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Carbonate-hosted zinc and lead deposits in the Silesian-Cracow area, Poland

Marek SZUWARZYŃSKI[1]

ORE BODIES IN THE SILESIAN-CRACOW Zn-Pb ORE DISTRICT, POLAND

(with 15 Figs.)

Abstract. The purpose of the present paper is the description of the habits of Mississippi Valley-type (MVT) ore bodies and ore occurrences in the Silesian-Cracow Zn-Pb ore district. Main factors controlling the distribution and variation of ore aggregates within Triassic and other rock seqences are discussed. The influence of the lithological factor appeared in the occurrence of ore horizons containing tabular metasomatic ore bodies, known in the Bytom and Chrzanów Synclines. Similar regularities of ore distribution in the Olkusz field are probably the result of the same factor. The second factor of equal importance is fault tectonic, as it is apparent in the distribution of ore aggregates in the Silesian-Cracow Monocline. Moreover, one may indicate a connection of some ore occurrences with paleokarst systems.

Key words: Poland, Silesian-Cracow Zn-Pb ore district, ore body.

INTRODUCTION

Ore mining in the Silesian-Cracow (Upper Silesian) district developed based on both carbonate-hosted zinc and lead ores comparable to Mississippi Valley-type (MVT) ores and limonite concentrations in karst pockets (described e.g., by F. Raefler, 1915, and P. Assmann, 1946). The exploitation of these ores started in 12th century. In the beginnings, lead, silver and iron were produced. Additionally, some amount of zinc carbonate was manufactured (it was component of brass and/or another copper alloys). Important use of zinc ores was undertaken in turn of the 18th century.

Mining activity developed in several fields around the towns of Bytom, Tarnowskie Góry, Siewierz, Chrzanów and Olkusz (Fig. 1; Table 1). As late as at the end of 19th century, considering the similarities of the ore deposits in individual fields, one began to regard the deposits as members of the same ore district (the first map of the district in this sense has been published by F. Bartonec, 1906). This integration concerned essentially the carbonate-hosted deposits.

SILESIAN-CRACOW Zn-Pb ORE DISTRICT

Among the common features of the ore bodies in the individual fields, the connection of the ore mineralization with the Muschelkalk series (Middle Triassic) has been early indicated, and within this carbonate sequence — with a peculiar type of dolostone called by miners "ore-bearing dolomite". It has been traditionally accepted that

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[1] Zakłady Górnicze Trzebionka S.A., Trzebinia, ul. Sikorskiego 71.

Fig. 1. Ore mining in the Silesian-Cracow Zn-Pb ore district

Geological sketch of the district (without units younger than Triassic, based on T. Gałkiewicz and S. Śliwiński, 1985, simplified and modified): *1* — Paleozoic, *2* — Triassic, *3* — borders of the district (range of the ore-bearing dolomite); structure of mining district: *4* — limit of mining fields, both historical and new established, *5* — intact areas, *6* — active mines of ZGH Bolesław: O — Olkusz, B — Bolesław, P — Pomorzany; ZG Trzebionka S.A.: T — Trzebionka; *7* — active smelting works: HMS — Miasteczko Śląskie (Imperial Smelting Furnace — ISF — plant, zinc and lead), HB — Bolesław (electrolytic plant, zinc), HS — Szopienice (electrolytic plant, zinc)

Table 1

Ore mining in the Silesian-Cracow (Upper Silesian) Zn-Pb district

Field	Mining activity		Metals in run-of-mine ore* (till 1994)		Metals in ore resources** (for 1995)	
			in million tons			
	from	till	zinc	lead	zinc	lead
Bytom	XII century	end 1989	12.5	2.6	0.2	0.0
Tarnowskie Góry	XVI century	1918–1919	1.9	0.5	0.0	0.0
Chrzanów	XIV century	active***	2.3	0.8	1.0	0.4
Olkusz	XVI century	active****	3.7	1.3	3.2	1.3
Siewierz	XVI century	?1914	0.4	0.1	0.6	0.2
Zawiercie	undeveloped		—	—	2.5	1.5
Nord	undeveloped		—	—	non estimated	
Total*****			20.8	5.3	7.5	3.4

* Sources: current and retrospective statistics published in technical bulletins, issued in XIX and first half of XX century (e.g. Kohle u. Erz, Oster. Z. Berg- u. Hüttenw., Z. Oberschles. Berg- u. Hüttenm. Ver., Prz. Techn., Prz. Górn.-Hutn. etc.), published reports by H. Łabęcki, 1841, W. Szajnocha, 1893 and J. Pawłowska, 1977, unpublished reports of recent mining companies, and results of calculation of capacity in abandoned mines by the present author.

** Cut-off grade is 2 weight percent of Zn+Pb; sources: unpublished annual reports of mining companies (from Olkusz field by courtesy Mr. Jerzy Socha), report of Polish Geological Institute (S. Przeniosło *et al.*, 1992) with modification of some data according to the change of cut-off grade by the present author, unpublished reports of Geological Enterprise Cracow (by courtesy Mr. Stefan Kurek).

*** Potential activity till 2005.

**** Potential activity till 2015; reserves of active ore mines in the Olkusz field: 2.0 of zinc and 0.8 million tons of lead.

***** Total reserves of mining leases in the district: 3.0 of zinc and 1.2 million tons of lead.

the borders of the Silesian-Cracow Zn-Pb ore district were determined by the extension of the ore-bearing dolomite occurrence. Despite the knowledge of the larger extension of Zn-Pb ores, both lateral and vertical (P. Assmann, 1946), this opinion is common till today. Definite determination of the district borders has been possible due to intensive prospecting works in fifties till seventies this century. This resulted in estimate of a new field with center at Zawiercie, and borders of another possible field located northwards, has been outlined (Fig. 1).

Quantity of metals in mineable ore bodies locates the Silesian-Cracow district between mining areas of world-wide importance. According to the present author estimation (Table 1), till 1994 in the described area the zinc-lead ores have been mined that yielded about 26 million tons of metals[2].

Exploitation of zinc-lead ore is continued in four underground mines belonging to two mining companies (Fig. 1). Three mines and concentrator with total capacity of about 10,400 t/day of crude ore operates in the Olkusz field, and one mine and concentrator with output of about 7,800 t/day — in the Chrzanów field. Primary zinc and lead production is carried in three smelting works (Fig. 1).

Activity of the listed mines will terminate between the years 2010 and 2015, after the ore resources will finish. One cannot exclude, however, that the exploitation could be extended to the intact areas (Fig. 1). The preliminary recognition of several tens of ore bodies (Table 1) may suggest such development, however, low grade of the ore mentioned and difficult exploitation conditions discourage currently to their commercial use.

GEOLOGICAL SETTING

The Triassic carbonate formation including Upper Bunter and Muschelkalk series (in "Silesian" sense, see K. Zawidzka, 1975) displays a crucial role in the ore district structure, as considered in the current elaboration. The attention will be further paid mainly to this formation, and the remaining parts of the rock sequence will be regarded as its sections of marginal importance.

SUBSTRATUM AND COVER OF THE TRIASSIC CARBONATE FORMATION

Two regional structures in the substratum of Triassic carbonates of Zn-Pb ore district can be divided (details and the updated bibliography are given by E. Górecka, 1993a). The Upper Silesian Coal Basin, a Variscan depression, occurs in the south, and the Caledonian-Variscan uplifted structure, including Upper Silesian Block, Cracow-Myszków tectonic zone, and small part of Małopolska Block, are developed in the north (Fig. 2A).

The substratum of the Triassic formations in the Upper Silesian Basin consists of coal-bearing clastic deposits of Upper Carboniferous age up to several thousand meters thick. They are broadly folded and cut with faults. Many of these tectonic structures are repeated in the younger structural units including Triassic beds and their cover (E. Herbich, 1981), and among others also the synclinal belt comprising the Bytom and Chrzanów Synclines (Fig. 2; also called "ore troughs" — F. Bartonec, 1906; F. Löwe, 1927; P. Assmann, 1946; M. Szuwarzyński, 1993).

Other part of the substratum consists of various Paleozoic sedimentary rocks several times folded and faulted, and intruded by magmatic bodies (E. Górecka, 1993a). Immediate basis of the Triassic sequence in this area is forming mostly by carbonates of Middle and Upper Devonian and Lower Carboniferous age, and along the southern margin of Upper Silesian Coal Basin by the Lower Permian fanglomerates, clays and volcanic rocks (Fig. 2).

Mesozoic formations cover the Paleozoic rocks monoclinally, being inclined to NE or N (Silesian-Cracow Monocline; S. Bukowy, 1974), though also there the wide folds sometimes occur (F. Ekiert, 1959). The horst-graben structures are so important that area than in Upper Silesian Coal Basin. The structures either follow the older tectonic directions or they have directions typical of the fore-Carpathian area (J. Bednarek *et al.*, 1985, E. Górecka, 1993a).

In the both parts of the district, the Paleozoic rocks are generally covered with a layer of red or motley clastic sediments. One supposes that they are an equivalent of the early Bunter, older than Röt, thus they represent the lower part of the Triassic sequence (P. Assmann, 1933). In the Silesian-Cracow Monocline locally the Triassic carbonates lie directly on the Devonian or Permian rocks.

Thickness of cover of the Triassic carbonate rocks ranges from about 1 m (outcrops of the Triassic carbonates in the exact meaning of this term are practically absent) to about. 200 m. The oldest members in this sequence represent the Keuper and Rhaetian age, thus belonging to the uppermost Triassic. They consist of mudstones and claystones with dolomite, limestone, sandstone, and sometime gypsum intercalations (W. Bilan, 1976). They occur in the Chrzanów Syncline and in almost whole Silesian-Cracow Monocline.

The Triassic rocks are covered by Middle and Upper Jurassic beds, mainly limestones and marls (J. Bednarek *et al.*, 1983), near Chrzanów and in NE part of the district (Fig. 2). In their southern part, i.e. in the fore-Carpathian deep there occur also clastic sediments of the Tertiary age

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[2] Exploitation of limonite ore terminated in the beginning of 20th century with result about 1.0 million tons of iron in ore.

Fig. 2. Geological setting of the Silesian-Cracow district (sketch without units younger than Triassic)

1 — Röt and Muschelkalk (according to S. Śliwiński, 1969, modified), *2* — Upper Carboniferous and Permian, *3* — borders of the district, *4* — boundary of the Upper Silesian Coal Basin (according to S. Bukowy, 1974), *5* — range of Permian (according to E. Górecka, 1993a), *6* — range of Jurassic (according to E. Górecka, 1993a).
A. Structures of the Triassic substratum (according to A. Kotas, 1982): *1* — Upper Silesian Coal Basin, *2* — Cracow-Myszków tectonic zone

(M. Szuwarzyński, 1993), and in the whole area — Quaternary sediments, mainly sands, covering almost completely the older formations.

TRIASSIC CARBONATE SEDIMENTS

Carbonate formations of Lower and Middle Triassic in the described area consist of dolomites, limestones and marls, bearing in the bottom and roof parts clayey and sandy intercalations (Table 2). Their sedimentation developed in the eastern, marginal part of the Permo-Triassic basin usually known as German basin.

The profiles of the discussed area are characterized by smaller thickness and diachronous development of the lithostratigraphic units, if compared with the classic German series of the Triassic (K. Zawidzka, 1975). The transgressive distribution of the Lower Triassic beds, appearing as the absence of the lower units of Bunter in the eastern parts of the described area, is another peculiar feature of this region. Carbonate rocks occur there locally directly on the Paleozoic beds (see Fig. 12).

In the Zawiercie and Siewierz regions, and also to lesser degree elsewhere, the pre-Triassic morphology was diversified, thus elevations with the carbonate Devonian and Lower Carboniferous rocks were islands in the sea during sedimentation of the Muschelkalk beds (J. Wyczółkowski, 1982). Many of them were buried under the Triassic sediments as late as in Middle Muschelkalk (Table 2).

In the other parts of the discussed area the lateral variations of lithology of the individual layers show also the eastward decrease of the sedimentation basin depth during development of these sediments. Comparing the Röt and Muschelkalk sequences in the Chrzanów and Bytom Synclines, one may notice the eastward increasing participation of the early-diagenetic dolomites in individual layers (this is pertinent to the rock mass before the development of the epigenetic ore-bearing dolomite; Table 2; P. Assmann, 1944; S. Siedlecki, 1949). A comparison within the ranges of the Silesian-Cracow Monocline yields similar conclusions (J. Pawłowska, 1979), especially, the profiles in the Opole Silesia are accepted as the reference ones (K. Zawidzka, 1975).

ORE-BEARING DOLOMITE

The described sequence contains also the earlier mentioned ore-bearing dolomite, developed due to epigenetic alteration of the "primary" carbonate rocks. This lithosome occupies about 20 volume percent of the currently existing carbonate massif described in the Table 2 (the balance is comprised by "primary rocks"). Because the term "ore-bearing dolomite" used to be understood differently, in the present publication it is applied in the sense defined by K. Bogacz *et al.* (1972), i.e. as dolosparite of variable texture, and chemical, and mineral compositions (S. Śliwiński, 1969; A. Krzyczkowska-Everest, 1990).

Table 2

Lithology of the unaltered Röt and Muschelkalk sequence ("primary rocks") in the Silesian-Cracow Zn-Pb ore district

Lithostratigraphic unit (J. Pawłowska, 1977; A. Różkowski, Z. Wilk, 1980)		Upper Silesian Basin		Silesian-Cracow Monocline			
		Bytom	Chrzanów	Kalety	Olkusz	Zawiercie–Siewierz	Myszków–Żarki
Muschelkalk	Boruszowice Beds	eroded	black shales with sandstone intercalations (8–15 m) dolomite (4–10 m)	black shales with intercalations sandstone and dolomite (about 10 m)	eroded		
	Tarnowice Beds	dolomitic marl and marly dolomite (max 17 m)	dolomite and dolomitic marl (10–15 m)	limestone, with dolomite intercalations (2–10 m)*, marly dolomite (15–20 m)	marly dolomite (max 15 m)	marly dolomite (max 15 m)	marly dolomite (max 10–15 m)
	Diplopora Dolomites	dolomite (25–30 m)	dolomite (17–25 m)	dolomite with limestone intercalations (30–40 m)	dolomite (25–30 m)	dolomite (6–40 m)**	dolomite (about 30 m)
	Terebratula and Karchowice Beds	limestones, occasionally with intercalations of dolomite (about 45 m)	dolomite with limestone intercalations (18–20 m)	limestones with dolomite intercalations (40–50 m)	limestones with dolomite intercalations (20–25 m)	limestone with dolomite intercalations, near "Devonian islands" clays and conglomerates (0–45 m)**	limestone (about 15 m) marly limestone (about 14 m)
	Górażdże Beds		dolomite (10–13 m) limestone (7–10 m)		crystalline limestone (16–20 m)		limestone (18–20 m)
	Upper Gogolin Beds	limestone and marl (about 40 m)	limestone and marl, near the top an intercalation of dolomite (about 30 m)	limestone and marl (about 40 m)	limestone and marl (20–25 m)	limestone and marl, near "Devonian islands" clays and conglomerates (0–25 m)**	marl and marly limestone (20–45 m)
	Lower Gogolin Beds	limestone and marl (about 15 m)	dolomites, limestones and marl (12–15 m)	limestones, dolomites and marl (about 15 m)	dolomites, limestones and marl (about 15 m)	dolomites, limestone and marl, near "Devonian islands" cconglomerates (0–15 m)**	limestone (about 15 m)
Bunter	Röt	limestone (about 15 m) dolomite and dolomitic marl (20–30 m)	dolomite and dolomitic marl, in bottom sandstone and clay (about 30 m)	dolomites and dolomitic marl, intercalations: in bottom — gypsum, in top — limestone (about 40 m)	dolomites and dolomitic marl, in bottom also clay (6–35 m)**	dolomites, dolomitic marl, conglomerate, occasionally gypsum (0–50 m)**	dolomites and dolomitic marl, with gypsum intercalation (15–50 m)**

* Wilkowice Beds in classical subdivision of P. Assmann (1944).

** Thickness variation caused by relief of the Paleozoic basement.

One may distinguish two varieties of the rock, that can be included to the group defined as ore-bearing dolomite (J. Pawłowska, M. Szuwarzyński, 1979; K. Mochnacka, M. Sass-Gustkiewicz, 1981; M. Narkiewicz, 1993). They are related to age of formation and differ in chemical composition, lithological type and occurrence form.

The early variety of the ore-bearing dolomite is represented by dolostone and calcareous dolostone with relatively low contents of base metals. It forms large bodies within the Muschelkalk beds. Form of most of these bodies may be determined as tabular and their occurrence is concordant with the formation bedding, through in small-scale examples the contacts of the ore-bearing dolomite may be very complicated and the body of ore-bearing dolomite may contain many enclaves of the nonaltered carbonate rocks. There occur also dolomite bodies diagonal to the host rock bedding; they were found in the Chrzanów Syncline and in the Olkusz area along certain faults (F. Ekiert, 1959; M. Szuwarzyński, S. Panek, 1983).

Dolomite bodies concordant with the formation bedding are located in the vertical interval between the uppermost Gogolin Beds and the roof part of Karchowice Beds. In the zone of the ore troughs, the 20 m thick bottom part of this interval is especially occupied by epigenetic dolomite. In the Olkusz region the bottom contact of the ore-bearing dolomite is more complicated and most frequently it extends in the lower part of Gorażdże Beds. Other areas of the monocline have a similar location the dolomite bodies, and north of Zawiercie the dolomites occur also in the lower part of the Diplopora Dolomite.

The bodies with diagonal contacts extend behind the above mentioned interval. They were found from Lower Gogolin Beds (the lowermost position) to Diplopora Dolomite (the uppermost one). In any section the "roots" of the dolomite bodies have not been found, that would link the tabular bodies with an undefined basement (such suggestion has been published in the discussion on ore-bearing dolomite origin; C. Harańczyk, 1963). The described ore-bearing dolomite appears only in the Muschelkalk beds, what would imply its intraformational nature. Origin of the early ore-bearing dolomite bodies is dated for Upper Triassic–Lower Jurassic (K. Bogacz *et al.*, 1972, 1975).

Clusters of ferruginous dolomite, frequently enriched in zinc, may be considered the late variety of ore-bearing dolomite. Their close connection to the presence of the ores accumulations are very distinct. Probably the late ore-bearing dolomite formed due to local alteration of the older variety during the ore mineralization processes and it is a specific halo surrounding the metasomatic ores cluster (M. Narkiewicz, 1993). Time of its origin was not determined till now.

The both varieties of the ore-bearing dolomite at many places were desaggregated (this process is called "sandification", "pulverisation", etc.), resulting in an aggregate of loose or poorly cemented dolomite sand and mud, remaining *in situ* or redeposited in voids of the rock massif (Fig. 6; K. Bogacz *et al.*, 1973a, b; S. Dżułyński, M. Sass-Gustkiewicz, 1993; M. Szuwarzyński, 1993). This process repeated several times in the geological history of the described area. Its oldest signs accompanied the mineralization processes or proceeded them (certain authors conclude that process to the results of "hydrothermal karst", e.g. K. Bogacz *et al.*, 1970; S. Dżułyński, M. Sass-Gustkiewicz, 1993). It is also bound to Lower Tertiary meteoric karst and the accompanying weathering of the ore deposits (S. Panek, M. Szuwarzyński, 1975). One may notice similar phenomena products among the aggregates resulting from periglacial or even recent weathering close to the ore-bearing dolomite outcrops (B. Radwanek-Bąk, 1995).

ORE MINERALIZATION

Ore-bearing dolomite is the most important rock hosting Zn-Pb ore in the Silesian-Cracow ore district. According to various estimations, this lithosome embeds 95 to 99 weight percent of metals in the district. Moreover, ore concentrations are observed in unaltered Triassic carbonate rocks and also in Devonian and Lower Carboniferous carbonates, and rarer in clastic sediments of various age.

Ore minerals form two types of aggregates in these rocks: replacements, and cavity fillings and linings. Within the ranges of the ore district, the first type is of the greatest importance; it is developed as so-called bedded, ribbon, earthy and/or rocky ores (K. Seidl, 1927; F. Wernicke, 1931; K. Bogacz *et al.*, 1973a, b), i.e., sphalerite replacement of beds of the ore-bearing dolomite. Estimated 65–70 weight percent of the metal resources exploited till present have occurred in this type of ores.

Veins, veinlets and mineralized breccias, representing the second type of ore body is of lesser importance. They contain sphalerite, galena, pyrite and marcasite sometime accompained by gangue minerals: dolomite and calcite, rarer barite, chalcedony and quartz. Fillings or encrustations in caverns of a similar mineral composition also occur. Other types of the sulfide minerals accumulation appear rarely (M. Sass-Gustkiewicz, 1985).

Galmei ore, i.e. zinc carbonates, rarer zinc silicates, usually replaced carbonate rocks or older sulfide ore bodies. In the latter case galmei may contain relics of the sulfide ores.

Shape of the ore accumulations may be considered in various size ranges. In the range of the present author's interest, the shape of the object is defined by arbitrary criteria, detaching the object in the rock massif. In a case of the ore accumulations of noneconomic importance the selection seems to be relatively simple: probably the "intuitive" criteria are sufficient, when related to earlier described standards (P. Wernicke, 1931; I. Smolarska, 1974; M. Sass-Gustkiewicz, 1985).

In the case of mineable ore bodies the cut-off grades will be used. Before 1975, i.e. before introduction of the mining methods with use of LHD equipment, the cut-off for sulfide ore was 4 % Zn+Pb, but after 1975 — about 2% Zn+Pb. For galmei ores during the whole period of their exploitation, i.e. till 1989, the cut-off was near 6% Zn+Pb. One should remember, that changes of the cut-off grade may cause essential changes in opinions on the ore bodies habits. This is important when older mining elaborations are considered.

Internal variability of the ore bodies (R. Blajda, 1993; M. Szuwarzyński, 1993) helps to solve this problem. Within the ore bodies there occur aggregates of various ore minerals and the barren host rocks. The latter generally comprise the prevailing volume of the ore body. Even in the case of thin tabular bodies of consequent structure

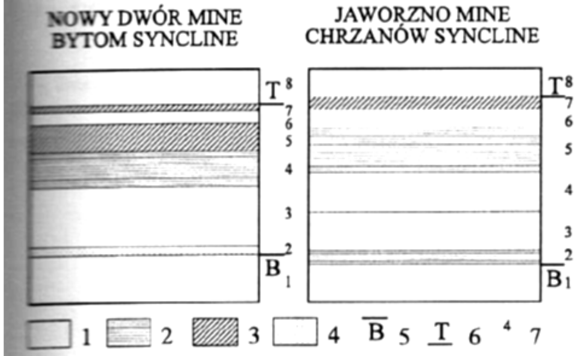

Fig. 3. Structure of simple tabular ore bodies

1 — dolomite, occasionally with ore veinlets and/or impregnations, *2* — zinc ore aggregate replacing dolomite bed (sphalerite in Jaworzno mine, smitsonite and sphalerite in Nowy Dwór mine), *3* — galena veins, *4* — argillite with disseminated sulfides of iron and zinc, *5* — bottom of ore body, *6* — top of ore body; numbers of the bed (1–8) specified in Table 3

and distinct borders, usually considered as "naturally defined" (H. Gruszczyk, 1956), the "ore mineralized rocks" occupy no more then 30 to 40 volume percent (Fig. 3, Table 3).

Table 3

Variation of metals content in ore bodies

Nowy Dwór mine				Jaworzno mine			
Number of bed	Thickness [m]	Content [%] of		Number of beds	Thickness [m]	Content [%] of	
		Zn	Pb			Zn	Pb
8	0.28	0.80	0.17	8	0.24	1.88	0.11
7	0.06	3.35	71.57	7	0.12	0.19	33.55
6	0.12	1.14	0.88	6	0.17	0.97	0.43
5	0.23	1.50	2.35	5	0.38	23.79	0.58
4	0.30	34.86	1.10	4	0.35	1.05	0.38
3	0.52	1.84	0.56	3	0.33	0.56	0.43
2	0.07	3.35	0.11	2	0.10	20.05	0.28
1	0.42	0.71	0.20	1	0.31	0.13	0.19
Ore grade (average for beds 2–7; thickness of ore body 1–3 m)		9.49	4.28	Ore grade (average for beds 2–7; thickness of ore body 1.45 m)		8.13	3.19

Number of bed shown in Figure 3.

This favourizes the spliting of an ore body to smaller units when the cut-off grade increase. On the other hand, many ore accumulations remain behind the ore body because they do not fit to the cut-off. Contrary, the decrease of the cut-off may cause the including of certain ore accumulations in the newly established ore body. Remembering these facts is reasonable when an ore mineralization of small metal concentrations, e.g. a veinlet type, is considered.

TYPES OF ORE BODIES AND ORE CONCENTRATIONS HOSTED BY TRIASSIC CARBONATES

Most of the ore bodies distinguished within the Triassic carbonate sequence have typically tabular form and the position concordant with the wallrock bedding (Figs. 4–8). Defining the tabular form, we imply the ore body shape that has the horizontal dimensions ten or more times exceeding its thickness. Also tabular form with swellings (Figs. 6 and 8) are included to this group. "Independent" ore bodies of horizontal outline approaching circle or ellipse and with relatively large thickness, i.e. ore pockets (Fig. 9), are rarer.

Ore accumulations that do not meet the cut-off grades, most frequently also display these forms. Moreover, one may distinguish the zones of vein-veinlet mineralization, so-called "stockworks" (Fig. 10; M. Szuwarzyński, 1991, 1993).

Variations of form and composition of ore bodies are connected with their location. For this reason we shall consider individual cases, for which it was possible to collect relatively complete data, i.e. Bytom Syncline, Chrzanów Syncline, Olkusz environs and Kalety region (Fig. 2). In any of the cases one may consider a local geometric model of the deposit (Fig. 11).

Bytom Syncline. The Bytom Syncline (Fig. 2) may be divided in two parts; first, Bytom Trough including both

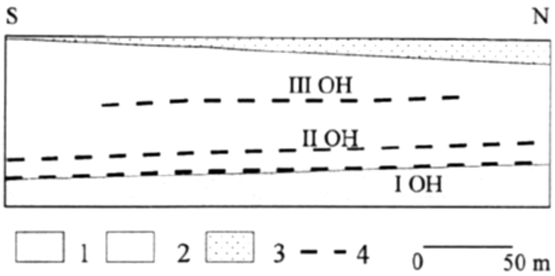

Fig. 4. Distribution of ore horizons in the Triassic carbonate sequence of Nowy Dwór mine, Bytom Syncline (after P. Assmann, 1946)

Muschelkalk: *1* — limestones and marls, *2* — dolomites; Quaternary: *3* — sands and clays; *4* — range of ore bodies in ore horizon (OH)

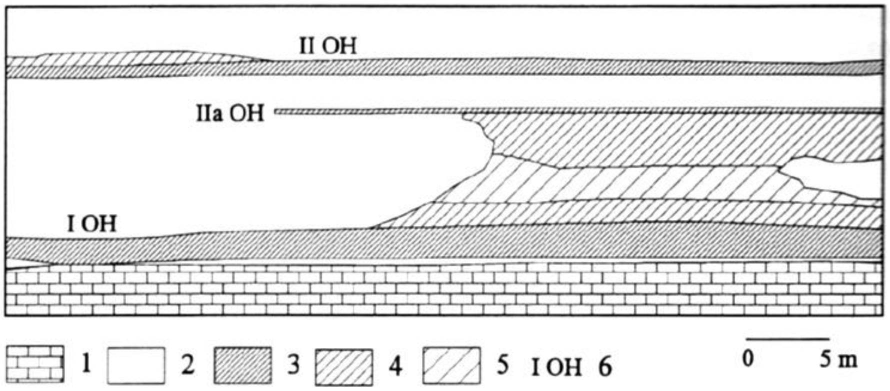

Fig. 5. "Irregular" ore body from Orzeł Biały mine, Bytom Syncline (based on unpublished report of the geological survey of former mining company, SBiDGR Bytom; see also K. Seidl, 1927)

1 — limestones and marls, *2* — barren dolomite (for cut-off grade 2.0 weight percent Zn+Pb), *3* — ore bodies within ore horizons (cut-off grade 4.5 weight percent Zn+Pb, without cut-off thickness); "expansion" of orebodies: *4* — for cut-off grade 3.5 weight percent Zn+Pb; *5* — for cut-off grade 2.5 weight percent Zn+Pb; OH — ore horizon

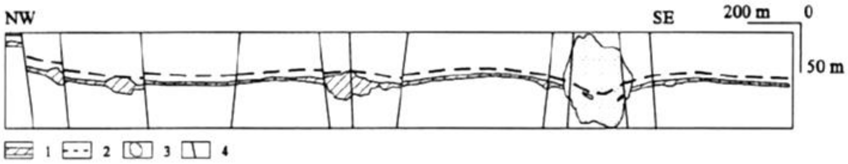

Fig. 6. Cross-section (along strike) of the ore body within ore horizon II from Trzebionka mine, Chrzanów Syncline

1 — ore body, *2* — marker horizon (bed g — M. Szuwarzyński, 1993, fig. 2F), *3* — altered (disaggregated) dolomite along fault zone, *4* — faults

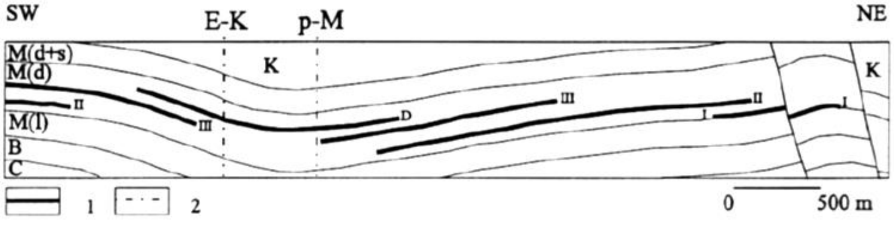

Fig. 7. Cross-section of the Chrzanów Syncline near Trzebionka mine, with distribution of ore bodies

1 — ore body, *2* — axis of Chrzanów Syncline: E-K — formed during Early Kimmerian tectonic movement, p-M — resulted from pre-Miocene movement; I, II, III, D — symbols of ore horizon; specification of beds subdivided in the section: C — Carboniferous, B — Bunter (Röt), M — Muschelkalk: l — limestones, d — dolostones (including dolomite units of Lower, Middle and Upper Muschelkalk), d+s — dolomites, sandstones and shales; K — Keuper

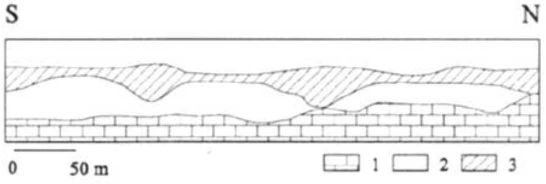

Fig. 8. Cross-section of a typical ore body from the vicinity of Olkusz (after R. Blajda, 1993)

1 — limestones (both Upper Gogolin Beds and Górażdże Beds); *2* — dolostones (mainly ore-bearing dolomite), *3* — ore body

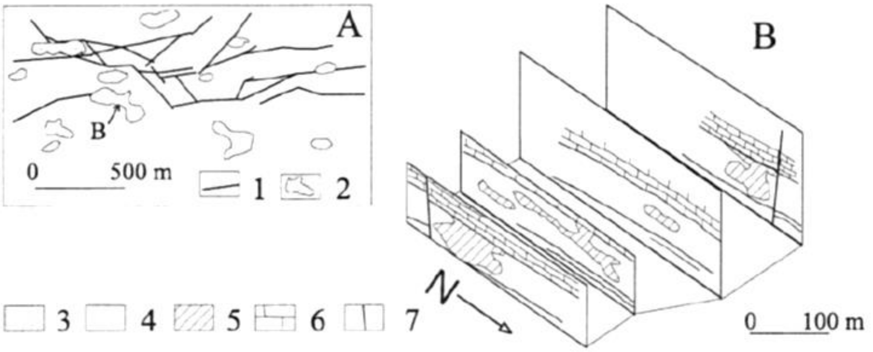

Fig. 9. Ore bodies within the Röt sequence from the Boleslaw mine, Boleslaw Graben near Olkusz (after M. Nieć *et al.*, 1993)

A. Structural map of the discussed area: *1* — faults, *2* — ore bodies (arrow shows body showing in part B)
B. Structure of an ore body: *3* — clays and sandstones (lower part of the Bunter), *4* — dolomites and dolomitic marls (Röt), *5* — ore body, *6* — limestones and marls (Gogolin Beds, Lower Muschelkalk), *7* — faults

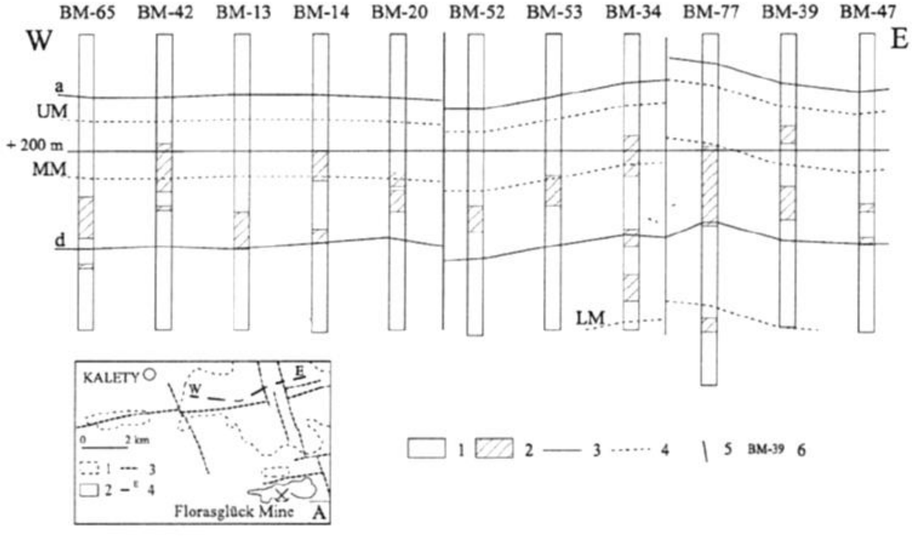

Fig. 10. Diagram of ore distribution in drill cores in the prospecting area near Kalety (based on unpublished reports of Geological Enterprise Cracow, distance between drillings ranged from 300 to 550 m)

1 — carbonate rocks without ore mineralization, *2* — carbonate rocks with metals content up to 1% Zn+Pb, *3* — lithological boundary (a — bottom of argillitic deposits of the Boruszowice Beds, d — bottom of the ore-bearing dolomite), *4* — lithostratigraphic boudary (LM — bottom of Lower Muschelkalk, MM — bottom of Middle Muschelkalk, UM — bottom of Upper Muschelkalk), *5* — faults, *6* — number of borehole
A. Sketch of the prospecting area near Kalety: *1* — range of veinlet mineralization visually determined in drill cores (see also M. Szuwarzyński, 1991), *2* — location of extracted ore body in the abandoned Florasglück mine (active till 1915), *3* — faults, *4* — line of the diagram shown above

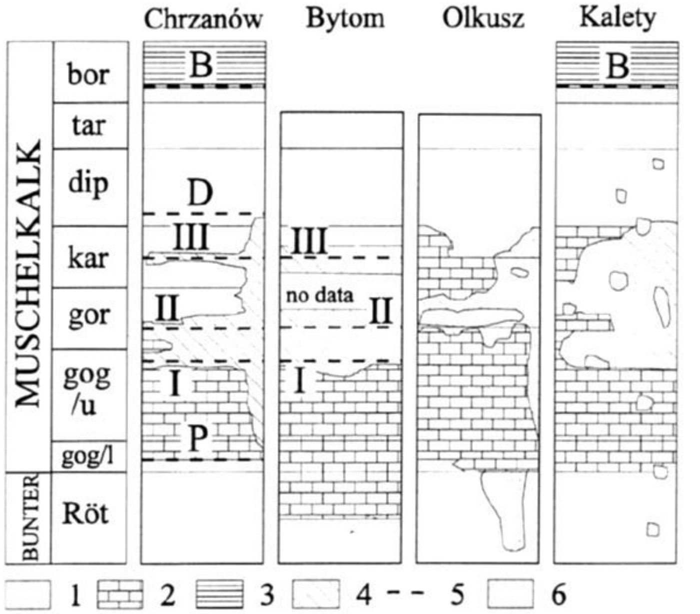

Fig. 11. Geometrical models of ore deposits in the Triassic carbonate sequence of the Silesian-Cracow Zn-Pb ore district
1 — "primary" dolomites, *2* — limestones and marls, *3* — argillites and sanstones, *4* — epigenetic ore-bearing dolomite, *5* — lithostratigraphy-controlled ore horizons, *6* — ore bodies distributed without lithological control; lithostratigraphic units (see also Table 2): gog/l — Lower Gogolin Beds, gog/u — Upper Gogolin Beds, gor — Górażdże Beds, kar — Terebratula and Karchowice Beds, dip — Diplopora Dolomite, tar — Tarnowice Beds, bor — Boruszowice Beds; I, II and III — horizons with mineable ore bodies, P, D and B — horizons with noneconomic concentration of metals

the areas of the historic Bytom mining field (K. Seidl, 1927; R. Stappenbeck, 1928; P. Assmann, 1946; H. Gruszczyk, 1956) and the Będzin environs (K. Bohdanowicz, 1909; C. Kuźniar, 1932), and the second part, so-called Tarnowskie Góry Trough, a lower rank synclinal element located NW of Bytom (G. Gürich, 1903; P. Assmann, 1946).

A multilayer deposit occurred in the Bytom Trough; it has been completly exploited. Ore accumulations were located there in several continuous lithostratigraphic horizons called ore horizons (German — Erzlagen); three of them could be named the essential ones (Figs. 4 and 11; R. Stappenbeck, 1928; P. Assmann, 1946). The horizon I was that one of the largest mineable resource. Most of the ore bodies of this horizon were located under the town of Bytom (K. Seidl, 1927). The economic ore accumulations in the horizons II and III occurred also in the same area. To the east and to the west of Bytom the ore mineralization suitable for mining was only in the horizon I.

All ore bodies were tabular and they occurred concordantly with the wallrock bedding (the mode of most of the ore accumulations below the cut-off were the same). In the zone of the most intensive mineralization the ore bodies achieved horizontal dimensions up to several kilometres and thickness from 1.2 to 2.5 m, and locally to about 4.0 m (C. Kuźniar, 1932; P. Assmann, 1946; H. Gruszczyk, 1956). Swellings exceeding ten metres occurred exceptionally (G. Gürich, 1903; M. Kwaśniewicz, 1932). Dimensions of small bodies in horizon I and in other horizons did not exceed several hundred metres and their thickness was similar to that characterized above (C. Kuźniar, 1932; P. Assmann, 1946).

Poorly cemented sphalerite accumulations (so-called earthy zinc blende) replacing completely the ore-bearing dolomite beds were the main component of the large ore bodies. Thickness of the sphalerite layer was equal several tens centimetres, and locally it achieved 3 m. Above there occurred dolomite with veinlet mineralization (often of the crackle breccia type). The roof was marked by a concordant vein of galena.

Locally within the ore bodies there occurred solution-collapse breccias consisting of dolomite fragments cemented with schalenblende. The occurrence of aggregates of this "blende", probably filling and lining caverns, has been also noticed. Except the mentioned cases (M. Kwaśniewicz, 1932), the breccia presence did not disturb the tabular habit of the ore body. The thickness increased locally to about 3 m, as the result of brecciation.

Smaller ore bodies located to the east and west of Bytom were similar (K. Bohdanowicz, 1909; K. Seidl, 1927). Small dimensions of the ore accumulations within this kind of the bodies were the first difference, resulting in lower grade of the ore possible for mining, and the second difference was the fact, that they were formed almost exclusively of galmei ore.

Decrease of the cut-off "revealed" a local occurrence of mineralization within the layer separating the horizons I and II (Fig. 5). It consisted of sphalerite veinlets, schalenblende aggregates in interbed fissures, and concordant galena veins. By this mode the thickness of the described ore bodies locally "increased" to more than ten metres.

In the Tarnowskie Góry Trough the ore bodies were smaller and occurred only in the horizon I (G. Gürich, 1903). They had similar internal structure but very deep weathering caused that galena was the prevailing component of most of the ore bodies.

Chrzanów Syncline. The Chrzanów Syncline (Fig. 2) may also be divided in two parts: Chrzanów Trough, and many of small throughs contacting the Chrzanów Through at its northern side, and located in the disslocation zone Trzebinia–Będzin (M. Szuwarzyński, 1993). Like in the Bytom Trough, the ore deposit in the Chrzanów Trough is multilayer and consists of tabular ore bodies occurring concordantly to the wallrock bedding and containing mainly ore accumulations of the replacement type (Fig.7).

Larger number of the identified ore horizons in the Chrzanów Trough is a difference of this area when compared with the Bytom Trough (Fig. 11), though the ore bodies suitable for exploitation occur only in three horizons, the same as in the Bytom Trough. In the small troughs of the Trzebinia–Będzin zone, like in the Tarnowskie Góry Trough, ore concentrations occurs only in the horizon I.

The occurrence of the largest ore accumulation in the horizon II instead in the horizon I. It is another important difference compared with the Bytom area. Moreover, in the Chrzanów Trough, there occurs a smaller number of large ore bodies and in larger distances one from another. Only three of them, located in the zone of most intensive mineralization under the town of Chrzanów, approach with their dimensions to the Bytom ore bodies (M. Szuwarzyński, 1993). The largest one (Fig. 6), moreover, has a shape different than the typical ore body of the ore troughs: its tabular habit is disturbed by numerous distinct swellings connected with breccia zones.

Other ore horizons (marked with the symbols P, D and B: Fig. 11) do not contain ore accumulations above the cut-off. Two of them (P and D) seemingly have an extent limited to the Chrzanów Trough area. The horizon B (M. Szuwarzyński, 1988) is probably an equivalent of the regional geochemical anomaly of very large extension. It has been also found in the Kalety region (Fig. 11; H. Gruszczyk, 1956). One, cannot exclude, that similar ore occurrences in the Trochiten Kalk (Upper Muschelkalk) in Germany are the continuation of this horizon.

To complete the above characteristics, one should mention the occurrence of the vein-veinlet mineralization in the discussed area. Almost continuous belt of low grade sphalerite-galena mineralization several hundred metres wide extends along the northern margin of the Chrzanów Syncline. Probably this belt continues to NW along the northern side of the Bytom Trough (apparently parts of this belt were areas of ore exploitation near Wojkowice, W of Będzin; C. Kuźniar, 1932).

Another zone of similar ore mineralization is located along the "younger" axis of the Chrzanów Syncline ("younger" means the axis that appeared after the re-modelling of the syncline after Upper Jurassic; Fig. 7). Smaller ore occurrences of a different mineral composition are also known (M. Szuwarzyński, 1993).

Southern part of the Silesian-Cracow Monocline (Olkusz environs). Unlike the ore-bearing troughs, in the deposits of the Olkusz environs the ore-mineralized breccias prevail (M. Sass-Gustkiewicz, 1985; R. Blajda, 1993), though also in this area the ores are present, which replaced wallrocks. Two types of ore bodies may be distinguished there: tabular bodies occurring concordantly to the wallrock bedding (Fig. 8), and ore pockets (Fig. 9). In numerous boreholes the abundant vein-veinlet mineralization has been found, however, more exact information is not available (B. Niedzielski, L. Szostek, 1977).

Tabular ore bodies occur in one lithostratigraphic horizon, in the lower part of Górażdże Beds. Apparently, this horizon may be considered as an equivalent of the ore horizon II from the ore-bearing troughs (Fig. 11). Mineral occurrences, though of noneconomic value, have been found in the positions equivalent to horizons I, III and D (F. Ekiert, 1959; B. Niedzielski, L. Szostek, 1977; R. Blajda, 1993).

The horizontal dimensions of the described ore bodies range from several tens metres to over 2 km and the thickness varies from few to about 20 m. Most of the ore bodies have elongation close to WNW–ESE or W–E, i.e. according to the faults in this area (P. Assmann, 1946; F. Ekiert, 1959). To the west and to the south of Olkusz one may recognize the tendency to accumulation of small bodies close to these directions. The approximate W–E direction probably displays a certain role in variation of ore mineralization in the area north of Olkusz (J. Jarrin, M. Nieć, 1993).

Because of the breccia type of ore mineralization, the described bodies reveal distinctly more complicated structure then the earlier characterized ones. In cross-sections the undulose outlines of ore bodies are typical. This is connected with the occurrence in these bodies certain zones a larger thickness and higher ore concentration, separated with area of poorer mineralization or barren ones. The latter are also of W–E orientation (R. Blajda, 1993).

Ore pockets occur mainly within the Röt beds (Fig. 9). There are indications, which they are located in the strike-slip faults zones of the strike SW-NE and NW-SE (R. Blajda, 1991). They have relatively small horizontal sizes (rarely exceeding 100 m), large thickness (up to 50 m) and high zinc and lead concentrations (M. Nieć *et al.*, 1993; R. Blajda, 1993). Wallrocks of this mineralization do not contain ore-bearing dolomite, a case not found in earlier described areas; it happened only, that the borders of an ore body overstepped the extent of the ore-bearing dolomite (M. Szuwarzyński, 1993).

Kalety region. In the northern part of the ore province, where large ore bodies are absent, small, irregular ore accumulations have been exploited. Few currently investigated old mining workings in the vicinity of Kalety, Mrzygłód, Myszków and Siewierz revealed assemblages of veins and veinlets, usually of complicated patterns, sometimes called stockworks (C. Kuźniar, 1932). In the rock volume occupied by this mineralization it has been possible to determine small ore bodies of economic importance: ore pockets, chimneys, diagonal plates etc. (Fig. 11).

Boreholes drilled to the north of old mine of this type, Florasglück mine near Kalety (Fig. 10), are the basis of a reconstruction of the background of such ore bodies. The background consists of a network of thin diagonal veinlets of sphalerite, galena and iron sulfides plus calcite (other types of ore accumulations have been found rarer).

Such mineralization has been revealed in drilling core sections form several metres to several tens metres long. Sometimes there occur few ore mineralized intervals separated by barren rock, of the total length of over 100 m (M. Szuwarzyński, 1991). The ore mineralization occurs along faults of the strike close to W–E. Width of the zones is few hundred metres, and at crossings with transversal dislocations it extends even to few kilometres.

Although the ores occur mainly in dolomite, any connection of the mineralization intensity with the lithological features of the wallrock, particularly with the presence of ore-bearing dolomite, has not been noticed. In the western part of the described zone, relatively large ore accumulations occur in the nonaltered Diplopora Dolomite, similarly to the Siewierz region (C. Kuźniar, 1932; S. Śliwiński, 1964). In the eastern part they appear in the whole profile of Lower and Middle Muschelkalk as well as in Röt (Fig. 10). Even in the drilling cores of boreholes made close one another, the ore mineralized sections have variable position both in hypsometric and lithostratigraphic sense.

ORE MINERALIZATION OUTSIDE RÖT AND MUSCHELKALK CARBONATE BEDS

Three cases of the described type mineralization events outside the carbonate beds of Röt and Muschelkalk may be listed. Two of them are ore occurrences in the substratum of this formation or their cover, without geometric continuity with the above described ore bodies. The third case comprises the situations, where the ore mineralization in the Triassic beds connects directly with the ores in the underlying or overlying rocks.

Ore mineralization in the substratum of Triassic beds. Occurrences of minerals of zinc and lead in the substratum of Triassic have been noticed both in Upper Silesian Coal Basin and in Silesian-Cracow Monocline (Fig. 12). In the first mentioned area the mineralization signs occurred most frequently distantly form the presently known extent of this mineralization in Triassic beds. Nowhere they had commercial importance, thus they have been rarely noted, though they are probably quite common.

Most frequently they were veins of galena or calcite, or barite with galena and iron sulfides, as well as networks of veinlets of iron sulfides, bearing accessory galena and sphalerite. They occurred in Carboniferous sandstones and sometimes within hard coal beds. Cement replacements by galena in sandstones have been also found.

Exceptionally larger accumulations of sphalerite have been described (P. Krusch, 1929). The present author had an opportunity to investigate a small schalenblende occurrence of the Namurian rock series, which was, according

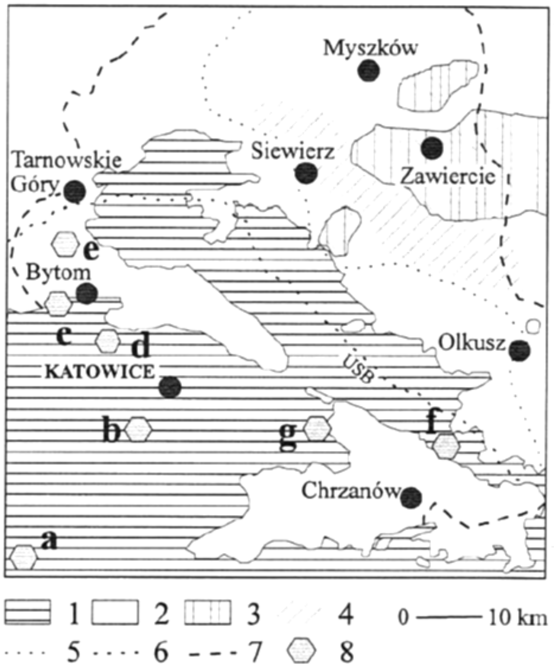

Fig. 12. Zinc and lead mineralization in the Paleozoic substratum of Triassic

Geological sketch (without units younger than Muschelkalk): *1* — Upper Paleozoic, *2* — Röt and Muschelkalk, *3* — "islands" built of the Paleozoic rocks, not covered by sediments of Röt (after J. Wyczółkowski, 1982, generalized), *4* — area of possible occurrence of ore mineralization hosted by paleokarst system in the Devonian and Lower Carboniferous carbonate rocks (according to S. Kurek, 1988, 1993), *5* — limit of area with distinct paleorelief of the Triassic substratum (after J. Wyczółkowski, 1982), *6* — boundary of the Upper Silesian Coal Basin (USB), *7* — range of ore mineralization in the Triassic rocks, *8* — occurrences of zinc-lead mineralization in the coal-bearing sandstones of Upper Carboniferous: a — a group of points in the vicinity of Rybnik and Jastrzębie (B. Kossmann, 1884; P. Krusch, 1929, also unpublished reports by Geological Enterprise Katowice), b — Łaziska (P. Krusch, 1929), c — Bytom (P. Assmann, 1946), d — Chorzów (J. D. Ridge, I. Smolarska, 1972), e — Radzionków (B. Źródłowski, pers. inf.), f — Siersza (see Fig. 13), g — Jaworzno (S. Thugutt, unpublished data) to the opinion of miners, typical of the fault zones in that area (Fig. 13).

Ore mineralization in the substratum of Triassic in the Silesian-Cracow Monocline concentrates in the carbonate beds of Devonian and Lower Carboniferous. Partly it is a veinlet-type mineralization similar to that in Triassic beds (C. Kuźniar, 1932), and partly it is interpreted as fillings of the fossil karst system, developed in carbonate Paleozoic rocks before Triassic transgression (S. Kurek, 1988, 1993; E. Górecka, 1993a).

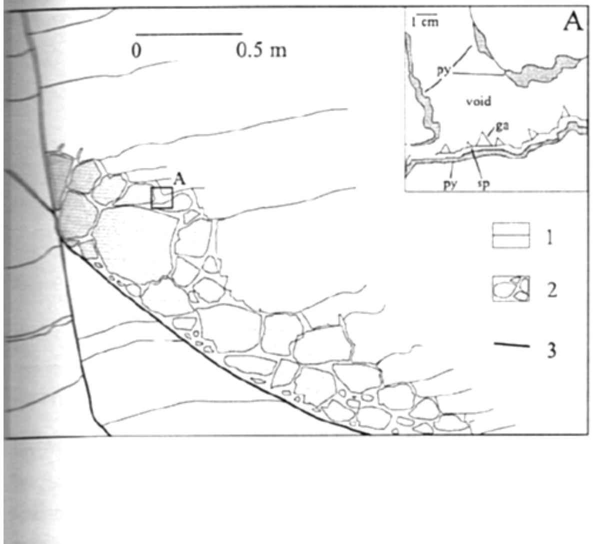

Fig. 13. Occurrence of schalenblende in the Carboniferous sandstone from Siersza mine (hard coal)

1 — barren sandstone, *2* — mineralized breccia, *3* — faults
A. Detail of mineralized breccia: py — iron sulfides (mainly marcasite), sp — sphalerite, ga — galena

As it has been mentioned, the transgression entered the area of diversified morphology (Fig. 12). In part it was a surface of the karst type with a connected underground cavity system several tens metres deep. This system consisting of horizontal and vertical channels, was preserved by filling with clayey or carbonate masses (Fig. 14). The filling was locally replaced by ores of zinc and lead.

Ore mineralization in the cover of the Muschelkalk beds. Ore mineralization events produced in the cover of the Muschelkalk sequence are dispersed ores in Keuper and Rhaetian beds, and veinlets in Jurassic rocks. Mineralization in Upper Triassic is not recognized well (P. Assmann, 1946; W. Grodzicka-Szymanko, 1978; M. Szuwarzyński, 1988). On the basis of the points observed one may suppose, that the mineralization is similar to best known ore occurrences in the Keuper and Rhaetian beds in Germany.

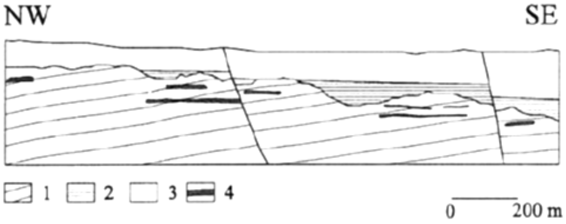

Fig. 14. Setting of paleokarst-hosted mineral occurrences near Siewierz (after S. Kurek, 1988, modified)

1 — Devonian (dolomite), *2* — Röt (dolomite), *3* — Muschelkalk (limestone, and ore-bearing dolomite), *4* — sections of paleokarst channel system filled with breccia, occasionally containing zinc and lead mineralization

Ore mineralization in Jurassic limestones has a different character. Ore veins of various size formed by iron sulfides (the largest ones were even exploited as a source of pyrite; C. Kuźniar, 1925) or by calcite with galena, sphalerite and iron sulfides (J. Bednarek *et al.*, 1985) occur there. These veins are closely connected with fault zones (in the region of Olkusz) and with fractures associated with the "younger" axis of the Chrzanów syncline (Fig. 7).

Ore mineralization in the sequence Devonian–Tertiary. The above description used to be related to the whole ore mineralization in the Silesian-Cracow district (T. Gałkiewicz, S. Śliwiński, 1985), though till now the ore accumulations cutting the borders of the Triassic carbonate formation and joining the accumulations within other lithostratigraphic units were found in two cases: in the western part of the Klucze Graben, where the sequence Devonian–Triassic–Jurassic occurred, and in old Matylda Mine at Chrzanów, where the sequence Triassic–Tertiary was recognized.

Ore occurrences from Klucze have been detected by a relatively sparse prospection grid, thus it is difficult to make their clearly defined geometric model. First interpretation of these results has been given by C. Harańczyk (1963; C. Harańczyk *et al.*, 1971). He attributes to this mineralization a form of vein network in the dislocation zone connected with a compression graben of latitudinal strike. This theory has been further developed by E. Górecka (1993b).

Another interpretation of the mineralization at Klucze has been proposed in 1992 by S. Kurek from Geological Enterprise Kraków (unpublished technical report). Based on the connection of ore mineralization in Devonian beds with pre-Triassic karst system stated by him (S. Kurek, 1988), he suggested that the ore mineralization at Klucze occurred in sollution-collapse breccia structure like a sink-

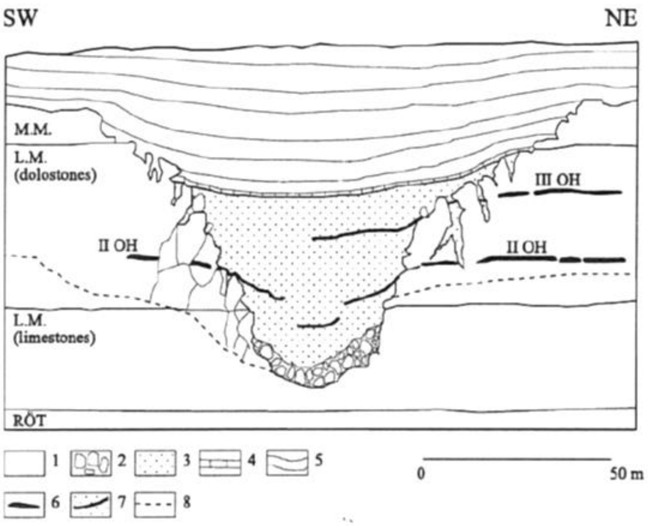

Fig. 15. Cross-section of pre-Miocene outcrop o MVT ore deposit in the abandoned Matylda mine nea Chrzanów (after M. Szuwarzyński, 1978, modified)

1 — Triassic carbonate rocks (L.M. — Lower Muschelkalk, M.M. — Middle Muschelkalk), *2* — rubble and residual clay (Early Paleogene), *3* — argilite, clay and sand (Late Paleogene–Early Neogene), *4* — clay with concentration of oyster shells, partly shelly limestone (bottom of the marine Miocene sequence), *5* — clay and marl (Upper Miocene), *6* — ore bodies within ore horizon, *7* — galena and galmei (both carbonate and silicate of zinc) placer deposits within clay, *8* — basis of Tertiary karst system

hole, developed as a result of rejuvenation of this karst system after Jurassic.

The situation in the Matylda Mine has been recognized with mine workings (S. Panek, M. Szuwarzyński, 1975; M. Szuwarzyński, 1978). They revealed a part of the pre-Miocene karst unconformity with deeply eroded valley and fossil sinkholes cutting the tabular ore bodies (Fig. 15). The valley and sinkholes were filled by Tertiary (Paleogene and Lower Miocene) deposits represented by residual sediments with elluvial concentrations of detrital galena and galmei ore, and Miocene sediments represented by brackish clays with intercalation of oyster limestone in the bottom.

Mineralization in form of thin veinlets and impregnations of iron sulfides and galena occurred at the border of sediments filling the erosion valley, embedding both dolomites and Tertiary rocks, the clastic ones and oyster limestones (S. Dżułyński, 1976). Similar ore mineralization occurs in fossil sinkholes (M. Szuwarzyński, 1978).

CONCLUDING REMARKS

The lithological varieties of carbonate rocks and different tectonic forms probably are the main controls of the distribution of the described ore accumulations in the rock massif. Moreover, one may indicate a connection of some mineral occurrences with meteoric karst. It is also possible that ore concentrations in the uppermost Muschelkalk and in Upper Triassic were formed syngenetically with host rocks.

The influence of the lithological factor appeared in the occurrence of the ore horizons (Fig. 11). The tabular form and occurrence of the majority of ore bodies concordant with the wallrock bedding, including the situations, where the ore horizons are not clearly defined, are other consequences of the lithological control.

It is probable that in the above named cases the paleohydrogeological relations, influenced mainly by the lithological factors, displayed an important role. Such their influence may be legible in case of the ore accumulation below the impermeable marly-limestone layer, as it occurs in case of the pocket bodies from the Olkusz environs. The regularities of the ore bodies distribution in ore troughs are probably the result of the same factor (M. Szuwarzyński, 1993), Ńand the second, equally solving factor is the presence of the tectonic structures (synclines and grabens).

The influence of faults as a control factor is important for the swelling distribution in tabular bodies. It is possible to decipher it in distribution of ore bodies and ore occurrences in the Silesian-Cracow Monocline, especially in the case of vein-veinlet mineralization. This type of mineralization is not influenced by the lithological factor. It is possible, that mineralization in these zones may overstep the Triassic carbonate formation borders, entering its substratum and cover.

Translated by Andrzej Kozłowski

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CHARAKTERYSTYKA CIAŁ RUDNYCH W ŚLĄSKO-KRAKOWSKICH ZŁOŻACH RUD CYNKU I OŁOWIU

(z 15 fig.)

Słowa kluczowe: Polska, śląsko-krakowskie złoża rud cynku i ołowiu, ciała rudne.

STRESZCZENIE

Przedmiotem opracowania jest charakterystyka form ciał rudnych i skupień kruszcowych w złożach obszaru śląsko-krakowskiego, jednej z największych prowincji złożowych typu Mississippi Valley w świecie (fig. 1, 2; tab. 1). Główną uwagę zwrócono na jednostki litostratygraficzne związane z węglanowymi utworami triasu środkowego (tab 2), a zwłaszcza z dolomitem kruszconośnym w sensie podanym przez K. Bogacza i in. (1972). Rozpatrzono też wystąpienia okruszcowania w podłożu i nadkładzie triasu (fig. 12–15).

Analiza formy skupień rudnych i ich rozmieszczenia (fig. 11) pozwala sformułować następujące wnioski:

1. Głównym czynnikiem wpływającym na rozmieszczenie i zmienność skupień rudnych jest zróżnicowanie litologiczne profilu utworów triasowych, którego skutkiem jest tendencja do koncentracji kruszców w warstwach zwanych poziomami rudnymi (fig. 4, 5, 7, 11) oraz płytowa forma ciał rudnych i ich zaleganie zgodne z warstwowaniem skał bocznych, nawet w przypadkach występowania poza poziomami (fig. 3, 5, 6, 8). Wpływ litologii zaznacza się najwyraźniej w synklinach bytomskiej i chrzanowskiej, a mniej wyraźnie w rejonie Olkusza (fig. 2). Jest prawdopodobne, że w istocie na formę mineralizacji wpływ miały stosunki paleohydrogeologiczne, zależne jednak głównie od litologii masywu.

2. Czynnikiem równie ważnym przy kształtowaniu prawidłowości budowy złóż śląsko-krakowskich jest obecność struktur tektonicznych, zwłaszcza uskoków. W synklinach bytomskiej i chrzanowskiej oraz w regionie Olkusza zaznacza się wpływ uskoków na występowanie zgrubień w płytowych ciałach rudnych (fig. 6). Na monoklinie śląsko-krakowskiej (fig. 2), gdzie dominuje mineralizacja żyłkowo-żyłowa i gniazdowa, wpływ uskoków jest jeszcze większy (fig. 9–11).

3. Lokalnie stwierdzono związek niektórych przejawów mineralizacji z kopalnymi systemami krasowymi. Dotyczy to przede wszystkim okruszcowania utworów nietriasowych (fig. 14, 15).