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THE ORIGIN OF PYRITE IN MIOCENE LIGNITE FROM THE „BEŁCHATÓW" DEPOSIT

Abstract: Sulphide mineralization in Miocene lignite from the "Bełchatów" deposit is represented mainly by iron disulphides, i.e. predominant pyrite and rare marcasite. Their presence in the lignite is a result of syngenetic, subordinately epigenetic processes. By fermentation of hydrogen disulphide, enhanced by bacterial activity, pyrite formed as framboidal grains. The framboidal pyrite may be treated as a primary form of inorganic sulphur in the lignite of the "Bełchatów" deposit. Idiomorphic crystals of pyrite developed later as a result of growth and transformation of the framboidal forms.

Key words: lignite, iron sulphides, framboidal pyrite.

INTRODUCTION

Sulphur is one of the elements characterizing coal quality. It is bound in inorganic compounds, i.e. sulphides and sulphates, and in organic compounds, i.e. macromolecules being fragments of organic coal substance (Wiser 1978). Among the sulphides, most common are iron disulphides (FeS_2), pyrite and marcasite. At lower temperatures marcasite which crystallizes from acid solutions is metastable. Higher temperatures and neutral or weakly acid pH of the solution favour formation of pyrite. Marcasite turns into pyrite at temperatures above 400^oC, but H. Lechmann (1953) did not exclude formation of pyrite below 400^oC. In his opinion, most significant part of iron sulphides in coal formed primarily as marcasite. Then, when the coal rank increased, marcasite was transformed into pyrite at higher temperatures and pressures. This view is adequate in the case of bituminous coals that were metamorphosed. Accordingly, iron sulphides in the deposits of lignite should be represented mainly by marcasite, while pyrite should not occur as the main mineral of sulphide mineralization.

RESULTS

X-ray investigations show that in Miocene lignite from the „Bełchatów" deposit, iron sulphides occur first of all as pyrite, while marcasite is very rare (Ratajczak, Stachura 2002). This observation may point to a genesis of pyrite present in the lignite different than that proposed by Lechmann (1953). Reflected light investigations reveal several types of pyrite. It may occur as individual, massive grains of various shapes and sizes, as nests, lenses and small veins; additionally, it is present as small grains within the main mass of lignite. Another

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typical form of pyrite is represented by framboid with characteristic, globular shapes. Framboids may be present as single grains or their aggregation. The most frequent are the aggregates within which framboids do not touch each other, but the authors also observed such in which framboids are densely packed, occurring in massive aggregates. Pyrite that fills fractures, cracks and other voids in lignite is rare; this form is accompanied by marcasite that occurs as inclusions in the pyrite.

Under the scanning electron microscope pyrite is visible in the form of individual crystals within the organic mass of lignite. Their sizes are diversified from the fine grains, around 1µm, up to larger, around 20-30 µm, with idiomorphic habit. The diameter of framboid is usually in the range 20-30 µm. They are built of microframboids, but some of them reveal angular outlines, resulting probably from partial recrystallization of globular forms. The shapes and sizes of the latter are close to those of the microcrystals of the pyrite present in the lignite. Some of globular pyrites form poliframboidal aggregates, oval or irregular in shape, with sizes from 200 to 300 µm. Their sizes and shapes correspond to those of the pyrite in the form of lenses and nests.

DISCUSSION

Micromorphological observations and the sizes of the framboidal forms suggest that the idiomorphic crystals of pyrite formed as a result of growth and associated transformation of the framboid. In the same way could have been formed pyrite nests and lenses, but in this case their precursor is seen in the poliframboidal concretions.

The forms of pyrite occurrences in lignite from „Bełchatów" suggest that the genesis of pyrite should be linked mostly with syngenetic and only partly with epigenetic processes of lignite mineralization. The primary and, at the same time, major source of sulphur in coals are proteins of lignite-forming plants. Reducing conditions in the peat-bog result in decomposition of aminoacids with evolution of H_2S (Olszewska 1971). The Bełchatów peat-bog was supplied with highly mineralized groundwater and also was recurrently inundated with lacustrine water; additionally, numerous rivers meandered across its surface (Słomka et al. 2000). Inflow of fresh waters in different formation stages of the „Bełchatów" deposit was controlled mainly by permeability of its overburden. These waters provided, among others, iron compounds. Due to the processes described, in the peat-bog there developed zones with alkaline-reducing conditions, rich in hydrogen disulphide; under such conditions Fe^{3+} was reduced to Fe^{2+}, favouring crystallization of pyrite (Wasilewski, Kobel-Najzarek 1973). First, iron sulphate ($FeSO_4$) precipitated in reaction of iron compounds with other, easily soluble in water sulphates (mainly of calcium). Then, with the participation of sulphur-reducing bacteria (e.g. *Desulforibiori desulfuriceus*), the sulphates were reduced and their sulphur was bound in H_2S (Roga 1958). Further formation of pyrite followed probably the reaction:

$$2FeSO_4 + 5H_2S \rightarrow 2FeS_2 + 2S + H_2SO_4 + 4\,H_2O$$

Elemental sulphur formed during this process could have reacted with organic substances and, eventually, entered carbon-sulphur compounds. It can be thus concluded that the organic-bound sulphur in the lignite of the „Bełchatów" deposit originated in two genetically different processes. The primary organic sulphur could have been formed from the peat-bog plant material, mainly from protein- and fat-rich substances. The secondary carbon-bound sulphur may have been incorporated into the lignite due to geochemical alterations of inorganic compounds (Wawrzynkiewicz 1997).

Another type of sulphur components in the lignite of the „Bełchatów" deposit is represented by epigenetic pyrite, which fills fractures, cleats and other hollows left behind due to dewatering and compaction of lignite seams or being results of tectonic disturbances. Most probably, the water circulating through these openings contained iron ions that reacted with sulphide ions migrating from lignite. These occurrences of pyrite are of minor importance and are associated with low amounts of marcasite.

CONCLUSION

Precipitation of pyrite under conditions controlling formation of the lignite in the „Bełchatów" deposit took place due to bacterial action during fermentation of hydrogen disulphide. Framboidal pyrite was a result of these reactions. Simple pyrite framboids formed due to aggregation of iron sulphides, facilitated probably by their magnetic properties. Further processes, such as breakdown and renewed aggregation controlled by organic substance gave rise to formation of more complex forms, represented by polyframboids. Growth of the framboids and polyframboids resulted in the first case in idiomorphic pyrite crystals, in the other in massive pyrite occurrences. Such processes can only progress if the supply of iron and sulphur compounds during formation of framboidal forms is uninterrupted (Sawłowicz 2000).

Pyrite framboids, due to their specific surface and magnetic properties, could accumulate when growing a number of heavy metals, such as Hg, Pb, As, Cd, Cu, and others (Sawłowicz 2000). Pyrite from Bełchatów is strongly enriched in mercury. The elements sorbed by the framboids were incorporated during their growth into the crystalline structure of pyrite and, due to that, their redistribution to the environment is strongly limited. Therefore, these are iron disulphides that are responsible for bulk of toxic elements in the lignite of the „Bełchatów" deposit (Stachura et al 2003).

Sulphur in the Bełchatów lignite was fixed at the stage of peat-bog formation and its quantitative changes in further development stages of the deposit were insignificant. The processes taking place during the lignite seam formation, diagenesis and consolidation could only change the forms in which sulphur was bound. The primary form of sulphur bounding in the lignite of the „Bełchatów" deposit has been recognized as the pyrite framboids.

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