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SOME ASPECTS OF USING GOAFS FOR LOCATING POST-FLOTATION WASTE IN LGOM MINES

NIEKTÓRE ASPEKTY WYKORZYSTANIA ZROBÓW DO LOKOWANIA ODPADÓW POFLOTACYJNYCH W KOPALNIACH LGOM

As a result of mining of deposits of mineral raw materials, spaces are formed in the rock mass, which get partially filled with roof rocks or by the backfill, most often sand. However, some voids remain in the rock mass, and can be used as a place to locate waste.

The thesis analyses systems and operating conditions of mining deposits, in terms of the possible existence of spaces for filling in the LGOM mines. It was determined that the most probable option is to use goafs after mining the ore with a thickness of over 3 m in the last 5 years, with the systems of roof deflection and their partial lifting. Quantitative evaluation of the voids is based on the comparison of the subsidence over the extraction field and the volume of the extracted deposit. It has been proved that the existing voids provide the possibility of locating approximately 8 million m^3 of waste in goafs. It is highly possible to locate further 11 million m^3 of waste after obtaining positive results of the practical location of them and gaining relevant experience. The goafs after mining with hydraulic filling, goafs in the deposit of the thickness of up to 2 m and mined more than 20 years ago were recognized as useless for locating waste.

Keywords: voids in the rock mass, location of waste, subsidence, post-mining goafs

W wyniku eksploatacji złóż surowców mineralnych powstają w górotworze przestrzenie, które ulegają częściowemu wypełnieniu przez skały stropowe, względnie przez podsadzkę, najczęściej piaskową. Pozostają jednak w górotworze pustki, które stanowią zainteresowanie jako miejsce lokowania odpadów.

W pracy przeanalizowano systemy i warunki eksploatacji złóż w aspekcie możliwości istnienia pustek do wypełniania w warunkach LGOM. Ustalono, że najbardziej prawdopodobne jest wykorzystanie zrobów po wybraniu rudy o miąższości ponad 3 m w ostatnich 5-ciu latach, przy systemach z ugięciem stropu oraz częściowym ich podsadzaniu. Ilościową ocenę pustek oparto o porównanie obniżeń powierzchni terenu nad polami eksploatacyjnymi i objętości wyeksploatowanego złoża. Wykazano, że istniejące pustki stwarzają bardzo prawdopodobne możliwości ulokowania w zrobach około 8 mln m^3 odpadów. Są duże szanse na ulokowanie dalszych 11 mln m^3 odpadów po uzyskaniu pozytywnych rezultatów praktycznego ich lokowania i zdobycia odpowiednich doświadczeń. Za nieprzydatne do lokowania odpadów uznano

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zroby po eksploatacji z podsadzką hydrauliczną, zroby w złożu o miąższości do 2 m i wybierane ponad 20 lat temu.

Słowa kluczowe: pustki w górotworze, lokowanie odpadów, obniżenia terenu, zroby poeksploatacyjne

1. Introduction

As a result of the mining of the deposits of mineral raw materials, spaces are formed in the rock mass, which get partially filled with rock mass or with backfill, most often sand. They are also object of interest as a place for locating waste. This problem has important ecological and economic aspects. It was also considered for the mining conditions of deposit of copper ore in LGOM. During the process of ore enrichment, huge quantities of post-flotation waste is generated, which so far has been stored in the surface area, which required the construction of sedimentation tanks, in which almost billion tons of deposits has been located already.

The previous experience with the world mining concerning the location of waste in underground mines mostly is not positive (Mazurkiewicz, 1983). There are no previous examples of the location of waste on a mass scale, mainly due to the lack of a suitable, economically reasonable technology. In the opinion of the authors, it is highly possible to locate post-flotation waste in LGOM. In this case, conducting the works on the technology of underground storage of post-flotation waste by KGHM „Polska Miedź" S.A. is impressive.

The authors decided that the basis for further studies is the possibly accurate estimation of post-mining voids existing in the goafs of copper mines, which can be used for locating waste with a large likelihood. The authors' long experience concerning the location of waste (waste rocks, fly ash) in coal mining was used.

The basis for analyses was the observed subsidence over the mining fields and their correlation with the thickness of the exploited deposit, taking into account the system of its mining.

After determining the conditions in which the possibility of locating post-flotation waste exists, the fostering regions were selected, and the hypothetic volume of the voids possible to be used were defined. Also, the regions with adverse conditions for locating waste were recognized.

2. Systems of the Deposit Exploitation and the Character of Goafs

2.1. Caving as the Place for Locating Waste

The investigation of issues of the mechanism of caving formation and its character has been conducted for many years. Staroń summarizes them in his work (Staroń, 1979). It was conducted along with discussions over stresses found in rocks around the mining headings. Their results with regard to the mechanism of formation, cover the results obtained by Ropski (Ropski, 1966; Plewa, 2006). He states that the height of the full caving reaches on average the thickness increased 1 – 2 times as compared to the mined bed.

All researchers, dealing with the issues of the formation of caving (Bartecka,1975; Butra, 2003; Mazurkiewicz,1998; Znański, 1958), pay attention to certain „zones" occurring in it. From the point of view of absorbency, the significant ones are those with voids between the blocks.

Such voids may affect (penetrate) sealing fluids and mixtures containing waste. Fig. 1 presents the classic scheme of a caving present in the carboniferous rock mass. It implies the presence of the so-called full caving zone, which may constitute a place of discharging fluids containing waste in the goafs of the caving for the purpose of its sealing. The nature of caving in carboniferous rocks extracted using the wall system, which we will discuss in further parts of the thesis, differs substantially from the caving in Permian rocks extracted using chamber systems. Therefore, direct transfer of experience from coal mines to ore mines is not possible.

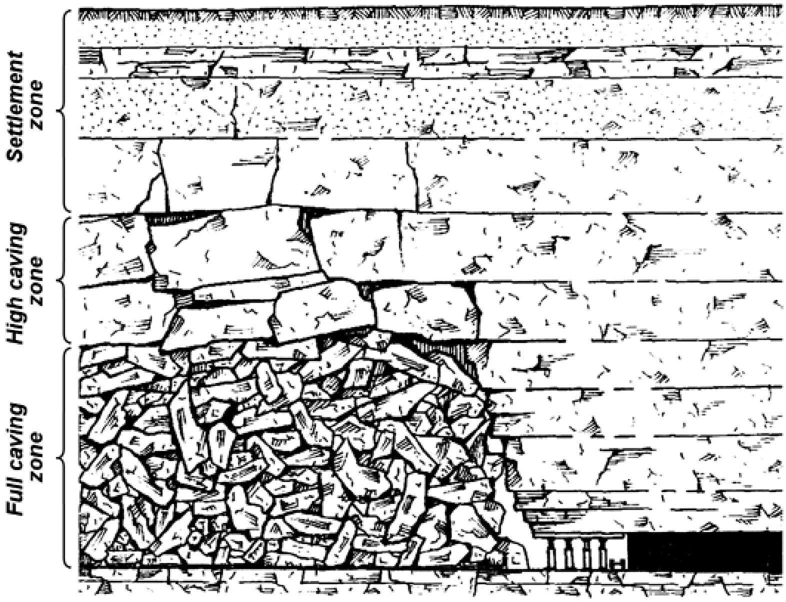

Fig. 1. Caving zones, according to Ropski (Ropski, 1966)

2.2. Properties of Permian roof-rocks and the character of formed caving

The mechanism of caving formation and its nature (including porosity) is primarily determined by the character of roof-rocks. In copper mines, the roof consists of carbonate rocks. They were audited in terms of strength properties. The tests were conducted mostly in the aspect of the rock bursts hazard (Monografia KGHM, 2007). The mechanism of caving formation depending on the type of rocks or their properties were not analysed. Nonetheless, in one of the adopted roof classifications, attention is paid to the fact that the class I roof (ratio of stability $L_t < 15$) "presents the possibility of additional sealing of goafs because of pieces of rock automatically breaking and falling off" (Monografia KGHM, 2007; Szecówka, 1977). Therefore, analysing mining fields in terms of the existence of voids, the regions in which the mining was conducted under the roof classified to this class should be excluded. The caving will be tight and potential voids will be poorly unobstructed.

2.3. Impact of the Mining System

In LGOM mines, over the years, a few dozen of exploitation systems were used (Butra & Kicki, 2003), and since 1968 these have been different forms of the chamber-pillar system. In the thin deposits (up to 3 m) and of medium thickness (3 m to 5 m), the deposit was mined with the caving, in the thick deposits, as well as in mining most of the protective pillars, the hydraulic backfill was used along with the sand or sand-slag mixture.

The lack of research conducted (Mazurkiewicz, 1998) makes it impossible to make reference to the problem of the impact of the method of removing goafs (caving, roof deflection) to the volume of the voids between the blocks. Nonetheless, when analysing and comparing the conditions of the formation of debris, it can be assumed that:

- in systems with caving, the debris will have smaller vertical scope and will be more tightened; it will also consist of more minor blocks,
- debris, in systems with roof deflection, it will be made of larger blocks, and its vertical scope, in particular in the form of delaminations, will be larger.

Therefore, it seems that the goafs of the systems with roof deflection make more beneficial conditions for locating waste, which is illustrated on figure 2.

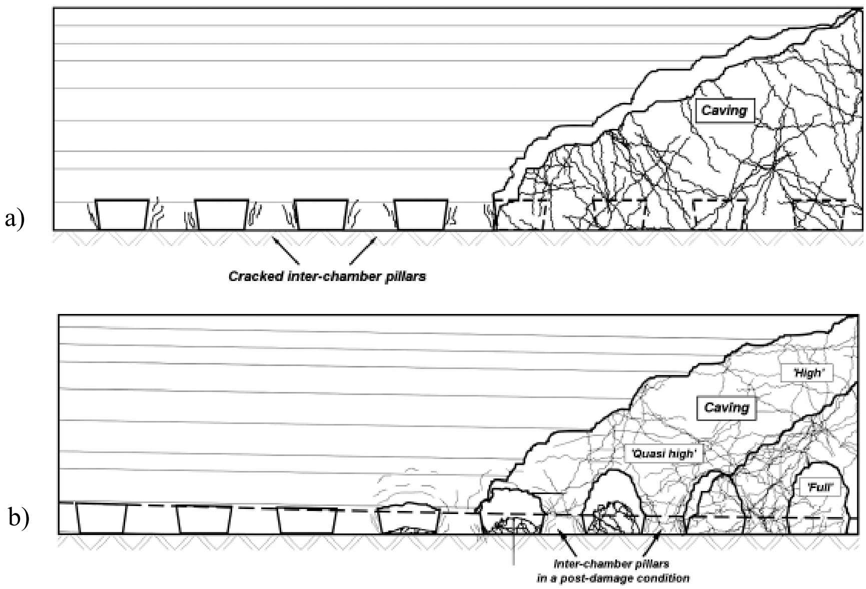

Fig. 2. Diagram of the formation of caving in the room-pillar systems: a) classic, b) with the roof deflection (according to Dębkowski et al., 1996)

Assessing the impact of the height of the mining headings convergence on the capacity of the goafs, it can be assumed that at the caving chamber-pillar systems in the thin deposits, if they have any capacity, it would be small, and the permeability between the voids would be doubtful.

To sum up, it can be assumed that the areas useful for the location of waste are the mining fields in the deposits of the thickness above 3 m extracted with the roof deflection no later than

10 years back (Popiołek & Mazurkiewicz, 2011). In the deposits of the thickness of 2-3 m and extracted more than 10 years ago, the voids may be in the old goafs. However, the possibility of using them for locating post-flotation waste should be evaluated sceptically.

3. Selection of Regions Fostering the Location of Waste

3.1. The Selection Criteria

The considerations conducted in the previous chapter indicate the following conclusions concerning the possible presence of voids in the old goafs of the copper ores related to using them for organized location of post-flotation waste:

1) the goafs after mining using a full hydraulic filling, goafs after mining of the thickness of 2.0 m (and smaller) and the regions of old mining from more than 20 years back, should be excluded as useful for organized location of waste,
2) the goafs after mining of the thickness of more than 3.0 m using systems with roof deflection, partial hydraulic filling and location of stone, implemented in a recent period of five years (in justified cases, up to 10 years back) are the most useful for locating waste
3) the goafs in which there are voids with little possibility for the location of post-flotation waste are the mining fields from deposits of the thickness of 2.0-3.0 m extracted in the period of the last 20 years and situated in favourable conditions (fields surrounded by the ore or the network of gate roads providing access to the deposit).

3.2. Selection of Regions in the LGOM Mining Areas

The analysis covered the whole mining of the copper deposit in LGOM performed so far, conducted by 3 mining plants: O/ZG „Lubin", O/ZG „Rudna" and O/ZG „Polkowice-Sieroszowice". It was performed on the basis of background maps of the mining in particular mining areas (as at 2nd/3rd quarter of 2010).

In the mining area of "Lubin – Małomice", the exploitation of deposits of copper ore is conducted by O/ZG "Lubin". 11 regions of the greatest possibilities of locating waste in old goafs have been determined there, according to the adopted criteria (Chapter 3.1). They account for nearly 11 million m^3 of the nominal volume of the mining fields (deposit volume theoretically possible to be mined).

In the mining area of "Rudna", the mining of the deposits of copper ore is conducted by O/ZG "Rudna". 14 regions most useful for the location of waste in old goafs have been determined there. They account for approximately 28 million m^3 of the nominal volume of the post-mining voids.

In the mining areas of "Polkowice" and Sieroszowice", the mining of deposits of copper ore is conducted by O/ZG "Polkowice-Sieroszowice". 11 regions with hypothetical possibilities of the location of waste in old goafs have been determined there. They account for approximately 13 million m^3 of the nominal volume of the mining fields.

It should be emphasized that the volumes reported above include the cubature of the deposit (theoretically possible to be mined), without considering the remnants of the deposit in technological pillars.

4. Estimation of the Capacity of Caving Goafs

4.1. Assessment of the Porosity of Caving Debris in Room-Pillar systems of the Copper Mining

The recognition of this phenomenon is of fundamental importance for estimating the capacity of caving goafs related to organized location of post-flotation waste. The considerations on the porosity of caving debris are based on the simplified scheme of the mechanism of caving formation provided on figure 2. When assessing the porosity of three types of the caving, it can be assumed that:

- high caving, similarly like in the case of carboniferous rocks and wall systems, would be characterised by voids, in the form of gaps, closed to a large extent,
- *quasi* high caving would be similar to the high caving. Its porosity may be slightly greater than the porosity of the high caving,
- full caving would be similar to such caving described for the carboniferous rocks. It may be assumed that because the strength parameters of carbonate rocks are higher than those of shales and carboniferous sandstones, the full caving debris will consist mostly of larger blocks.

For estimating the porosity of full caving, it is important to define the "unit area" where the caving occurs. Let us adopt another simplified scheme in the form of a section of goafs, covering 4 neighbouring residual pillars (assuming the dimensions given in "Monografia POLSKA MIEDŹ S.A.", 2007), introducing simplifications with regard to the shape of the pillars. The area of the caving, in the projection onto the floor amounts to 460 m^2. Assuming that the deposit has the thickness of h_{zl} = 3.5 m, and the falling roof layers have the thickness of 2.0 h_{zl}, the volume of the caving along with the residual pillars has been estimated as approximately 4 800 m^3. From this volume we subtract the volume of the residual pillars (of approximately 200 m^3), and the volume of the *quasi* caving. It has been assumed that its average area in the horizontal projection amounts to 1.5 of the area of the residual pillars, therefore, the volume of such a caving will be approximately 400 m^3. On the other hand, the estimated volume of the high caving for the adopted section will be approximately 4 200 m^3, that is approximately 80% of the whole volume of the caving.

Taking account of the experience gained during researching this issue in coal mines, it can be assumed that the voids existing in the debris would amount to approximately 20% of its volume. As for the volume of the mined ore, it can be estimated that the voids in the caving debris constitute the maximum of approximately 60% of its volume.

The above considerations are confronted in further parts of the thesis, by conducting the comparison of the volume of the area settlement basin with the volume of the mined deposit.

4.2. Estimation of the Porosity by Comparing the Volume of the Subsidence Basin and the Mined Deposit

4.2.1. Analysis Method

For the analysis, we selected regions in which it is possible to separate the final subsidence basin, corresponding to the mining in a given area, meeting the criteria of the selection of mining fields useful for locating waste (Chapter 3.1).

After a detailed analysis of the current condition of deformation for mining areas in LGOM and conducted mining, the region providing the possibility of the execution of above described analyses, leading to estimating the capacity of voids in the goafs left after mining in connection with the subsidence caused by the exploitation of deposits, was selected.

4.2.2. Location of the Region Selected for the Analysis

In the selected area selected for the analysis (Fig. 3), there are two fields: 23 and 24. The first one has been mined since 2004 at the height of the gate of 3.2 m to 9.6 m, while the second field was mined from 2000 to 2008 at the height of the gate of 2.0 m to 5.8 m.

In the analysed area, two systems of mining were used: the single-layer system with the roof deflection for the deposit of the thickness of up to 7 m (fields G-24/3, G-24/4) and the system with the partial dry backfill for the deposit of the thickness of above 7 m (fragments of field G-6/7).

4.2.3. Calculation of the Volume of the Void after Mining the Deposit

The mining performed in this area is divided into three fields marked with numbers 23, 24A and 24B (Fig. 3). The diversity covers, above all, the height of the mining gate and the system of mining. On the basis of the mining map, the area of the horizontal projection of separated mining plots was calculated. Then, for each field, the average height of the mining gate was determined. This made it possible to calculate the nominal value of the volume of the post-mining void, i.e. such that would arise after the complete mining of the whole mining field. Owing to the use of the room-pillar system for the mining of the copper deposit, the void does not reach the nominal volume due to leaving in so-called residual pillars, ensuring partial support of the roof. Thus, some loss of the volume connected with the volume of residual pillars should be considered. It depends, first of all, on the height of the heading. The residual pillars usually have the shape of a cone. The greater the height of the heading, the greater the residual pillars and their volume. The loss coefficient (marked in table 1 as Loss 1), according to data concerning the use of deposit made available in O/ZG "RUDNA", may have the following estimated values:

- 10 – 11%, for the deposit of the thickness of up to 3 m,
- 14 – 15%, for the deposit of the thickness of 3 – 7 m,
- 22 – 23%, for the deposit of the thickness above 7 m.

The volume of the post-mining void for all three fields was estimated, taking account of the loss of the volume of the left residual pillars (tab. 1). The total volume of the void after mining the deposit was the basis for the comparison with the surface basin registered above the analysed fields of mining.

Additionally, for a better reference of the size of losses to all branches of KGHM "Polska Miedź" S.A., the data from 2002 which define the global coefficient of the loss of the deposit as 10.5% (marked in Table 1 as Loss 1') were used.

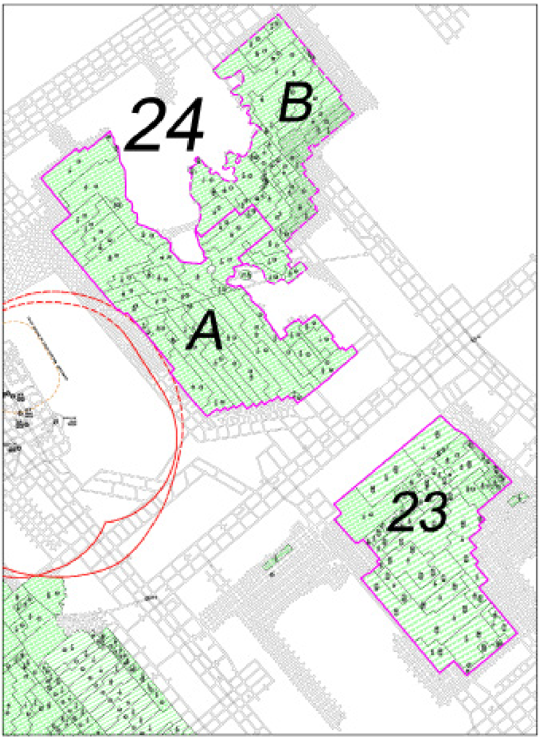

Fig. 3. The region selected for the analysis of the capacity of voids in the goafs left after mining

TABLE 1

The volume of the post-mining voids for the fields adopted for analysis

Field no.	$g_{śr}$	P [m^2]	V_n [m^3]	**Loss1 [%]**	**Volume loss [m^3]**	**Void volume V1**	**Loss1' [%]**	**Volume loss' [m^3]**	**Void volume V1'**
23	6.2	373 242	2 314 100	15%	347 115	**1 966 985**	10.5%	206 533	**2 107 567**
24A	3.4	481 075	1 635 655	14%	228 992	**1 406 663**	10.5%	147 700	**1 487 955**
24B	2.3	245 790	565 317	11%	62 185	**503 132**	10.5%	52 829	**512 488**
Total		1 100 107	4 515 072		638 292	**3 876 781**		407 062	**4 108 010**

4.2.4. Determination of the Volume of the Post-Mining Basin

In order to enable the comparison of the volume of the subsidence basin on the surface, formed as a result of tightening the void of the volume of post-mining void, the long lasting impact of the dehydration of the rock mass on deformations on the surface should be considered. For this reason, it was necessary to obtain data on the condition of large-surface subsidence basin in the analysed area, and then remove this impact from the current condition of deformation of the area surface, according to the following formula:

$$w^{up} = w^{tot} - w^{deh}$$

The calculation of the volume of the surface basin, containing only the impact of mining, was performed on a numerical model using the module Volume Golden Software Surfer v 8. The calculated volume is presented in table 2 and figure 4.

TABLE 2

Comparison of the primary volume of goafs to the volume of the subsidence basin, and determining the reduction in the void in the test area

No.	Area of mining fields	$g_{śr}$	Nominal volume of the void ($P\,g_{śr}$)	Loss 1 (residual pillars)	Size actual void	Volume of subsidence basin	Void reduction degree	The remaining volume of the void in the goafs
	[m^2]	[m]	[m^3]	[m^3]	[m^3]	[m^3]	V_{basin}/V_{void}	
1	1 100 107	4.0	4 515 072	638 292	**3 876 781**	**2 274 184**	**0.59**	**0.41**
2	1 100 107	4.0	4 515 072	407 062	**4 108 010**	2 274 184	0.55	0.45

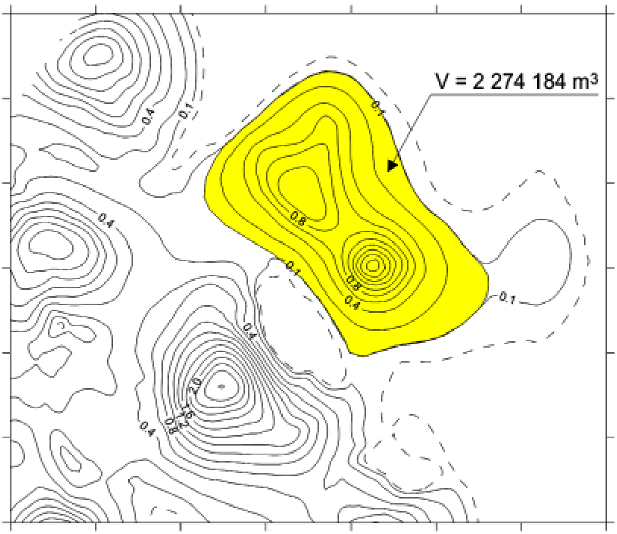

Fig. 4. Subsidence basin (mining) above the fields of mining selected for the analysis

4.2.5. Determination of the Reduction in the Void

The volumes of the void (table 1) and the surface basin in the test area, received as a result of the calculations, were then compared with each other, by calculating the coefficient of the reduction in the underground void for two cases of determining the coefficient Loss 1 (see table 1). The coefficient considers all elements included in the process of deformation occurring under the roof rocks, in the rock mass and on the surface, i.e.:

- convergence (tightening) of the post-mining void,
- generation of the rock debris (caving) in the heading,
- loosening of the overburden rocks,
- deflection of overlaying rocks and the area, and generation of the subsidence basin.

The coefficient of the reduction in post-mining void resulting from the calculations for the analysed area, depending on the calculation method, amounts to **0.55** or **0.59** (tab. 2). This means that approximately 60% of the volume of the post-mining void was revealed on the surface in the form of the subsidence basin. It can, therefore, be concluded that in LGOM, slightly more than 40% of the initial volume of the post-mining void still remains untightened in the form of a porous caving debris.

Considering the above statements and data from tables 1 and 2, in further parts of the thesis, the value of 0.4 (rounded) was adopted for determining the degree of filling the post-mining voids resulting from the process of tightening and caving in the goafs.

5. Impact of Time for Tightening of the Void

From the point of view of modelling the process of deformation of the rock mass, the most important issues are the time of tightening of the excavations and scope of convergence in front of the mining and in the caving goafs. Significant knowledge about this topic can be gained from the results of the measurements of the mining headings convergence conducted constantly by the relevant services of particular mining plants. However, the measurements of convergence are performed only in the working fields. After fencing the zone of goafs, it is not possible to determine the course of tightening of the mining space over time. Thanks to the measurements of convergence, performed for the prevention purposes, there is a possibility to get to know the geometrical and temporary characteristics of the convergence process at least in the working zone of the mining field.

Considering the results of the above research concerning the speed of tightening the goafs based on the coefficient of convergence, it can be stated that with adequately large dimensions of the post-mining goaf field, the time of practically total tightening of the post-mining space amounts to (Hejmanowski, 2004):

- approximately 7 – 8 years for a hydraulic filling,
- approximately 3 – 5 years for a caving.

The scope of time also depends on whether the field was extracted in the area of old goafs or in the intact rock mass.

6. Attempt of Assessment of the Capacity of Goafs Fostering the Location of Waste in LGOM

On the basis of the analyses conducted and described in the previous chapters, the criteria for the selection of regions and mining fields, which may be used for organized location of post-flotation waste in the goafs were formulated. The criteria are as follows:

1) period of operation up to 5 years back (in reasonable cases up to 10 years),
2) fields extracted using the system with the roof deflection or regions with the thick deposit extracted with the partial backfill (locating stone),
3) the height of mining headings were not smaller than 3.0 m,
4) fields of the volume (V2) below 100 000 m^3 were recognized as economically useless.

Taking into account the above criteria, the final selection of mining fields from among the originally selected ones in Chapter 3 was made. It significantly reduced the number and scope of mining fields possible to be used at the location of waste.

Tables 3, 4 and 5 compare the fields particularly useful for organized location of waste, strictly corresponding to the above criteria. The presented tables contain the following information about the fields in particular mining areas:

- area of the horizontal projection of mining fields ,
- nominal volume of the post-mining void,
- actual volume of the post-mining void resulting from leaving the residual pillars (V1),
- volume reduced due to the process of the deformation of the rock mass (V2),
- volume of the void left in the caving debris (only for the fields meeting the selection criteria).

In order to estimate the final capacity of the mining goafs of the selected fields, the following coefficients determining the reduction in the volume of the void have been adopted:

1) the coefficient of **loss 1,** connected with the limitation of the volume by residual pillars left in the heading (see Chapter 4.2.3),
2) the coefficient of **loss 2**, introducing a correction on the process of the post-mining tightening of the heading and vertical displacements of the rock mass and surface area; it was adopted as equal to 0.4, on the basis of the result of the analysis in Chapter 4,
3) also, the coefficient of **loss 3** enabling the estimation of practical capacity of the goafs with regard to locating liquid post-flotation waste was introduced. It was adopted as 0.5 to 0.7, depending on the thickness of the mined deposit. It was based on experiences and experiments from hard coal mining.

TABLE 3

Data on the capacity of mining fields fostering the location of waste in O. G. "Lubin-Małomice"

O/ZG LUBIN							
Field no.	**Volume** $[m^3]$	**Loss 1** residual pillars	**V1** $[m^3]$	**Loss 2** basin	**V2** $[m^3]$	**Loss 3** caving porosity	**Goaf capacity**
3	596 538	0.14	513 023	0.4	307 814	0.7	215 470
4	312 220	0.14	268 509	0.4	161 105	0.7	112 774
5	567 585	0.14	488 123	0.4	292 874	0.7	205 012
6	204 467	0.14	175 841	0.4	105 505	0.7	73 853
7a	223 488	0.14	192 200	0.4	115 320	0.7	80 724
7B	249 228	0.14	214 336	0.4	128 601	0.7	90 021
7c	414 334	0.14	356 327	0.4	213 796	0.7	149 657
7F	1 002 049	0.14	861 762	0.4	517 057	0.7	361 940
10	827 275	0.14	711 457	0.4	426 874	0.6	256 124
11A	1 519 943	0.14	1 307 151	0.4	784 290	0.7	549 003
11B	221 790	0.15	188 522	0.4	113 113	0.5	56 557
TOTAL	**6 138 916**		5 277 250		3 166 350		**2 151 135**

As Table 3 shows, the total capacity of goafs in the mining area „Lubin-Małomice" is approximately 2.2 million m^3.

TABLE 4

Data for mining fields fostering the location of waste in O. G. "Rudna"

O/ZG RUDNA							
Field no.	**Volume [m³]**	**Loss 1 residual pillars**	**V1 [m³]**	**Loss 2 basin**	**V2 [m³]**	**Loss 3 caving porosity**	**Goaf capacity**
12B	172 872	0.15	146 941	0.4	88 165	0.5	44 082
12C	283 279	0.15	240 787	0.4	144 472	0.5	72 236
12D	381 159	0.14	327 797	0.4	196 678	0.7	137 675
12E	331 453	0.15	281 735	0.4	169 041	0.5	84 520
13A	91 560	0.22	71 417	0.4	42 850	0.5	21 425
13B	188 334	0.22	146 901	0.4	88 140	0.5	44 070
13C	191 367	0.22	149 266	0.4	89 560	0.5	44 780
13D	59 378	0.22	46 315	0.4	27 789	0.5	13 895
13E	127 023	0.23	97 808	0.4	58 685	0.5	29 342
13F	213 129	0.23	164 109	0.4	98 466	0.5	49 233
14	80 010	0.15	68 009	0.4	40 805	0.5	20 403
16A	591 463	0.15	502 743	0.4	301 646	0.6	180 988
17	201 584	0.22	157 236	0.4	94 341	0.5	47 171
18A	73 292	0.14	63 031	0.4	37 819	0.6	22 691
18B	350 952	0.14	301 819	0.4	181 091	0.6	108 655
19A	1 881 575	0.14	1 618 154	0.4	970 892	0.7	679 625
20A	268 032	0.14	230 507	0.4	138 304	0.6	82 983
20B	240 797	0.22	187 821	0.4	112 693	0.5	56 346
20C	909 956	0.14	782 562	0.4	469 537	0.7	328 676
20F	2 333 416	0.22	1 866 733	0.4	1 120 040	0.5	560 020
22A	55 890	0.14	48 066	0.4	28 839	0.7	20 188
22B	582 186	0.14	500 680	0.4	300 408	0.7	210 285
22C	375 499	0.14	322 929	0.4	193 758	0.7	135 630
22E	129 099	0.14	111 025	0.4	66 615	0.7	46 631
23	2 314 100	0.15	1 966 985	0.4	1 180 191	0.5	590 096
24	872 804	0.14	750 611	0.4	450 367	0.7	315 257
25	1 466 750	0.14	1 261 405	0.4	756 843	0.7	529 790
TOTAL	**13 300 207**		11 151 986		6 691 192		**3 946 901**

As table no. 4 shows, the total capacity of post-mining goafs in the mining area „RUDNA" is approximately 3.9 million m^3.

TABLE 5

Data for mining fields fostering the location of waste in O. G. „Polkowice" and O. G. „Sieroszowice"

O/ZG POLKOWICE-SIEROSZOWICE							
field no.	Volume [m³]	Loss 1 residual pillars	V1 [m³]	Loss 2 basin	V2 [m³]	Loss 3 caving porosity	Goaf capacity
26A	538 763	0.15	457 949	0.4	274 769	0.7	192 339
26B	1 165 789	0.14	1 002 578	0.4	601 547	0.7	421 083

26C	1 031 651	0.14	887 220	0.4	532 332	0.7	372 632
28A	821 767	0.14	706 719	0.4	424 032	0.7	296 822
28B	114 538	0.14	98 502	0.4	59 101	0.7	41 371
29A	81 561	0.14	70 142	0.4	42 085	0.7	29 460
29D	47 646	0.14	40 976	0.4	24 585	0.7	17 210
29E	330 454	0.14	284 190	0.4	170 514	0.7	119 360
30A	483 344	0.14	415 676	0.4	249 406	0.7	174 584
31B	220 992	0.14	190 053	0.4	114 032	0.7	79 822
32A	240 476	0.14	206 810	0.4	124 086	0.7	86 860
32B	158 577	0.14	136 377	0.4	81 826	0.7	57 278
TOTAL	**5 235 558**		4 497 193		2 698 316		**1 888 821**

As table no. 5 shows, the total capacity of goafs in the mining area „Polkowice" and „Sieroszowice" (using the adopted assumptions) debris amounts to approximately 1.9 million m^3.

The fields of exploitation selected for locating post-flotation waste, from all analyzed mining areas have the total capacity of approximately **8 million m^3**.

In the thesis (Popiołek, Mazurkiewicz, 2011), the possibility of taking into account all fields extracted in the last 10 years was considered, which is substantiated. With such an assumption, the estimated volume of goafs increased to 19.2 million m^3.

7. Summary and Final Conclusions

Based on previous experiences in locating waste in underground mines, and especially in coal mining, it was recognized that the most probable option in the LGOM mines is the possibility of locating waste in the goafs formed after mining the ore of the thickness of more than 3 metres conducted in the last 5 years, with the systems of roof deflection and partial lifting of excavations with hydraulic sand or sand-slag filling or partial filling the goafs with waste rock. The estimated volume of voids in the goafs amounts to, respectively:

- O/ZG "Lubin" – 2.2 million m^3,
- O/ZG "Rudna" – 3.9 million m^3,
- O/ZG "Polkowice – Sieroszowice" – 1.9 million m^3,

The total capacity of the goafs is approximately 8 million m^3.

The possibility of locating waste in the goafs after mining the deposit ore with thicknesses from 2 to 3 m, which were formed after mining completed in the last 10 years were recognized as less likely. They are accordingly:

- O/ZG "Lubin" – 4.8 million m^3,
- O/ZG "Rudna" – 7.5 million m^3,
- O/ZG "Polkowice – Sieroszowice" – 6.8 million m^3.

One may thus estimate that for all branches of KGHM PM S.A. the capacity of the goafs is approximately 19.2 million m^3.

The goafs after mining with hydraulic filling, goafs in the deposit of the thickness of up to 2 m and areas of mining completed more than 20 years ago were recognized as useless for locating waste.

At the end of the discussion, on the basis of experience from coal mining, the authors stress the fact that the existence of voids in the goafs does not mean that locating waste in them is possible. There are known cases of silting up of the area around places of introducing pipeline. Despite the use of high pressures (of several MPa) for the application of waste – such a zone was not always managed to be started.

In the light of the analyses presented in the thesis, it seems necessary to continue detailed research on the technology of introducing waste in goafs subject to self-filling "on the current basis" (Dębkowski et al., 1996, 1997, 1998, 2000). This is, in the opinion of the authors, technologically the simplest way for the implementation of locating post-flotation waste in LGOM

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