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The geometric-mathematical model of the zinc and lead ore deposits from the Olkusz region

The regularities of structure of the Zn-Pb ore deposits within ore-bearing dolomites and in the Roethian dolomites from the Olkusz region have been stated applying the statistic and geostatistic methods, trend analysis of ore parameters as well as the results of observations in mines. Assuming significant continuity of mineralization within the ore-bearing dolomites the richest ore bodies of nest type form elongated, nearly latitudinal, cyclically repeated zones. The distances between them are from about 150 m in more rich deposit parts up to 300 m in impoverished ones. The deposit in the Roethian dolomites occurs as irregular, isolated ore nests with high metals content. The studies on the exploitation areas of the Roethian deposit and analysis of cartographic materials, related to the deposit located within the ore-bearing dolomites, indicate the coherence of the Zn-Pb mineralization distribution and regular tectonic pattern.

INTRODUCTION

The complete recognition of the ore requires defining of its descriptive, geometric and mathematical model (M. Nieć et al., 1989). Only such versatile image allows proper genetical conclusion (generating the genetical model) as well as practical applying in planning the recognition, management and exploitation of the ore deposit (M. Nieć, 1991).

The descriptive model is based on the results of direct observations in prospecting workings and on data from laboratory studies of mineralogical-petrographical features of the ore. The starting-point for geometric (defining the form and dimensions of ore bodies) and mathematical (description of variability of deposit parameters) modelling are the results of chemical analyses of samples, taken for documentation aims. For the geometric model the deposit boundaries are in practice definited as

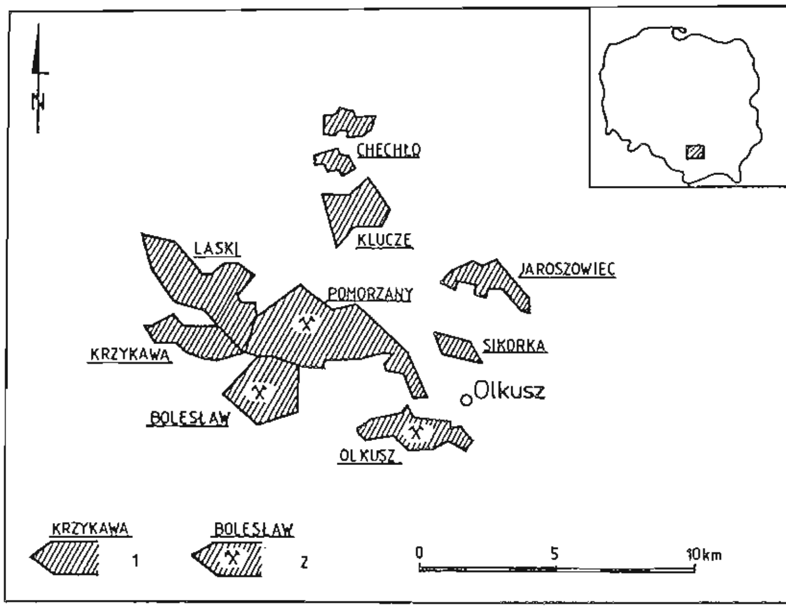

Fig. 1. Location map of the Zn-Pb ore deposits in the Olkusz region
1 — the deposit recognized with boreholes; 2 — exploited deposit
Lokalizacja złóż rud Zn-Pb w rejonie olkuskim
1 — złoża rozpoznane otworami wiertniczymi; 2 — złoża eksploatowane

marginal values of ore parameters, limited by the balance criteria. Although these values are conventional it could be assumed that they delimit the concentration boundaries of useful component. Such boundaries are determinated by the ore-generating process.

The zinc and lead ore deposits from the Silesian-Cracow area are characterized with large extent of mineralization (from the Devonian up to Jurassic), highly variable intensity of mineralization and different state of recognition. Due to carried on exploitation the relatively best studied ones are the ore deposits in the Triassic rocks, particulary within dolomitized deposits of the Muschelkalk. Their descriptive models could be regarded as complete but the genetic ones are still controversial (see I. Smolarska, 1974; T. Gałkiewicz, 1983; M. Szuwarzyński, 1983*a*; M. Sass-Gustkiewicz, 1985). It results from the faet that in the genetic analysis there are not assumed in general the geometric model of ore bodies and structure of variability of the deposit parameters. Applied traditional formal method of geometrizing ore bodies using the Boldyriev polygons eauses that their image interpreted according to borehole data often differs from that one based on observations from mine workings (see M. Szuwarzyński, 1983*b*, 1991). It changes also with variation of location pattern of prospecting boreholes (R. Blajda, 1991).

INVESTIGATION METHODS

The creation of proper model of strueture of zinc and lead ore deposits is — therefore of their signifieant variability — possible just during exploiting prospeetion. Presented here model has based on results of sampling and profiling the eompaet pattern of mine workings from several parts of the Olkusz, Pomorzany and Bolesław mines and on data from surfieial and intra-mine prospecting drills (Fig. 1). Both were studied the mineralization within ore-bearing dolomites, eharacterizing with signifieant planar continuity, and the isolated, nesty ore eoneentrations within the Roethian deposits.

The statistic and geostatistie methods as well as isoline and trend maps of deposit parameters have been used for modelling studies. Variograms deseribes the strueture of variability in geostatistics. It is a function, illustrating eontribution of the random and non-random components in general variation of parameter, depended on the distance between data points. It allows to define the dimensions of statistically uniform fragments of ore deposit (ore bodies, deposit parts with higher mineralization, etc.). The regularities of parameter variation are presented on trend maps in a case of distinctly marked non-random eomponent. The contribution of definited with trend function the non-random variability within total variability of diseussed parameter is indicated by the determination coefficient.

The description of ore deposit variability, based on geostatistic methods, trend analysis and isoline maps, makes possible ereation the geometric model of its structure. It supplies also data for explanation the factors, determinating the mineralization distribution, which in the case of the Zn–Pb ore deposits are invisible directly.

MODEL OF MINERALIZATION DISTRIBUTION WITHIN ORE-BEARING DOLOMITE

In the Upper Silesian deposits of Zn-Pb ores the mineralization embrances the whole complex of ore-bearing dolomites but its intensity is different (R. Blajda, 1985*a*). The observations of M. Sass-Gustkiewicz (1985) indicate that the ore deposits with economical value occurs in form of metasomatic ore bodies, initial karst forms (assemblages of fine veins or small nests of breccias) and within karst-collapse breccias (the ore deposits of mature karst). In the deposits from the Olkusz region such mineralized, karst-collapse breccias prevail.

Within the limits of modelling studies has been done the analysis of content variability of zinc and lead in vertical section of dolomites and in the level of exploited workings. They indicated that in all studied parts of mines, although significant variation of metals content in ore (V_{Zn}= 60–90%, V_{Pb}=120–150%), are observed some regularities of mineralization distribution. They are notified mainly in distribution of zinc eontent, whieh in the Olkusz region determinates the eeonomical value of the ore deposits. The values of determination eoefficients of trends of zinc eontent (for trend surfaees of fourth–sixth degree) in some regions were up to 35% but related to thickness of balance ore deposit they were up to 70%. In distribution of lead

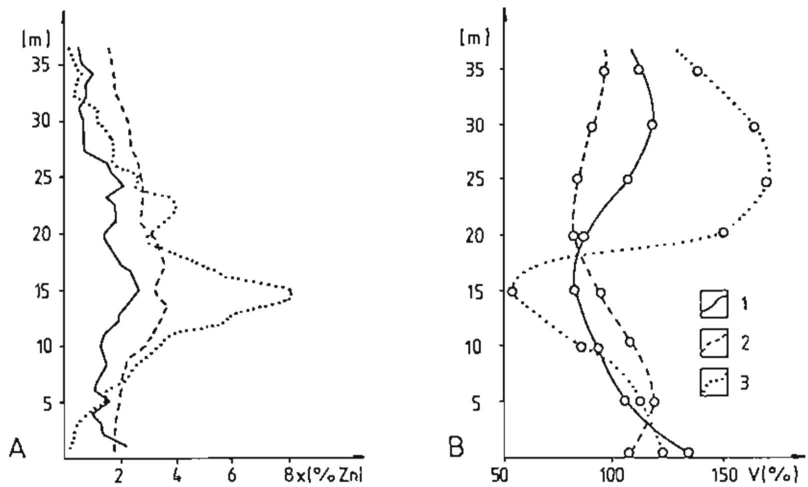

Fig. 2. Differentiation of the average zinc content (A) and of variability coefficients of metal content (B) in the profile of ore-bearing dolomites

The deposits: 1 — Pomorzany, 2 — Boleslaw, 3 — Olkusz

Zróżnicowanie średniej zawartości cynku (A) i współczynników zmienności zawartości metalu (B) w profilu dolomitów kruszconośnych

Złoża: 1 — Pomorzany, 2 — Bolesław, 3 — Olkusz

mineralization prevails the random component of variability but the balance concentrations of this metal occur commonly in limits of balance zinc mineralization.

Statistic analysis of results of sampling of surficial and underground drillings has indicated that in all ore deposits from the Olkusz region the most intensive zinc mineralization locates in almost constant position in relation to bottom of ore-bearing dolomites (Fig. 2A). This interval is placed about 10 m from dolomite bottom and its thickness varies from several meters in the deposit Pomorzany up to 10 m in the deposit Olkusz. It characterizes with most uniform, in relation to other parts of profile, distribution of metal (Fig. 2B). Analogous regularities have been found in vertical section of karst-collapse breccias, also when their bottom coincided with bottom of ore-bearing dolomites (R. Blajda, 1985*b*). In sections of studied parts of mines (Fig. 3) the described tendency of mineralization distribution marks in location of balance ore deposit, especially in W-E direction. Also large variation of deposit thickness are observed in meridional direction and relatively small in latitudinal one. The model of differentiation of zinc content in section planes is presented on Fig. 4.

Studies of regularities of mineralization distribution in planar section have based on data from workings, located within most mineralized ore interval. The scheme of such distribution on isoline maps indicates that in all studied areas, with distinct continuity of balance mineralization, the most rich parts of ore deposits (with content higher than average metal content, it means, from 4 up 5% of Zn) form the zones oriented nearly paralell to directions W-E and N-S (Fig. 5A). The trend analysis of

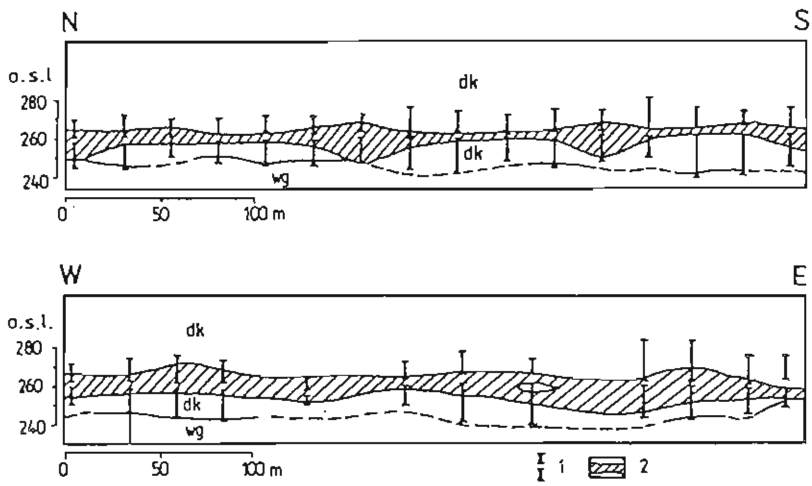

Fig. 3. Geological sections of the ore deposit within ore-bearing dolomites (Olkusz mine)
1 — underground drills; 2 — balance deposit; dk — ore-bearing dolomites; wg — Gogolin Limestones
Przekroje geologiczne przez złoże w dolomitach kruszconośnych (kopalnia Olkusz)
1 — otwory podziemne; 2 — złoże bilansowe; dk — dolomity kruszconośne; wg — wapienie gogolińskie

deposit parameters documents that such zonal distribution of mineralization results from regular location of highly mineralized ore nests (Fig. 5B, 6). Their position on trend maps coincides with definited in mine workings location of karst-collapse breccias.

The geometrized model of mineralization distribution in horizontal section of ore-bearing dolomites is presented on Fig. 7. In all studied parts of ore deposits the

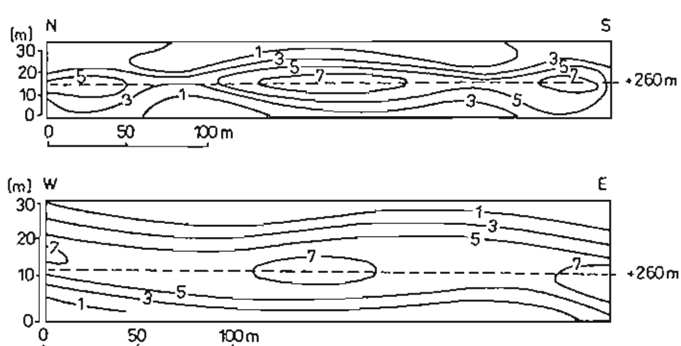

Fig. 4. Trend maps of zinc content in vertical sections of ore-bearing dolomites in the Olkusz deposit (approximation with polynomial of sixth degree)
Mapa trendów zawartości cynku w przekrojach pionowych dolomitów kruszconośnych w złożu Olkusz (aproksymacja wielomianem szóstego stopnia)

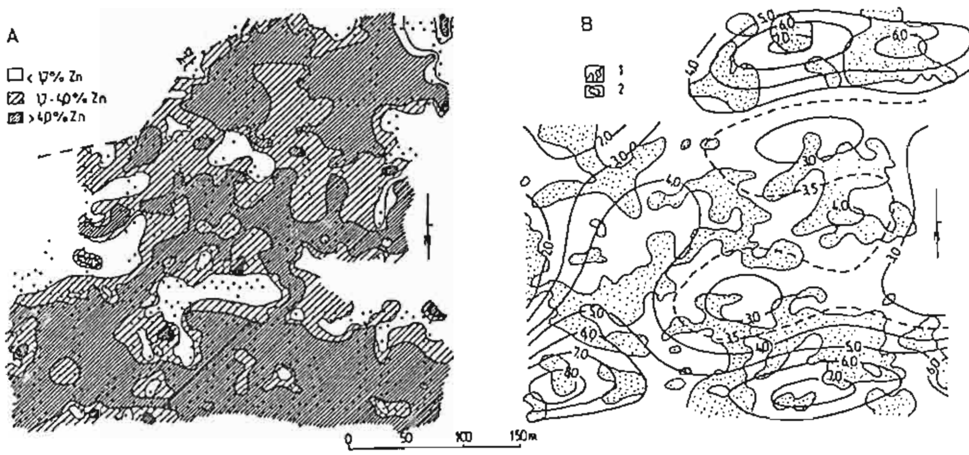

Fig. 5. Distribution map of balance zinc mineralization (A) and trend map of zinc content (B) within ore-bearing dolomites in the fragment of the Pomorzany mine

1 — isolines of trend surfaces (approximation with polynomial of sixth degree); 2 — fields of positive deviations from the trend

Mapa rozmieszczenia bilansowej mineralizacji cynkowej (A) oraz mapa trendu zawartości cynku (B) w dolomitach kruszconośnych na przykładzie fragmentu kopalni Pomorzany

1 — izolinie powierzchni trendu (aproksymacja wielomianem szóstego stopnia); 2 — pola dodatnich odchylek od trendu

almost meridionally oriented (in range from WNW to WSW) zones with rich, nesty concentrations of ore are characterized with cyclic occurrence. The distances between axes of these zones changes from 150 m in more rich parts of ore deposits (Fig. 6A) up to 300 m in poorer ones (Fig. 6B). Simultaneously they form ore intervals with relatively constant and large thickness (Fig. 3, 4). According to geostatistic analysis of zinc content (Fig. 8) it could be assumed that horizontal dimensions of ore nests within these zones varies from 50-60 m in N-S direction to 100 m in W-E one.

The presented model documents distribution of mineralization within exploited, central and most rich parts of ore deposits from the Olkusz region. The peripherial parts of these deposits have been up till now recognized by boreholes: in C_1 category (a distance between boreholes is 150-200 m) or B one (such distance is about 75 m). Neverless existed there, in B category, the compact pattern of prospection drills documents the regularities of mineralization distribution, similar to described in discussed model. They are indicated in location of zones with balance ore (R. Blajda, 1991).

According to V. Nemec (1981) the cyclic distribution of ore bodies (also the ore deposits, ore-bearing areas) is common phenomenon in Earth crust and it should be correlated with periodicity of faults or joints systems. On studied areas such direct connection between mineralization distribution and tectonics has been not noticed. It is difficult to found due to polyphase ore generation and obliteration of primary tectonic structures by processes of dolomitization and hydrothermal karst. Neverless

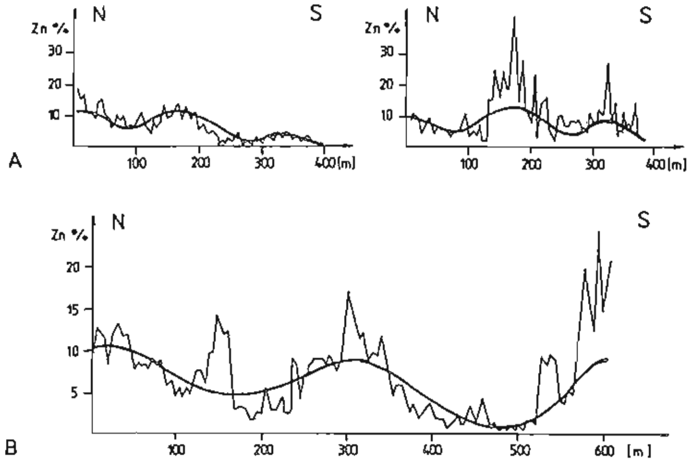

Fig. 6. Sketches of observed (broken line) and calculated with polynomial of sixth degree (continuous line) the zinc content data in the mine workings N-S

The deposits: 1 — Olkusz, 2 — Bolesław

Wykresy obserwowanych (linia łamana) i wyznaczonych wielomianem szóstego stopnia (linia ciągła) zawartości cynku w wyrobiskach górniczych N-S

Złoża: 1 — Olkusz, 2 — Bolesław

the influence of tectonic disturbances on development of ore-generating processes has been described many times (see T. Gałkiewicz, 1983; M. Szuwarzyński, 1983*a*; S. Kibitlewski, E. Górecka, 1988; E. Górecka et al., 1991). Done for one of studied areas of the Pomorzany mine the analysis of structural maps and sections and trend maps of deposit parameters for whole mine, based on data from prospection boreholes — indirect method — has given the principles to connect the found regularities with pre-ore strike-slip dislocations of SW-NE orientation.

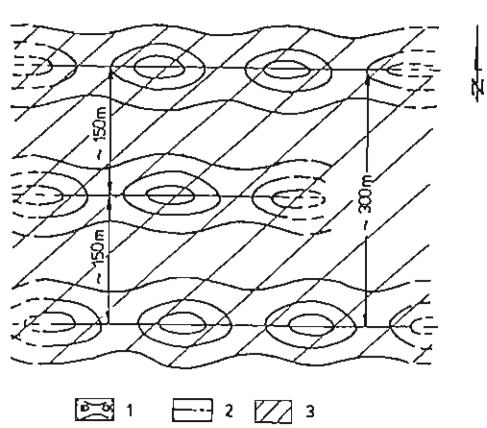

Fig. 7. Distribution model of zinc mineralization within ore-bearing dolomites

1 — zones with high zinc content (over 4-5%); 2 — axis of the mineralization zone; 3 — balance mineralization (over 1.7% of Zn)

Model rozmieszczenia mineralizacji cynkowej w dolomitach kruszconośnych

1 — strefy wysokich zawartości cynku (powyżej 4-5%); 2 — oś strefy mineralizacji; 3 — mineralizacja bilansowa (powyżej 1,7% Zn)

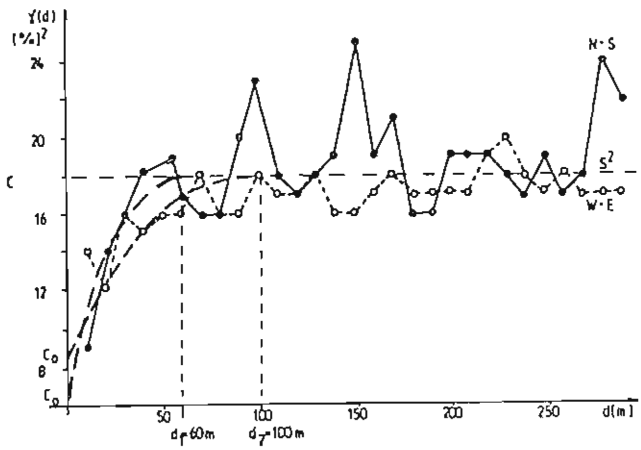

Fig. 8. Examples of variograms of zinc content in ore-bearing dolomites (the Pomorzany deposit)
Przykłady wariogramów zawartości cynku w dolomitach kruszconośnych (złoże Pomorzany)

REGULARITIES OF ORE DEPOSITS STRUCTURE IN THE ROETHIAN ROCKS

In the Olkusz region, except of the deposit within dolomitized rocks of the Middle Triassic, there are located irregularly, in the Bolesław mine, the ores in the Roethian deposits. From ore-bearing dolomites, where mineralization demonstrates significant continuity, the ore deposit in the Roethian dolomites differs with occurrence in form of isolated nests of small dimensions. Hitherto have been recognized four ore nests, the three ones (nest of the 71 shaft, Karol and Joanna) have been totally exploited. Recently is exploited the ore from the Gwiazda nest. All three nests occur in southern, upthrown side of the Bolesław tectonic graben. On this area the Roethian rocks occur at small depth and the ore deposit has been easily noticed by boreholes.

Except of mentioned, relatively large ore bodies, several other ore concentrations have been found in the mine within the Roethian rocks (Fig. 11). They are nesty ore aggregates, distinctly smaller than earlier ones or dispersed mineralization, occurred on small areas (several — several tens of meters) in the mine workings or registered in single boreholes.

Although existed many works on problem of mineralization in the Roethian dolomites hitherto have been not detaily explained the regularities of its distribution. From practical observations on ore exploitation results (B. Niedzielski, 1979) that typical ore nest characterizes with small horizontal dimensions (about several tens of meters), large thickness up to 50 m, irregular form and high zinc and lead content. Analysis of internal structure of ore deposits in areas of old exploitation suggests some connection of mineralization with lithology of the Roethian rocks (M. Nieć et al., 1993). Also its connection with tectonics is suspected (M. Nieć, 1984) but these discussed relations have been invisible there.

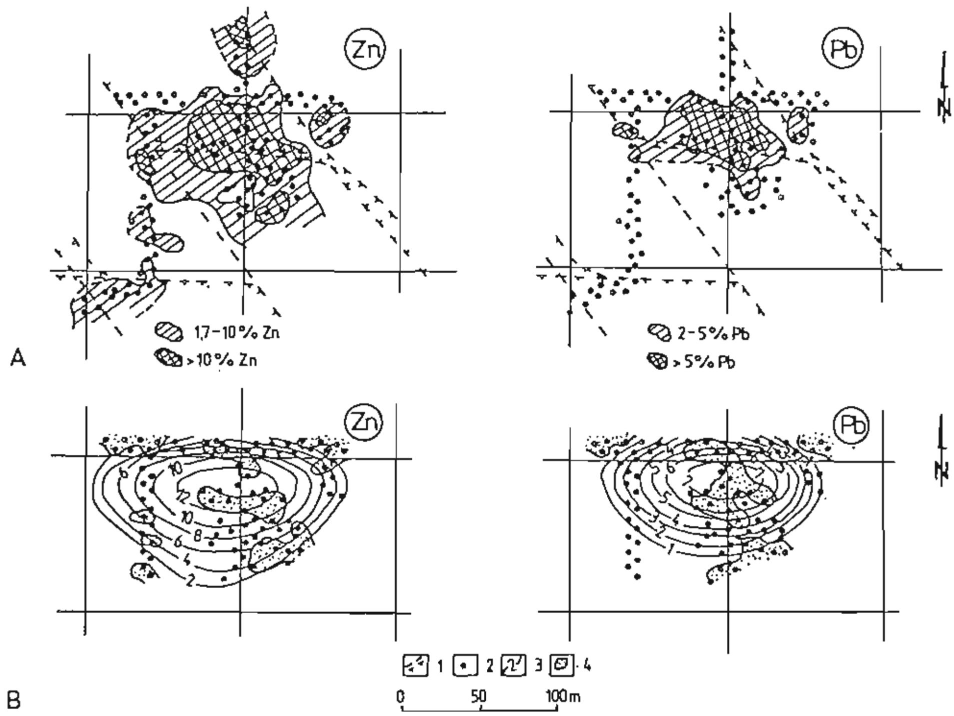

Fig. 9. Distribution of Zn and Pb mineralization (A) and trend maps of metals contents (B) within the Roethian dolomites from the Joanna region

1 — faults; 2 — sampling points of mine workings; 3 — isolines of trend surfaces (surfaces of third degree); 4 — fields of positive deviations from trend

Rozmieszczenie mineralizacji Zn i Pb (A) i mapy trendów zawartości metali (B) w dolomitach retu rejonu Joanny

1 — uskoki; 2 — punkty opróbowania wyrobisk górniczych; 3 — izolinie powierzchni trendu (powierzchnie trzeciego stopnia); 4 — pola dodatnich odchyłek od trendu

Resumed in last years the exploitation of following ore nests within the Roethian (nearby Joanna and Gwiazda) anabled the author to eomplete former informations about regularities of their strueture. Both ore regions are located in plaees where the Roethian deposits form small, anticlinal elevations but the ore mineralization con-eentrates on their slopes (R. Blajda et al., 1990). Both on studied areas and on other recognized mine regions the main ore bodies within the Roethian rocks are aecompa-nied with small ones, located upper, in the Gogolin Beds.

The internal structure of the ore deposit on studied areas has features, definited by M. Nieć et al. (1993). Both in horizontal sections (Fig. 9A) and in vertieal section (Fig. 10) the deposit eontours are variable and high zinc content eorrelates with high eontent of lead. Visible in vertical section the layered structure of ore deposit confirms earlier suggested relation between mineralization and lithologieally differentiated Roethian dolomites.

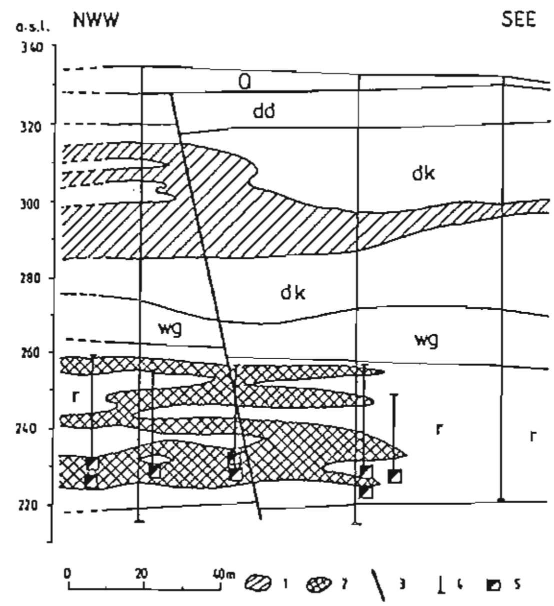

Fig. 10. Geological section of the ore deposit in the Gwiazda region
1 — oxidized ores; 2 — sulfide ores; 3 — strike-slip fault; 4 — boreholes; 5 — mine workings; Q — Quaternary; dd — Diplopora Dolomites; dk — ore-bearing dolomites; wg — Gogolin Limestones; r — Roethian
Przekrój geologiczny przez złoże w rejonie Gwiazdy
1 — rudy utlenione; 2 — rudy siarczkowe; 3 — uskok przesuwczy; 4 — otwory wiertnicze; 5 — wyrobiska górnicze; Q — czwartorzęd; dd — dolomity diploporowe; dk — dolomity kruszconośne; wg — wapienie gogolińskie; r — ret

The studies of variability of zinc and lead content are limited to well recognized, wholly exploited ore nest Joanna. Statistic analysis of sampling results has indicated that the variability of metals content in ore is comparable with observed one within ore-bearing dolomites (in vicinity of the 71 shaft the coefficients of variability of metals content were higher). From the trends analysis results that in the distribution of both metals significantly indicates the non-random component of variability. The coefficients of trend determination, defining this variability (Fig. 9B) are: 45% for zinc and 38% for lead. The pattern of isolines on maps suggests distinct elongation of ore body in W-E direction.

Both in mine workings, on maps (Fig. 9) and sections (Fig. 10) is visible suggested by M. Nieć (1984) relation between mineralization and tectonics. During the mapping in both regions have been registered a number of dislocations, mainly of NW-SE orientation and small vertical displacement, from zero up to several meters. Outcropped during tunnel drilling the slickensides with horizontal slip groves, suggest that they have strike-slip character. They are accompanied with numerous fractures with large vertical range or dip-slip faults with strikes close to W-E direction (Fig. 9A). Occurrenee of such, well visible faults of W-E orientation has been noticed also

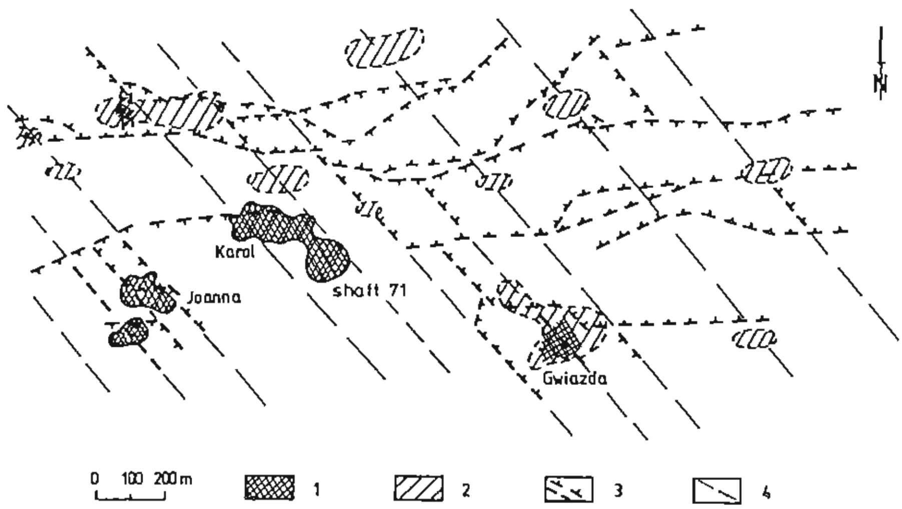

Fig. 11. Distribution model of ore nests within the Roethian rocks of the Boleslaw mine
1 — worked out or exploited nests; 2 — signs of mineralization noticed in boreholes; 3 — faults; 4 — hypothetical, pre-ore dislocation zones
Model rozmieszczenia gniazd rudnych w recie kopalni Bolesław
1 — gniazda wyeksploatowane lub obecnie eksploatowane; 2 — przejawy okruszcowania stwierdzone otworami wiertniczymi; 3 — uskoki; 4 — hipotetyczne przedzłożowe strefy dyslokacyjne

in other regions of ore nests findings in the Roethian rocks (B. Niedzielski, 1979). The tectonic pattern, registered on maps, has some regularity, indicating the equidistant, concordant with the rule of V. Nemec (1981) of faults (dislocation zones) distribution. Ore bodies locate in their immediate vicinity or around the fault planes of NW-SE orientation (Fig. 9A, 10) but the richest mineralization concentrates along faults or fractures with W-E direction. This tendency is confirmed by trends analysis (Fig. 9B).

Analysing on the base of collected materials (direct observations and map interpretations) the location of known ore bodies and mineralization manifestations, found in boreholes, the model could be applied for further prospection works in the Roethian rocks. In this model the main, pre-ore dislocation zones are located regularly and distance between them is — according to the rule of V. Nemec (1981) — about 150 or 300 m (Fig. 11). Ore bodies are often placed in cross-points of these zones with dislocations of W-E orientation. It is possible that similar tectonic pattern determinates the distribution of ore bodies within the Late Paleozoic deposits. The drill prospection of these ore deposits indicates that — similar as in the case of Roethian rocks — the balance mineralization occurs there in form of isolated nests with complicated internal structure. Part of these nests has shape of steeply inclined bodies or chimmneys (S. Kurek, 1988), connected probably with the development of vertical karst systems (S. Kurek, 1991). It is possible they are narrow zones, developed immediately at or around the faults.

FINAL REMARKS

The presented facts and modelling studies document that observed regularities of ore distribution within the Triassic deposits reflect the older tectonic pattern. It seems that decisive role in the mineralization process have played the strike-slip dislocations with NW–SE and SW–NE orientation, recently weakly visible, obliterated by later ore-generating processes. Assuming that the input of mineralizing solutions has taken place through the fault fractures of this orientation, the ore bodies elongation (zones with high mineralization) in directions approximated the W–E direction would be the result of solution migration (they involved the development of karst processes and metasomatosis) through fractures and joints, accompanying the strike-slip movements. The relation of karst processes and joints, mainly ones of latitudinal orientation, was indicated by S. Kibitlewski and E. Górecka (1988) after their detail tectonic studies in mine workings of the deposit Pomorzany. The post-ore faults of W–E direction (in range from WSW to WNW), noticed often in the Olkusz region, could result from the weakening of mass rock by selective, operating mainly along these directions, development of ore-generating processes.

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Renata BLAJDA

GEOMETRYCZNO-MATEMATYCZNY MODEL ZŁÓŻ RUD CYNKU I OŁOWIU REJONU OLKUSKIEGO

Streszczenie

Ważnym elementem opisu złoża tak ze względów poznawczych, jak i praktycznych jest sformułowanie jego modelu geometrycznego (określenie formy i wymiarów ciał rudnych) i matematycznego (opis struktury zmienności parametrów złożowych). Przedstawione prawidłowości wewnętrznej budowy złóż rud Zn-Pb określono na podstawie wyników profilowania i opróbowania gęstej sieci wyrobisk górniczych i otworów wiertniczych kopalni Olkusz, Pomorzany i Bolesław. Badaniami objęto mineralizację w dolomitach kruszconośnych, która cbarakteryzuje się znaczną ciągłością w planie, oraz odosobnione, gniazdowe skupienia kruszców w utworacb retu. Wykorzystując w badaniach izoliniowe mapy parametrów złożowych, mapy trendów oraz metody statystyczne i geostatystyczne, skonstruowano geometryczny model budowy złóż Zn-Pb.

Rozpatrując zmienność zawartości metali w profilu pionowym dolomitów kruszconośnych stwierdzono, że najintensywniejsza mineralizacja (w złożach olkuskich decydujace znaczenie ma mineralizacja cynkowa) zajmuje dość stałe położenie w stosunku do ich spągu. Jest to interwał odległy od spągu dolomitów o około 10 m, a jego miąższość zmienia się nieznacznie w kierunku W-E i wyraźnie w kierunku N-S. W przekroju poziomym dolomitów, przy znacznej ciągłości mineralizacji bilansowej, najbogatsze, gniazdowe ciała rudne tworzą prawie równoleżnikowo wydłużone, cyklicznie powtarzajace się strefy (fig. 7). Odległości między nimi wynoszą około 150 m w bogatszych częściach złóż i około 300 m w częściach uboższych. Na peryferiach zagłębia kruszcowego opisanemu modelowi podlega rozmieszczenie stref rudy bilansowej.

Złoże w dolomitach retu występuje w formie izolowanych gniazd o wysokich zawartościach cynku i ołowiu i nieregularnych konturach w planie i w przekrojach pionowych. W rozmieszczeniu metali w obrębie

gniazd zaznacza się w dużym stopniu nielosowy składnik zmienności, wskazujący na tendencję do koncentracji najbogatszej mineralizacji wzdłuż kierunku W-E. Stwierdzone w wyrobiskach górniczych uskoki przesuwcze NW-SE i zrzutowe W-E podlegają regularnemu planowi tektonicznemu (zgodnemu z regułą ekwidystancji V. Nemeca, 1981), z którym można wiązać występowanie odosobnionych gniazd w recie (fig. 11), a także strefowe, cykliczne ułożenie mineralizacji w poziomie dolomitów kruszconośnych.

Przyjmując że drogami dopływu roztworów mineralizujących były szczeliny uskoków przesuwczych NW-SE, prawdopodobnie też SW-NE, wydłużenie ciał i stref rudnych w kierunku zbliżonym do W-E byłoby konsekwencją migracji roztworów (powodujących rozwój procesów krasowych i metasomatozy) poprzez szczeliny i spękania towarzyszące ruchom przesuwczym.