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Manifestations of hydrotectonics in Zn-Pb mineralization at Trzebionka mine (Silesian-Cracow zinc-lead ore district, Poland)

Mesostructures of zones of zinc-lead ore mineralization in Trzebionka mine suggest a forced flow of mineralizing fluids, stimulated by tectonic stresses, instead of the broadly accepted hydrothermal/karst mechanism. The joint action of tectonic activity and abnormal fluid pressures was a cause of hydraulic fracturing of host rocks which in its turn was opening the ways for further penetration of the fluid and for precipitation of its mineral content during phases of pressure drop.

INTRODUCTION

Long-time tradition of investigation of zinc-led sulfide deposits in the Silesian-Cracow area makes it hard for a casual observer to enter the debate. However, a look not restricted by routine may help to become free from seasonal „research fashions". For the ores mentioned (classified as Mississippi Valley-type), a dominant idea to explain their origin is, since the beginning of the seventies, the idea of hydrothermal karst (K. Bogacz et al., 1970; M. Sass-Gustkiewicz, 1975, 1985, 1988; S. Dżułyński, 1976; M. Sass-Gustkiewicz et al., 1982). In a common opinion, an important part is played also by the ores of hydrothermal/metasomatic origin.

According to a working hypothesis assumed by the present author, considering the genesis of hydrothermal ores one should not ignore an essential energetistic factor: tectonic stresses and abnormal pressure of mineralizing fluids, evoked by them (comp. W. Jaroszewski, 1986). Strange enough, apart from seismic pumping (R. H. Sibson et al., 1975), active tectonic factor has not been taken into account by investigators of

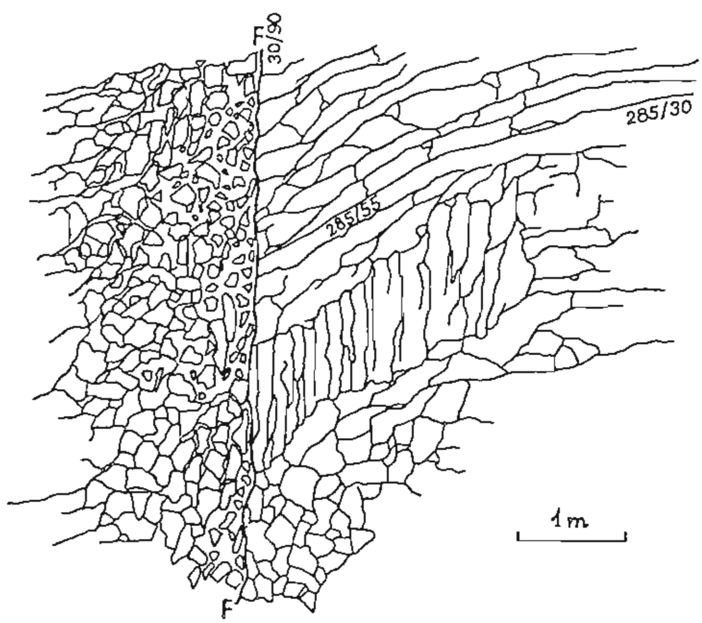

Fig. 1. Vertical dip-slip fault (*FF*) with a fault drag and internal shearing of strata on the upthrown side and with brecciated downthrown side

Uskok progowy (*FF*) z fleksurowym ugięciem i wewnętrznym pościnaniem warstw w skrzydle wiszącym oraz ze zbrekcjowanym skrzydłem zrzuconym

Silesian-Cracow Zn-Pb province, including those who were analysing just the sources of energy (A. Wodzicki, 1987). Tectonic dynamics and migration of hydrotherms must not be connected (and coeval), but their correlation is highly probable. Moreover, tectonic stresses may be energetistically effective even without accompanying structural rearrangement (folding etc.).

What regards methodology, the author has concentrated so far upon mesostructural context of ore deposits. This aspect was rather neglected by former investigators, except for works of S. Kibitlewski and E. Górecka (a.o., S. Kibitlewski, E. Górecka, 1988; E. Górecka et al., 1991). It was the experience and cooperation of the last authors, as well as the kindness of Mr M. Szuwarzyński, which enabled the present author to collect his observations in the Trzebionka mine. Majority of data came from the mining blocks no.no. 4252, 4253 and 4352 (see S. Kibitlewski, 1993, Fig. 1).

STYLE OF FRACTURE TECTONICS

The tectonic/hydraulic conditions of mineralization can be somewhat enlighted by studying natural conduits for trans-bedding circulation: faults and joints. The faults

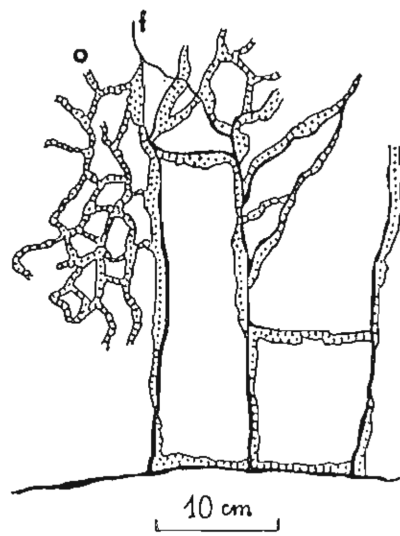

Fig. 2. Ore mineralization (dotted), partly predisposed by fractures (*f*), but also penetrating into the rock as a net of irregular ore veins (*o*)
Okruszcowanie (partie zakropkowane), częściowo zdeterminowane przez spękania (*f*), ale także przenikające w głąb skały w postaci sieci nieregularnych żył kruszcowych (*o*)

in Trzebionka mostly show dip-slip kinematics and a relatively ductile style: some fault drag, anostomozing course of the fault surface, even initial cleavage (Fig. 1). As it has been known since a long time, fault fissures in ore-bearing dolomite have not became a site for a mass mineralization, but they had to make ways for hydrothermal fluids ascending from the depth. Judging from the described character of faults, those were not conduits open for free circulation, and the less — karstified openings. In this connection some earlier signals are worth attention about association of the mineralization with reverse faults (C. Harańczyk et al., 1971) — the signals confirmed more recently (E. Górecka, 1991).

The paradox of a week permeability of the fracture conduits is even more striking in the case of joints. It can be taken for granted that already in early phases of ore mineralization a net of systematic joints existed, which was locally used as routes of

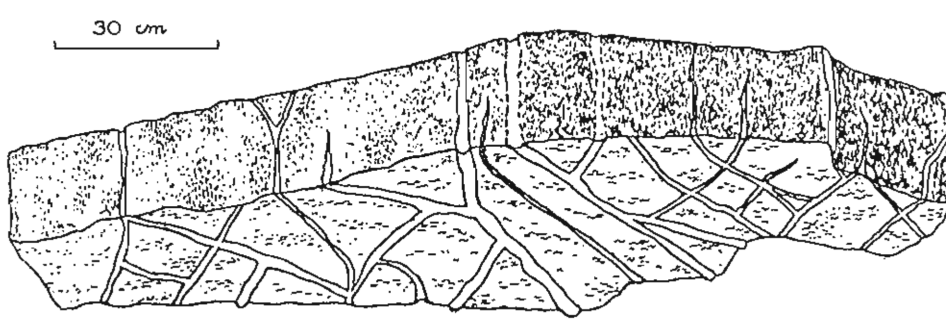

Fig. 3. A bed of dolomite at the roof of a gallery, showing relatively regular net of syndiagenetic joints
Ławica dolomitu w stropie chodnika, ujawniająca dość regularną sieć spękań syndiagenetycznych

fluid migration and sites of ore deposition. However, situations as in Fig. 2 indicate that the fracture conduits did not compete radically with the penetration of mineralizing solutions through the rock. This fact becomes comprehensible if character of the early fractures is taken into account. Namely, in carbonate sequence cropping out in Trzebionka mine, a rather regular net of syndiagenetic fractures has been found, particular fractures being infilled by sediment (Fig. 3). Most of those fractures (joints) are completely sealed, although their traces on all bed surfaces may be quite distinct. Just those tight planes of no more than slightly facilitated filtration were tracing the routes for mineralizing fluids (together with irregular fractures, bedding surfaces and *en masse* penetration through the rock), since prevailing trends of diagenetic joints (about 115 and 25°) correspond with strikes of many steep veins. True, some fracture conduits could have not been marked by deposition of minerals (comp. R. Blajda, 1983), but, if an open fracture space did play in that time an essential role, the observed mineral penetration of closed fractures must had been doubtful.

MESOSTRUCTURES OF MINERALIZED ZONES

Association of a part of ore concentrations with strongly fractured or even brecciated parts of ore-bearing dolomites is rather obvious. It must not certify, however, the traditional idea on open rock voids, produced by tectonic extension or hydrothermal karst and making free way for mineralizing fluids. In Trzebionka mine there are numerous zones of very strong brecciation and fault shearing devoid of any traces of mineralization. In no one of the „knots of mineralization" (especially rich of ores) the author found proofs for collapse origin of fracture systems and of breccias, in particular, the corresponding space contours. True, it is rather hard to find them even in the material considered to be classic for the hypothesis of hydrothermal karst (e.g. M. Sass-Gustkiewicz, 1985).

On the contrary, there are many forms of fractures and veins which suggest non-mechanical and non-karst origin. One of them is shown on the Fig. 4. We have to do here with an intense, multidirectional fracturing of a horizon within ore-bearing dolomite, lithologically the same as surrounding rock. The fracturing has not influenced the adjoining beds, nor has it changed the vertical joints within them, and the contact surfaces of the fractured horizon are very irregular: hence, the crushing of rock could not have resulted from a purely tectonic process. At the same time, it bears no features of collapse phenomenon: neither in the fracture pattern, nor in the distribution of potential voids (filled with sphalerite), nor in the shape of external contour. Instead, there are conspicuous symptoms of action of concentrated bursting forces: the radial fracture patterns, interfering one with the other. Some of the fractures are occupied by sphalerite veins, but majority of the ore has concentrated along a half-circular edge of the radial/concentric systems. At the point where two such systems converge, a wide strip of ore branches out, narrowing downwards and being full of minor rock fragments.

In this author's opinion, the picture as above (similar to many others) may receive the best explanation on the base of the theory of hydraulic fracturing, i.e. assuming an

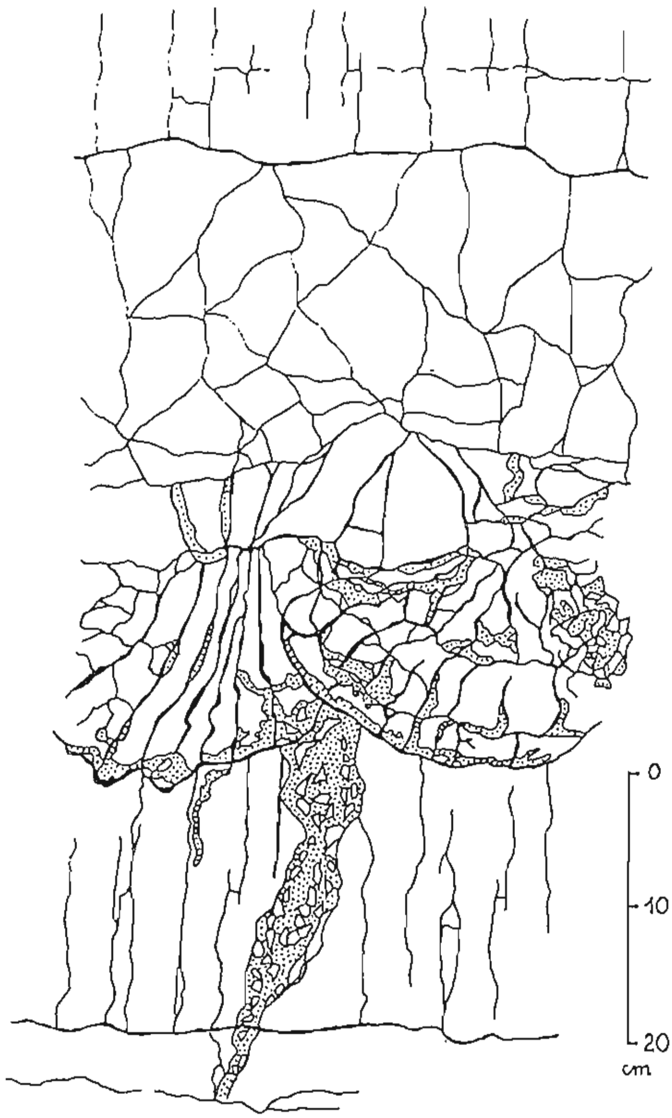

Fig. 4. Fragment of a horizon radial/concentric fracturing within the ore-bearing dolomites. The ores (dotted) — mainly sphalerite
Fragment horyzontu radialno-koncentrycznego spękania dolomitów kruszconośnych, okruszcowanego głównie sfalerytem (partie zakropkowane)

abnormal pressure of ore-bearing solutions, which were pumped through the rock massif and which stimulated the process of rock fracturing in places with concentrated flow and with favourable state of tectonic stress. This process was pushing ways for

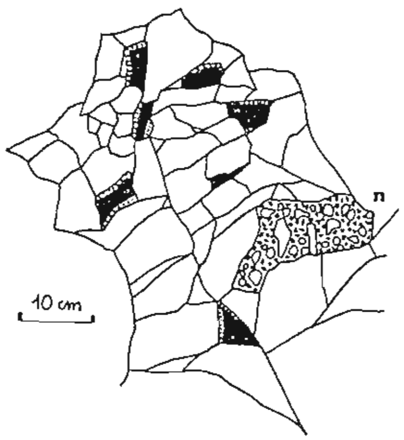

Fig. 5. The fractured ore-bearing dolomite with angular voids (partly coated with sphalerite — dotted) and with a nest of cemented products of probable hydrocataclasis (*n*)

Spękany dolomit kruszconośny z pustkami o kanciastych kształtach (częściowo wyścielonymi powłoczką sfalerytową — zakropkowane) i z gniazdem scementowanych produktów prawdopodobnej hydrokataklazy (*n*)

further penetration of the fluid, according to a meehanism best described by W. J. Phillips (1972), at the same time creating conditions for cyclic precipitation of the mineral content during the drops of fluid pressure. That is why the ore has been concentrated at the front of propagation of the fracture systems. In a more general sense, the same mechanism seems to provide a best explanation for pulsational nature of mineralization process (comp. M. Sass-Gustkiewicz, 1985).

Manifestations of action of hydrofracturing processes are not restricted to local geometries of fracture systems. For instance, there exist some interesting forms of crushing of the ore-bearing dolomite in spots far from any distinct tectonic disturbances as well as any karst-like openings. Those forms consist of tightly adjoining rock fragments, but with a number of angular voids between them, sometimes coated with a thin mineral cover (Fig. 5). In the author's view, the phenomenon like this cannot be produced by massive karst dissolution („triangular caves" — M. Sass-Gustkiewicz et al., 1982), but rather by hydromechanical disintegration of rock fragments between fracture walls and then by pushing out or by secondary solution of the products. Probably not by a chance, near the voids some angular or irregular nests appear, filled with fine crushed or mylonitised dolomitic material (Fig. 5). Elsewhere, the same phenomenon occurs even in massive rock (Fig. 6). The shapes of the nests as well as the type of their infilling exhibit a close analogy to hydrocataelastic formations described by W. Jaroszewski (1982) from the sole of Križna Nappe Overthrust in Tatra Mountains, *nota bene* developed in similar lithologic context. In spite of appearances, tectonic dynamics has played a second-order role in those phenomena, and this was rather not a direct influence, but an action evoking abnormal pore pressures. In this respect, the situation in course of Zn-Pb ore-forming processes in Silesian-Cracow region must not have been much different.

Since the shape of the nests of hydrocataclasis may be even more complex than that of karst caves, the standard morphological argument for collapse origin some breccias (M. Sass-Gustkiewicz, 1974) partly loses its value. There is an interesting contribution to the whole question made by J. Motyka and M. Szuwarzyński (1989), who described

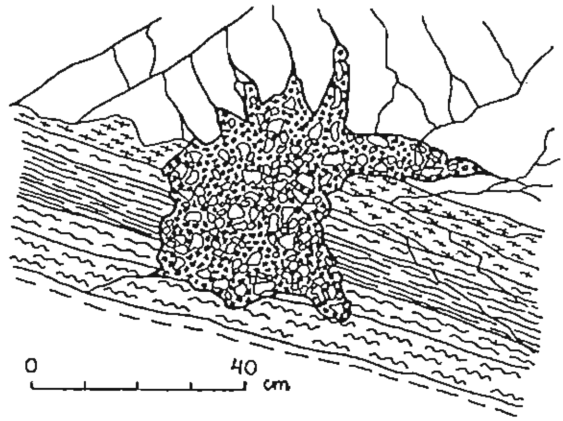

Fig. 6. A nest of finely crushed and somewhat cemented dolomitic material within a sequence of strongly stratified dolomites, which exhibit symptoms of metasomatic changes
Gniazdo drobno skruszonego i nieco scementowanego materiału dolomitowego w obrębie pakietu dolomitów wyraźnie warstwowanych, wykazujących objawy zmian metasomatycznych

(from the same ore deposits) some rock voids, after those authors, produced by bubbles of a pressurized gas. When such a void was cut across, a burst of gas with loose rock fragments followed. It should be noted here that the notion of hydrocataclasis applies not only to action of liquids, but also to that of gases.

What regards stratiform deposits, interpreters tend to ascribe metasomatic origin to them (see e.g. M. Sass-Gustkiewicz, 1985). Also this opinion raises some doubts in Trzebionka mine, at least in the form, according to which the metasomatosis went ahead of the process of massive ore mineralization („initial and mature karst deposits" — M. Sass-Gustkiewicz, 1985, 1988). The question is, why the ore bodies, dispersed in bed-like manner within the types of dolomitic rocks usually considered as metasomatic, exhibit at places some forms evidently determined by fractures, although the fractures themselves underwent partial or full obliteration (Figs. 7, 8). It looks like, at least some ore bodies had already existed, before the metasomatic changes of rock material (dolomitization of limestones, recrystallization of primary dolomites) took place, and even the very process of chemical replacement was predisposed to an extent by an earlier net of fractures, not always harmonized with bedding (Fig. 8). The bedding surfaees themselves, which must have traced out the course of many stratiform bands of galena nodules, are often hard to discern, as if some primary, solid veins have experienced a disintegration in time of later metasomatosis, together with obliteration of determining surfaces of beds (Fig. 7.).

Particularly significant is the faet, that such solid, „layered" ore bodies reach their best development at the places, where mesostructural picture tells about evident tectonic dynamism in time of mineralization. The most interesting of those places are shown on the Figs. 9 and 10. The Fig. 9 shows a set of dolomite beds, intercalated by „layers" of galena, galena and sphalerite, rock inclusions and sulfides or secondary

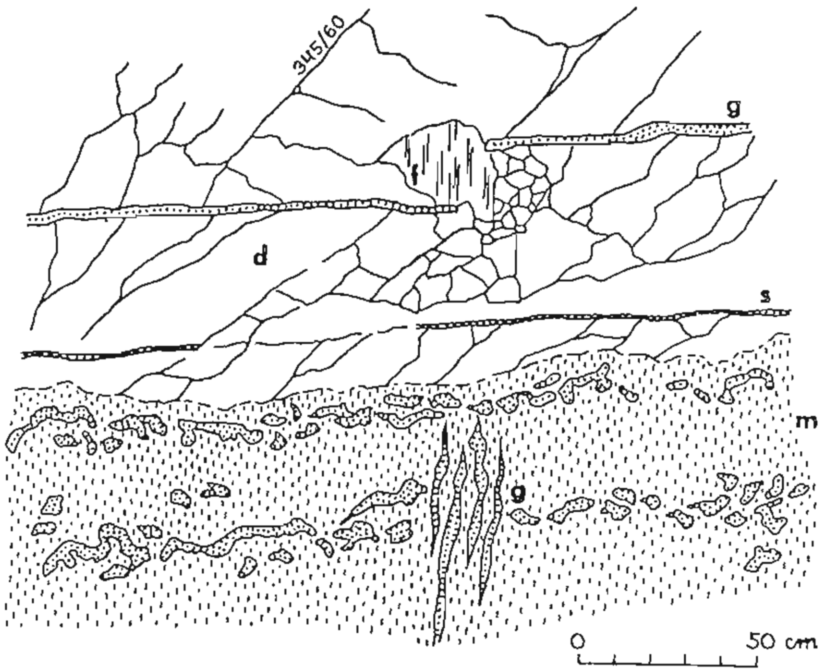

Fig. 7. Forms of ore mineralization by galena (*g*) and sphalerite (*s*) within a solid dolomite (*d*) and in a dolomitic rock metasomatically changed (*m*); *f* — minor fault with E-W strike

Formy okruszcowania galeną (*g*) i sfalerytem (*s*) w litym dolomicie (*d*) i w ziemistym produkcie przemian metasomatycznych (*m*); *f* — drobny uskok o przebiegu równoleżnikowym

hydroxides of iron. The dolomite beds have been cut by dense, inclined fractures of „Sigmoidalklüftung" type (G. H. Wagner, 1967), which suggest a slip along bedding surfaces. The ore minerals locally penetrate the fractures, which are considered in tectonics as typically tight disjunctions, perhaps resulting from relatively ductile deformation.

Within the same complex of beds, at a distance of 30 m, we find still more evident symptoms of subhorizontal tectonic transport, with the same kinematics (generally to W) — Fig. 10. The mineral stripes, together with the bedding surfaces, form here typical duplex pattern (S. E. Boyer, D. Elliott, 1982). It seems impossible for so complex vein system to originate by a passive reproduction of the duplex pattern of slip surfaces. One should rather assume that the mineralization took place along with the tectonic dynamics (of typically contractional character). That is the reasonable explanation for the exceptional development of „layered" ore bodies at the foreground of the duplex structure — area supplied with streams of fluids squeezed out of the rock massif in time of the duplexing. This interpretation is corroborated by other signs of interbed shifts, recently registered by some investigators (e.g. E. Górecka et al., 1991).

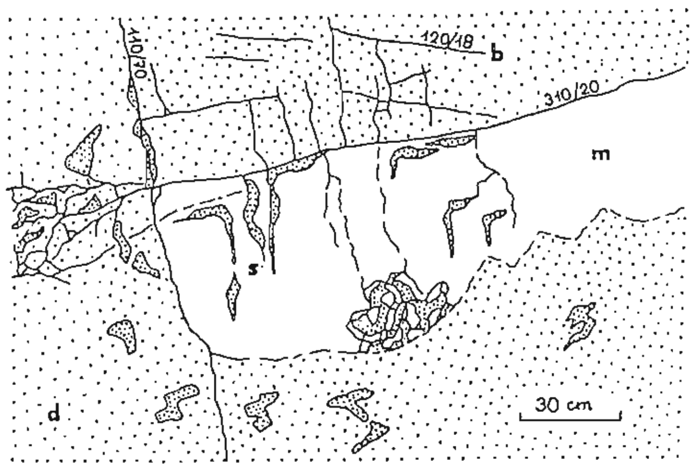

Fig. 8. Symptoms of fracture determination for ore mineralization (*s*) and for metasomatic changes (*m*) within micritic dolomite (*d*). Bedding in dolomite (*b*) disagrees with a set of low-angle fractures

Objawy szczelinowego uwarunkowania mineralizacji (*s*) i zmian metasomatycznych (*m*) w obrębie dolomitu mikrytowego (*d*). Uławicenie dolomitu (*b*) niezgodne z zespołem spękań połogich

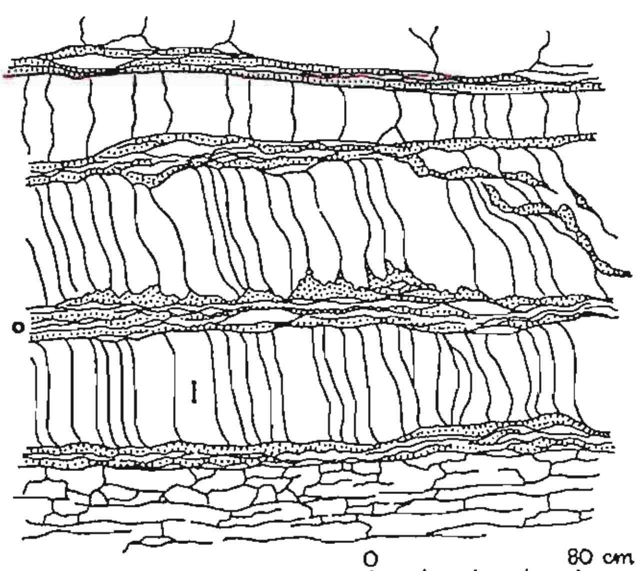

Fig. 9. „Layered" ore bodies (*o*) at the contacts of beds in ore-bearing dolomite. The beds are cut by dense joints, partly of sigmoidal type (*j*)

„Pokładowe" ciała rudne (*o*) na granicach ławic dolomitu kruszconośnego, pociętych gęstymi spękaniami, częściowo typu sigmoidalnego (*j*)

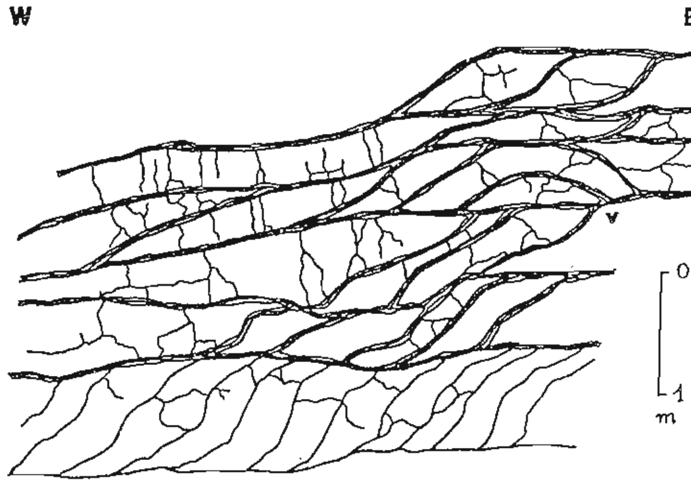

Fig. 10. Duplex structure expressed by a pattern of mineral veins (v)
Struktura dupleksowa widoczna w układzie żył mineralnych (v)

STRUCTURE OF ORE VEINS

A research on this question obviously demands a corresponding refinement of methods. Here the author would merely mention that many of the ore veins, including those „layered" ones, seem to represent the dilational type, i. e. one resulting from extension of host rock, and not by its replacement with the vein substance. Strictly symmetric structure of many veins (sphalerite at the edges, galena inside), at places emphasized by a central seam (Fig. 11), is one of arguments in favour of that view. Instead of the seam, a strip of aleuritic dolomitic substance often occurs, regarded by most investigators as „internal sediment" deposited by ore-bearing solutions. In opinion of this author, however, many of those inclusions of non-ore matter inside the veins represent rather remnants of rock fragments separated from walls of the veins in the course of episodic fracturing of craek-seal type (comp. e.g. J. G. Ramsay, M. I. Huber, 1983, p. 241). Such fragments naturally must have been especially sensitive to intense chemical and petrostructural tranformations. The above interpretation accords with a tendency of sphalerite shells to develop radial structure (Fig. 11). Since there are often no proofs for empty space inside growing vein, the radial structure suggests synkinematic growth of a part of the vein fillings. As it is also worth mentioning, the crack-seal processes offer a simplest explanation for so-called multiple breccias, known in Silesian-Cracow Zn-Pb deposits (e.g. M. Sass-Gustkiewicz, 1985, p. 32).

Incidentally speaking, eventual existence of a regional rhythm of mineral sueeession (M. Sass-Gustkiewicz, 1975) eould be much easier harmonized with the hydrotectonic model (where the penetration of fluids is realized by teetonically foreed „pulses" of a great extent), than with the karst circulation — in terms of its natural

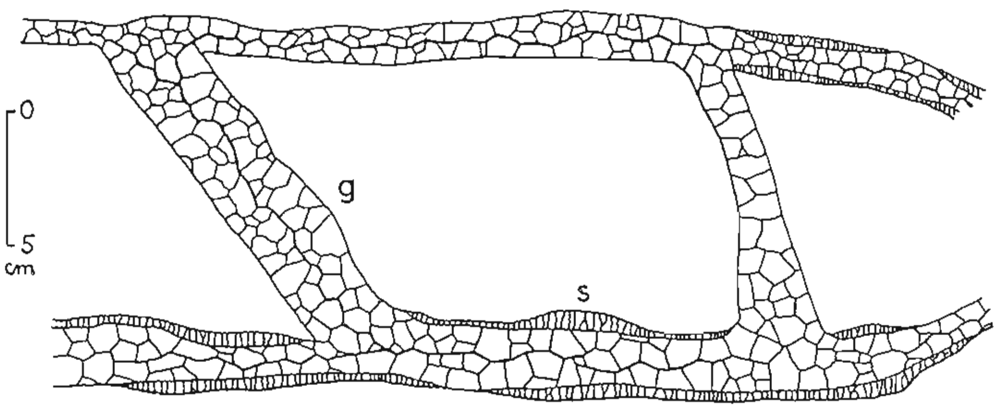

Fig. 11. Internal structure of galena (*g*) and sphalerite (*s*) veins; the veins run parallel or cross the bedding of host rock

Budowa wewnętrzna żył galeny (*g*) i sfalerytu (*s*), przebiegających równolegle i poprzecznie do poziomego uławicenia skały otaczającej

differentiation and regional dispersion. The same is true for a zonal/concentric distribution of minerals within particular nests of ore-bearing breccias (M. Sass-Gustkiewicz, 1985, p. 36–38), as well as for affinity of the ores from Paleozoic and Mesozoic rocks (E. Górecka, 1991).

CONCLUSION

A number of structural indications from the Trzebionka mine suggest conditions of forced and not free flow of mineralizing solutions, at least during some phases of the zinc-lead ore-forming processes. Some proofs, although local, also exist for tectonic dynamics of contractional style as a reason of the abnormal pressure of ore-bearing fluids. Faults and joints were mostly tight at that time and were being nsed only due to the high fluid pressures, more as transfer conduits than as places of deposition of mineral content (earlier suggestions for such a role of the fractures: R. Blajda, 1983; S. Kibitlewski, E. Górecka, 1988). The places predestined for preeipitation of ores were those, where the fluid flow was meeting special obstacles or where growing dimension of flow was exceeding permeability of the routes of eoneentrated filtration. In such plaees it was eoming to episodic hydraulic fracturing aceompanied by sudden drops in fluid pressure, when the mineral substance was deposited. At least a part of ore bodies of „layered" type has probably similar origin. At least a part of them originated before the wave of metasomatic transformations of rock environment.

The above suggestions are virtually opposite to the commonly accepted, hydrothermal/karst model of ore concentration, which places the traditional stress on the open spaces in rock, produced by leaching or collapse and being passively occupied by mineral solutions. However, the present author does not intend to negate neither the existence of paleokarst in ore-bearing horizon of Silesian-Cracow Zn-Pb province, nor a role of it in ore-forming processes. The fact of the matter is only that this role, at least in mining field of Trzebionka, could have been much smaller, than it appears from the broad acceptance of karst model. It cannot be excluded, that the metasomatic mechanism of ore mineralization have been over-appreciated, too.

A possible confirmation for an essential partieipation of the hydrotectonic mechanism would have some prospecting eonsequenees. From that perspective, we should point our attention not to those parts of a rock massif, which were structurally predisposed to a loosening (in time of mineralization), but, on the contrary, to those, where contractional tectonie eonditions helped to reach the high fluid pressures, and where hydraulic conditions made possible a necessary refilling of the fluids at the same time. Perhaps just such a coincidence has determined the location of the rieh Trzebionka deposit within Chrzanów Syneline.

The observations made so far suggest a validity of the mentioned rules also in local seale. For instanee, a privileged development of ore mineralization in downthrown fault blocks (E. Góreeka et al., 1991) deserves attention, because the downthrown side of a fault usually exhibits a higher level of stress (during the faulting as well as later on). The phenomenon of rhythmie spatial distribution of ores (R. Blajda, 1991) one could interpret, after that author, as a result of so-ealled equidistant disjunetions in the substratum. However, the striking analogy perhaps is not incidental whieh exists between R. Blajda's observation and zonal arrangement of reeent tectonic stresses (associated with zonal distribution of jointing), found in limestones of Crimea by E. S. Shtengelov (1980). In world literature one can also find many striking examples of a direct eorrelation between concentration of Zn-Pb ores and the most tight and stressed parts of tectonie structures (see e.g. A.Johansson, 1984, p. A-5).

A loeal character of described observations prevent referring them to a more general, regional background. However, it seems natural to seek energetistic impulses for mass migration of hydrothermal fluids in tectonieally active Carpathian Belt (no matter whether the mineralized solutions had their source in brines of Silesian Carboniferous, as recently assume a number of authors). Notwithstanding categorieal statements of A. Wodzicki (1987), age of Zn-Pb mineralization has been by no means deeided, and moreover, the documented dynamics of the Carpathians covers now such a long time, that its correlation with almost all potential ore-forming phases appears possible. In this context, an association seems interesting with the idea of J. Liszkowski (1989) on orogenetic-descensive model of salt concentration in the Carpathian Foredeep. In the case of Zn-Pb deposits we should have to do with an „orogenetie-aseensive" model.

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REFERENCES

BLAJDA R. (1983) — Analiza tendencji rozmieszczenia mineralizacji Zn-Pb w nawiązaniu do tektoniki złóż rejonu olkuskiego. Prz. Geol., 31, p. 77-81, nr 2.

BLAJDA R. (1991) — Modele matematyczne ciał rudnych w złożach Zn-Pb rejonu olkuskiego. Prz. Geol., 39, p. 147-151, nr 3.

BOGACZ K., DŻUŁYŃSKI S., HARAŃCZYK C. (1970) — Ore-filled hydrothermal karst features in the Triassic rocks of the Cracow-Silesian region. Acta Geol. Pol., 20, p. 247-267, nr 2.

BOYER S. E., ELLIOTT D. (1982) — Thrust systems. AAPG Bull., 66, p. 1196-1230, nr 9.

DŻUŁYŃSKI S. (1976) — Hydrothermal karst and Zn-Pb sulfide ores. Rocz. Pol. Tow. Geol., 46, p. 217-230, z. 1-2.

GÓRECKA E. (1991) — Wpływ zjawisk tektonicznych na kształtowanie się złóż Zn-Pb (na przykładzie złoża Klucze, rej. olkuski). Prz. Geol., 39, p. 137-147, nr 3.

GÓRECKA E., KIBITLEWSKI S., KRYZA A., SZUWARZYŃSKI M. (1991) — Uwarunkowania tektoniczne mineralizacji Zn-Pb na przykładzie złoża Trzebionka. Prz. Geol., 39, p. 158-163, nr 3.

HARAŃCZYK C., SZOSTEK L., FILIPOWICZ-LESIAK W. (1971) — Związek mineralizacji Zn-Pb z odwróconymi uskokami rowu kompresyjnego Klucze — Jaroszowiec. Biul. Inst. Geol., 241, p. 61-90.

JAROSZEWSKI W. (1982) — Hydrotectonic phenomena at the base of the Križna nappe, Tatra Mts. In: Alpine structural elements: Carpathian-Balkan-Caucasus-Pamir orogene zone (ed. M. Mahel), p. 137-148. Veda. Bratislava.

JAROSZEWSKI W. (1986) — Tektonika a mineralogeneza; wybrane aspekty. Prz. Geol., 34, p. 560-566, nr 10.

JOHANSSON A. (1984) — The geology and genesis of lead-zinc veins in Sweden. Medd. Stockh. Univ. Geol. Inst., 262.

KIBITLEWSKI (1993) — Tectonic control of the origin of Zn-Pb deposits in the Chrzanów region. Kwart. Geol., 37, p. 229-240, nr 2.

KIBITLEWSKI S., GÓRECKA E. (1988) — O strukturach tektonicznych w dolomitach kruszconośnych w kopalni Pomorzany (olkuski rejon złóż Zn-Pb). Prz. Geol., 36, p. 408-413, nr 7.

LISZKOWSKI J. (1989) — Orogeniczno-descensyjny model genetyczny mioceńskich formacji salinarnych regionu karpackiego wschodnich obszarów Centralnej Paratetydy. Pr. Nauk. UŚl. w Katowicach, nr 1019.

MOTYKA J., SZUWARZYŃSKI M. (1989) — Growth of speleothems below the karst-water table: considerations on the genesis of sulphide stalactites from the Upper Silesian Zn-Pb ore bodies. Ann. Soc. Geol. Pol., 59, p. 417-433, nr 3-4.

PHILLIPS W. J. (1972) — Hydraulic fracturing and mineralization. Jour. Geol.Soc. Lond., 128, p. 337-359, pt. 4.

RAMSAY J. G., HUBER M. I. (1983) — Modern structural geology, 1: Strain analysis. Academic Press. London.

SASS-GUSTKIEWICZ M. (1974) — Collapse breccias in the ore-bearing dolomite of the Olkusz mine (Cracow-Silesian ore-district). Rocz. Pol. Tow. Geol., 44, p. 217-226, z. 2-3.

SASS-GUSTKIEWICZ M. (1975) — Zinc and lead mineralization in collapse breccias of the Olkusz mine (Cracow-Silesian region, Poland). Rocz. Pol. Tow. Geol., 45, p. 303-326, z. 3-4.

SASS-GUSTKIEWICZ M. (1985) — Górnośląskie złoża rud Zn-Pb w świetle migracji roztworów mineralizujących. Zesz. Nauk. AGH, nr 1032, Geol., z. 31.

SASS-GUSTKIEWICZ M. (1988) — Hydrodynamiczne warunki depozycji rud Zn-Pb w rejonie olkuskim. Prz. Geol., 36, p. 401-403, nr 7.

SASS-GUSTKIEWICZ M., DŻUŁYŃSKI S., RIDGE J. D. (1982) — The emplacement of zinc-lead sulfide ores in the Upper Silesian district — a contribution to the understanding of Mississippi Valley-type deposits. Econ. Geol., 77, p. 392-412, nr 2.

SHTENGELOV E. S. (1980) — Zony nowejszego i sowremennogo razdwiżenija kontinentalnoj kory. Izw. An SSSR, nr 6, p. 5-19.

SIBSON R. H., MOORE J. Mc M., RANKIN A. H. (1975) — Seismic pumping — a hydrothermal fluid transport mechanism. Jour. Geol. Soc. Lond., 131, p. 653-659, nr 6.

WAGNER G. H. (1967) — Druckspannugsindizien in den Sedimenttafeln des Rheinischen Schildes. Geol. Rundschau, 56, p. 906-913, H. 3
WODZICKI A. (1987) — Origin of the Cracowian-Silesian Zn-Pb deposits. Ann. Soc. Geol. Pol., 57, p. 3-36, nr 1-2.

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PRZEJAWY HYDROTEKTONIKI W PROCESACH OKRUSZCOWANIA Zn-Pb W KOPALNI TRZEBIONKA

Streszczenie

Dominującą od dwudziestu lat konwencją interpretacyjną dla genezy okruszcowania Zn-Pb w śląsko-krakowskim regionie złożowym jest idea krasu hydrotermalnego. Obserwacje tektoniczno-mezostrukturalne przeprowadzone w kopalni Trzebionka koło Chrzanowa nie zgadzają się z tym podejściem. Wskazują one, że naturalne drogi ascenzji roztworów hydrotermalnych, którymi musiały być szczeliny uskokowe (fig. 1) i spękania (fig. 2), podczas mineralizacji odznaczały się słabą drożnością, a znaczna część spękań ciosowych miała nawet charakter syndiagenetyczny (fig. 3). Penetracja fluidów kruszconośnych w obręb tych zwartych płaszczyzn świadczy o wysokim ciśnieniu przenikającego ośrodka. Jeżeli chodzi o migrację poziomą fluidów, w Trzebionce brakuje wskazówek na istotną rolę kanałów czy komór krasowych, obecne są natomiast formy pękania i mineralizacji sugerujące akcję skupionych sił rozsadzających (fig. 4), które należałoby odnosić do mechanizmu pękania hydraulicznego (*hydraulic fracturing*). Nie rzadkie są też przejawy zaawansowanej postaci tego procesu, czyli hydrokataklazy (fig. 5 i 6), nasuwające analogie ze zjawiskami znanymi ze strefy nasunięcia kriżniańskiego w Tatrach.

Pewne wątpliwości budzi także tradycyjny pogląd, zgodnie z którym przemiany metasomatyczne wyprzedzały zwartą mineralizację rudną. W obrębie zmetasomatyzowanych typów skalnych istnieją bowiem drobne ciała kruszcowe wyraźnie zdeterminowane szczelinowo i ułożone warstwowo, mimo że predysponujące je powierzchnie nieciągłości uległy zupełnemu lub częściowemu zatarciu (fig. 7 i 8), zapewne podczas procesów metasomatycznych. Również sam zasięg zmian metasomatycznych wykazuje uwarunkowanie przez spękania (fig. 8).

W kopalni istnieją też lokalne, ale wyraziste, przejawy bezpośredniego wpływu dynamiki tektonicznej na proces okruszcowania, w postaci wyjątkowo silnie rozwiniętych „pokładowych" ciał rudnych (fig. 9) na przedpolu struktury dupleksowej (fig. 10). Ta ostatnia wiąże się z poślizgami międzyławicowymi; spiętrzający się dupleks powodował przetłaczanie mas zmineralizowanego fluidu wzdłuż powierzchni międzyławicowych i zasilaną przez nie, obfitą precypitację. Również struktura wewnętrzna niektórych żył „pokładowych" i stromych, analizowana mezoskopowo (fig. 11), sugeruje nie metasomatyczny, lecz dylatancyjny proces zajęcia przestrzeni przez substancję mineralną.

Obserwacje w kopalni Trzebionka nie pretendują do uogólnienia na całą prowincję złożową i do wyeliminowania roli krasu hydrotermalnego w procesach okruszcowania. Nakazują one jednak większą uwagę dla czynników: tektonicznego i ciśnieniowo-hyraulicznego, które w wielu przypadkach miały zapewne decydujące znaczenie. Ewentualne potwierdzenie roli tych czynników zmuszałoby do rewizji kryteriów poszukiwawczych: perspektywiczne byłyby już nie strefy strukturalnego rozluźnienia, jak to nakazuje tradycja, lecz strefy największych naprężeń i ciśnień hydraulicznych, a więc często struktury kontrakcyjne lub ich bliskie sąsiedztwo. Niektóre dane makrostrukturalne z prowincji śląsko-krakowskiej sugerują słuszność tego przypuszczenia. Jeżeli chodzi o generalne źródło napięć tektonicznych, zasilające energetycznie proces migracji hydroterm, najlogiczniej byłoby upatrywać je w mobilnym pasie karpackim — bez względu na sytuację rezerwuaru roztworów mineralizujących.