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Stanisław KIBITLEWSKI

Tectonic control of the origin of Zn-Pb deposits in the Chrzanów region

An example of distinct interdependence between processes of Zn-Pb ore deposit formation and tectonic events has been described. The process of mineralization shows close relation to the tectonic structures of different origin and scale.

INTRODUCTION

Tectonic studies have been done in some of the Zn-Pb deposits in the Chrzanów and Olkusz regions. Remarks summarized here were widely presented before in the Polish papers and reports (S. Kibitlewski, E. Górecka, 1988; E. Górceka et al., 1991; S. Kibitlewski, 1992). Those papers contain wide list of references concerning the geological setting of the regions, main problems and discussions as well.

In the Chrzanów region the studies were done in the Trzebionka mine. The Trzebionka deposit lies in the northern part of the Chrzanów Syncline (the Chrzanów Trough) which displays sublatitudinal running. The structure seems to have Variscan foundations and is cut with numerous transversal and longitudinal faults of Alpine age (comp. M. Szuwarzyński, 1993, Fig. 2). In the mining area dominant faults display the NNE-SSW direction.

In the Trzebionka mine the small and middle scale tectonic structures in the ore-bearing Lower Muschelkalk beds have been analysed. In their profile there dominate dolomites , both early diagenetic and epigenetic — so-called the ore-bearing dolomites. In general, ore-bearing dolomites replace carbonate rocks, mainly lime-

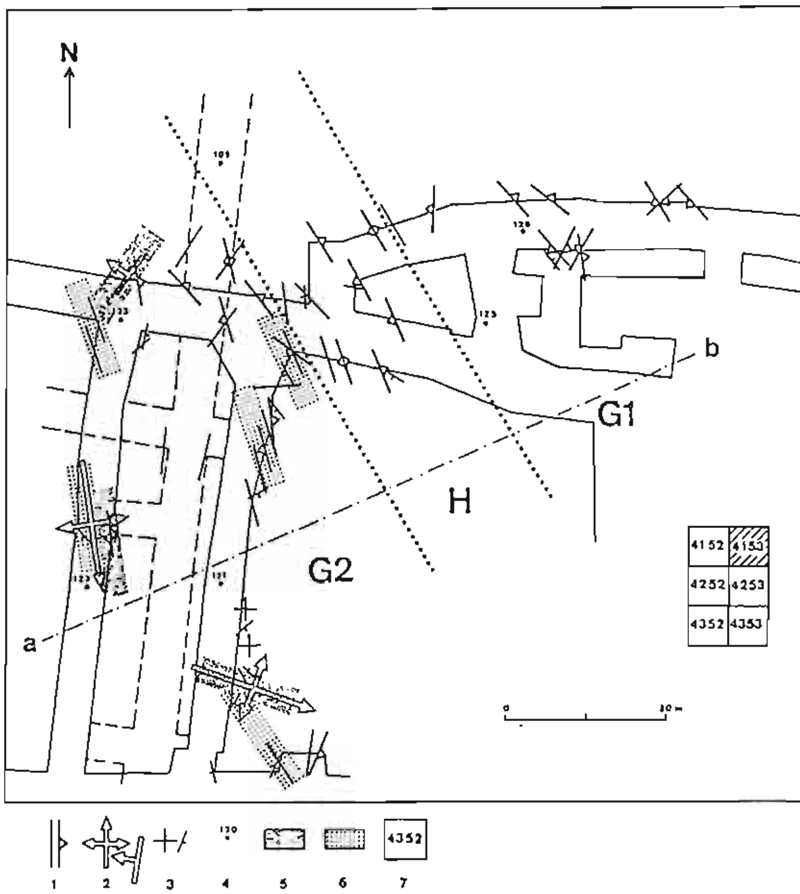

Fig. 1. Map of distribution of small- and middle-scale structures in one of the mining block (Trzebionka mine)

1 — small faults and large fractures often with slickensides — vertical and inclined; 2 — anticlines, flexure zones; 3 — bedding planes — horizontal and inclined; 4 — elevation points; 5 — zones of intensive development of dolomite breccias; 6 — zones of intensive development of ore breccias; 7 — mining block number; H — horst; G1, G2 — graben structures; a-b — line of idealized cross-section (comp. Fig. 5)

Mapa występowania drobnych i średnioskalowych struktur tektonicznych w jednym z bloków eksploatacyjnych kopalni Trzebionka

1 — drobne uskoki i większe spękania, często zlustrowane — pionowe i nachylone; 2 — antykliny i fleksury; 3 — powierzchnie uławicenia — poziome i nachylone; 4 — punkty wysokościowe; 5 — strefy intensywnego rozwoju brekcji dolomitowych; 6 — strefy intensywnego rozwoju brekcji kruszcowych; 7 — numery bloków eksploatacyjnych; H — struktura zrębowa; G1, G2 — struktury rowowe; a-b — linia schematycznego przekroju (por. Fig. 5)

stones of the uppermost layers of the Gogolin Beds and the lower part of the Górażdże Beds. The upper and lower boundaries of their occurrenee are irregular.

Detailed studies on the meso- and small-scale tectonic structures and mineralization were done mainly in the area of about 300 m in length and about 200 m in width, especially in 100 x 100 m mining block no. 4153 (Fig. 1). In total - about 600 measurements of different tectonic structures were done, together with a macroscopic estimation of the intensity and kind of the related ore mineralization, as well as sampling aiming at mineralogical and geochemical studies (analyses in progress).

The tectonic style of deformation and the scope of tectonic structures developed in the area in question are characteristic of the areas of platform structure. Middle scale dip-slip (mostly vertical) faults, flexures, folds and buckling of beds are common as well. The small scale structures are represented by the regular joint and other fractures of different origin, generally related to the local folds and faults. Very typical, in the discussed area, are slickensides present on genetically different discontinuity surfaces, being the most frequent on the vertical surfaces. General mutual relation of the structures and mineralization in the small part of the area (1 ha, mining block no. 4153) is shown in Fig. 1.

SYSTEMATIC FRACTURES

The systematic joints display usually vertical or subvertical position, locally with a kathetal tendency (being perpendicular to bedding planes, irrespective to the dip angle of the beds). There exist some sets of the joints with prevailing orientation of 160-170 , 100-110, and 50-60° . The first set is dominant and the most regular within the whole area in question, the others are subordinate and show uneven frequency in the different sites. Another systematic fractures are related to the regular fault and fold structures developed in the area.

There existed at least two main factors which caused the development of the systematic fractures. The first factor corresponds to the processes generating regional joint and cleavage which evidently show an early foundation (comp. W. Jaroszewski, 1993). The second factor results mostly in shear fractures, developed during different rotation of beds. The last one corresponds to the local inter-bed slip, related to a horizontal compression (small thrust faults) and/or to bending (flexuring effect of dip-slip faults — see below).

Some systematic fractures seem to be connected with the local faults and folds, of limited mechanical influence. As for the trends of those fractures, the oblique and transversal sets are dominant while the longitudinal ones subordinate. The whole described pattern rotates with the change of the trend of the local folds.

FAULTS AND SLICKENSIDES

The faults observed in the block no. 4153 show the stable orientation of 140-180°, generally coincident with the main (160-170°) set of joints. Striae reveal mostly dip-slip character of the faults. Small slickensides are frequently developed on joints.

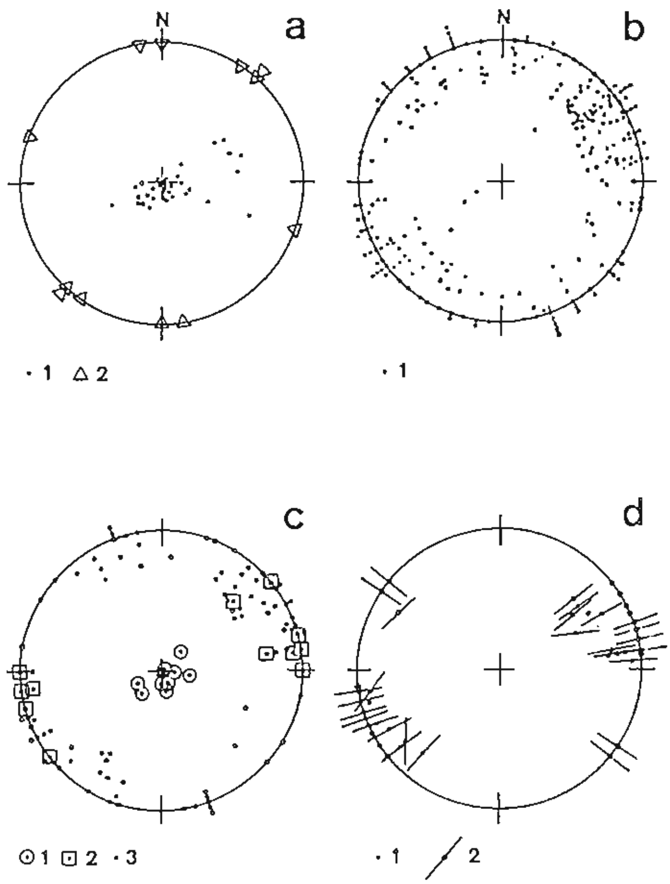

Fig. 2. Statistical diagrams (area as in Fig. 1; upper hemisphere of equiarea net)
a — bedding: 1 — pole of bedding plane, 2 — position of fold axis (β axis); b — fractures: 1 — pole of fracture plane; c — mineralized surfaces: 1 — bedding surfaces, 2 — slickenside surfaces, 3 — other fissures; d — slickenside surfaces: 1 — pole of slickenside surface, 2 — striae azimuth

Diagramy statystyczne (dla obszaru jak na Fig. 1; górna półkula siatki równopowierzchniowej)
a — uławicenie: 1 — biegun powierzchni ławicowej, 2 — położenie osi fałdu (oś β); b — spękania: 1 — biegun powierzchni spękaniowej; c — powierzchnie zmineralizowane: 1 — ławic, 2 — luster tektonicznych, 3 — innych szczelin; d — powierzchnie luster: 1 — biegun powierzchni zlustrowanej, 2 — azymut rys ślizgowych

Those facts as well as frequency of the vertical dip-slip faults suggest that the area in question is dominated by dip-slip kinematics in the Paleozoic substratum.

Directional analysis of the faults and of sense of their movements shows the existence of the middle scale horst-and-graben structure (Fig. 1, G1-H-G2) in block discussed. It is significant that vertical faults and the densely spaced slickenside surfaces, which border the horst structure, separate the zones at the same time. Those zones display the different degree of tectonic complication. In the graben zones the fold and flexure structures are common as well as faults and dense fractures, cataclasis and brecciation of rocks. The horst zone is less disturbed — only cut by the spaced fractures.

The intensity of ore mineralization in the zones under discussion is different: high in downthrown (graben) parts and very low in the practically barren horst one.

FOLD- AND FLEXURE-DEFORMATIONS

In the block no. 4153, bedding outside the flexured parts is mostly horizontal or subhorizontal (Fig. 2a). Although the prevailing direction of dip is not evident, there is a kind of π belt, which points to a predominance of bends with submeridional axes. Attitude of real fold axes, determined in field (β axis), suggests the same tendency, corresponding with the direction of the main faults in the block.

Most of the discussed folds are non-linear and display presumably the character of brachyforms. Some of them may be developed as the local buckling forms related to the small overthrusts (squeezing along bedding surfaces), the others (more rare) — as the true tectonic folds which engage thicker packets of beds. The last folds seem to be significantly dependent on fault-blocks occurring probably in the basement of the described horizon. The relation of some fold deformations to the vertical and sub-vertical disjunctive structures suggests that the folds and flexures have mainly character of the bending folds (fault-overlying folds) and/or drape folds.

ZONES OF CATACLASIS AND BRECCIAS

As a result of the detailed observations, it can be stated that different stages and degree of disintegration of the massif rock are present in the area under discussion. The following features can be observed:

a — systematic fracturing (jointing). The systematic fractures occur in multi-directional systems (usually with one predominant direction) rather than in single sets;

b — the rock material intensively fractured in different directions. It is difficult but not impossible to select the dominating orientations. The traces of bedding are still preserved;

c — cataclasites — strongly fractured rock complexes with no privileged directions, but without separation or rotation of the inter-fracture fragments;

d — cataclastic breccias — rock masses displaying independent movements of the angular rock fragments and conspicuous voids (empty or filled with inter-fracture cement);

e — breccias with more separated rock fragments, still not rotated or rounded; those breccias display properties of the hydraulic breccias;

f — typical breccias with the rotated and differently rounded rock fragments.

In respect of the content of the rock fragments and matrix, two kinds of breccias can be distinguished:

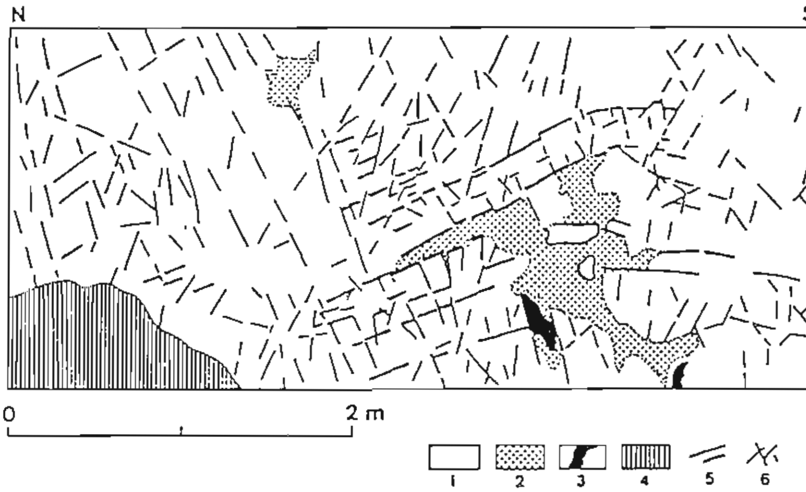

Fig. 3. Dolomite-ore breccia zone developed in partially destroyed hinge part of small fold (Trzebionka mine)

1 — ore-bearing dolomite; 2 — dolomite-ore breccia; 3 — cavern; 4 — crushed material; 5 — bedding traces; 6 — small fracture traces

Strefa brekcji dolomitowo-kruszcowej rozwinięta w częściowo zniszczonej przegubowej partii drobnego fałdu w kopalni Trzebionka

1 — dolomit kruszconośny; 2 — brekcja dolomitowo-kruszcowa; 3 — kawerna; 4 — luźny materiał zwałowy; 5 — przebieg ławic; 6 — przebieg drobnych spękań

1 — dolomite breccia — in which sharp-edged dolomite fragments occur in the dolomitic matrix of another character;

2 — ore breccia — in which sharp-edged rock fragments of different dolomites (early-diagenetic, epigenetic) are cemented with sulfides (mainly ZnS). Some rock fragments are built of dolomite breccia as in point 1. The contacts between rock fragments and the ore matrix are sharp and quite clean. This kind of breccias accompanies the hinge zones of the local folds (Fig. 1, expl. 5; Fig. 3).

STRUCTURAL RELATIONS

The spatial relations between different structures in the block no. 4143 are presented in Fig.1. Three zones of different structures of sub-meridional trend may be distinguished there. In the eastern part, there lies the zone G1 with distinct development of cataclasis and ore mineralization. This zone is generally lowered due to the faults of the small scale and different orientation. The adjoining horst H is less intensively fractured and practically barren. The western side of the horst is formed by a zone of the strong, sub-meridionally oriented, vertical or steep fractures of joint character, with numerous dip-slip slickensides when passing to the G2 zone. Within the interval of more than 10 m, between H and G2, all the faults throw their western

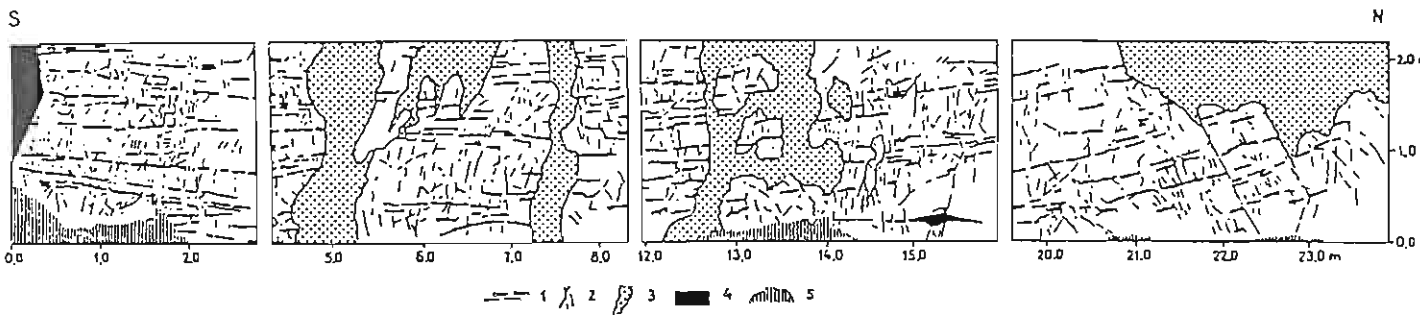

Fig. 4. Vertical chimney-like dolomite-ore breccia in drift-wall profile (Pomorzany mine)
1 — bedding traces; 2 — fracture traces in ore-bearing dolomite; 3 — dolomite-ore breccias; 4 — transversal drift; 5 — crushed material
Pionowe, kominowe strefy brekcji dolomitowo-kruszcowej w profilu chodnika w kopalni Pomorzany
1 — przebieg ławic; 2 — przebieg spękań w dolomicie kruszcowym; 3 — brekcje dolomitowo-kruszcowe; 4 — chodnik poprzeczny; 5 — luźny materiał zwałowy

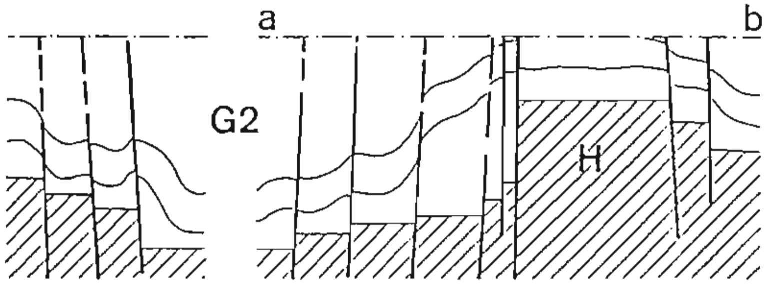

Fig. 5. Possible structural position of discussed Trzebionka mining block no. 4153 (comp. Fig. 1) in relatively large area

H — horst; G2 — graben structures; a-b — cross-section as in Fig. 1

Możliwa pozycja omawianego bloku eksploatacyjnego (nr 4153) na szerszym tle strukturalnym (por. Fig. 1)

H — struktura zrębowa; G2 — struktury rowowe; a-b — przekrój jak na Fig. 1

wings, i.e. the zone represents gradual transition from the horst to the graben. Small folds and flexures are characteristic for this graben, their directions being similar to the directions of the main disjunctive structures. Degree of the ore mineralization in that graben increases.

Three categories of tectonic structures condition the formation of the zones discussed above: joints, minor faults and flexures, and small folds. Most of minor faults and sets of slickensides have used steep surfaces of earlier joints. The fault pattern suggests an influence of movements along some steep faults in substratum on the formation of the horst-graben structures. Idealized model is shown in Fig.5. Folds developed in the graben parts are widely-spaced and have small amplitudes (up to some meters, e.g. Fig. 3). Similar assemblage of structures, with associated ore mineralization, occurs in the blocks nos. 4352 and 4353. In spite of the little distance (250 m) from the block no. 4153 discussed above, however, the structural directions are quite different (for details comp. E. Górecka et al., 1991 — Fig. 2, also diagrams in Figs. 3-6 — *ibidem*). In the present author's opinion this striking fact is due to a selected structural appearance of faults contouring the basement blocks. The fault of NE direction was active in the south (described in the paper quoted) whereas the NW one in the north. The result of activity of the latter fault is described in the present article.

Zonation in Zn-Pb mineralization was influenced by the similar scale rhythm of repeated changes, conditioned by the regular tectonic features as it has been shown by R. Blajda (1991) who was using the statistical methods. In the area in question, the fact may be explained as a result of locally different components of the fault system which consists of NW and NE sets. Those components could be the block-faults of dip-slip type, generating uplifted and downwarped zones also in the larger area than the area in question. Whether the downwarped parts (inter-fault blocks, grabens) are the sites of richer mineralization as a rule (in the whole region e. g.) still remains an open problem. Such an assumption, however, may be supported by the tectonic data on geological setting of the distant Olkusz region (Klucze deposit, comp. E. Górecka, 1991).

ORE MINERALIZATION PROCESS VERSUS TECTONIC BACKGROUND

Studies on spatial relations between the tectonic structures and the degree of mineralization, especially an analysis of mineralization along different fractures, gave the important data on mutual relations between tectonic events and ore mineralization. A connection between the intensity of the ore mineralization on one side and

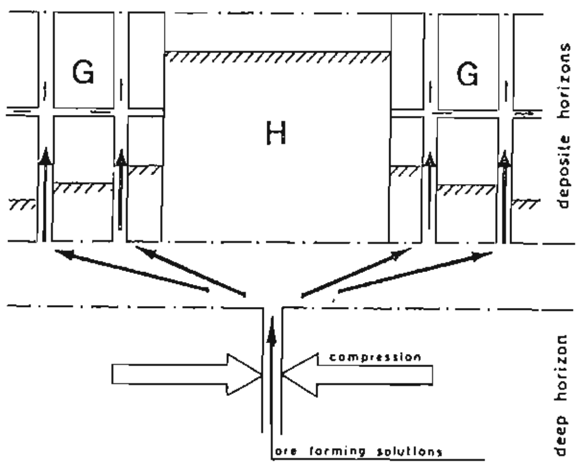

Fig. 6. Schematic presentation of possible tectonic pumping of ore forming solutions from the depth into the ore deposit levels
Explanations as in Fig. 1
Schemat możliwego tektonicznego przetłaczania roztworów kruszconośnych z głębszych poziomów w horyzonty złożowe
Objaśnienia jak na fig. 1

the intensity of the fracturing as well as position of mineralization in bigger tectonic structures on the other, has been stated. The richest mineralization occurs in the strongly fissured zones, cataclased and brecciated. In majority of cases, kathetal or subkathetal fractures are more strongly mineralized. Among those fractures the predominant are those displaying directions of 120–150° (sector NW-SE, Fig. 2c). Also the mineralized slickensides are generally steep. In the strongly fractured zones the ore mineralization also occurs in the inter-bed fissures, but this kind of the ores is less stable. Significant ore concentrations are observed in places where fractures are crossing the inter-bed fissures. The most distinct ore mineralization occurs in the zones of intensive fracture disintegration of cataclasites and cataclastic breccia, developed in the strongly faulted parts, corresponding to the downthrown sides of bigger vertical dip-slip faults discussed above, which generated the horst-graben structure (Fig. 1, G1–H–G2). In many cases, the ore mineralization of the steep and vertical, longitudinal fractures has been observed in the parts close to the axial hinge parts of the anticlinal folds. This fact is probably connected with the tension zone along the fold crest. Majority of the fold-like structures, mineralized in such a way, are accompanied by faults developed in the sub-axial parts. In the case of greater faults, more rich mineralization is generally observed in the downthrown sides.

Vertical zones of ore breccias with thickness reaching some tens of centimeters, appear occasionally in the same structural position as the vertical faults. This fact concerns also some faults which limit the horst from the west (Fig. 1, expl. 6). Relatively large zones of such character have been observed in the Pomorzany mine, Olkusz region (see Fig. 4). Their orientation shows close relation to the general pattern of the regional joint (comp. S. Kibitlewski, E.Górecka, 1988).

CONCLUSIONS

To summarize the observations of intensity of mineralization, it can be assumed that the ores concentrate mainly in the downthrown sides of the faults, as well as in the hinge parts of anticlinal structures. All those structures are possibly controlled by a net of steep faults in the basement. Downthrown sides of those structures have resulted in the tectonic effects in cover, which in their turn were responsible for the sites of an ore concentration. Therefore, it is evident, that the hitherto made small-scale observations should be now extended into a bigger scale, especially — more general structural plan of the region.

An important but still open problem regards the paths by which the mineral solutions penetrated „the ore-bearing dolomite" complex. All the data mentioned above suggest, that the migrating fluids followed mainly the tectonic paths. Tectonic stress was probably the factor of this migration, whereas the final structures were controlling the process of local flow and precipitation. At present, it is possible to introduce only a simplified mechanism of tectonic pumping as the mechanism of movement of the mineralizing solutions under discussion, as in Fig. 6. The determination of the range of mechanic effects of solutions forced into the rock formation remains still open. The problem has not been widely discussed yet (in relation to the Zn-Pb ores), although this factor seems to be inevitable in every model of deep circulation. The first opinions have been presented by W. Jaroszewski, 1986, 1993).

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Zespół Kartografii Geologicznej i Teledetekcji
Państwowego Instytutu Geologicznego
Warszawa, ul. Rakowiecka 4

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Stanisław KIBITLEWSKI

PROCESY TEKTONICZNE W ROZWOJU ZŁÓŻ Zn-Pb W REJONIE CHRZANOWSKIM

Streszczenie

Przedstawiono wyniki badań nad zależnością procesów mineralizacji Zn-Pb a tektoniką dolomitów kruszconośnych w złożu kopalni Trzebionka. Zespół struktur tektonicznych takich jak fałdy, uskoki, fleksury, struktury ślizgowe, strefy kataklazy i zbrekcjowania, zbadany szczegółowo na przestrzeni sześciu bloków wydobywczych (ok. 6 ha), łącznie ze związanymi z nim przejawami mineralizacji siarczkowej dostarczył dowodów na postawienie tezy o wyraźnych związkach między procesami okruszcowania a budową tektoniczną zbadanego odcinka. Stwierdzono strefowość okruszcowania związaną z istnieniem tak dysjunktywnych, jak i ciągłych form deformacji, w których wyniku zachodziło ekstensyjne powiększanie przestrzeni skutkujące wzmożoną precypitacją z roztworów mineralizujących. Uzyskane dane sugerują ważną rolę — w rozwoju tektonicznym badanego obszaru — pionowych uskoków typu progowego działających w podłożu badanej formacji dolomitowej.