Rudarsko-geološko-naftni zbornik	Vol. 1	str. 11—16	Zagreb, 1989.

UDC 553.065.44

Izvorni znanstveni članak

TWO SOLUTIONS — MULTIPULSATIONS MODEL OF GENESIS OF THE SILESIAN-CRACOVIAN Zn-Pb ORE DEPOSITS

Czesław HARAŃCZYK

Institute of Geological Sciences, Jagellonian University, Kraków, 2a Oleandry St., Poland

Key-words: Zn-Pb ore deposits, Structural control, Ore zoning, Pulsations of hydroxermal activity, Mixing of hydroterms and surficial waters, Sulfur isotopes

Silesian-Cracovian Zn-Pb ore deposits are hosted in Mesozoic cover and are located near main dislocations in the area between Upper Silesian Coal Basin and buried Caledonian mountains. A screen of Keuper clayely beds controls mixing of surficial waters with intermittently introduced hydrotherms. Sulfur isotopes relation in ores depend on mixing relations.

Ključne riječi: Zn-Pb rudna ležišta, Strukturna kontrola, Rudno zoniranje, Pulzacije hidrotermalnih aktivnosti, Miješanje hidrotermi i površinskih voda, Sumporni izotopi

Šlesko-Krakovska cink-olovna rudna ležišta smještena su u mezojoskom pokrovu i nalaze se blizu glavnih dislokacija, u području između gornjošleskog ugljenog bazena i pokrivenog Kaledonskog gorja. Ekran glinovitih slojeva keupera kontrolira miješanje površinskih voda s intermitentnim ascedentnim hidrotermalnim otopinama. Sastav i odnos izotopa sumpora u rudama ovisi o stupnju i odnosu miješanja otopina.

Introduction

The Silesian-Cracovian Zn-Pb ore deposits rank among the largest in the world, and they are the largest stratabound ores of the Mississipi Valley-type. Total reserves were estimated on 4×10^7 tons of zinc and 10^7 tons of lead metal. Half of these reserves have alerady been exploited (Gałkiewicz, 1967). The proved economic Zn-Pb ores are mainly confined to one hundred meters thick Middle Triassic Muschelkalk Formation and especially to ore-bearing dolomite. Ores occur also in Givetian and Dinantian carbonate beds. The discovery of Paleozoic magmatism and mineralization including skarns in Ordovician marbles and porphyry copper mineralization (Harańczyk, 1980) has induced investigations of the Paleozoic basement, moreover the discovery of the Cracovian branch of Caledonides (Krakovides) and of Paleozoic mineralization has completely changed the metallogenic position of the Zn-Pb mineralization (Harańczyk, 1979).

The present paper deals with new data on tectonic control of mineralization and on multipulsation influx of hydrothermal solutions bearing metals which mixed with surficial waters rich in sulfur. The rate of mixing of the two types of solutions was controlled by the screen of Keuper clayely beds overlying Triassic carbonate strata, and greately influenced isotopic composition of the ore minerals.

Structural Zoning

The Cracovian-Silesian ore deposits are located near the northeastern boundary of the Upper Silesian basin and near the main suture dislocation bordering the uplifted blocks of Caledonides (Fig. 1). The buried Caledonic mountains lie between the Upper Silesian basin which has basement of pre-Cambrian consolidation and cca 7.000 meters of Carboniferous sediments, and the Małopolska massif also of pre-Cambrian consolidation (Harańczyk, 1979). Four zones of the Zn-Pb ore deposits areas, underlain by a different Palezoic basement, may be distinguished here:

1. Marginal zone of the Upper Silesian basin, including post-Triassic troughs, Bytom and Trzebionka troughs bordered by WNW dislocations.
2. Zone between geophysical boundaries of the Upper Silesian basin and Zawiercie-Rzeszotary suture dislocation bordering the uplifted blocks of the Caledonien mountains. Bolesław Mine, Pomorzany Mine and Olkusz Mine are located here.
3. Zone of the Zawiercie-Rzeszotary dislocation, including adjacent area of the depressed blocks of the Krakovides where the epi-Caledonian carbonate cover is preserved. Several new middle size ore deposits have been explored here.

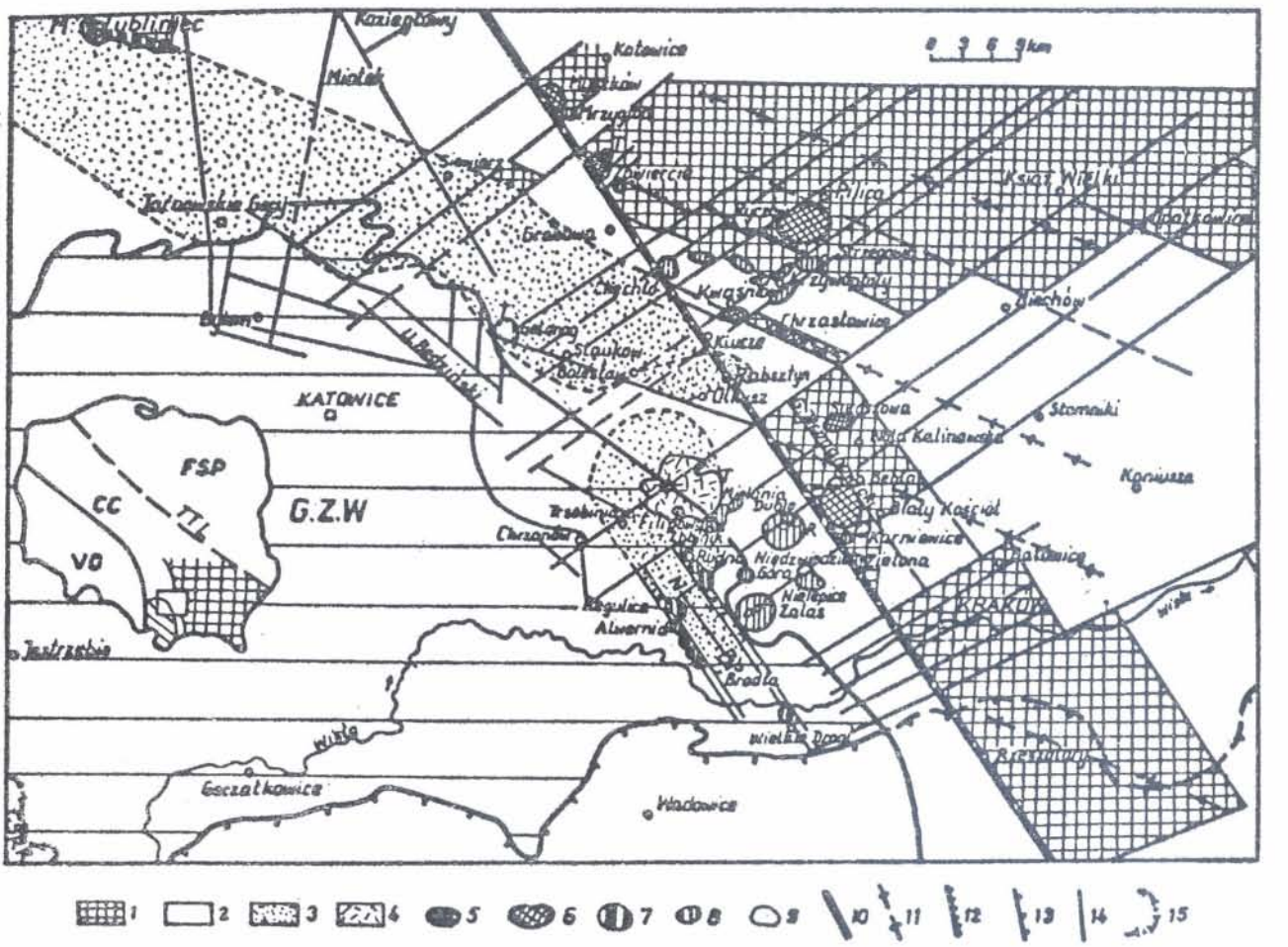

Fig. 1 The Mesozoic and Tertiary Zn-Pb ore mineralization superposed on the basement structures shown on geological map without formations younger than Permian.

1. Strata older than Devonian. 2. Strata younger than Devonian. 3. Permian conglomerates. 4. Permian pyroclasts. 5. Caledonian gabbro and granodiorite intrusions. 6. Variscan volcanites: M — melaphyres. RD — rhyodacites. R - K — rhyolites. A — andesites. T — trachite. L — lamprophyre. 7. Suture dislocation Zawiercie—Rzeszotary. 8. Axis of Caledonian fold-scale structures. 9. Thrust faults. 10. Front of Carpathian nappes. 11. Different polichronic dislocations, simplified. 12. Zn-Pb ore deposits in Mesozoic and Paleozoic rocks. 13. Country border. VO — Variscan Orogen. CC — Caledonian consolidation. TTL — Tornquist-Teisseyre Line. FSP — Fenno-Sarmatian Plate.

4. Internal zone of the Caledonian mountains (Krakovides). In this zone, numerous gabbro, granodiorite and vein porphyry intrusions bearing Paleozoic mineralization were discovered.

In the second and third zones, the Mesozoic strata 100 m. or less thick, are underlain by 2—3 hundred meters thick bed of the Lower Permian conglomerates and 2—3 thousand meters thick Givetian to Namurian carbonate sequences. Beneath, the Emsian sandstone and Caledonian molassa up to one thousand meters thick rest unconformably upon folded and metamorphosed Cambrian to Silurian mainly turbiditic sediments contributing to the Caledonian orogen. In the fourth zone, the Mesozoic beds lie on relicts of epi-Caledonian cover or directly upon Cambrian to Silurian folded and metamorphosed rocks of Krakovides. A paleoinsular zone was formed in the Muschelkalk sea. The Paleozoic carbonate rocks of the uplifted blocks have stood high in relief and were subjected to an intensive karstification. Zn-Pb ore bodies continue laterally from Triassic to Devonian beds crosscutting cliff contacts. The caves of the Paleozoic karst system were visited by hydrothermal solutions causing dolomitization of speleothem and lining with Zn-Pb ores the collapse breccia fragments. The vertical fissure system seems to serve as feeding channels for mineralizing solutions. The economic ores were followed by drillings down to 1500 meters. The different mineral parageneses formed by subsequant pulsations of the mineralizing solutions were identified in the root veins (Harańczyk, 1979, 1983).

Ore zoning

Ore zoning must be discussed separately in the four distinguished zones substantiated by three different basement blocks (Fig. 1). In the first zone, the ore mineralization was greatly influenced by very good hanging wall screening and bottom lining with clayely layer of vitrioletten (W e r n i c k e, 1931) in Bytom trough, therefore the stratabound features of the Zn-Pb ores confined to the Muschelkalk sequence is best developed. The characteristically banded zinkblende crustifications are most commonly occurring ore-types here. More metasomatic features are seen at the bottom of ore bodies distributed especially on axis of the trough i. e. in Cecylia Mine. On the contrary, the collapse breccia ore-type is abundant at top of the mineralization zones. The brunckite ores occurred in the northern fault zone rimming Byton trough. Thin root ore veins associated with faults are encountered in the stopes of the coal mines, and are regarded as feeding channels of the ore bodies in Mesozoic beds (K o s m a n n, 1884).

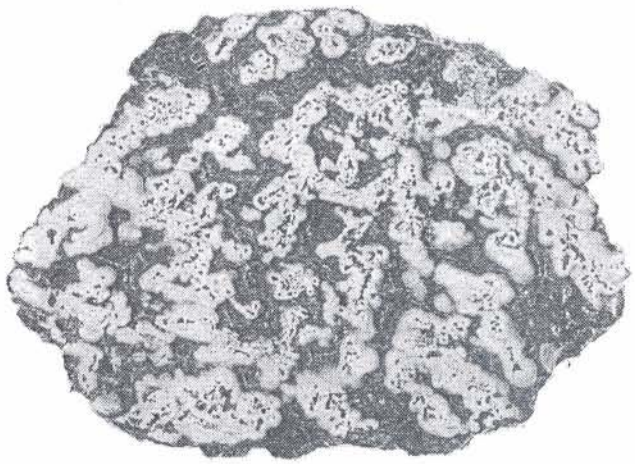

Fig. 2 Colloform Zn-ores with skeletal gallena distributed in white brunckite. Bolesław Mine, 71 Shaft. Reflected light, natural size.

In Trzebionka Mine, the widely extended horizontally zebra zinc ores grade into up to 30 meters thick hydrothermal karst caves, filled with ore crustifications (Fig. 3), extended along NE dislocations. Only intensive marcasite mineralization was noticed in fault zone in the Siersza Coal Mine located nearby.

In the second zone, the horizontal system of hydrothermal karst caves filled with ore crustifications of dolomitic collapse breccia are the dominant ore-type in the Triassic level, however an uniform hydrotermal karst system is including also a vertical and less horizontally extended hydrothermal karst system of caves developed a few hundred meters deeper in

Fig. 3 Schalenblende-Zn crustifications built of sphalerite paramorphoses after wurtzite with shadow layer of galena. Isotope temperature ca 300 °C. Trzebionka Mine, Ore-bearing dolomite level. Reflected light, 1/2 natural size.

Dinantian limestones. This uniform system of caves substandiated two floor patern of migration of the mineralizing solutions. During the interpulsation break of hydrothermal activity the oxidizing surficial solutions percolated down along the fault fissures to the Paleozoic basement, inducing oxidation of ore minerals of the early generations (H a r a ń c z y k, 1988b). In the best isolated by the Keuper screen of clayely beds, the eastern part of the Pomorzany Mine and eastern part of the Olkusz Mine, a real banded zinc crustifications built of wurtzite and sphalerite have been formed. In the lower level of the uniform hydrothermal karst system of caves in the Dinantian limestones, the caves are surrounded by a few meters wide orebearing dolomite zone. Breccia fragments of the dolomitized Dinantian limestones covered by crustifications of white milky dolomite-bearing sphalerite and more rarely galena bands or separate grains. In the Triassic level near open fault fissures, nests filled with white pulverulent brunckite have been deposited in the caves earlier partly filled with crustification ores showing oxidation symptoms in places (H a r a ń c z y k, 1988b).

In the third zone directly adjacent to the suture dislocation Klucze-Rzeszotary (Fig. 1) which is regarded as one of the main ascending ways for mineralizing solutions, ore bodies display distinct vertical zoning. For the first time such a vertical ore zoning was described in Klucze-Rudnica ore deposit (H a r a ń c z y k, 1963).

The described ore zoning and grading from coarse crystalline sulfides in the Paleozoic rocks to colloform varieties in Mesozoic rocks may also be regarded as a good evidence of mixing of ascending mineral solutions with surficial waters.

In the Mesozoic carbonate rocks of the fourth zone only traces of sulfides are encountered sporadically near fault zones, moreover, dolomitization of Jurassic rocks was noticed near some faults. Root veins built of vein milky dolomite with sphalerite, and also Zn-Pb ore crustifications with barite were perforated by deep drillings and they associate with Paleozoic Cu-Mo mineralization in the same diachronic strike-slip fault systems cutting Lower Paleozoic turbidite metamorphosed rocks.

Pulsation of ascending solutions

Several pulsations of ascending mineralizing solutions were induced by tectonic events of distinct tectonic phases which caused a rebuilt of geological structures in the described areas, for example Laramide inversion of block tectonics.

The first pulsation introduced mineralizing solutions which formed rich metasomatic Zn-Pb ores associated with dolomitization of Triassic and Dinantian limestones. The mineralizing solutions of this pulsation were emplaced at Jurassic time as the screen of Keuper clayely beds has already protected Triassic carbonate strata so that existance of hydrothermal anoxic environment could be possible.

The second pulsation introduced mineralizing solutions paternal for development of the hydrothermal karst caves* filled with crustified dolomite breccias completely isolated from integrated surficial waters (Bogacz et al. 1970, Sass-Gustkiewicz, 1988). These solutions ascended after events of post-Jurassic compresive tectonics. A good evidence is furnished by a superposition of two Triassic sequences overthrusted in the zone of the high angle thrust fault. Both the sequences have one uniform ore mineralization in fractures, showing vertical zoning with Zn-maximum in lower sequence. This thrust fault surface and complete two Triassic sequences have been perforated by BK-16 drill hole located in the border zone of the compression graben in Klucze north of Olkusz (Harańczyk et al., 1971). However it must be added that Tertiary rivers eroded Triassic beds, and fragments of galena clasts were found on river valley slopes (Panek & Suwarzyński, 1976).

The next, already Tertiary pulsation of mineralizing solutions has formed Zn-Pb ores asociated with barite. The largest Zn-Pb-barite ore deposit with reserves sufficiant for large mine has been proved by drillings in Zawiercie (Fig. 1).

The last pulsation of mineralizing solutions introduced marcasite which in root veins in the Paleozoic basement is associated with blue gypsum. In the Mesozoic rocks this marcasite builds crustifications or massive ores in caves filled with collapse breccia cemented with older Zn-Pb crustification ores, which were subsequently cemented with Tertiary brown coal, and once more faulted before the marcasite mineralization was emplaced (Harańczyk, 1988). In the area partly depleted of Keuper Screen near the 71 Shaft of the Bolesław Mine, a vertical ore body filled with colloform ores (Fig. 2) cut whole Triassic carbonate sequence of 80 meters thickness.

Sulfur isotopes and two solutions model of genesis

The ore deposits hosted in carbonate platform cover above a discordance, are always subjected to infiltration of downward percolating meteoric waters, if they are not protected by a screen of the impermeable clayely rocks. The Keuper clayely rocks forming a few ten meters thick bed represent such a screen in the Silesian-Cravovian ore deposits, however due to post-Jurassic tectonic events and especially Laramide tectonic phase this screen was partly destroyed in much of the discussed area. It was best preserved in the first zone while in the second zone it has usually been torn and displaced by tectonic dislocations. Consequently some caves of hydrothermal origin in Triassic beds later were opened for surficial waters and the ore bodies have partly been oxidized. This grade of isolation of the hydrothermal karst caves for downward percolating meteoric water during the operation of the ore deposits genetic processes, beside the composition of the ascending mineralization solutions, is responsible for the observed variation of structures and textures of the ore, trace elements content and sulfur isotope composition of the ore minerals. The ore minerals of the Silesian-Cracovian Zn-Pb ore deposits may be divided into a group enriched in heavy sulfur and another group enriched in light sulfur. The Zn ore crustifications built of heavy sulfur, heaviest in last bands up to $\delta^{34}S = +67{,}1$ ‰ (Gehlen & Nielsen, 1967, Harańczyk, 1978), are typical for ores from Bytom trough where the Keuper screen well isolated caves hosting ores. The cascade effect has produced needed enrichment in heavy sulfur isotopes in the well isolated caves. On the contrary, in the second zone the ores contain mainly light sulfur, the lightest ca $\delta^{34}S = -30$ ‰ in brunckite. This contrasting

* Actual formation of hydrothermal karst caves the present author investigated in 1961 in travertine surficial cover in Penen area, North Sumatra.

tendency seems to elucidate many regularities of distribution of the ore varieties. Mixing of the integrated stream of the surface water with ascending hydrothermal fluids produces pulverulent sulfides extremely enriched in light sulfur isotopes. Admitedly it must be added that metasomatic ores formed in the isolated system have troilitic sulfur representing isotopic composition of sulfur of the ascending solutions (Harańczyk, 1973).

In addition it must be emphasized that the put forward two solutions model of genesis of the Zn-Pb ores of the Silesian-Cracovian ore deposits accepts that in all cases methane introduced from the basement is responsible for reduction of sulfates.

Received: 28. XII. 1988.

Accepted: 6. II. 1989.

Conclusions

1. Four structural zones with different geological setting were distinguished in the Silesian-Cracovian Zn-Pb ore deposits.

2. The pulsation influx of hydrothermal fluids, generated by deep magmatic or tectonic events, ascended intermittently along fissures of the main dislocations, and filled the two floor karst system of the interconnected caves formed and mineralized by hydrothermal solutions, only in the paleoinsular zone, the caves were of usual karst origin.

3. Sulfur isotopes in the ores indicate rate of isolation of the caves during ore genesis and strongly suggest two solutions hypothesis of ore genesis.

REFERENCES

Bogacz, K., Dżułyński, S. & Harańczyk, Cz. (1970): Ore-filled hydrothermal karst features in the Triassic rocks of the Cracovian Silesian region. *Acta Geol. Polon. 20, 2,* 247—267.

Gałkiewicz, T. (1967): Genesis of Silesian-Cracovian zinc-lead deposits. *Econ. Geol. Monograph 3,* 156—168.

Gehlen, K. & Nielsen, (1969): Schwefel Isotope aus Blei-Zink-Erzen von Oberschlesien. *Mineral Deposita,* 3.

Harańczyk, Cz. (1963): Vertical ore zoning in the zone of faulting observed in Klucze near Olkusz. Problems of Postmagmatic ore deposition. v. 1, 248—253. Prague.

Harańczyk, Cz. (1978): Skład izotopowy siarki kruszców ze złóż śląsko-krakowskich. *Pr. Inst. Geol.* 83.

Harańczyk, Cz. (1979): Metallogenic evolution of the Silesia-Cracow region. *Pr. Inst. Geol., 95,* 109—132.

Harańczyk, Cz. (1980): Paleozoic porphyry copper deposits in Poland. European Copper Deposits, 89—95, Belgrade.

Harańczyk, Cz. (1983): Mineral paragenesis of Krakovides and its cover. *Ann. Soc. Geol. Polon. 53,* 91—126.

Harańczyk, Cz. (1988a): Two floor flow pattern of the mineralizing solutions in the Silesian-Cracovian Zn-Pb ore deposits. Bouladon Symposium, Mobilite et concentration des metaux de base dans les couvertures sedimentaires. BRGM, Orleans.

Harańczyk, Cz. (1988b): W sprawie wieku kruszców złoża kopalni Pomorzany. *Przegl. Geol. 36, 7,* 403—405.

Harańczyk, Cz., Szostek, L. & Filipowicz-Lesiak, W. (1971): Relation of the Zn-Pb mineralization of the thrust faults of the compression graben Klucze-Jaroszowiec. *Inst. Geol. Buil. 241,* 61—88.

Harańczyk, Cz. & Lis, J. (1973): Zróżnicowanie składu izotopowego siarki w kruszcach powstałych w warunkach krasu hydrotermalnego. *Prze gl. Geol. 5.* 21. 5.

Kosmann, K. (1884): Über Erzgänge und Erzmineralien in dem Steinkohlengebirge Oberschlesiens. *Österr. Z. Berg. Hüttenman Ver. 31,* 289—291, 302—304.

Panek, S. & Suwarzyński M. (1976): O przedtortońskiej dolinie erozyjnej wypełnionej osadami trzeciorzedowymi w dolinie Chrzanowa. *Rocz. Pol Tow. Geol.* z. 4.

Sass-Gustkiewicz, M. (1988): Hydrodynamiczne warunki depozycji rud Zn-Pb w rejonie olkuskim. *Przegl. Geol. 36.7.* 401—403.

Wernicke, F. (1931): Die primären Erzmineralien der Deutsch-Bleischarley Grube bei Beuthen/Oberschlesien/. *Arch. Lagerstättenforsch. 53.*

Zwierzycki, J. (1950): Lead and zinc ores in Poland. 18 Int. Geol. Congr. 1948. 7. 314—326, London.

Model geneze šlesko-krakovskih cink-olovnih rudnih ležišta miješanjem dviju otopina višestrukom pulzacijom

Cz. Harańczyk

Autor u svom radu opisuje četiri strukturne zone s različitim tektonskim sklopovima koje je identificirao u šlesko-krakovskim cink-olovnim rudnim ležištima.

Pulzacioni dotok hidrotermalnih otopina koji je nastajao pri dubokim magmatskim i tektonskim aktivnostima ascendirao je isprekidano vremenski duž prslina glavnih dislokacija i punio dva nivoa karstnih sistema međusobno povezanih špilja mineraliziranim hidrotermalnim otopinama i to samo u paleoinzularnoj zoni. Špilje su nastale uobičajenom karstifikacijom.

Izotopi sumpora u rudama svojim odnosima ukazuju na stupanj izoliranosti špilja za vrijeme geneze ruda i jasno upućuju na hipotezu o porijeklu ruda na bazi miješanja dviju otopina, descedentnih površinskih (meteorskih) i ascedentnih hidrotermalnih.