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 area 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 defined as
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 determined 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, particularly 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, 1983a; M. Sass-Gustkiewicz, 1985). It results from the fact 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 Boldyrev polygons causes that their image interpreted according to borehole data often differs from that one based on observations from mine workings (see M. Szuwarzyński, 1983b, 1991). It changes also with variation of location pattern of prospecting boreholes (R. Blajda, 1991).
INVESTIGATION METHODS

The creation of proper model of structure of zinc and lead ore deposits is — therefore of their significant variability — possible just during exploiting prospection. Presented here model has based on results of sampling and profiling the compact pattern of mine workings from several parts of the Olkusz, Pomorzany and Boleslaw mines and on data from surficial and intra-mine prospecting drills (Fig. 1). Both were studied the mineralization within ore-bearing dolomites, characterizing with significant planar continuity, and the isolated, nesty ore concentrations within the Roethian deposits.

The statistic and geostatistic methods as well as isoline and trend maps of deposit parameters have been used for modelling studies. Varigrams describes the structure of variability in geostatistics. It is a function, illustrating contribution 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 component. The contribution of deinfited with trend function the non-random variability within total variability of discussed parameter is indicated by the determination coefficient.

The description of ore deposit variability, based on geostatistic methods, trend analysis and isoline maps, makes possible creation the geometric model of its structure. It supplies also for explanation the factors, determinat ing 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 Silesiatl deposits of Zn-Pb ores the mineralization embraces the whole complex of ore-bearing dolomites but its intensity is different (R. Blajda, 1985a). 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 content, which in the Olkusz region determinates the economical value of the ore deposits. The values of determination coefficients of trends of zinc content (for trend surfaces 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
mineralization prevails the random component of variability but the balance concentra-
tions 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, 1985b). 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 isoleine 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 parallel to directions W-E and N-S (Fig. 5A). The trend analysis of
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 defined 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
almost meridionally oriented (in range from WNW to WSW) zones with rich, nested 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 peripheral parts of these deposits have been up till now recognized by boreholes: in C₁ category (a distance between boreholes is 150–200 m) or B one (such distance is about 75 m). Nevertheless 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. Nevertheless...
The geometric-mathematical model of the zinc and lead...

The deposits: 1 — Olkusz, 2 — Bolesław

Wykresy obserwowanych (linia lamana) 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. Galkiewicz, 1983; M. Szwarzyński, 1983a; 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. 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

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 kruszoconosnych

1 — strefy wysokich zawartości cynku (powyżej 4–5%); 2 — oś strefy mineralizacji; 3 — mineralizacja bilansowa (powyżej 1.7% Zn)
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 Boleslaw 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 Boleslaw 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. 8. Examples of variograms of zinc content in ore-bearing dolomites (the Pomorzany deposit)
Przykłady wariogramów zawartości cynku w dolomitach kruszośnośnych (złoże Pomorzany)
The geometric-mathematical model of the zinc and lead...

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

Resumed in last years the exploitation of following ore nests within the Roethian (nearby Joanna and Gwiazda) enabled the author to complete former informations about regularities of their structure. Both ore regions are located in places where the Roethian deposits form small, anticlinal elevations but the ore mineralization concentrates 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 accompanied 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 vertical section (Fig. 10) the deposit contours are variable and high zinc content correlates with high content of lead. Visible in vertical section the layered structure of ore deposit confirms earlier suggested relation between mineralization and lithologically differentiated Roethian dolomites.
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). Occurrence of such, well visible faults of W–E orientation has been noticed also...
The geometric-mathematical model of the zinc and lead.

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 wyeksploataowane lub obecnie eksploatowane; 2 — przejawy okruszczowania 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 determines 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 chimneys (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.
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 metasomatism) 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. Gorecka (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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GEOMETRyczNO-MATEMATyczNY MODEL ZŁOŻ RUD CYNku i OLOWIoW REJONu OŁKUSKIEGO

Streszczenie

 Ważnym elementem opisu złoża tak ze względów poznawczych, jak i praktycznych jest sformułowanie jego modelu geometrycznego (określenie formy i wymiarów ciągów rudnych) i matematycznego (opis struktury, zmienności parametrów złożowych). Przedstawione prawdopodobieństwo wewnętrznej budowy złoża Rud Zn-Pb określono na podstawie wyników profilowania i opróbkowania gęstej sieci wyrobisk górniczych i otworów wiertniczych kopalni Olkus. Pomorzan i Bolesław. Badaniami objęte mineralizacje w dolomitach kruszcowych, która charakteryzuje się znamienitą ciągłością w planie, oraz odosobnione, gniazdowe skupienia kruszcowych w utworach retu. Wykorzystując w badaniach izolinie mapy parametrów złożowych, mapy trendów oraz metody statystyczne i geostatystyczne, skonstruowano geometryczny model budowy złoża Rud Zn-Pb.

Rozpatrując zmienność zawartości metali w profilu pionowym dolomitów kruszcowych stwierdzono, że najintensywniejsza mineralizacja (w złożach olkuskich decydująca znaczenie ma mineralizacja cynkowa) zajmuje dość stale położenie w stosunku do ich spągu. Jest to inteval o długości 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 znacznjej ciągłości mineralizacji bilansowej, najbogatsze, gniazdowe ciała rudne tworzą prawie równoleżnikowo wydłużone, cyklicznie powtarzające się strefy (fig. 7). Odległości między nimi wynoszą około 159 m w bogatszych częściach złoża oraz około 300 m w częściach uboższych. Na peryferyjach zagłębia kruszcowego opisanej modelowi podlega rozmieszczenie strefy rud 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 obiebie
gniazd zaznacza się w dużym stopniu nieelastowy 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 ekwistancji V. Nemeca, 1981), z którym można wiązać występowanie odosobnionych gniazd w recie (fig. 11), a także strefowe, cykliczne ułożenie mineralizacji w poziomie dolomitów kruszcowych.

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 metamorfozy) poprzez szczeliny i spękania towarzyszące ruchom przesuwczym.