

THE NEED AND ADVANTAGES TO INTENSIFY EXPLORATORY AND EVALUATIVE WORKS ON THE AREAS OF UNDEVELOPED ZINC AND LEAD ORES' DEPOSITS OF THE SILESIAN AND CRACOVIAN REGION

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Abstract:

Zinc and lead metal ores are minerals intended for strategically producing raw materials for the Polish economy, as indicated in the key Polish document: State Raw Materials Policy (PSP2050). It was specified among others that an important factor that will influence the development of Polish economy will be the access to key mineral raw materials from domestic resources. Currently Polish Zn-Pb ores mining no longer exists as the last operating mine Olkusz-Pomorzany that belonged to the Mining and Metallurgic Plant "Bolesław" Joint Stock Company due to the depletion of resources finished extraction in 2020. Despite this fact there still are areas of great potential in the scope of these minerals in Poland. It is the Zawiercie region, where there has been no extraction of these ores so far and is believed to have the best perspectives for future development. One should connect with this region the nearest future of functioning of the domestic Zn-Pb ores' mining. It is in this region that the "Zawiercie 3" ore is situated. The ore was documented in 2014 by a private investor within the framework of the permit to search for and identify Zn-Pb ore deposits and it is currently the largest as to resources Zn-Pb ores' deposit in Poland. Its resources are currently over 35 million tonnes, which constitutes app. 39% of all the documented balance sheet resources of Zn-Pb ores in Poland. The presented geological works performed by the private investor on the area of the "Zawiercie 3" ore and the results that were achieved thanks to them clearly indicate that well-designed and thoroughly performed exploratory and evaluative works that combine international standards and Polish guidelines can significantly influence the degree of documentation and the increase of resources in undeveloped Zn-Pb ores' deposits.

Key words: Zn-Pb ores, Zawiercie region, exploratory and/or evaluative works, raw materials safety

INTRODUCTION

Obviously metallic raw materials are an indispensable element for production in many technologies and they are a key to the performance of the planned power transformation. Pursuant to the *State Raw Materials Policy* (hereinafter referred to as PSP2050) (Regulation of the Council of Ministers of 1st March 2022) for zinc and lead ores, they are in the group of minerals for the production of raw materials strategic for the Polish economy.

Despite the fact that Zn-Pb (zinc and lead) ores' mining is currently out of operation in Poland, the country still has significant potential of resources regarding sulphate zinc and lead ores that can satisfy the domestic economy needs in the future. In Poland the stratoidal MVT (Mississippi Valley Type) Zn-Pb ores' deposits connected with the Triassic carbonaceous formations of the Silesian and Cracovian region situated in the N and NE edge of the

Upper-Silesian Coal Basin have been of the largest importance [1, 2, 3, 4, 5, 6]. This region is considered the largest of the type in the world. Its area has distinguished five regions: the Tarnowskie Góry region, the Chrzanów region, the Bytom Region, the Olkusz region and the Zawiercie region (Figure 1), whereas the first three are already only of historical importance [1]. Whereas the Olkusz and the Zawiercie regions are considered as the most prospective regions for further development [1, 2]. According to data included in the *Balance sheet of the minerals' deposits in Poland as of 31.12.2021*, in the Olkusz region there are 11 documented Zn-Pb ores' deposits of total resources amounting to 55.794 m. tons, whereas 34.053 m. tons are balance sheet resources and 21.741 m. tons are off-balance sheet resources.

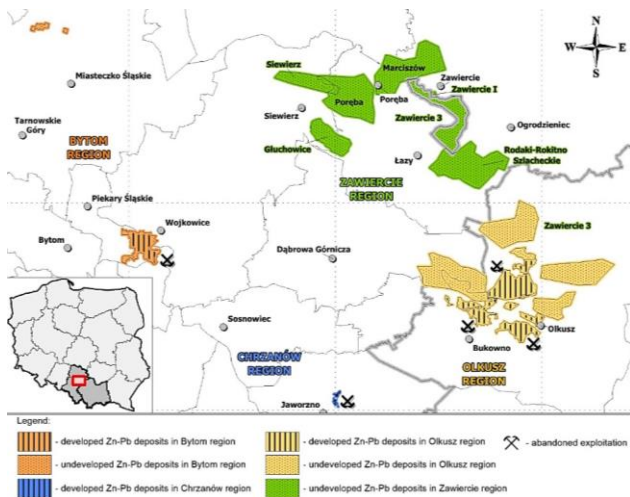


Fig. 1 Location of Zn-Pb deposits and deposit areas in the Silesian and Cracovian region
Source: [14].

Out of 11 Zn-Pb deposits, five are no longer mined: “Bolesław”, “Klucze I”, “Krzykawka”, “Olkusz” and “Pomorzany”. The remaining 6 deposits: “Klucze”, “Chechło”, “Laski”, “Laski 1”, “Sikorka” and “Jaroszowiec-Pazurek” are deposits that have not been mined so far. In most deposits, the condition of development was specified as R, meaning that they are deposits of resources evaluated in detail [3]. Only the “Chechło” and “Jaroszowiec-Pazurek” deposits were classified as deposits of resources evaluated initially (P). The total area of undeveloped Zn-Pb deposits in this region amounts to almost 50 km² and total resources were estimated at the level of 26.956 m. tons, out of which 20.217 m. tons are balance sheet resources and the remaining ones – off-balance sheet resources. In case of the Zawiercie region in which Zn-Pb ores have not been mined so far, there are 7 documented zinc and lead deposits of total area of over 75 km² and balance sheet resources amounting to 56.925 m. tons (Figure 1). Four deposits have the status of initially evaluated resources: the deposits “Marciszów”, “Poręba”, “Rodaki-Rokitno Szlacheckie” and “Siewierz”. Whereas the condition of development of 3 deposits: “Gołuchowice”, “Zawiercie I” and “Zawiercie 3” was specified as R meaning that it is a deposit of resources evaluated in detail. Whereas the “Zawiercie I” Zn-Pb ores’ deposit in the category C₁+C₂ currently has the shape of two triangles of a total area of 24.18 ha and resources amounting to only 338 thous tons (within its borders, there are 15 “historical” openings situated, out of which only in 4 the presence of Zn-Pb ores that meet the balance sheet criteria was confirmed) [3, 7]. On the other hand, in the “Gołuchowice” and “Zawiercie 3” deposits there are app. 92% of resources documented in this region. At this juncture we should point out to the fact that the most abundant deposit not only for the Zawiercie region but for all the above mentioned is the “Zawiercie 3” deposit, documented for the first time in 2014 by the private investor: Rathdowney Poland Limited Liability Company (hereinafter referred to as the Company, entrepreneur, investor). Their current total balance sheet resources are 35.146 m. tons [3, 8], which constitutes adequately app. 62% of the

documented balance sheet resources of the Zawiercie region and app. 39% of all documented balance sheet resources of Zn-Pb ores in Poland. Before the year 2014 within the border of the current deposit “Zawiercie 3” there existed two previously documented Zn-Pb ores’ deposits – the “Zawiercie I” and “Zawiercie” deposits – the “Zawiercie II” area of total balance sheet resources 19.873 m. tons (Figure 2) [9, 10, 11]. As a result of geological works, including geological works performed by Rathdowney Poland Limited Liability Company in the years 2010-2013 within the Permit No. 26/2010/p of 12.05.2010 “for exploring and evaluating zinc and lead ores on the area comprising parts of 3 Zn-Pb ores’ deposits “Zawiercie I”, “Zawiercie II” and “Rodaki-Rokitno Szlacheckie” and Permit No. 34/2010/p of 2.07.2010 “for exploring and evaluating zinc and lead ores comprising parts of Zn-Pb ores “Zawiercie I” and “Marciszów”, in 2014 there was documented the new “Zawiercie 3” deposit, the balance sheet resources of which were at that time 32.202 m. tons [12, 13]. The deposit in administrative terms is entirely situated in the south-eastern part of the Zawiercie powiat (the Silesian voivodship), on the area of parts of the communes: Łazy, Zawiercie and small parts on the area of the communes Ogradzieniec and Poręba (Figure 2).

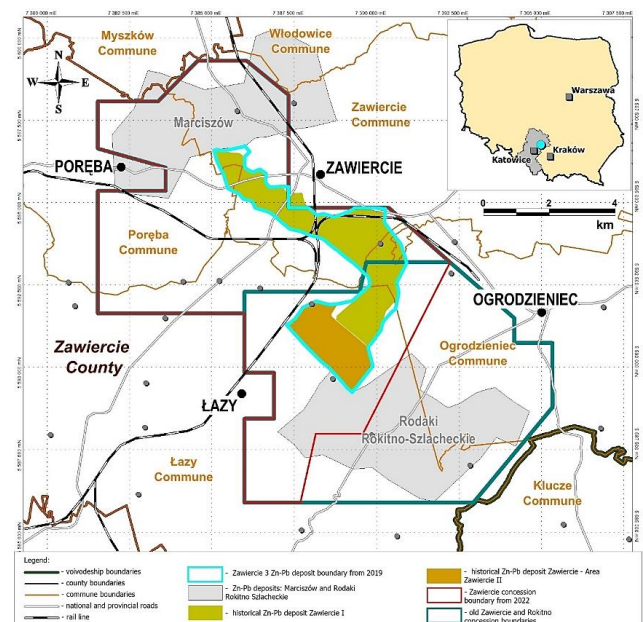


Fig. 2 Location of the “Zawiercie 3” Zn-Pb ores’ deposit in the background of the exploratory and evaluative permits granted to Rathdowney Poland Ltd.

At this juncture it should be pointed out to the fact that in the Zawiercie region there has been no mining so far and before the exploratory and evaluative works performed by Rathdowney Poland Ltd. only the Gołuchowice deposit in the Zawiercie region was considered as sufficiently evaluated [1]. The above data significantly indicate that the best perspectives of Zn-Pb ores’ increase are in the Zawiercie region, which can in the future become sulphate zinc and lead ores’ mining basin satisfying the needs of domestic economy and guaranteeing raw materials safety of our country in this scope. It is possible only in

case of intensification of geological works comprising field works on this area within the framework of the permit for exploring and/or evaluating these ores.

In case of the Zawiercie region in which Zn-Pb ores have not been mined so far, there are 7 documented zinc and lead deposits of total area of over 75 km² and balance sheet resources amounting to 56.925 m. tons (Figure 1). Four deposits have the status of initially evaluated resources: the deposits "Marciszów", "Poręba", "Rodaki-Rokitno Szlacheckie" and "Siewierz". Whereas the condition of development of 3 deposits: "Gołuchowice", "Zawiercie I" and "Zawiercie 3" was specified as R meaning that it is a deposit of resources evaluated in detail. Whereas the "Zawiercie I" Zn-Pb ores' deposit in the category C₁+C₂ currently has the shape of two triangles of total area 24.18 ha and resources amounting only 338 thous. tons (within its borders there are 15 "historical" openings situated, out of which only in 4 the presence of Zn-Pb ores that meet the balance sheet criteria was confirmed) [7]. On the other hand, in the "Gołuchowice" and "Zawiercie 3" deposits there are app. 92% of resources documented in this region. At this juncture, we should point out the fact that the most abundant deposit not only for the Zawiercie region but for all of the above mentioned is the "Zawiercie 3" deposit, documented for the first time in 2014 by the private investor: Rathdowney Poland Limited Liability Company (hereinafter referred to as the Company, entrepreneur, investor). Their current total balance sheet resources are 35.146 m. tons [3, 8], which constitutes adequately app. 62% of the documented balance sheet resources of the Zawiercie region and app. 39% of all documented balance sheet resources of Zn-Pb ores in Poland. Before the year 2014 within the border of the current deposit "Zawiercie 3" there existed two previously documented Zn-Pb ores' deposits, namely the "Zawiercie I" and "Zawiercie" deposits – the "Zawiercie II" area of total balance sheet resources 19.873 m. tons (Figure 2) [9, 10, 11]. As a result of geological works, including geological works performed by Rathdowney Poland Limited Liability Company in the years 2010-2013 within the Permit No. 26/2010/p of 12.05.2010 "for exploring and evaluating zinc and lead ores on the area comprising parts of 3 Zn-Pb ores' deposits "Zawiercie I", "Zawiercie II" and "Rodaki-Rokitno Szlacheckie" and Permit No. 34/2010/p of 2.07.2010 "for exploring and evaluating zinc and lead ores comprising parts of Zn-Pb ores "Zawiercie I" and "Marciszów", in 2014 there was documented the new "Zawiercie 3" deposit, the balance sheet resources of which were at that time 32.202 m. tons [12, 13]. The deposit in administrative terms is entirely situated in the south-eastern part of the Zawiercie powiat (the Silesian voivodship), on the area of parts of the communes: Łazy, Zawiercie and small parts on the area of the communes Ogrodzieniec and Poręba (Figure 2). At this juncture it should be pointed out to the fact that in the Zawiercie region there has been no mining so far and before the exploratory and evaluative works performed by Rathdowney Poland Ltd. only the Gołuchowice deposit in the Zawiercie region was considered as sufficiently

evaluated [1]. The above data significantly indicate that the best perspectives of Zn-Pb ores' increase are in the Zawiercie region, which can in the future become sulphate zinc and lead ores' mining basin satisfying the needs of domestic economy and guaranteeing raw materials safety of our country in this scope. It is possible only in case of intensification of geological works comprising field works on this area within the framework of the permit for exploring and/or evaluating these ores.

This article presents a short outline of "historical" research made before 2010 on the area of the existing "Zawiercie 3" deposit as well as a short description of geological works performed in the years 2010-2014 by the private investor – Rathdowney Poland Ltd. within the framework of the obtained permit for exploring and evaluating Zn-Pb ores on this area. It is the first of three stages/campaigns that the company realized. The second stage was finished with *Addendum No. 1 to the Geological documentation of the "Zawiercie 3" zinc and lead ores' deposit*, approved by the Minister of Environment by virtue of the Decision No. DGK-VIII.4741.23.2019.AJ of 2nd July 2019 [8] and the third one is performed currently. The situation regarding exploratory and evaluative permits possessed by the investor has also changed. Currently Permit No. 26/2010/p no longer exists, and Permit No. 34/2010/p has been extended by a part of the area of the no longer existing, abovementioned permit (area app. 71 km²) and thus the entire "Zawiercie 3" deposit and the adjacent areas are currently within one exploratory and evaluative permit (Figure 2).

The scope of works performed by the private investor in the years 2010-2014 and the basic results that they achieved thanks to them should unequivocally show how important well-designed and thoroughly performed exploratory and evaluative works can be and how significant information on the Zn-Pb ores' deposits of this area they can deliver. Moreover, they also show how intensification of exploratory and/or evaluative works can impact the degree of documentation and the increase of resources in the undeveloped, stratoidal MVT Zn-Pb ores' deposits of the Silesian and Cracovian region.

LITERATURE REVIEW

It was a review of the academic literature on stratoidal Zn-Pb ore deposits of the MVT type, both global and these from the Silesia-Cracow region [15, 16, 17, 18, 19, 20, 21, 22], which are considered to be one of the largest in the world, as well as literature on responsible management of minerals and the need to ensure the security of raw materials [23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43]. Despite the popularity of terms such as "raw materials crisis" and "strategic resources", there is no clear indication in both the world and domestic literature which is the basis for ensuring sufficient quantities of these raw materials in the future. In this article, the research was carried out for Polish zinc-lead metal ores from the "Zawiercie 3" deposit, clearly indicating that in order to obtain strategic raw materials, it is necessary to extract these minerals from deposits, and this is possible

only when the deposits have been documented in detail. It was also analyzed how well-designed and executed exploration and/or appraisal works can influence this. Due to the lack of detailed data in the literature regarding the type, scope and achieved results of both "historical" exploration and appraisal work and the contemporary ones in the area of the "Zawiercie 3" deposit, first of all, the focus was on the analysis of unpublished "archival" geological documentation and the latest geological documentation regarding the "Zawiercie 3" deposit, prepared by a private investor - Rathdowney Polska Sp. z o.o.

METHODOLOGY

The research methodology was adopted, consisting of an analytical review of data regarding prospecting and appraisal works in the area of the current Zn-Pb ore deposit "Zawiercie 3", which was contained in both archival geological [43, 44, 45, 46, 47] and "contemporary" documentation prepared by a private investor - Rathdowney Polska Sp. z o. o., under the concessions granted to it for the exploration and appraisal of Zn-Pb ore deposits (licences no. 34/2010/p and 26/2010/p) [7, 8, 12, 48, 49, 50, 51]. Step-by-step analysis of the stages carried out by Rathdowney Polska Sp. z o. o., geological works, as well as the results obtained as a result of them. A comparison was made of the most important parameters, e.g. the size of resources in condition as before 2010 and after 2014, which allowed to formulate an answer to the question whether modern exploration and appraisal works can bring satisfactory results on undeveloped, thinly explored Zn-Pb ore deposits in the Silesia-Cracow region and whether they can have an impact on ensuring the security of raw materials in this respect.

The scope of works performed before 2010 on the areas of the "Zawiercie I" and "Zawiercie" historical deposits – "Zawiercie II" area

In the Zawiercie region exploratory works were performed from the beginning of 1950s to the end of 1980s by the Polish Geological Institute in Warsaw and by the Geological Company in Cracow. They started with the performance of the first 5 openings of the BM symbol by the Geological Company in Cracow (GC-Cracow) in the years 1953-1954. The next two openings of the Ch symbol were performed by the Non-Ferrous Metals Ores' Deposits Institute of the Polish Geological Institute in Warsaw in the years 1956-1957, which starting from 1961 to 1967 continued drilling works in this area performing the total of 193 openings of the TN symbol. The results from these openings became the basis for the elaboration of the *Geological documentation of zinc and lead ores' deposit in the Zawiercie region in the cat. C₂* [43]. The next stage of works performed by the Polish Geological Institute in Warsaw in the years 1968-1969 comprised the performance of 39 openings of the Z symbol and finished with the elaboration of *Addendum No. 1 to the Geological documentation of the zinc and lead ores' deposit in the Zawiercie region – Region Zawiercie North in the category C₂* [44], which presented in detail the resources in the C₂

category. The next stage of works was performed by GC-Cracow in the years 1970-1974 within the so-called elevated, NE part of the "Zawiercie" deposit, where the total of 302 openings in the network 200x200m were performed. The result of these works was separation from the "Zawiercie" deposit its elevated, NE part and creation of the "Zawiercie I" deposit – *Geological documentation of the "Zawiercie I" zinc and lead ores' deposit in the cat. C₁* [45]. For the remaining so-called lowered/tossed, SW part of the "Zawiercie" deposit, the settlement addendum was prepared *Settlement Addendum No. 2 to the Geological documentation of the "Zawiercie" zinc and lead ores' deposit in the cat. C₂* [46]. The last geological works in the scope of the "Zawiercie I" deposit were performed in the years 1975-1988 and comprised the performance of 107 openings. They constituted the basis for next GC-Cracow's documents updating information on the deposit, which however have not been approved.

Whereas in the lowered/tossed part of the "Zawiercie" deposit named "Zawiercie II", works were performed from 1977 to 1980, however for economic reasons only 25% of the planned drillings – 132 openings covering only a part of the deposit were performed. *Addendum No. 3 to the Geological documentation of the "Zawiercie" zinc and lead ores' deposit in the cat. C₂. The region "Zawiercie II" in the cat. C₂ and beyond the cat. C₂ (estimated resources)* summed up the works [47].

The last geological works performed in these areas were: *Addendum No. 1 to the Geological documentation of the "Zawiercie I" zinc and lead ores' deposit in the cat. C₁+C₂ (DGiKGzk-4791-28/7799/6519/08/EZD)* [9] and *Addendum No. 4 to the Geological documentation of the "Zawiercie" zinc and lead ores' deposit, Region "Zawiercie II" in the cat. C₁+C₂ (DGiKGzk-4791-29/7800/6518/08/EZD)* [10], however within the framework of the elaboration, no additional field works (drillings) were done, and all of the included calculations were based on the results of historical samples from the previously elaborated documents [43, 44, 45, 46]. These addenda were performed in connection with the assumption of new features' criteria: *Regulation of the Minister of Environment of 9th January 2007 amending the regulation on the criteria of the minerals' deposits balance sheet inclusion* (J.o.L. 2007 No. 7 it. 57). The basis for the new estimation of resources in Addenda No. 1 and 4 [9, 10] was a series of elaborations performed within the framework of the performance of the subject ordered by the Department of Geology and Geological Permits of the Ministry of Environment: *"Re-documentation of the undeveloped Zn-Pb ores' deposits in accordance with the requirements of spatial development and the possibilities of deposits' management."* In these addenda for the "Zawiercie I" deposit and "Zawiercie" – region "Zawiercie II" deposit new methods of estimation and qualification of resources were applied. The resources were calculated using the autocorrelation radius method [1].

The scope of works performed in the years 2010-2014 on the "Zawiercie 3" deposit area and their results

The below shortly described geological works performed in the years 2010-2014 constitute the first of three stages/campaigns of exploratory and evaluative works that Rathdowney Poland Ltd. performed in this area. They were performed within two permits granted by the Minister of Environment to Rathdowney Poland Ltd.: Permit No. 26/2010/p of 12.05.2010 within the framework of which were the previously documented deposit areas "Zawiercie" – Region "Zawiercie II" and Permit No. 34/2010/p of 2.07.2010 comprising the deposit areas "Zawiercie I". The detail scope of the designed works including geological works was included in the geological works projects and annexes prepared to these projects constituting enclosures to the permit applications and to applications for the amendment of the permits and their results were included in the *Geological documentation of the "Zawiercie 3" zinc and lead ores' deposit in the category C₁+C₂+D*, constituting their summary [48].

The exploratory and evaluative works performed in the years 2010-2014 comprised four main stages: preparatory works, geophysical research, field works and documentation works.

First stage – preparatory works

It was a very important stage preceding further field works (geophysical and drilling tests), which comprised among others a very detailed analysis of archival materials as well as attempts to "find" the cores from previous drillings. At this point we should emphasize that it was impossible to verify archival data as out of 461 openings performed in the years 1953-1988 in the original areas comprising the "Zawiercie I" and "Zawiercie" – Region "Zawiercie II" Zn-Pb ores' deposits, in the physical sense only single boxes with the core from 35 drilling openings have been maintained [49]. Therefore, a very significant stage of preparatory works was the performance of digital data base comprising archival data from openings drilled up to the year 1988 on the area of both Rathdowney Poland Ltd.'s permits. In order to verify the correctness of archival data in the scope of openings coordinates, which were written down in several systems, including: "1942", "1965" and "1992", an attempt to verify the location in the field of signs-witnesses (concrete pedestals or piping elements protruding above the soil surface) marking the place of historical drillings – it was successful in case of 115 drillings for which the coordinates were measured. This data base comprised apart from "historical" locations also a series of other data, among others: information regarding lithology, stratigraphy, core yield, results of ore chemical analyses etc. Thanks to its adequate construction, all key information could be imported to other databases at further stages of work to plan geological works and resource estimation correctly.

Second stage – geophysical tests

This stage was preceded by the preparation of geodetic network for the planned works (delineating in the area of profile lines for the selected parcels). The geophysical tests were performed using the method of Induced

Polarization (IP), in the variants "pole-dipole" and "gradient-array" on the selected measurement parcels: on the area Permit No. 26/2010/p tests along 15 IP lines of total length 17.35 km were made and on Permit No. 34/2010/p they were 14 lines of 9.71 km. The results of these tests served for verification of the correctness of the assumed main mineralization trends, which were intended for designing of geological works.

Third stage – field works

The third most important stage of works covering not only drilling but also important field works connected with the core was preceded by the field visit of the places of the planned drillings and detailed analysis of GIS spatial data: topographic and satellite maps, aerial photographs etc. The purpose was among others to design optimum location of drilling equipment so that the area taken for drilling be limited as much as possible, to mark the best access roads to and from the area of drillings and locations closest to fire hydrants in order to obtain water for drillings etc. All "new" openings before drilling were marked in field by authorized surveyors and the marked geodetic points were stabilized with pickets 0.1m over the ground and additionally marked with 1.2 m high stakes [12]. Each time before starting drilling works irrespectively of the property ownership structure, agreements allowing access to property for the purpose of geological works performed with the drilling method were concluded and protocols of site entry and photographic documentation were made.

The total of 218 new drilling openings were made. Their total surface was 27,779.5 m and they were from 77.0 to 223.0 m deep (the average 127.0 m) [12]. The majority of the openings were vertical and only 4 of them were made under the angle of 30° from the area surface. The drilling works were performed by 6 drilling companies (both Polish and foreign ones) and comprised among others repetition of 31 most resourceful historical drilling openings performed for the verification of historical data. The other openings were made in accordance with the known trends of mineralization in the distance similar to autocorrelation radius.

At this juncture it should be pointed out that Rathdowney Poland Ltd. undertook a series of actions (both those resulting from the provisions of law and additional ones) connected with environment protection, including protection of surfaces, waters, air so that the performed geological and drilling works would cause no threat to natural environment. After the performance of each drilling opening, on the basis of the geological supervision decision, it was immediately liquidated in accordance with the highest standards and applicable provisions of law and the area for drilling was restored to the initial condition from before starting drilling works. There were also geodetic control measurements made: as-built measurements of each opening and a geodetic survey was made from the performed measurements. The protocols of leaving the site along with the photographic documentation were also made.

The core was taken from each of the openings, and it was on an ongoing basis subject to geotechnical profiling and detail geological profiling (among others: detail lithological description, intervals with macroscopically present aggregate mineralization with macroscopic assessment of the percent value of ore minerals etc.).

A very significant element of works was taking samples of cores for laboratory tests and the laboratory tests themselves. The company decided to take samples of cores in accordance with the currently applicable around the world QAQC procedure. Its basis was separation of ore accumulation area (the area of visible mineralization = the total of Zn+Pb sulphates content > 0.5 %) with 4.0 m margin of the surrounding rocks (without visible mineralization) in the roof and in the foot. Both in the ore accumulation area and in the barren areas there were intervals for taking the sample on the basis of the applicable criteria [12]. In order to verify the analytical results in each ore accumulation area there were control samples placed: the so-called blind sample (the sample of barren limestone from quarry in Czatkowice), the standard industrial sample of specified Zn, Pb and Ag content and the so-called duplicate sample, i.e., the repetition of the chemical analysis of the selected sample.

Every separated sample was written down in the adequately designed sampling book and data regarding sampling was entered to the data basis on an ongoing basis.

After finishing actions connected with taking samples from the core, the samples were handed over for testing for the purpose of measurement of the cores' volumetric density, which was performed based on the Polish Norm: The methods of natural stone testing – Determination of density and volumetric density as well as total and open porosity (PN-EN 1936:2010P) and on the internal Rathdowney Poland Ltd.'s internal procedure called "the hydrostatic method" [9].

The total for testing by the accredited laboratories was 6561 samples of cores for the purpose of analytical determination, using the ME-ICP-OES + ICP-AAS and ME-ICP61 + ICP-AES method, of the content of the following elements: Zn, Pb, S, Fe, Ca, Al, Mg, K, Na, Cd, Ag, Ga, Ge, Tl, As, Ba, Be, Bi, Ce, Co, Cr, Cu, Hg, La, Li, Mn, Mo, Nb, Ni, P, Rb, Sb, Sc, Se, Sn, Sr, Ta, Te, Th, Ti, U, V, W, Y, Zr. The analytical determination of the ZnO and PbO and control determination of analytical results were also performed [12].

Photographic documentation of the drilling cores performed in accordance with the boxes numbering was made. It contained the cores both before and after cutting.

At this stage there were also performed among others mineralogical and petrographic tests, test of enrichment of zinc and lead ores, hydrogeological, hydrological, zoological and geological and engineering tests.

Fourth stage – documentation works

It comprised the elaboration of the so-called "basic" documentation of the new Zn-Pb ores' deposit: the *Geological documentation of the "Zawiercie 3" zinc and lead ores' deposit in the category C₁+C₂+D* [9], which was a summary of geological works (including field works) performed

within the limits of Permit No. 26/2010/p and No. 34/2010/p by Rathdowney Poland Ltd. in the years 2010-2013. Moreover, settlement addenda were elaborated: *Settlement Addendum No. 2 to the Geological documentation of the "Zawiercie I" zinc and lead ores' deposit in the cat. C₁+C₂* [50] and *Addendum No. 5 to the Geological documentation of the "Zawiercie" Region "Zawiercie II" zinc and lead ores' deposit in the cat. C₁+C₂* [51]. All the above documents were approved by the Ministry of Environment by virtue of the decisions of 30th July 2014.

The main and thus the most important result of the above described exploratory and evaluative works was documentation of the new zinc and lead ores' deposit "Zawiercie 3" in the category C₁+C₂+D (deposit code in the MIDAS system: RC 17226). It was facilitated by data obtained during geological works, including field works (218 newly performed openings of total surface 27 779.5m), which provided information on the continuity of ores' accumulation in the "historical" deposits: "Zawiercie I" (RC: 13) and "Zawiercie" – Region "Zawiercie II" (RC: 14) and no clear border between them. This allowed merging them into one coherent deposit area and inclusion into the newly documented deposit "Zawiercie 3". Thus, the dominant part of the "Zawiercie I" deposit situated within the borders of the permits owned by Rathdowney Poland Ltd. and the entire "Zawiercie" – Region "Zawiercie II" deposit became a part of the newly documented deposit "Zawiercie 3". The part of the "Zawiercie I" zinc and lead ores' deposit documented at the level of DK1 in the cat. C₁+C₂ remaining beyond the scope of Rathdowney Poland Ltd.'s Permit No. 34/2010/p maintained its existing name "Zawiercie I" and was settled by *Addendum No. 2 to the Geological documentation of the "Zawiercie I" zinc and lead ores' deposit*, which was approved by the Minister of Environment by virtue of the Decision No. DGK-VIII-4741-8199/46/31082/14/MW of 30th July 2014 [50]. The "Zawiercie 3" Zn-Pb ores' deposit created in 2014 was 1227.05 ha, out of which the majority were the areas of "historical" deposits: 875.97 ha of the "Zawiercie I" deposit and 345.23 ha of the "Zawiercie" – Region "Zawiercie II" deposit. One should remember that it is an "artificial" deposit surface, marked with horizontal borders, whose border points are marked by the edge openings with the so-called mineralization symptoms. It is not identical to the actually documented deposit areas and in no way reflects the nature of stratoidal non-continuous and nest-like MVT Zn-Pb ores' deposits. The areas of ore bodies (ore fields/deposit areas) defined by the surfaces of inflow, resulting from the assumed method of resources' calculation, i.e., the so-called autocorrelation method is of much greater importance here. Based on the exploratory and evaluative works performed by the Company, these deposit fields were marked not only in the metalliferous dolomites at the DK1 and DK2 levels as in the previous addenda to geological documentation [9, 10], but also in the Devonian formations and in the diplopore dolomites.

The exploratory and evaluative works performed in 2010-2013 "fructified" with the app. 80% increase in total

deposit fields compared to previously documented ones in the borders of the existing deposit "Zawiercie 3" (Table 1), (Figure 3).

Table 1
Comparison of the documented deposit areas within the "Zawiercie 3" deposit compared to the "historical" Zn-Pb ores' deposits: "Zawiercie I" and "Zawiercie" – region Zawiercie II", decreased proportionally by the deposit areas of the existing deposit "Zawiercie I"

Level and category of evaluation	The area of deposits within the sediment "Zawiercie I"* and "Zawiercie" – region "Zawiercie II" [ha]	The area of deposits within the sediment "Zawiercie 3" [ha]	Area increase [%]
Zn-Pb sulphate ores			
level DD in the cat. C ₂		1.31	
level DK2 in the cat. C ₁		11.17	
level DK2 in the cat. C ₂	11,04	27.02	144,8
level DK2 in the cat. D		24.32	
level DK1 in the cat. C ₁	74,12	86.60	16,8
level DK1 in the cat. C ₂	158,92	173.47	9,2
level DK1 in the cat. D		112.03	
level D in the cat. D		1.26	
Zn-Pb oxidized ores			
level DK1 in the cat. C ₁		0.69	
level DK1 in the cat. C ₂		1.33	
Total	244.08	439.20	79.94

* decreased by the deposit areas that were not included in the deposit "Zawiercie 3" – deposit "Zawiercie I"
Source: [9, 10, 12, 23, 50].

The investor's selection of modern drilling technologies guaranteeing core yield in the deposit zone at the level of app. 90% was also of importance for obtaining such results [48]. As mentioned previously thanks to data from the drillings, it was possible to document for the first time the resources not only at the level of DK1 and DK2, metalliferous dolomites, but also for the first time the resources occurring in the Devonian formations and in the diplopore dolomites were characterized.

Also, for the first time on this area two subtypes of main minerals were separated: the zinc and lead sulphate ores dominant in the deposit and Zn-Pb oxidized ores occurring locally. The first subtype of minerals was found starting from the roof at the level: (level DK1 and DK2) and in the Devonian carbonate formations. Whereas the locally occurring second subtype – oxidized ores were documented in the metalliferous dolomites of the bottom muschelkalk at the DK1 level.

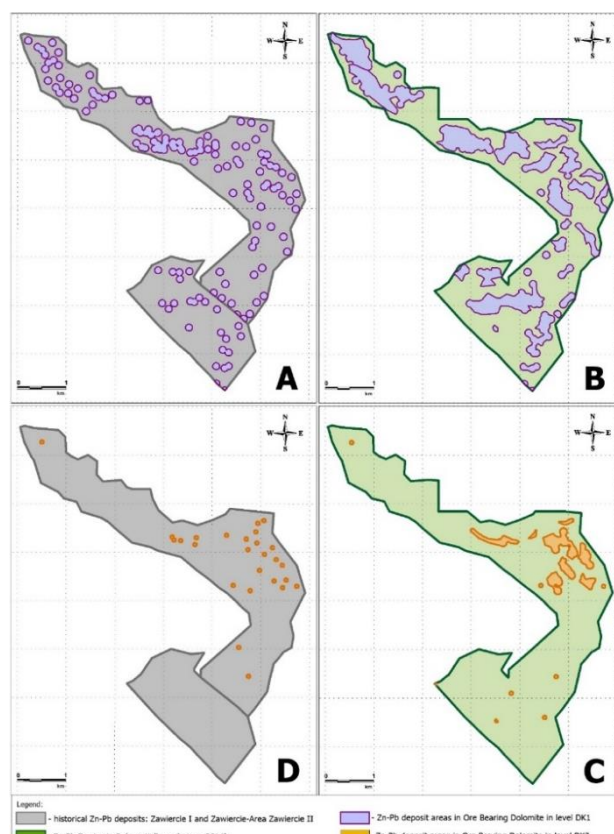


Fig. 3 The areas of deposit fields documented in the metalliferous dolomites at the level of DK1 and DK2 in 2008 [6, 7] and in 2014

Source: [12].

Table 2
Comparison of the documented "Zawiercie 3" Zn-Pb ores' deposit resources in the category C1+C2+D in relation to the total Zn-Pb ores' resources in the historical deposits "Zawiercie I" and "Zawiercie – Region Zawiercie II", proportionally decreased by the deposit fields' surfaces of the existing deposit "Zawiercie I"

	Summary geological resources of the "Zawiercie I" – Region "Zawiercie II" deposit* (DK1+DK2 in the category C ₁ +C ₂)	Geological resources of the "Zawiercie 3" deposit (DD+DK2+DK1+D in the category C ₁ +C ₂ +D)	Increase of resources [%]
Zinc and lead ore	19535.22	32 032.84	63.97
Zinc	1170.64	1 573.10	34.38
Lead	445.94	570.94	28.03

* decreased by the deposit fields' surfaces, which were not included in the "Zawiercie 3" deposit – the "Zawiercie I" deposit
Source: [9, 10, 12, 23, 50].

The share of sulphate ores in proportion to the total deposit resources amounted to app. 99.47% and of the zinc and lead oxidized ores – app. 0.53% [12].

Thanks to proper design of the field works (regular drilling network taking into account the main directions of mineralization trends on this area and close to the autocorrelation model, i.e. in the distance from 50.0m to 100.0m

from the repeated central opening) and thanks to reliable performance, the investor was able not only to significantly increase the exploratory network density on this area but also to drill many more openings with balance sheet mineralization than before. Out of 218 openings drilled by Rathdowney Poland Ltd., 137 turned out to be balance sheet openings, which constitutes app. 63% of all openings. In case of the "Zawiercie I" deposit there was only app. 23% (6) and in the "Zawiercie" – Region "Zawiercie II" only 16% [10].

Due to impossibility of verification of "historical" data caused by the lack of cores – out of 464 "historical" openings drilled on the border of the existing "Zawiercie 3" deposit only 39 currently has a drilling core in the form of single intervals/boxes [49], the Company decided to drill 31 openings that are a repetition of the balance sheet historical openings, including 4 openings with partially maintained core, thanks to which it could "really" compare the results obtained in the course of the performed works with "historical" data.

The above results as well as data from other additional tests (among others geological and engineering tests, hydrogeological tests etc.) unequivocally indicate that the "Zawiercie 3" Zn-Pb ores' deposit meets all basic criteria for the status of the "ideal" deposit for future mining using modern mining technologies and solutions in the scope of environment protection.

The performed tests of technological features of the main mineral also confirmed that zinc and lead ores of the "Zawiercie 3" deposit area have proper features for processing them using the methods of gravitational enrichment and floatation allowing production of zinc and lead concentrates of high quality.

Apart from the abovementioned results that are mainly of deposit and economic importance, the Company succeeded in significant extension and updating of information regarding the conditions of the occurrence of the deposit, among others: new interpretation of non-continuous tectonics was created, classification of the division of the deposit and of the neighbouring regions into 55 structural and tectonic blocks was made, particular geological model of this area was made and on the basis of the performed mineralogical and petrographic tests very detailed characteristics of main types of sulphate mineralization in the deposit was made.

DISCUSSION

The above presented results unequivocally confirm that well-designed and thoroughly performed geological works combining international standards and Polish guidelines can influence the degree of documentation and the increase of resources in the undeveloped deposits, in this case the stratoidal MVT Zn-Pb ores' deposits of the Zawiercie region.

The generally adopted opinion that Poland is a country rich in the natural resources, including metalliferous ores' deposits, has no reflection in their current domestic mining. At present in Poland only one group of metallic raw materials is mined – they are copper and silver ores.

Pursuant to data included in the *Balance sheet of the resources of minerals' deposits in Poland as of 31.12.2021*, their mining in 2021 was 30 million ore tons and compared to previous year it increased by 1.15% [52]. As for exploratory and evaluative works for metalliferous ores, they are intensified only in case of the abovementioned ores as well. As of December 2022 according to the Bulletin of Public Information of the Ministry of Climate and Environment: Geological Permits – Reports and summaries regarding granted permits (including summaries of drilling openings), we have in Poland five "active" permits for mining copper ores (all belonging to the Capital Group KGHM Polish Copper Joint Stock Company) and 10 permits for exploring and/or evaluating these ores, including 7 granted to KGHM Polish Copper Joint Stock Company and 3 granted to private companies. Comparing in case of zinc and lead ores there is currently no granted permit for their mining and the number of "active" permits for their exploring and evaluating is 2. In case of other metalliferous ores, the situation looks alike – no permits for mining and 1 or 2 maximum or no permits for exploring and/or evaluating. This situation actually makes it impossible to perform the supreme target of the assumed by virtue of the Regulation of the Council of Ministers No. 39 of 1st March 2022 *State Raw Materials Policy* (PSP2050), which is to guarantee raw materials safety, also in the scope of metallic raw materials, including zinc and lead ores, which are pursuant to PSP2050 minerals for the production of raw materials strategic for Polish economy. The results of geological works performed in the years 2010-2014 by Rathdowney Poland Ltd. within the permits granted for exploring and evaluating Zn-Pb ores' deposits: Permit No. 34/2010/p and 26/2010/p presented what effects can be achieved in case of undertaking exploratory and/or evaluative works on other undeveloped Zn-Pb ores' deposits of the Silesian and Cracovian region. Only intensification of this type of works can assure the performance of the supreme target of PSP2050, which is raw materials safety of our country. However, in order for this to happen, the performance of works among others PSP2050 in the scope of metalliferous ores should cover two concurrent actions: the education of society and the "encouragement" for private investors to induce them to invest (frequently quite large amounts) in the exploratory and/or evaluative projects, which in nature are burdened with large financial risk. In case of investors the matter seems quite simple. The most important seems that their investment risk is limited, in particular through simplification and mainly shortening of administrative procedures to several months so that the budget assumed by an entrepreneur for the performance of geological works is not "outdated" as a result of lapse of time of sometimes several years from the moment of filing an application until receiving decision on granting the permit for exploring and/or evaluating minerals. Shortening of administrative procedures is of key importance especially in case of investors who already have a permit for exploring and/or evaluating and file and application for its amendment e.g. increasing of the scope of drilling works, which results

from information obtained within the course of the performed works. The second significant issue is the necessity to verify, especially in the financial aspects, organizations, associations and foundations that plan to participate in the proceedings as a party. It would allow to eliminate the so-called “predatory” organizations, the supreme goal of which is not environment protection but benefits, among others financial benefits, and thus it would lead to shortening of the abovementioned permit procedures. It may raise many controversies, but since an entrepreneur applying for being granted a permit for exploring and/or evaluating minerals’ deposits attaches all information required by the provisions of law, including financial information, then why would these organizations not do the same – none of them operating legally should have any problem with this. Currently pursuant to the applicable provisions, each organization, which has been running statutory activities in the scope of environment protection of nature protection for the minimum of 12 months before the date of initiating the proceedings in the case of permit for the investment can apply for such right. At this point it should be emphasized that permits for exploring and/or evaluating minerals comprising geophysical tests and the performance of drilling works in most cases pursuant to the *Act of 3rd October 2008 on making available information on the environment and its protection, participation of society in environment protection and environment impact assessments* (J.o.L. 2022 item 1029) and *Regulation of the Council of Ministers of 10th September 2019 on undertakings that can significantly impact the environment* (J.o.L. 2019 item 1839 – Art. 2 p. 1) are not classified as undertakings that can significantly impact the environment (J.o.L. 2019 it. 1839 – Art. 3 p. 1) and therefore the assessment of the impact of the undertaking on the environment is not required (J.o.L. 2022, item 1029).

Shortly speaking, well-designed geological works and actions aiming at environment protection assure that such activities in no way negatively impact the environment. The adoption of the planned amendment of the geological and mining law (*Draft of 22nd October 2021 on the amendment of the act – Geological and mining law and of some other acts No. UD280, Government Legislation Centre*) would be of advantage for the entrepreneurs, especially in the aspect of minerals’ deposits protection. And as far as education of society is concerned, it should first of all focus on removing a spell of the vision of “outdated” mining, the effect of which are only ecological catastrophes. Strong emphasis should be placed on giving the society reliable information on modern mining methods and actions that are undertaken so as to minimize their impact on natural environments and information on the advantages for local societies and all the citizens. A large problem is treating identically the exploratory and/or evaluative permits and permits for mining minerals, which pursuant to the *Act of 9th June 2011 Geological and Mining Law* (J.o.L. 2022 it. 1072 as amended) constitute two separate activities and obtaining permits for them comprises two different administrative procedures that are not

connected with each other. In case of prognostic and perspective areas, only information and data obtained in the course of exploratory and/or evaluative works can provide information whether the deposit will meet “economic” criteria for the deposits eligible for mining. However, whether an entrepreneur having performed these works will decide to file the application for granting the permit for mining depends also on a series of other conditions, among others social ones or those connected with the environment protection.

Summing up each of us should be aware that transition to clean energy is connected with big challenges in the area of guaranteeing supplies of raw materials indispensable for power transformation [37, 41, 42]. Unfortunately the majority of us have no knowledge what raw materials we mine in the country and what we import and from what countries. Only a change of the approach of the society and facilitations encouraging private entrepreneurs (including foreign ones) to run activities in the scope of exploratory and evaluative works in the scope of minerals’ deposits in our country will enable their intensification and what follows will allow to create a reliable base of resources in our country, which will allow their rational and responsible management. One should also remember that the State Treasury is entitled to the rights to the geological information obtained by the entrepreneurs in the course of exploratory and/or evaluative works pursuant to Art. 99 it. 1 of the *Act of 9th June 2011 Geological and Mining Law* (J.o.L. 2022 it. 1072 as amended), which means that the State Treasury receives geological information, the obtaining of which depending on the scope of works would cost from several dozen to several hundred million Polish zlotys.

The problem of insufficient amounts of critical raw materials to relative to the projected increase in demand due to the constant the population growth and changing consumption modules in the economy is not only a Polish problem, but also a global problem, which is signaled for years by many scientists from around the world, including [23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43].

CONCLUSIONS

Both economic progress and raw materials safety as well as sustainable development cannot be performed without responsible and efficient management of natural resources comprising among others metal ores’ deposits, including Zn-Pb ores. And rational raw materials development is possible only when the domestic resources’ base is well evaluated – i.e., the condition of deposit development is specified as detailed. It takes place only in case of well-designed and well-performed exploratory and/or evaluative works. So, one can very briefly equate raw materials safety and intensification of exploratory and evaluative works in the scope of minerals.

The exploratory and evaluative works performed on the area of the existing “Zawiercie 3” Zn-Pb ores’ deposit clearly show what results they can bring on areas of other

undeveloped Zn-Pb ores' deposits of the Silesian and Cracovian region.

They are among others:

- verification of "historical" data, in case of no physically available core from drilling performed several dozen years ago;
- confirmation and specification of vertical and horizontal range of balance sheet mineralization of Zn-Pb in drill holes as well as the possibility of confirming the presence or lack of continuity of minerals' accumulation between the previously documented deposits' areas;
- thickening of the evaluative net and decreasing the average openings distance and thus its adjustment to the autocorrelation radius model;
- documentation of new deposit areas and what follows increasing of aggregate surface of previously documented deposit fields as well as the possibility to gain a significant increase of resources compared to the previous ones;
- documentation of resources in the levels/pieces that have not been previously documented;
- change of the condition of deposit development from the deposit of preliminary evaluated resources to the deposit of detailed evaluated resources;
- gaining new geological information on the conditions of deposit occurrence and thus verification of the previously assumed geological models.

The advantages of the exploratory and/or evaluative works in the scope minerals are invaluable and there are no negative aspects connected with them. They are the starting point (the initial stage) for guaranteeing national raw materials safety. The next stage is their extraction. In connection with the present economic and geopolitical situation everyone should ask themselves the question whether the planned "green transformation" (power transformation), the basis of which are metallic raw materials, is to be based on the raw materials obtained in our country pursuant to the effective provisions of law by virtue of which only such mining/extracting activities are allowed that are performed in accordance with rational deposit(s) management, strict protection of other elements of natural environment and respecting local communities or is it to be based only on the import of these raw materials that for economic reasons will be gained from the sources offering the lowest price, which usually means that they will come from countries without such "strict" provisions regarding among others human rights or environment protection or without such provisions at all. Moreover, the disruptions in the continuity of supplies that have occurred in the previous years showed that the assumption of the second option is equivalent to the lack of possibility to guarantee permanent raw materials safety for Poland.

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