wt.% (Przeniosło et al. 1992; Blajda 1993).

Apart from mineralization hosted in the Ore-bearing Dolomite, in the Olkusz region massive ore bodies located in Roethian dolomites were intermittently worked at the "Bolesław" Mine. These ore bodies were irregular nests, several tens of meters in diameter, grading up to dozen of wt.% Zn and several wt.% Pb (Nieć et al. 1993).

The Zn-Pb mineralization discovered in Devonian carbonates is known only from the drill cores. Ore bodies show highly irregular thickness – from some tens to over 100 meters and horizontal extent up to several tens of meters (Kurek 1993; Blajda 2006a).

The undeveloped Zn-Pb ore deposits are located in the peripheral parts of the Upper Silesian Ore District. Exploration results indicate that economic-grade mineralization forms irregularly distributed nests hosted mostly within the Ore-bearing Dolomite, less commonly in Roethian and Devonian carbonates (Blajda 2009). The main industrial mineral is sphalerite. Drill-core data reveal that average thickness of economic-grade bodies rarely exceed 3 meters and average Zn grade varies from 3 to 5 wt.%.

2. Analysis of previous assessment principles of Zn-Pb ore deposits

2.1. Methods of exploration and resources calculation

Systematic exploration of the Upper Silesian Zn-Pb district was run between the early 1950-ties and late 1980-ties. At the initial stage ore prospects were explored with vertical drillings. Drilling grids were predetermined in the instructions issued by the President of the Central Bureau of Geology as appendices to the "Regulations for determination of the resources of mineral raw materials". Recommendations concerning the densification of drilling grids for undeveloped Zn-Pb ore deposits were issued in the years 1954, 1963 and 1980 (Table 1)

TABLE 1

Recommended grids of exploration drillings for the Upper Silesian Zn-Pb ore deposits

TABELA 1

Zestawienie zalecanych odległości między wyrobiskami dla rozpoznania złóż rud Zn-Pb

Instruction date	Distance between drillings for assessment category [m]		
	C_2	C_1	B
1954	at least one well per 0.25–2km^2	500–100	100–50
1963	600–300	300–150	150–75
1980	400–200	200–100	100–75
2002	300–150	to be decided by the author of assessment report	to be decided by the author of assessment report

Taking into account these regulations, it was presumed that, despite the geometry of ore accumulations, the 300-meters grid is sufficiently accurate for the C_2 assessment category whereas 300–150-meters grid fits to the C_1 category and, finally, 100–75-meters grid ensures accuracy at the level of B assessment category. Such densification led to the completion of almost 1,400 exploration wells on the area of ore deposits in the Olkusz region. Moreover, very optimistic estimations of ore potential of the Zawiercie region resulted in almost 2,500 exploration wells drilled in that area. Finally, in the Olkusz region five deposits were discovered of total area about 75 square kilometers and in the Zawiercie region seven deposits were disclosed (total area about 125 square kilometers) (Fig. 1). Total resources calculated in accordance with the regulations for assessment categories from C_2 to B (Blajda 2010) amounted about 190 Mt of ore.

The "Regulations for determination of the reserves of mineral raw materials" issued in 1980 were in force until 1991 when the new, 12.04.1991 Geological Law has been passed. In 1992 the new guidelines for assessment of mineral deposits were issued, replaced in 2002 with the "Principles of the assessment of mineral deposits" (see Zasady… 2002). In the latter document the strict requirements concerning the density of exploration wells for assessment categories C_1 and B were cancelled and the decision was left to the authors of assessment reports.

The resources of Zn-Pb deposits explored with the drillings were calculated with the use of polygonal ("Boldyrev") method. This method assumes that the values of parameters measured in a particular well are valid also for its neighborhood within whole polygonal block (Nieć 1990). Hence, for sparse grids single and not always credible information about ore mineralization was extended over surprisingly large areas. Serious problems have appeared at the initial stage of exploration. Drilling equipment used before the middle 1970-ties did not ensure the proper core recovery, which forced the usage of additional information obtained from cuttings observations. Although special calculation procedures were implemented, even the corrected grades of metals based on well data commonly differed from those obtained later from ore-grade control run during mining operations (Wnuk et al. 2007). It was found that the displacement of cuttings in the wells might result in positioning of ore bodies beneath their true localization (Szuwarzyński 1983).

The methodology of exploration as well as reserves calculation and categorization applied in the 1950-ties provided credible results only for central parts of deposits in the Olkusz region where high-grade, continuous ore bodies occurred. Their exploitation was based upon assessment at C_1 category. Generally, subsequent mining operations confirmed the spatial models of ore bodies presented in the early assessment reports. For B-category the estimation errors of ore and metallic zinc resources did not exceed allowed error limit ±20% (Niedzielski 1985). However, when mining operations approached the marginal, lower-grade and uncontinuous parts of the Olkusz region deposits the assessment and calculation methodology appeared to be less efficient and hardly applicable to rather limited sizes of ore bodies (Blajda 1993). Similar mineralization patterns were found in other parts of the Upper Silesian Zn-Pb District. As a result, the application of traditional assessment methods to nest-like ore bodies gave rise to significant overestimations of ore reserves (Blajda 2010). Moreover, the maps of resources distribution provided erroneous impression of horizontal continuity of mineralization despite variable positions of ore bodies in the vertical sequence.

In order to obtain more realistic information on economic value of undeveloped deposits the methodology of resources calculation and categorization must have been modified. The new assessment principles for undeveloped deposits were prepared in 2006 at the order of the Department of Geology and Geological Concessions of the Ministry of Environment (Blajda et al. 2006).

2.2. Criteria for delineation of ore deposits and methods of evaluation of spatial distribution of the resources of undeveloped deposits

The criteria applied for resources estimations of undeveloped Zn-Pb ore deposits were issued by the Minister of Heavy Industry on April 18, 1975. These criteria included several parameters dependent on ore types, planned mining methods and depths to ore bodies.

Basic criterion for evaluation of resources was 1.7 wt.% Zn and 2.0 wt.% Pb cut-off grade.

The minimum deposit thickness was determined as 2.0 meters. Barren rocks in both the top and the bottom of ore bodies might have been included to the ore body if the total Zn or Pb content after such inclusion is below cut-off value. Such attempt resulted in both the overestimation of ore resources and the deformation of real geometry of ore bodies.

The first attempts to more realistic estimations of Zn-Pb ore resources in Poland were undertaken in 1992, after the amendment of the Geological Law. The new, modified criteria, respecting mining exigencies, were introduced. Ore bodies were determined by the cut-off grade 2.0 wt.% Zn+Pb in sulphide forms. Instead of minimum thickness, the new parameter the minimum zinc accumulation on 1 m^2 was adopted. The resources of oxidized ores were categorized as sub-economic due to low grade, which made their processing unprofitable and environmentally hazardous.

The recalculation of ore resources in developed deposits using the new criteria resulted in their reduction by 60% (Bilans zasobów… 1993). Similar results were obtained from verification of the resources of undeveloped deposits (Kurek, Gładysz 1993; Blajda 2006b). Moreover, the verification proved the nest-like geometry of peripheral deposits. The corrected criteria defining ore bodies, reduced the share of "positive" wells to only 30% of total number of exploration drillings (Table 2).

TABLE 2

Exploration details of undeveloped Zn-Pb ore deposits applying the new criteria implemented in 1992 (after Blajda 2006b)

TABELA 2

Zestawienie wyników rozpoznania niezagospodarowanych złóż rud Zn-Pb przy uwzględnieniu kryteriów bilansowości z 1992r. (wg Blajdy 2006b)

Deposit (year of basic assessment report completion)	Number of wells completed within the reserves calculation blocks	Number of positive wells (share of total number of exploration wells)	Drilling grid within the resources calculation blocks [m]	Assessment category
Laski (1980)	268	70 (26%)	150–75	$B+C_1$
Sikorka (1977)	107	12 (11%)	200–100	C_1
Chechło (1977)	63	12 (19%)	300–150	C_1+C_2
Jaroszowiec-Pazurek (1987)	11	2 (18%)	500–300	C_2
Gołuchowice (1988)	430	88 (20%)	200–100	C_1
Zawiercie I (1991) – report	322	107 (33%)	240–100	C_1
Zawiercie II (1990)	113 66	17 (26%) 12 (11%)	200–100 750–600	C_2 D
Rodaki-Rokitno Szlacheckie (1977)	79	18 (23%)	450–250	C_2
Poręba (1965)	50	12 (24%)	400–200	C_2
Siewierz (1991)	50	8 (16%)	350–200	C_2

3. New criteria for evaluation of assessment categories of undeveloped Zn-Pb ore deposits

3.1. Formal requirements for assessment of a deposit or its part

Legal regulations on the assessment of mineral deposits in Poland, implemented in 1950 adopt four assessment categories: C_2, C_1, B and A. The new regulations of the Minister of Environment issued in 2001 and 2005 added an additional category: D, in which resources estimation is based on data obtained from dispersed, isolated wells. The requirements for resources assessment assigned to particular categories were determined descriptively and quantitatively. The quantitative measure of the accuracy of assessment was the allowed error (ε) of evaluation of mean values of deposit parameters and its resources. The following permissible values of estimation error were accepted:

Assessment category	Estimation error (ε) [%]
D	>40%
C_2	up to ± 40%
C_1	up to ± 30%
B	up to ± 20%
A	up to ± 10%

The estimation error (ε) is decisively controlled by the variability of deposit parameters, which can be determined using statistical or geostatistical modeling (Nieć 1990). According to recommendations for the assessment procedures of mineral deposits (Zasady … 2002), the variability model of deposit parameters should be determined with geostatistical methods.

The geostatistical description of variability is based upon the variogram, which shows the structure of variability of particular parameter depending on the distance between observation sites. The variogram allows to determine the range (radius) of autocorrelation and the share of random and non-random components of variability of given parameter for any distance between observation sites (Mucha 1994). The autocorrelation radius enables the determination of the sizes of uniform parts of a deposit (ore body). Moreover, geostatistical methods can be applied also to contouring of deposits and to estimations of the accuracy of assessment and reserves calculations.

3.2. The principles of resources categorization based on their assessment accuracy

The geostatistical studies of Upper Silesian Zn-Pb deposits focused on variability of Zn contents were based bon data originated from sampling of both the mine workings

(Blajda 1993, 1995; Mucha 2002) and drill cores (Nguyen 1994; Blajda 1995; Blajda, Dolik 1995). They reveal the significant role (60–70%) of non-random component in the variability of Zn contents. The autocorrelation radii of Zn contents determined from geostatistical models are listed in Table 3.

TABLE 3

Autocorrelation radii determined from geostatistical variability models of Zn contents in the Upper Silesian Zn-Pb ore deposits

TABELA 3

Zestawienie zasięgów autokorelacji według geostatystycznych modeli zmienności zawartości cynku w złożach rud Zn-Pb obszaru górnośląskiego

Source data	Mine	Autocorrelation radius [m]
Samples collected in mine workings	“Pomorzany” (central part) “Pomorzany” (eastern part) “Trzebionka” (II ore zone)	100–60 75–50 130–70
	average	75
Weighted averages of Zn contents in drill cores	“Pomorzany” (eastern part) “Klucze” deposit	150–75 200

The new method of resources categorization for undeveloped deposits is proposed, based on the extrapolation procedure of data from positive wells along the distances corresponding to autocorrelation radii of deposit parameters. The radii were determined from geostatistical variability models of Zn-Pb ore deposits.

The geostatistical data demonstrated that average diameters of ore bodies, according to the data from mines workings are 75 meters whereas according to the data from drillings are up to 150 meters. Thus, it was proposed that at the present stage of exploration of Zn-Pb ore prospects and assuming the nest-like geometry of ore bodies, their horizontal contours may be defined by circles of radii $r_1 = 37.5$ and $r_2 = 75.0$ meters. Ore resources within the circles are categorized depending on position of ore zones in the lithostratigraphic column.

The experience gained from exploitation of Upper Silesian Zn-Pb deposits, demonstrates that the portion of the Ore-bearing Dolomite corresponding to the Góraždže Beds can be recognized as the main lithostratigraphic unit hosting the ore bodies (it is named DK1 ore zone). Considering geostatistical evaluation of the accuracy of deposit assessment, based on data from mine workings (Mucha 2002), it was accepted that within the radius $r_1 = 37.5$ meters, estimated resources may be considered as evaluated in C_1 category (Indicated) and those contained within the area extrapolated to radius $r_2 = 75$ meters as evaluated in C_2 (inferred) category (Fig. 3).

Contours of ore bodies hosted in the Ore-bearing Dolomite above and below the DK1 ore zone (named DK2 and DK3, respectively) are defined by circles of radius 37.5 meters and their reserves are categorized as C_2.

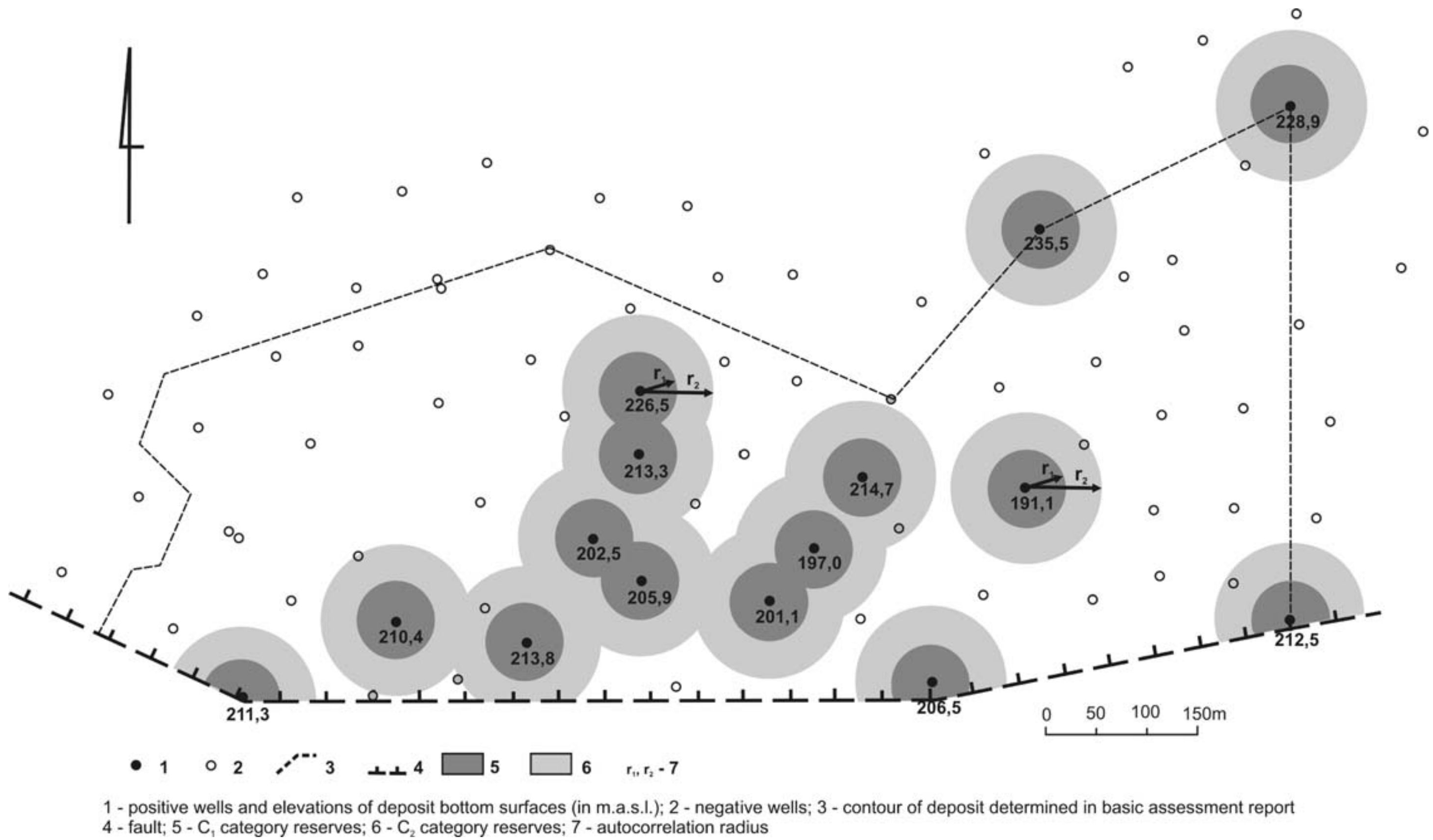

Fig. 3. Principles of categorization of Zn-Pb ore reserves in DK1 ore zone – example from the eastern part of the "Laski" deposit

Rys. 3. Zasady kwalifikacji zasobów złóż rud Zn-Pb w poziomie DK1 na przykładzie wschodniej części złoża „Laski"

Ore accumulations in the Roethian and Devonian carbonates were ascribed to D category with autocorrelation radius 37.5 meters.

4. Calculation methods of ore resources in undeveloped deposits

Considering the nest-like geometry of ore bodies, and in order to verify the assessment of undeveloped Zn-Pb ore deposits the new version of criteria for resources evaluation was proposed. For sulphide ores these new criteria do not differ significantly from those implemented in 1992 (Nieć et al. 1992) except for minimum zinc accumulation index which was reduced from 7 m% to 5 m%. Considering the growing interest in oxidized Zn-Pb ore in the world market, the separate criteria were proposed for these ores. Subeconomic reserves were cancelled for both the sulphide and the oxidized ores. The new economic criteria were approved in the 9.01.2007 Regulation of the Minister of Environment.

The resources calculation method for undeveloped deposits is a consequence of applied categorization method. The areas of ore bodies are represented by circles of radius 37.5 meters whereas the deposit parameters of ore bodies correspond to those measured in

TABLE 4

Criteria for assessment of Zn-Pb ore deposits
(introduced through the Regulation of the Minister of Environment from 9.01.2007)

TABELA 4

Kryteria bilansowości dla dokumentowania złóż rud cynku i ołowiu wprowadzone
Rozporządzeniem Ministra Środowiska z dn. 9 stycznia 2007 r.

Lp.	Parameter	Unit	Cut-off value
Sulphide Zn-Pb ore deposits			
1.	Cut-off grade (combined Zn+Pb in sulphides) in contouring sample despite oxidation degree of ore	%	2
2.	Minimum weighted average of combined Zn+Pb content (sulphide) in deposit including barren intercalations	%	2
3.	Cut-off ore accumulation index in ore zone	m%	5
4.	Maximum depth to deposit bottom surface	M	500
Oxidized Zn-Pb ore deposits			
1.	Cut-off grade (Zn) in contouring sample	%	5
2.	Minimum weighted average of Zn contents in deposit including barren intercalations	%	5
3.	Cut-off ore accumulation index in ore zone	m%	10
4.	Maximum depth to deposit bottom surface	M	500

central exploration well. Resources of ore bodies hosted within the DK1 ore zone are ascribed to C_1 category, those hosted in both the DK2 and DK3 ore zones belong to C_2 category and those located in Roethian and Devonian carbonates represent D category.

In the DK1 ore zone resources in C_2 category can be assessed, as well, by extrapolation of data from a positive well within 75-meters radius. At drilling grids ≥150 meters the resources of C_2 category are the difference between those calculated for radii 75 and 37.5 meters. For grids less than 150 meters the ore field is contoured by the circle of radius 75 meters (Fig. 3). Hence, in C_2 category the deposit area is the difference between the 75-meters circle and the area/areas located within this circle. Both the ore and metal resources are calculated using average values of parameters taken from all wells located within the 75-meters circle. Resources are calculated separately for each lithological horizon.

Boundaries of any deposit are determined by the contour of an area in which both the grade ores and ore manifestations were found. The latter are e.g., zones of low-grade ore (below cut off limit), accumulations of Fe-sulphides, calcite, dolomite and barite, which commonly form aureoles around the ore bodies. Additionally, the ore bodies located in undolomitized Gogolin Beds were also ascribed to ore manifestations. Such data are presented on special maps (maps of mineraluization phenomena) and repeated on resources assessment maps. It is a new element in assessment practice. Taking into account highly irregular distribution of mineralization within the vertical column of ore deposits, interpreted faults are presented also on ore resources maps.

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REFERENCES

Bilans zasobów kopalin i wód podziemnych w Polsce wg stanu na 31.XII.1992r. Wyd. PIG Warszawa, 1993.

Bilans zasobów kopalin i wód podziemnych w Polsce wg stanu na 31.XII.2007r. Wyd. PIG Warszawa, 2008.

Blajda R., 1993 – The geometric-mathematical model of the zinc and lead deposits from the Olkusz region. Geolog. Quart. vol. 37, nr 2, p. 176–188.

Blajda R., 1995 – Weryfikacja geostatystycznego modelu złoża rud Zn-Pb wschodniej części kopalni „Pomorzany” na podstawie danych z rozpoznania górniczego. Arch. WGGiOŚ, AGH.

Blajda R., 2006a – Analiza możliwości zagospodarowania złoża rud Zn-Pb „Klucze” z punktu widzenia modelu jego budowy. Prz. Górn., t. 62, nr 6, p. 7–13.

Blajda R., 2006b – Ocena bazy zasobowej i możliwości wykorzystania niezagospodarowanych złóż rud cynku i ołowiu obszaru śląsko-krakowskiego. Prz. Górn., t. 62, nr 6, p. 1–7.

Blajda R., 2009 – Weryfikacja zasobów niezagospodarowanych złóż rud Zn-Pb obszaru górnośląskiego w świetle nowych zasad ich dokumentowania. Kwart. AGH Geologia. t. 35, z. 2/1, p.115–122.

Blajda R., 2010 – Ocena stopnia rozpoznania i bazy zasobów surowcowych niezagospodarowanych złóż rud cynku i ołowiu obszaru górnośląskiego według nowych zasad dokumentowania. Biul. PIG, nr 439, p. 281–288.

Blajda R., Dolik M., 1995 – Opracowanie modelu geometrycznego złoża „Klucze” na podstawie zawartości Zn i Pb w profilach otworów wiertniczych. Arch WGGiOŚ AGH.

Blajda R., Nieć M., Przeniosło S., Szuwarzyński M., Kurek S., 2006 – Opracowanie metodyki określania kategorii rozpoznania, wyznaczania granic złóż i obliczenia zasobów. Sprawozdanie z prac realizowanych w ramach tematu: „Przedokumentowanie niezagospodarowanych złóż rud cynku i ołowiu zgodnie z wymogami zagospodarowania przestrzennego i możliwościami zagospodarowania złóż". Arch. CAG PIG, Warszawa.

Bogacz K., Dżułyński S., Harańczyk C., Sobczyński P., 1975 – Origin of the ore – bearing dolomite in the Triassic of the Cracow – Silesian Zn-Pb ore district. Rocz. Pol. Tow. Geol., vol. 45, p. 139–155.

Kurek S., 1993 – Problems of modelling of Zn-Pb ores of the Mississippi Valey-type in the sediments of the Younger Paleozoic. Geol. Quart., vol. 37, p. 147–155.

Kurek S., Gładysz J., 1993 – Weryfikacja zasobów złóż rud cynku i ołowiu na tle wymagań ochrony środowiska. Arch. PG S.A. Kraków.

Mucha J., 1994 – Metody geostatystyczne w dokumentowaniu złóż. Skrypt AGH. Kraków.

Mucha J., 2002 – Struktura zmienności zawartości Zn i Pb w śląsko-krakowskich złożach rud Zn i Pb. Studia, Rozprawy, Monografie PAN. Nr 108, pp.149.

Nguyen D.H., 1994 – Charakterystyka geologiczno-górnicza i problem rozpoznania złoża rud cynkowo--ołowiowych „Pomorzany". Arch. WGGiOŚ.

Nieć M., 1990 – Geologia kopalniana, Wyd. Geol. Warszawa.

Nieć M., 1997 – Złoża rud cynku i ołowiu. W: Surowce mineralne Polski. Wyd. CPPGSMiE PAN, Kraków, p. 9–46.

Nieć M., Blajda R., Niedzielski B., 1993 – Zinc-lead ore deposit in Lower Triassic (Roethian) dolomites at Bolesław (Olkusz region, Poland). Geol. Quart., vol. 37, p. 157–171.

Nieć M., Szuwarzyński M., Kurek S., 1992 – Projekt kryteriów bilansowości dla dokumentowania stratoidalnych złóż cynku i ołowiu w skałach węglanowych. Arch PG S.A. Kraków.

Niedzielski B., 1985 – Analiza informacji z wybranych dokumentacji geologicznych złóż rud cynku i ołowiu oraz doświadczeń z praktyki ich sporządzania i użytkowania. W: Analiza przydatności dokumentacji złóż rud Zn-Pb dla potrzeb projektowania. Arch. WGGiOŚ AGH.

Przeniosło S., Bąk B., Radwanek-Bąk B., Smakowski T., 1992 – Analiza gospodarki rudami cynku i ołowiu w Polsce. Wyd. PIG, Warszawa.

Sass-Gustkiewicz M., 1985 – Górnośląskie złoża rud Zn-Pb w świetle migracji roztworów mineralizujących. Zesz. Nauk. AGH, nr 31, pp. 119.

Smolarska I., 1968 – Charakterystyka złoża rud cynku i ołowiu kopalni „Trzebionka". Pr. Geol. Kom. Nauk. Geol. PAN, oddz. w Krakowie, t. 11/1, pp. 61.

Szuwarzyński M., 1983 – O porównaniu formy złoża stwierdzonej w wyrobiskach górniczych z formą określoną na podstawie wierceń. Prz. Geol., 2, p. 81–83.

Szuwarzyński M., 1996 – Ore Bodies in the Silesian-Cracow Zn-Pb district, Poland. Prace PIG, Warszawa, CLIV, p. 9–24.

Wnuk R., Retman W., Walczak K., Piątek G., Adamczyk Z., Kubański W., 2007 – Prognoza przyrostu zasobów niektórych złóż rud siarczkowych rejonu olkuskiego (z uwzględnieniem stanu zasobów rud tlenkowych) w aspekcie ich potencjalnego zagospodarowania. Mat. Konf. „Górnictwo cynku i ołowiu na początku XXI wieku", ZGH Bolesław S.A.

Zasady dokumentowania złóż kopalin stałych. Min. Środ. Kom. Zasobów Kopalin, Warszawa, 2002.

NOWA METODYKA KWALIFIKACJI I OBLICZANIA ZASOBÓW NIEZAGOSPODAROWANYCH ZŁÓŻ RUD CYNKU I OŁOWIU OBSZARU GÓRNOŚLĄSKIEGO

Słowa kluczowe

Górnośląskie złoża rud Zn-Pb, metodyka dokumentowania, kryteria bilansowości, zasoby

Streszczenie

Po wielu wiekach intensywnej eksploatacji górnośląskich złóż rud cynku i ołowiu nastąpiło znaczne wyczerpanie ich zasobów. Wydobycie rud Zn-Pb prowadzi obecnie tylko kopalnia „Olkusz-Pomorzany". Nadzieje na przedłużenie funkcjonowania krajowego górnictwa rud Zn-Pb wiąże się z niezagospodarowanymi złożami rejonu olkuskiego i zawierciańskiego. Udokumentowano je w latach 1970–1990 ubiegłego wieku. Złoża badano pionowymi otworami z powierzchni, ustalając kategorię rozpoznania w zależności od gęstości sieci wierceń. Zasoby złóż liczono metodą wieloboków Bołdyriewa. Zakłada ona, że wartości parametrów interwałów rudnych określone w otworze centralnym dotyczą także całego wieloboku. Przyjęty schemat nie budził zastrzeżeń w trakcie eksploatacji bogatych, ciągłych na znacznej przestrzeni ciał rudnych występujących w centralnych rejonach górnośląskiego zagłębia kruszcowego. Niezagospodarowane złoża rejonu olkuskiego i zawierciańskiego usytuowane są w peryferyjnych częściach regionu. Z rozpoznania wiertniczego wynika, że mineralizacja Zn-Pb występuje w nich przede wszystkim w formie rozproszonych w planie i w pionie skupień gniazdowych. Przy założeniu gniazdowego modelu złóż koniecznym stało się odejście od tradycyjnych metod ich dokumentowania. Zaproponowano procedurę szacowania zasobów takich złóż, polegającą na ekstrapolacji informacji z otworów pozytywnych do odległości wynikającej z promienia autokorelacji (zasięgu wpływu informacji). Wyznaczono go na podstawie wyników badań geostatystycznych modeli zmienności zawartości cynku w złożach eksploatowanych. Przyjęto, że zasoby szacowane są w otoczeniu otworów rozpoznawczych w obrębie okręgów o promieniu 37,5 m w kategorii C_1 i w odległości do 75 m w kategorii C_2. Granice obszaru złożowego wyznacza kontur obszaru, w którym stwierdzono pośrednie oznaki mineralizacji.

NEW METHODOLOGY OF RESOURCES CATEGORIZATION AND CALCULATION FOR UNDEVELOPED ZN-PB ORE DEPOSITS IN THE UPPER SILESIAN ORE DISTRICT

Key words

Upper Silesian Zn-Pb ore deposits, assessment methodology, economic criteria, and resources

Abstract

After long history of mining of Zn-Pb ore deposits their resources are considerably exhausted.

The "Olksz-Pomorzany" is the only active mine. Further mining is possible of undeveloped deposits in Olkusz and Zawiercie areas. They were explored since 1970–1990 with the use of vertical boreholes. The borehole density was the basic criteria for estimation of resources assessment accuracy. Resources were calculated with the use of polygonal (Boldyriew) method. The deposit parameters defined in particular boreholes were assigned individually to the whole surrounding polygons. This method was undisputable in the case of most rich startoidal ore bodies (ore zones). Undeveloped deposits are composed of several local, net like ore bodies horizontally and vertically dispersed. For assessment of their resources a new approach was proposed based on limited extrapolation of borehole data up to the distance corresponding to the autocorrelation radii of zinc content. It was evaluated by geoststistical study of zinc content variation (zinc content variograms). Within the circle with 37.5 m radii, surrounding each borehole, resources were evaluated in C_1 (indicated) category and up to 75 m in C_2 (inferred) category. The boundary of deposit defines the limit of the area on which indirect phenomena of mineralization processes were registered (Zn, Pb below cut off limit, marcasite, calcite, barite).