Ore Breccias in the Triassic Rocks of the Cracow-Silesian Region (Poland)

By St. Dżułyński—Maria Sass-Gustkiewicz*)

Summary

Much of the sulfide ores in the Cracow-Silesian district occurs in flat-lying breccia zones which are interpreted as underground manifestations of hydrothermal karst processes. It is assumed that the breccias represent solution-collapse structures produced by hot mineralizing solutions concomittantly with deposition of the ores.

Breccias are important in localizing sulfide ores in the Cracow-Silesian district. They trap more than 60% of economic resources and are important for the light they shed on the origin of ores. Before discussing the breccias some statements are needed concerning the ore district.

The Cracow-Silesian Zn-Pb ores belong to the world's classic examples of the Mississippi Valley type of deposits. They consist of sphalerite, galena and iron sulfides, and occur in horizontally disposed Muschelkalk (Anisian) carbonates. The ores are localized nearby and between two unconformities and show an adherence to burried-hill topography. The ores are confined to the southwestern flank of a ridge developed on the pre-Triassic erosion surface. The ridge itself is cut by abundant ore veins. Some of them are related to late Paleozoic igneous activity, and terminate at the contact with the Triassic. A few are observed to cross the contact and enter the Triassic rocks.

The host of ores is the ore-bearing dolomite, a crystalline neosome produced by recrystallization of early diagenetic dolostones and dolomitization of limestones. The sulfides are distributed throughout much if not all of this dolomite, and occur as cavity-filling and replacement ores (for details and references see Bogacz et al. 1973, 1975). Although opinions still differ as to the age of mineralization there is a good reason to suppose that much of the ores was emplaced before the end of Triassic time, following the formation of the host dolomite by narrow margin.

Respecting their mode of origin, the ore-breccias of the district fall into four classes: sedimentary, diagenetic, tectonic and karst breccias. The first two types represent structures inherited from the paleosome. Such structures antedate emplacement of ores. The tectonic breccias, volumetrically the least important, are chiefly post-ore deformations. Most abundant and, at the same time, genetically related to mineralization are the karst breccias. The karstic origin of such breccias has been demonstrated independently by Sass-Gustkiewicz (1970, 1974) and Bogacz et al. (1970). This interpretation appears now to be widely accepted by geologists working in the Cracow-Silesian region.

The karst breccias are scattered throughout the ore-bearing dolomite, but they tend to occur preferentially along its lower metasomatic boundary (fig. 1). The

---

*) Stanisław Dżułyński, Department of Geology — Polish Academy of Sciences in Cracow. Mailing adress: Geological Institute, Jagiellonian University, ul. Oleandry 2 a, 30-063 Kraków, Poland.

Maria Sass-Gustkiewicz, Institute of Geology and Mineral Deposits, Academy of Mining and Metallurgy, al. Mickiewicza 30, 30-059 Kraków, Poland.

breccias take a form of irregular tubular and often branching bodies. The traceable horizontal extension of such bodies amounts to several hundreds of meters and their maximum thickness may reach several tens of meters. Typically, the breccias consist of angular dolomite fragments (phot. 1). The central portions of the breccia bodies are comprised of a rubble of rotated fragments. Such rubble may pass vertically and laterally into crackle breccias with little or no rotation of fragments. The crackle breccias, in turn, merge into a network of cracks and sag fissures. Some of such fissures approximate a pattern of tension domes (SASS-GUSTKIEWICZ 1974, fig. 2 and 5).

The lower boundaries of breccias are sharp solution surfaces representing the former floors of caves. Often, above such surfaces there are cave sediments. Such sediments include; residual clays (HORZEMSKI 1962) and stratified cave ores composed of detrital and authigenic sulfides (SASS-GUSTKIEWICZ 1975a).

The above characteristics compel the view that the breccias resulted from solutional derangment and cave collapse. This conclusion is also supported by experiments on karst deformations (BALWIERZ and DŻUŁYŃSKI 1976).

Fracturing is a major requirement for solution collapse and the ore-bearing dolomite fits this requirement well. The dolomite possesses its own system of cracks. Some of them appear to have resulted from slight volume reduction and stress redistribution consequent upon recrystallization and dolomitization of the paleosome.

The interfragmental voids of breccias are partly or entirely filled with sulfides and the rock-matrix. The sulfides lining the voids show morphologies identical with those of recent calcite speleothems. Most of the sulfides have precipitated directly on the exposed rock surfaces. Some appear to have nucleated in solution and settled under gravity control to form caps and overhangs on the upper sides of rock fragments.

The ore breccias resulted from a succession of brecciation and mineralization processes. In the Olkusz Mine, one of us (SASS-GUSTKIEWICZ, 1975b) has recognized five stages of mineralization alternating and overlapping with four stages of brecciation. Each stage of mineralization is characterized by its own specific assemblage or ore minerals. The sulfides belonging to different stages have the same composition, but they may differ in texture, mode of occurrence and quantitative associations. What is more to the point, the successively younger ore minerals enclose and envelope the clastic products of earlier stages of mineralization and brecciation. In addition, the breccia bodies as seen in plan view follow a zonal and concentric arrangement with the younger stages covering progressively more extensive areas (for details see: SASS-GUSTKIEWICZ, 1975b). The observed temporal and spatial relationship may be explained on the basis of a prolongued transfer of mineralizing and aggressive solutions through the same breccia body. The relationship reflects the lateral growth of the breccia bodies, mirrors the paragenetic order and bears a record of chages in the character of the solutions.

The rock-matrix of breccias is composed of finer dolomite particles derived from "sanding" i.e., from disaggregation of the host dolomite through dissolution of crystal edges. The end-product of such disaggregation is a soft incoherent mass of grains in which the growing sulfide crystals may acquire euhedral shapes (BOGACZ et al. 1973a). The larger dolomite fragments suspended in such a mass show a self-crackling which cannot be accounted for by solution collapse. The fragments are apparently disrupted into smaller pieces and the space between such pieces is tightly

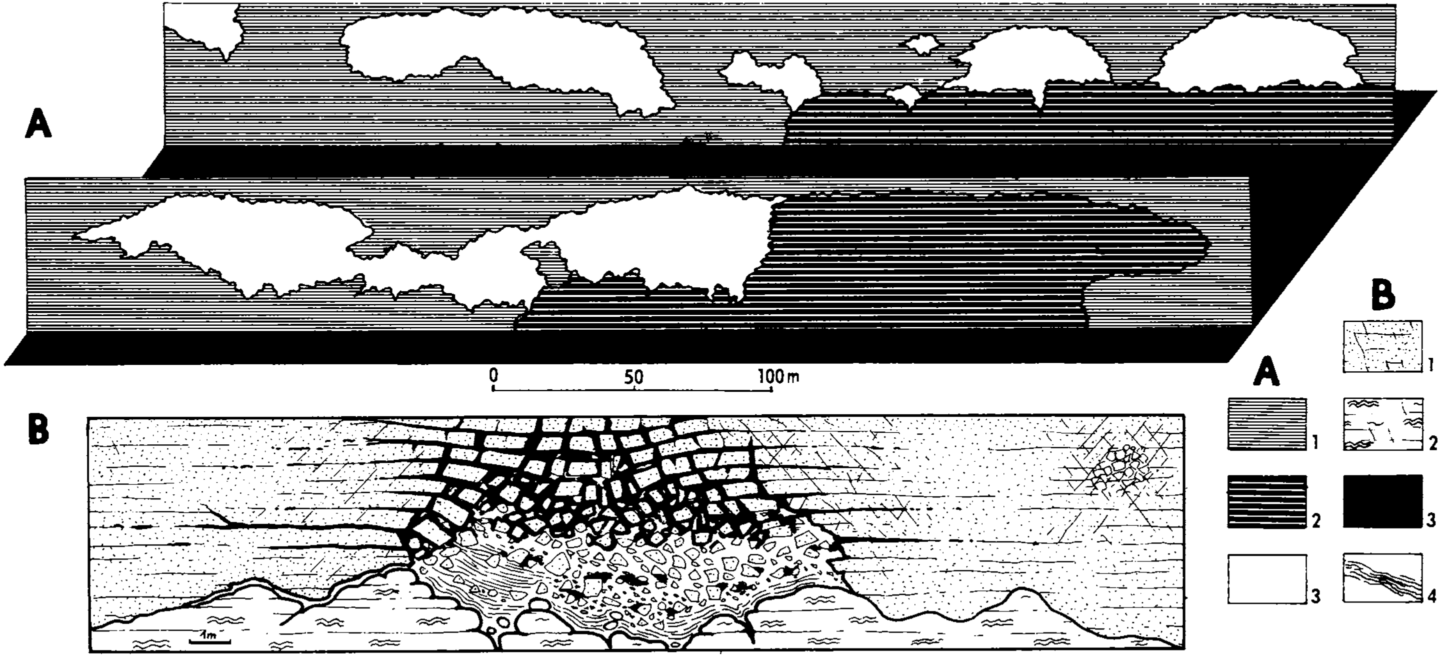

Fig. 1 : A : Distribution of breccia bodies along lower boundary of ore-bearing dolomite. — 1. ore-bearing dolomite. — 2. limestone. — 3. breccia bodies. — B : Idealized section through breccia body. — 1. ore-bearing dolomite. — 2. limestone. — 3. ores. — 4. stratified cave ores.

filled with disaggregated dolomitic grains. The comminution of larger fragments might have been initiated by the growth of crystals in preexisting fractures, but the work on further extension and wedging the fractures open appears to have been expended by a forcible injection of a slurry of water-saturated dolomitic grains.

The rock-matrix may contain the clastic products of earlier mineralizations. With disaggregation of the dolomite fragments enclosing subhorizontal or horizontal sulfide veins, these latter may break up into small pieces which may then sink down in the soft matrix. Such pieces may be mistaken for resedimented sulfide grains, notably if the enclosing dolomitic sand is again transformed into a hard rock by recementation processes (phot. 2).

The lithified matrix shows also evidence of dissolution and replacement processes. The dissolution is here facilitated by permeability and the large total surface of grains exposed to the acid attack. With progressing dissolution the larger rock fragments suspended in the matrix become unsupported and accumulate in a more condensed manner in the newly formed solution caverns. Significantly, such condensed or compacted breccias may consists of dolomite fragments that are entirely enveloped by sulfide bands. Such bands consist of outer incrustation-, and inner replacement-rims. The formations of the sulfide bands begins already in early stages of permeation and dissolution of the matrix. The sides of larger rock fragments suspended in matrix serve as loci for precipitation of sulfides and the fragments themselves are subject to replacement. The replacement proceeds from the sides towards the center of the fragments. The above process is yet another way in which the cockade structure may originate (compare: Kutina and Sedlackova, 1961). When replacement is carried to an extreme, the whole rock fragment is transformed into an ore piece. Significantly, it is always the dolomite that undergoes the replacement by sulfides. The limestone seldom if ever is subject to such transformation.

The question that arises is; what is the meaning of the observed association of karst breccias and sulfide ores ? There are here three possibilities (Walker 1928): 1. the karst structures and the ores were produced more or less simultaneously by hydrothermal solutions, 2. the karst structures originated from cold surficial waters before the introduction of hot mineralizing solutions, and; 3. both the karst structures and the ores resident in them resulted from the action of cold waters.

From what has been said earlier in this paper, it appears that the brecciation and mineralization processes were overlapping and close in time. This points to a common formative process for both, the breccias and the ores resident in them. On the other hand, all the evidence that bears on the origin of the Cracow-Silesian ores points to deposition from ascending hydrothermal solutions (for references see Bogacz et al. 1975). Consequently, it is the first of the three possibilities mentioned that fits best the field data. Due allowance is made, however, for local ingress of hydrothermal ore-bearing solutions into the preexisting system of karst structures produced by the action of cold descending waters. Such allowance is justified by the proximity of the ores to an ancient erosion surface. Among the inevitable consequences of such localization are also remobilization of sulfides and reactivation of collapse processes by cold surficial waters. The remobilization, however, is of minor importance and represents a secondary alteration superimposed upon the structures of hydrothermal origin.

The foregoing interpretation of ore-breccias in the Cracow-Silesian district finds support in recent hydrothermal karst processes. The reality of such processes is unquestionable. To quote only the best known examples from Central Europe (it was here where the terms "hydrothermal karst" and "thermomineral karst" originated — KUNSKY 1957) we mention the Hungarian and Czechoslovak caves produced by hot waters (e. g. PAVAI-VAJNA 1930—31, OZORAY 1961). Such caves, together with the associated structural (collapse breccias) and mineralogical features provide existing examples of hydrothermal karst processes from which extrapolations can hardly be avoided (DZÜLYŃSKI 1976). What is more to the point the hot waters that are responsible for the formation of the above mentioned caves carry metals and deposit ore minerals among which there are sulfides. The mineralogy of such ores is poorly known. Until recently, the hydrothermal karst structures have received too little attention from karst geologists and practically no attention from ore geologists. The time has come when it becomes indispensable for ore geologists to investigate the recent hydrothermal karst structures to obtain a better understanding of the origin of many Zn-Pb deposits.

References

BALWIERŻ, J., DŻUŁYŃSKI, S. (1976): Experiments on rock deformations produced by underground karst processes. Ann. Soc. Geol. Pol. 46, in press.

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

BOGACZ, K., DŻUŁYŃSKI, S., HARAŃCZYK, C., SOBCZYŃSKI, P. (1973): Sphalerite ores reflecting the pattern of primary stratification in the Cracow-Silesian Region. Ann. Soc. Geol. Pol. 43, 3, p. 285—300.

BOGACZ, K., DŻUŁYŃSKI, S., HARAŃCZYK, C., SOBCZYŃSKI, P. (1973a): Caves filled with clastic dolomite and galena mineralization in disaggregated dolomites. Ann. Soc. Geol. Pol. 43, 1, p. 59—72.

BOGACZ, K., DŻUŁYŃSKI, S., HARAŃCZYK, C., SOBCZYŃSKI, P. (1975): Origin of the ore-bearing dolomite in the Triassic of the Cracow-Silesian Pb-Zn ore district. Ann. Soc. Geol. Pol. 45, 2, p. 139—155.

DŻUŁYŃSKI, S. (1976): Hydrothermal karst and Zn-Pb sulfide ores. Ann. Soc. Geol. Pol. 46, 1/2, in press.

HORZEMSKI, J. (1962): On the Relation of the so-colled Vitriol Clays to the Limestones and Ore-bearing Dolomites of the Middle Triassic in Upper Silesia. Bull. Acad. Pol. Scienc., Serie geol. et geogr. 10, 4, p. 237—243.

KUNSKY, J. (1957): Thermomineral karst and caves of Zbrasov, Northern Moravia, Sbornik Zemn. Českoslov. Spol. 62, p. 306—351.

KUTINA, J., SEDLACKOVA, J. (1961): The role of replacement in the origin of some cockade textures. Econ. Geol. 59, p. 149—176.

OZORAY, G. (1961): The mineral filling of the thermal spring caves of Budapest. Atti del Symp. Intern. di Speleolog. Varenna — 1960, V-2, p. 152—170, Como.

PÁVAI-VAJNA, F. (1930—31): Über die Rolle heißer Lösungen, Dämpfe und Gase bei der Höhlenbildung. Hidrológiai Közlöny, 10—11, p. 63—69, Budapest.

SASS-GUSTKIEWICZ, M. (1970): Structural development of a part of Zn-Pb ore body in the Olkusz Mine. Sprw. Posiedz. Kom. Nauk Geol. PAN, XIV/1, p. 268—270, Kraków, in polish.

SASS-GUSTKIEWICZ, M. (1974): Collapse Breccias in the Ore-bearing Dolomite of the Olkusz Mine (Cracow-Silesian ore-district). Ann. Soc. Geol. Pol. 44, 2/3, p. 217—226.

SASS-GUSTKIEWICZ, M. (1975a): Stratified sulfide ores in karst cavities of the Olkusz Mine (Cracow-Silesian Region, Poland). Ann. Soc. Geol. Pol. 45, 1, p. 63—68.

SASS-GUSTKIEWICZ, M. (1975b): Zinc and lead mineralization in collapse breccias of the Olkusz Mine (Cracow-Silesian Region, Poland). Ann. Soc. Geol. Pol. 45, 3/4, 303—326.

WALKER, R. T. (1928): Deposition of Ore in Pre-existing Limestone Caves. American Inst. of Mining and Metal. Engin. Tech. Publ. No. 154, Class I, Min. Geol. 19, p. 3—35.