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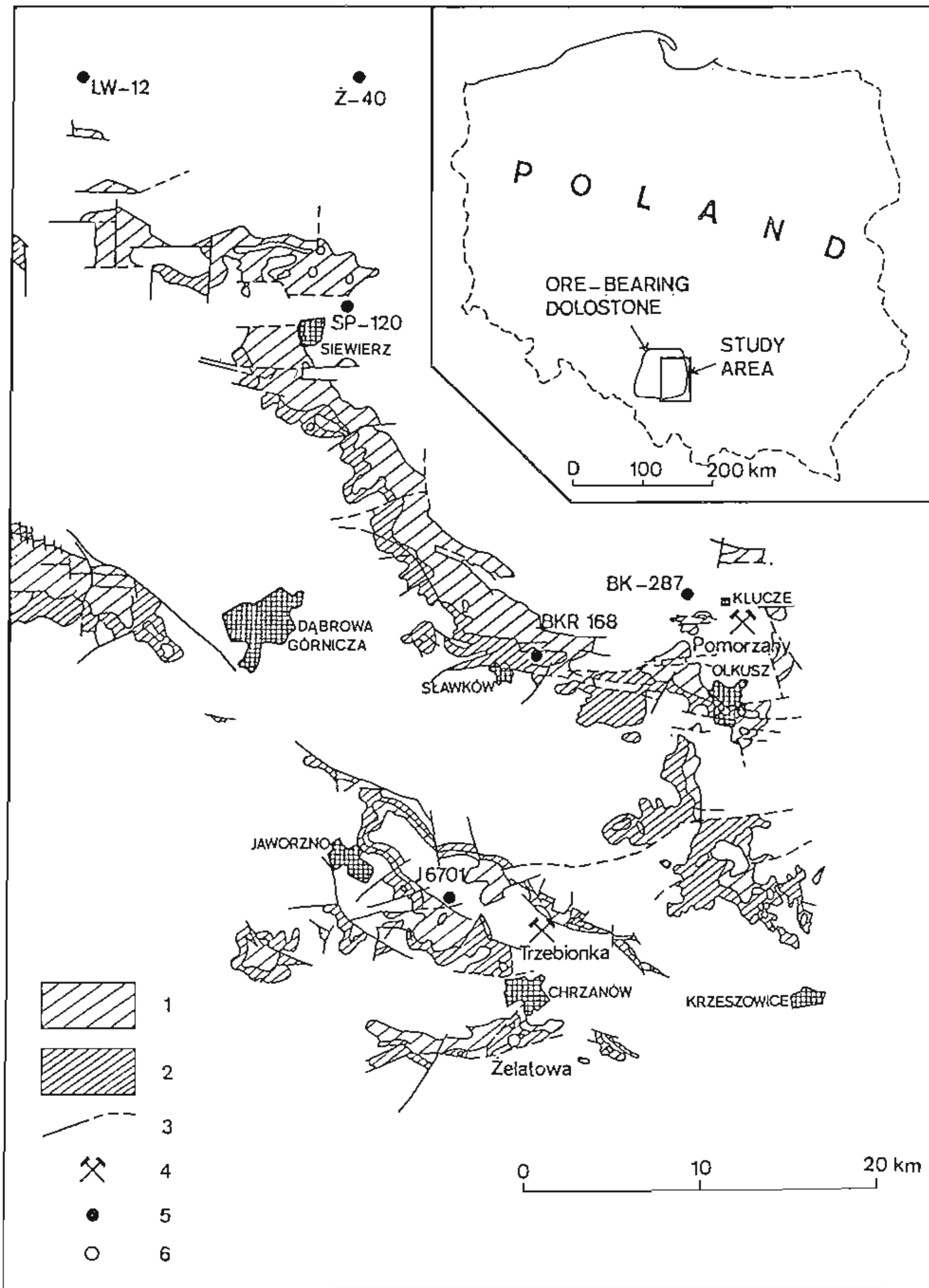
Cathodoluminescence study of the ore-bearing and related dolostones in the Triassic of the Silesian-Cracow district

Cathodoluminescence studies appear to be a useful tool in discriminating between the ore-bearing dolostone (hosting bulk of the MVT ores in the district) and, on the other hand, several types of the earlier formed („primary") dolostones. The latter are mostly micro- to finely-crystalline rocks and they show CL controlled by depositional texture. The former display characteristic zonation of larger dolomite crystals. Preliminary CL microstratigraphy of the ore-bearing dolostone reveals that the early zones are difficult to correlate throughout the district whereas the latest zone, largely non-luminescent one, is particularly conspicuous in the areas of the MVT deposits. Moreover, it post-dates or overlaps with the early sphalerite in the Trzebionka mine.

INTRODUCTION

During the last decade, observations of cathodoluminescence (CL) proved to be an important tool in dolomite studies, particularly in those devoted to MVT deposits (e.g. J. M. Gregg, 1985; E. L. Rowan, 1986). In the cited papers the emphasis was put on CL microstratigraphy of dolomite cements and its relationship to phases of ore formation. Such an analysis provides an evidence for interpretations of regional paleohydrologic systems responsible for both dolomitization and ore formation.

In spite of its growing importance in carbonate petrology, systematic CL studies have not been undertaken in the case of the Triassic dolostones hosting the MVT ore-deposits in the Silesian-Cracow district, southern Poland. The only results re-


LW-12
Ż-40
SP-120
SIEWIERZ
DĄBROWA GÓRNICZA
SŁAWKÓW
BKR 168
BK-287
KLUCZE
Pomorzany
OLKUSZ
JAWORZNO
J6701
Trzebionka
CHRZANÓW
KRZESZOWICE
Żelatowa
POLAND
ORE-BEARING DOLOSTONE
STUDY AREA
0 100 200 km
0 10 20 km
1
2
3
4
5
6

ported thus far are based on a few samples from the single Olkusz area (A. Krzyezkowska-Everest, 1990).

For the purposes of the present study nine localities were sampled. These are boreholes, quarries and active mines distributed over the large part of the district (Fig. 1). The aim of the study is twofold: 1) comparison of CL properties of all important dolostone types related to ore deposits; 2) testing the possibility of applying CL microstratigraphy for the ore-bearing dolostone (OBD) — main host of the Pb-Zn mineralization in the district. This would have important implications for a genetic model, by analogy to e.g. the Viburnum Trend studies in the U.S.A.

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MATERIALS AND METHODS

Location of sampled localities is shown on Fig. 1. In general, 37 polished thin-sections were prepared, 2-4 from each locality on average. More samples have been investigated only in the case of the Trzebionka mine (11 thin sections) and the BK-287 borehole (10 thin sections). In the former locality, all important dolomite-types were sampled, while in the latter — a vertical transition between the OBD and the overlying Diplopora Dolostone has been analysed in detail (Fig. 2, see below). In other localities mainly the OBD was sampled, including, if possible, both matrix and late dolomite cement.

The observations were conducted using Technosyn luminoscope (Cold Cathode Luminescence), model 8200 Mk II located in the Branch of Petroleum Geology, U. S. Geological Survey, Denver. Images of thin sections were recorded on 169 colour slides, in most cases pairs of CL and normal transmittent-light photographs. Most of the CL slides has been subsequently converted into colour prints in order to make visual comparisons easier.

Fig. 1. Location of the study area in Poland (inset) and location of the studied localities against the outcrop pattern of the ore-bearing dolostone and the Diplopora — Tarnowice Dolostone; based on the map by H. Kaziuk (1978)

1 — Diplopora Dolostone and Tarnowice Dolostone; 2 — ore-bearing dolostone; 3 — faults; sampled localities: 4 — subsurface mines, 5 — boreholes, 6 — surface exposures

Lokalizacja obszaru badań (mapka w prawym górnym rogu) oraz umiejscowienie badanych profili na tle zarysu wychodni dolomitu kruszconośnego oraz dolomitu diploporowego i tarnowickiego według H. Kaziuk (1978)

1 — dolomit diploporowy i tarnowicki (łącznie); 2 — dolomit kruszconośny; 3 — uskoki; 4 — kopalnie podziemne; 5 — otwory wiertnicze; 6 — odsłonięcia powierzchniowe

The CL observations were supplemented by other results of previous investigations carried out by the author in the Silesian-Cracow region between 1986 and 1991. Carbon and oxygen isotope data for the OBD to the Diplopora Dolomite transition in the BK-287 section are shown on Fig. 2. Isotope analyses were conducted by Prof. S. Hałas (M. Curie-Skłodowska, University Lublin). Fe and Mn was analysed in carbonate fraction of dolostones using the AAS method (P. Robinson, 1980). In addition, the supplementary study of 21 stained thin-sections has been undertaken.

OUTLINE OF STRATIGRAPHY

There exists an extensive literature on the stratigraphy of the deposits hosting Pb-Zn ores in the Silesian-Cracow district, in particular on the ore-bearing dolostone (OBD) and related carbonates of the Lower to Middle Triassic age (i.a. S. Śliwiński, 1969; K. Bogacz et al., 1972, 1975; several papers in: J. Pawłowska ed., 1978). The aim of the following brief review is to clarify the present usage of the most important stratigraphic terms and to outline the „primary" (i. e. pre-OBD and pre-ore) lithological succession in the district. This succession is exemplified by the BK-287 borehole section (Fig. 2) displaying stratigraphic relationships typical for the central part of the study area.

The majority of ores is hosted by the OBD — grey to almost black phanerocrystalline dolostone, commonly with vuggy and intercrystalline porosity and with poorly preserved primary depositional texture. As it was already shown by K. Bogacz et al. (1972, 1975) the OBD is a late diagenetic dolostone (mesogenetic using terminology of P. W. Choquette and L. C. Pray, 1970) that may span a wide stratigraphic interval ranging from an upper part of the Röt dolostones to the top of the Diplopora Dolostone. The illustrated section (Fig. 2) represents a more typical situation with the OBD spanning the Olkusz Beds and a bottom part of the Diplopora Dolostone. Thus, the ore-bearing dolostone is typically a product of both limestone replacement and dolostone recrystallization.

Given below are brief descriptions of the lithostratigraphic units involved in processes of dolomitization and ore-formation.

Röt. These are marly light-grey dolomite mudstones to grainstones, partly oolitic and with associated evaporites. The depositional facies is interpreted as eogenetic peritidal. Average thickness is between 40 and 80 m.

Gogolin Beds. Typically, these are marly grey to dark grey lime mudstones and wackestones displaying wavy to nodular bedding and a strong bioturbation. Some skeletal packstone to grainstone intercalations may occur, particularly in the bottom part of the unit. Single thin (2-3 m) dolomite mudstone horizon occurs in the middle part and is widespread throughout the region („cellular horizon" — Fig. 2). The Gogolin Beds commonly underlie the OBD and their thickness varies usually between 15 and 65 m (S. Śliwiński, 1969).

Olkusz Beds (S. Śliwiński, 1961). Very pure light-coloured lime mudstones interbedded with well-sorted laminated skeletal grainstones. Typical are tubular vertical to sub-vertical burrows. In the southern part of the study area (Trzebionka

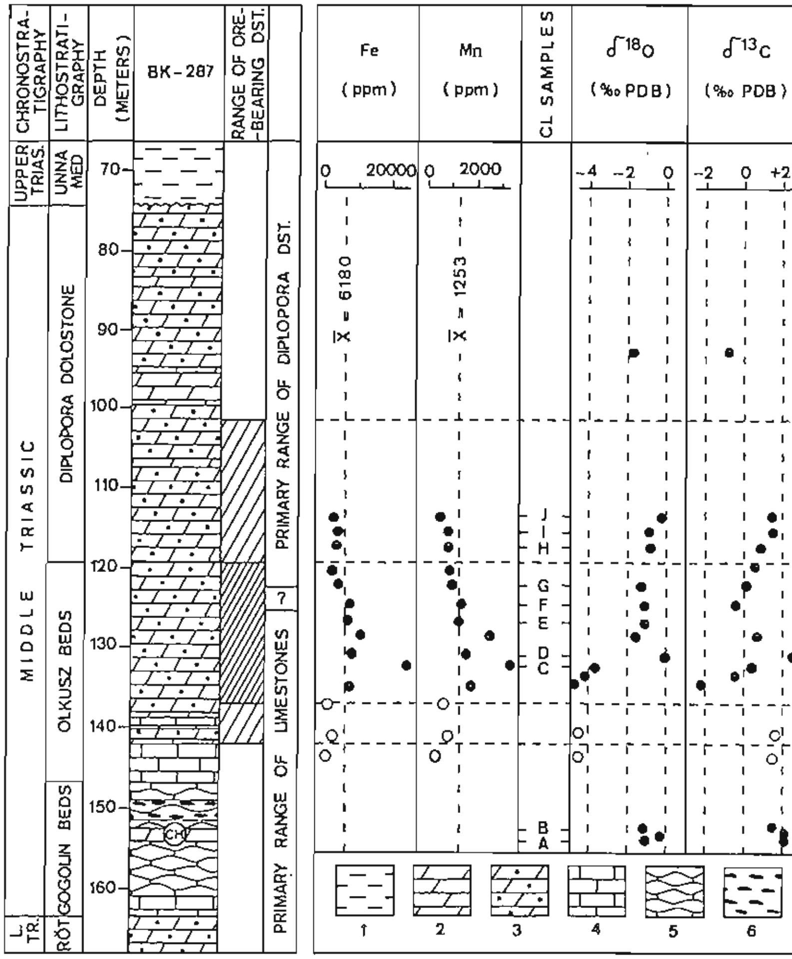

Fig. 2. Location of the investigated CL samples against the lithology and chemistry of the BK-287 borehole section

CH — „cellular horizon" in the Gogolin Beds; range of the ore-bearing dolostone represents homogeneous crystalline dolostone (dense pattern) and partly altered lithologies (loose pattern); Fe and Mn were analysed in carbonate fraction; isotope values are for bulk samples; open circles represent limestones, solid are dolostones; 1 — clay; 2 — dolomite mudstone; 3 — dolosparite (asterisks) and grained dolostone (dots); 4 — limestone; 5 — marly limestone with wavy/nodular bedding; 6 — intraformational conglomerate; for other explanation see the text

Umiejscowienie badanych próbek na tle litologii i składu chemicznego w profilu otworu wiertniczego BK-287

CH — poziom komórkowy w warstwach gogolińskich; zasięg dolomitu kruszconośnego odpowiada występowaniu jednorodnych dolomitów krystalicznych (gęste kreskowanie) i utworom częściowo zmienionym (rzadkie kreskowanie); Fe i Mn oznaczono we frakcji węglanowej, izotopy — w całej skale; puste kółka — wapienie, pełne kółka — dolomity; 1 — iłowiec; 2 — dolomikryt; 3 — dolosparyt (gwiazdki) i dolomit ziarnisty (kropki); 4 — wapień; 5 — wapień marglisty warstwowany faliście/gruzłowo; 6 — zlepieniec śródformacyjny; inne objaśnienia w tekście mine) the stratigraphic equivalent of the Olkusz Beds is developed partly as dolomite mudstones to waekestones (J. Pawłowska, M. Szuwarzyński, 1979). Over the most of the investigated area the Olkusz Beds are entirely replaced by the OBD. Average thickness varies between 35 and 45 m.

D i p l o p o r a   D o l o s t o n e. The predominant lithology consists of dolomite paekstones to grainstones with partly preserved interparticle porosity and well-preserved organic structures including i. a. oncolites. Another important lithology is dolomite mudstone commonly displaying irregular (algal?) lamination. At least part of the dolostones forming this unit is clearly replacive in origin, the replacement pre-dating the OBD formation. In most of the studied sections the OBD obscures the „primary" lithological boundary between the Olkusz Beds and the Diplopora Dolostone. The boundary is conventionally placed at the base of the lowermost lithology typical of the upper unit. However, the original lowermost range of the Diplopora Dolostone eould have run lower and is now indeterminable because of recrystallization. The original boundary between the Olkusz Beds and the overlying unit in the BK-287 section (Fig. 2) was interpreted basing on correlation with closely situated sections showing minimum development of the OBD. Thickness averages ca. 25 m.

The upper boundary of the Diplopora Dolostone is commonly erosive in nature. In places, however, there is a continuous sequence of marly unfossiliferous dolomite mudstones named Tarnowice Beds.

CL CHARACTERISTICS OF INVESTIGATED DOLOSTONES

„PRIMARY" DOLOSTONES

The term „primary" has no genetic connotation; it merely means that the dolostone in question originated prior to the OBD development, and in many eases underwent recrystallization to form the OBD.

R ö t   d o l o s t o n e s. The dolomite representing this unit displays dull dark-red luminescence. In packstones to grainstones, the grains or their fragments (e.g. coatings in microoncolites) show brighter luminescence.

C e l l u l a r   h o r i z o n. Under normal transmittent light one can commonly observe micrite relies e.g. in the form of peloids. Typically, however, primary dolomite mud recrystallized into micro- to finely crystalline spar. Under luminoscope the dolomite is dull dark-red to moderately luminescing red with tiny yellow dots. In general, micritic grains show brighter luminescence, with more yellow to orange dots.

T r z e b i o n k a   „ p r i m a r y"   d o l o s t o n e s. This category includes various dolomicrites (dolomite mudstones to packstones) representing stratigraphic equivalents of the Olkusz Beds in the Trzebionka mine. The dolomite shows dull to moderate luminescence. The CL is iniform in homogeneous micrites whereas it is fabric-selective in wackestones to packstones, i.e. showing darker or brighter grains against the contrasting matrix. In thin sections located close to the OBD more differentiated luminescence has been observed irregular transitions from dull brown to moderate red, and in the form of brighter „clouds" surrounded by less luminescing areas.

Diplopora Dolostone. Vertical transition between the Diplopora and underlying ore-bearing dolostone was sampled in the BK-287 section (Fig. 2, samples C–J). As no „intact" Diplopora Dolostone has been sampled, the observations given below are representative only of the intermediate, i.e. partly recrystallized zone between both the major dolostone types.

Sample J: brightly yellow luminescing dolomicrite matrix with less luminescing orange dolosparite rhombs.

Sample I: minor proportion of yellow-luminescing dolomicrite; predominant are moderately red-luminescing blotchy rhombs with thin outer zones of yellow/red/non--luminescing bands.

Sample H: moderate red CL of larger sub-anhedral dolomite crystals floating in microcrystalline matrix displaying a mosaic luminescence: from dull brown to moderate red to bright yellow.

Samples E–G: under normal light: non-equicrystalline anhedral mosaics with „dirty" inclusion-rich crystals; under luminoscope: mosaic of dull to moderate red and bright yellow areas. Some crystals show moderate red blotchy luminescence in the centres and thin bright yellow rims. Zoned dolomite cement is present in pores.

Samples C–D: coarse and equicrystalline subhedral mosaic. Matrix and cement crystals are zoned both under normal light and under luminoscope. Matrix dolomite is luminescing moderately red and blotchy. Both the samples represent the typical OBD secondary after an Olkusz Limestone.

ORE-BEARING DOLOSTONE

The ore-bearing dolostone as understood in the present paper, includes both late dolomite cement and products of a replacement/recrystallization of a limestone/dolostone. In thin sections one can usually distinguish between both the varieties. The matrix-type (i.e. replacive or recrystallized) dolomite typically displays dirty or cloudy appearance under normal light due to numerous irregular inclusions. In contrast, cement crystals or zones are clear or reveal regular zonation of inclusion-rich bands parallel to crystal faces. Under luminoscope matrix dolomite is usually blotchy showig dull brown to bright red luminesce with irregular brighter blotches or dots. At the same time there seem to be no major difference between the CL properties of a replacement- vs. recrystallization-type of a matrix dolomite.

The CL zonation of dolomite crystals in the OBD has been carefully studied in the Trzebionka mine in attempt to reconstruct at least the local sequence of differently luminescing zones (CL microstratigraphy). The complete restored succession embraces 8 zones with the following CL properties (from older to younger): 1) dull to brigh blotchy (= matrix); 2) thin and uniform moderate to bright red; 3) dull red to brown, weaker outwards; 4) thin moderate red; 5) thin dull red-brown; 6) thin moderate red; 7) thick very weak to non-luminescent; 8) thin bright red. Above composite sequence has never been observed in a single thin section. Some of the zones (2, 5–8) may be missing because of non-deposition (5–8) or dissolution (2?). Besides, the zones 4 to 6 may coalesce into the single thin moderately red to brightly orange luminescing zone. In one of the thin sections zones 1 to 3 seem to correlate with the matrix dolomite.

Regional correlation of CL zones is even less straightforward. In general, in the areas of major ore-deposits (Trzebionka, Pomorzany — Klucze) the CL zonation becomes more complex than in the peripheries of the district (e.g. sections Ż-40 and LW-12). In addition to above mentioned complexities, certain zones (e.g. 7 or 8) may be subdivided into subzones, or zone 7 may rest upon different zones: 6, composite 4 to 6, 2 and even 1. At this stage of investigations one may distinguish 3 generalized zones which may be correlated over the most of the investigated area:

I — blotchy matrix dolomite (= zone 1 in Trzebionka);

II — uniformly dull to moderately luminescent with a few (up to 3) thin brighter bands in some sections (= zones 2 to 6);

III — non-luminescent or (rarely) very dull with a few (1–3) thin luminescing bands (= zones 7 to 8 in Trzebionka).

Stained thin sections reveal that the zone III is composed of Fe-dolomite. It is absent only in the northernmost part of the study area, i.e. in the LW-12 and Ż-40 sections, whereas it markedly thins in the SP-120 section. On the other hand this zone is exceptionally thick and/or complex in direct neighbourhood of an extensive ore-mineralization in the Trzebionka and Pomorzany mines.

In two thin sections from Trzebionka, a sphalerite (probably the earliest sulfide phase) correlates with the boundary between the CL zones 6 and 7 or with zone 7. The latter is clear because of distinct CL-zonation developed in sphalerite-cement crystals in dolomite breccia. Early zones show moderate light-brown luminescence with brightly luminescing bluish bands. The dolomite zone 7 is not developed where the above sphalerite zones abut fracture walls. It is, however, developed on breccia fragments contacting with the late sphalerite zone displaying characteristic sparkling blue luminescence (Pl. I, Figs. 3, 4).

In several thin sections from the Pomorzany mine and in BK-287 section the uneven lower boundary of the zone III is suggestive of dissolution phenomena predating this zone. Similary, lack of the zone 2 and unclear boundary between the zones 1 and 3 may be related to dissolution event (Trzebionka, Żelatowa, BKR-168). In Trzebionka, the geopetal dolomite crystal sediment and associated cement fill fractures in „primary" dolostone and in the OBD. These infillings are composed of the dolomite zones 2 to 7. This evidences that fracturing post-dated most of the matrix-type dolomite and pre-dated precipitation of the zones 2 to 8.

DISCUSSION AND PRELIMINARY CONCLUSIONS

„Primary" dolostones markedly differ in their CL properties from the ore-bearing dolostone. Cathodoluminescence of the former dolostones to a large degree reflects sedimentary texture while in the latter it is controlled by secondary factors, most probably by Fe/Mn ratio of dolomitizing fluids.

Cathodoluminescence appears to be useful when studying recrystallization of earlier formed („primary") dolostones. In the case of the Diplopora Dolostone a degree of recrystallization is reflected in an increase of weakly luminescing large dolospar crystals replacing brightly luminescing dolomicrite or microsparite. This is paralleled by the increase of the bulk Fe and Mn contents in the carbonate fraction (Fig. 2). The OBD varieties with a maximum contents of late dolomite cement (including non-luminescent zone III) display also the maximum Fe contents in a carbonate fraction. This is consistent with Fe-dolomitic nature of the zone III.

This trend is also mirrored in isotope data (Fig. 2), particularly in $\delta^{18}O$ values declining downwards across the Diplopora Dolomite to the OBD transition. Sedimentary characteristics of the dolostone forming the „cellular horizon" point to its marine eogenetic origin. Moreover, its CL properties suggest a lack or a small degree of recrystallization. Thus, it seems conceivable that the oxygen isotope values of the dolomite forming CH reflect Middle Triassic marine signature. If so, the negative oxygen values of the bottom part of the OBD in the BK-287 section probably point to increased temperature of formation of at least dolomite cement which is particularly common here.

The dolomite cement of the OBD displays a clear CL zonation. However, the zonation appears more difficult to trace throughout the whole district when compared e.g. to the CL microstratigraphy of the southeastern Missouri district (J. M. Gregg, 1985). This is particularly true for the zone II reflecting to a larger degree some local controls on water/rock interactions and/or composition of dolomitizing fluids.

The non-luminescent zone III, consisting of a Fe-dolomite, is more uniform throughout the district. It is particularly well-developed and complex within the ore-deposit areas in the Trzebionka and Pomorzany mines. Moreover, the limited evidence from the Trzebionka mine reveals that the sphalerite mineralization post-dates the zone II and overlaps with the zone III. The above observations are collectively suggestive of a genetic relationship between the ore mineralization and the zone III of the late dolomite cement. This is of course not to imply the co-precipitation of carbonates and sulfides which would be difficult to assume on chemical grounds. It seems probable, however, that both zone III dolomite and sulfides originated from the same hydrologic system. If above conclusion is true then the presence of the zone III dolomite may become an important criterion when prospecting for ores in poorly studied parts of the district.

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STUDIUM KATODOLUMINESCENCJI DOLOMITÓW KRUSZCONOŚNYCH I INNYCH TOWARZYSZĄCYCH IM DOLOMITÓW TRIASOWYCH W REGIONIE ŚLĄSKO-KRAKOWSKIM

Streszczenie

Zbadano katodoluminescencję w 37 płytkach cienkich wykonanych z dolomitów triasowyeh regionu śląsko-krakowskiego. Łącznie opróbowano 9 profili wierceń i odsłonięć oraz czynnych kopalń (lokalizacja na fig. 1). Badano przede wszystkim dolomit kruszconośny z jego tłem krystalicznym i późnym cementem dolomitowym, a także kilka odmian dolomitów „pierwotnych" powstałych przed dolomitem kruszconośnym: dolomity retu, dolomity poziomu komórkowego warstw gogolińskich, dolomity warstw olkuskich (Trzebionka) i dolomity diploporowe. Luminescencja dolomitów „pierwotnych" odzwierciedla w znacznym stopniu pierwotne cechy sedymentacyjne, np. zróżnicowanie na tło mikrokrystaliczne i ziarna, czy też szczegóły budowy wewnętrznej ziaren obleczonych. W przypadku częściowej rekrystalizacji otoczenia dolomitu kruszconośnego, obserwuje się nieregularnie rozmieszczone partie o zróżnicowanych barwach i intensywności świecenia. Szezególnie czytelnie zjawisko to występuje w dolomicie diploporowym, może być zatem wykorzy-

stywane do określenia jego granicy z dolomitem kruszconośnym. Stopień rekrystalizacji koreluje się tu dodatnio z zawartością Fe i Mn we frakcji węglanowej oraz z danymi izotopowymi (fig. 2).

W dolomicie kruszconośnym kryształy tła charakteryzują się nieregularną plamkową luminescencją w przypadku zarówno zastępowania wapieni, jak i rekrystalizacji wcześniejszych dolomitów. Późny cement dolomitowy odznacza się obecnością wyraźnych jednorodnych stref różniących się intensywnością i barwą świecenia. Wcześniejsze strefy występują nieregularnie w pionie i poziomie, co wskazywałoby na lokalne uwarunkowania precypitacji dolomitu. Najbardziej zewnętrzna strefa cementu składa się w większości z nieświecącego dolomitu o znacznym udziale domieszki sieciowej żelaza. Strefa ta jest względnie najgrubsza w rejonach złóż Zn i Pb, a „wyklinowuje się" ku peryferiom badanego regionu. Ponadto, w pojedynczych próbkach z kopalni Trzebionka zauważono, iż sfaleryt, stanowiący przypuszczalnie najwcześniejszą fazę okruszcowania, poprzedza lub współwystępuje z wymienioną strefą (Pl. I, Figs. 3, 4).

PLATE I

Fig. 3. Dolomite breccia with pores partly filled by sphalerite (brown) and dolomite cement. Clasts are composed of dolomite mudstones to packstones representing „primary" dolostones of the Olkusz Beds in the Trzebionka mine. Sample VII, transmittent light, scale bar — 1 mm

Brekcja dolomitowa z porami częściowo wypełnionymi sfalerytem (brązowy) i cementem dolomitowym. Okruchy są zbudowane z dolomitów od mikrytowych do ziarnowo-mikrytowych, które odpowiadają dolomitom „pierwotnym" warstw olkuskich w kopalni Trzebionka. Próbka VII, światło przechodzące, długość skali — 1 mm

Fig. 4. Cathodoluminescence of the area shown in Fig. 1. Clearly visible are zonation in sphalerite and lack of luminescence (black colour) of the dolomite cement. Note that the non-luminescent dolomite is only developed at the boundary between the latest sphalerite zone and dolomite clasts

Katodoluminescencja obszaru przedstawionego na fig. 1. Wyraźnie widoczna strefowość w sfalerycie i brak luminescencji cementu dolomitowego (czarny). Zauważ, że cement ten jest rozwinięty między ostatnią strefą w sfalerycie a klastami dolomitowymi

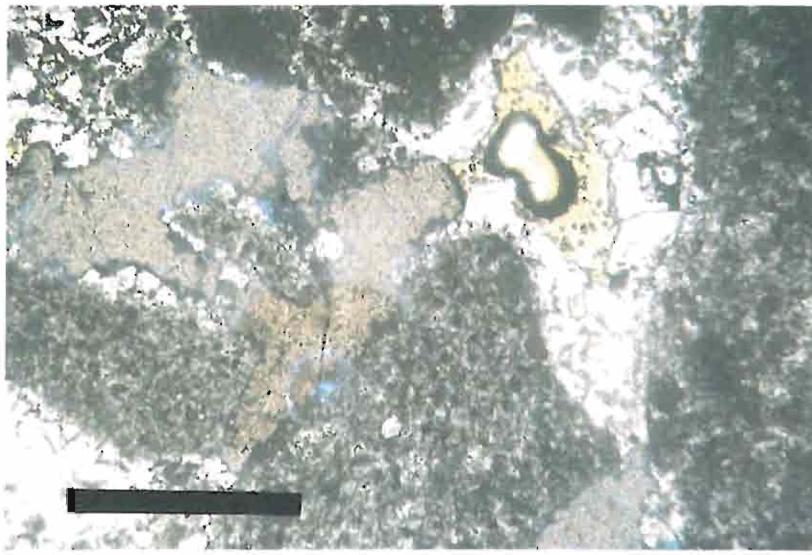

Fig. 3

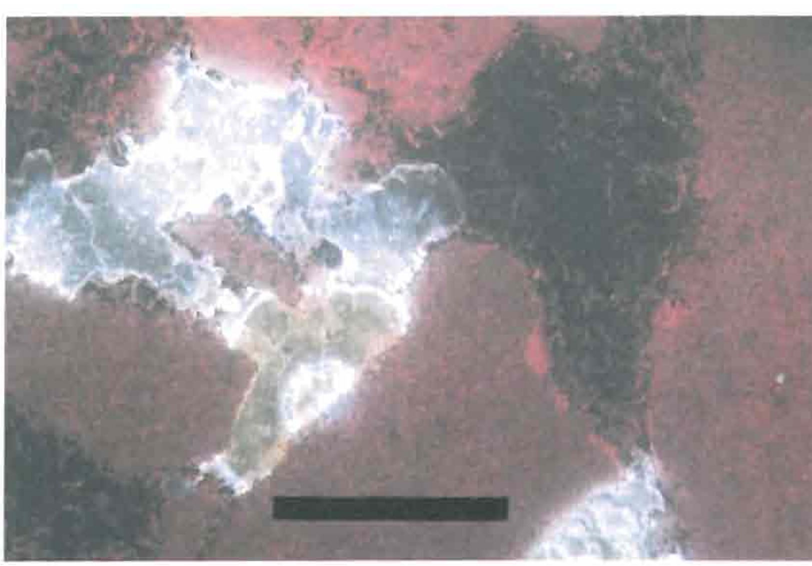

Fig. 4

Marek NARKIEWICZ — Cathodotermoluminescence study of the ore-bearing and related dolostones in the Triassic of the Silesian-Cracow district