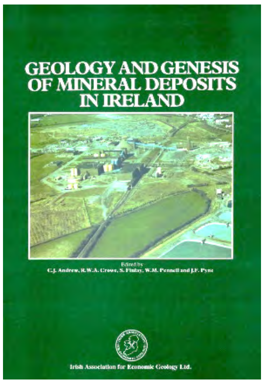

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Forgotten Pb-Zn veins in Westphalian strata of the Ruhr, West Germany.

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Abstract

In the Ruhr district, various Pb-Zn veins in the productive coal measures of Westphalian A age (Upper Carboniferous) have been worked from the early 1950s up to 1962. About 5Mt of ore has been mined grading 7% Zn, 4% Pb and about 60g/t Ag. Due to adverse mining conditions, mining of the ore was stopped in 1962 leaving about 5Mt of ore unmined. The distribution of the mineralization shows a close relationship with the structure of the district. The mineralization centres occur in an axial depression at the intersection of ancient zones of tectonic weakness (lineaments) and cross faults. A metal zonation with chalcopyrite in the centre of the axial depression and sphalerite, galena and barite laterally distributed around it suggests that mineralization developed under a decreasing thermal gradient. The ore occurs in brecciated, predominantly sandy shales and coal. The Pb-Zn veins in the Westphalian strata of the Ruhr are a coal-hosted vein-type of deposit. Similar mineralization also occurs in the English Pennines. No deposits of this type are known in Ireland since coal-bearing strata of this age are poorly developed or absent. Zn mineralization in coal has been reported from the Illinois basin.

Introduction

The Ruhr area, which is better known as one of the largest European coalfields than a metallogenic province, comprises an area of about 3000km^2. It runs south of the River Ruhr to north of the River Lippe; its median line is 51.5° N latitude and it lies between 6° W and 8° W longitude. Figure 1 shows a belt of Upper Carboniferous coal-bearing strata in the paralic zone extending in the Variscan Foreland from Belgium via Aachen — Erkelenz, the Rhein — Ruhr district, the area of Ibbenbüren, further towards the east into Silesia, and also to the north, i.e. in the subsurface of NW Germany and the North Sea.

The limnic zone is also developed in the Saar — Nahe Basin and some smaller deposits of Upper Carboniferous age in the south.

Pb-Zn mineralization in the Ruhr district, known for over 100 years, is hosted by Upper Carboniferous bituminous coal. However there was hardly any serious exploitation until 1930 when the first Pb-Zn vein was discovered in the Auguste Victoria colliery. Up to 1962 the following mines were in production:

Auguste Victoria:	5Mt with 7% Zn, 4% Pb, and 65g/t Ag (the vein was abandoned in 1962, although 2-3Mt of ore remains unmined);
Christian Levin:	334 000t with 1% Zn, 10% Pb, and 26g/t Ag.
Graf Moltke	(Klara vein) about 2Mt with 10% Pb and Zn combined remain unmined.

Since the mining of the veins tapped large quantities of water and caused serious rock falls, the mines were abandoned in 1962. Other Pb-Zn veins in the Julia, Pluto, Hannover and Shamrock collieries remain untouched. This paper summarizes the factual data about the Pb-Zn mineralization in various collieries, and then proceeds to deal with past and current genetic models. Finally it relates the mineralization in the Ruhr district to other vein deposits in coal. The most significant sources are Buschendorf et al. (1957), Pilger et al. (1961) and Pilger and Stadler (1971).

Stratigraphy

During the Upper Carboniferous, large basins formed in front of the Rhenohercynian orogene and were filled with about 5000m of Variscan molasse, extending from Namurian A up to Westphalian C. This succession contains the older barren measures of Namurian A and B and the younger productive Coal Measures of Namurian C and Westphalian A to C.

The Namurian A and B strata, consisting of greywacke, shales and sandstone, are about 2000m thick.

The productive Carboniferous in the Ruhr district has been subdivided as follows:

Westphalian C		Dorsten Beds	
Westphalian B	Upper	Horst Beds	
	Lower	Essen Beds	
Westphalian A	Upper	Bochum Beds	Containing the
	Lower	Witten Beds	Pb-Zn veins
Namurian C		Sprockhövel Beds	

This sequence is about 3000m thick.

North of the Essen-Bochum line, the Upper Carboniferous is unconformably overlain by Upper Cretaceous sediments. The unconformity dips at a shallow angle (2°-3°) to the north.

Structure

The NNE-trending metallogenic Ruhr province is truncated by lineaments that trend in two directions (Fig. 2).

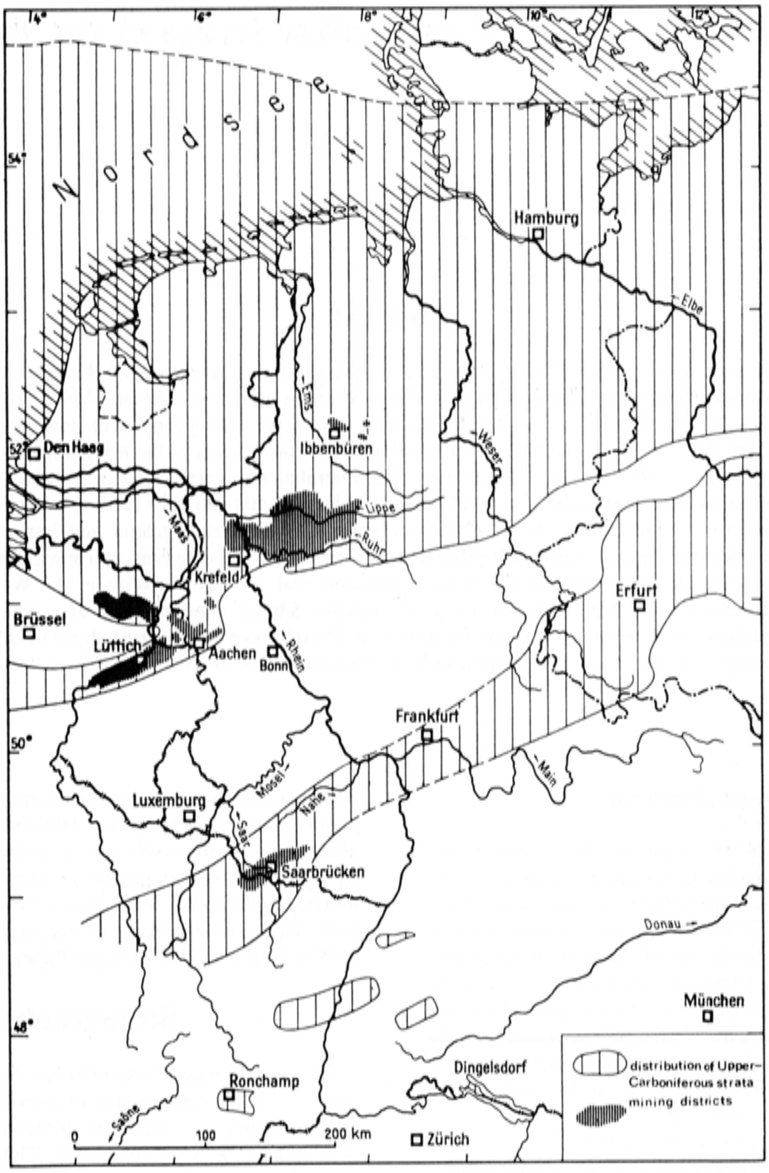


Figure 1. Distribution of the Upper Carboniferous strata in West Germany and adjoining countries.

The western zone trends from Essen to Dorsten as far as the River Lippe. The vein deposit of the Graf Moltke colliery (Klara vein) is associated with this zone.

The Auguste Victoria vein occurs in the Dortmund lineament, which runs from Dortmund through Recklinghausen to Wulfen in a NW-SE direction. Presumably the lineaments are of Devonian age and were reactivated during the later Variscan orogeny.

Pilger et al. (1961) postulated that the mineralization in the Ruhr district is controlled by these major lineaments which are commonly characterized by strong mylonitization and brecciation.

In general the area exhibits relatively simple structures which all originated during the Variscan orogeny (Asturic phase). Four tectonic events can be distinguished:

1. SW- to WSW-trending, N-verging fold systems (Fig. 2) e.g. the Dorsten anticline - Lippe syncline, Vestisch anticline-Emscher syncline etc. It can be seen that in the eastern part of the mineralized area the fold axes plunge towards the SW, and in the western part towards the NE, forming a NW-trending axial depression along a line between Bochum and Marl.
2. SE-dipping thrust faults striking parallel to the fold axes are contemporaneous with the fold system.
3. The fold system was cut by NW-striking cross faults with displacements of up to 1000m, e.g. the Primus, Secundus, Tertius Faults etc. The largest orebodies developed at the intersections of the lineaments and these cross faults, such as in the Christian Levin and Graf Moltke (Klara vein) collieries in the western part of the Essen - Dorsten lineament and in the Auguste Victoria colliery in the eastern part. Transverse movements gave rise to wide fissures; the greatest vein width of 40m in the Auguste Victoria mine results from this style of movement. It is assumed that the veins developed by hydraulic pressure provided by the mineralizing fluids.

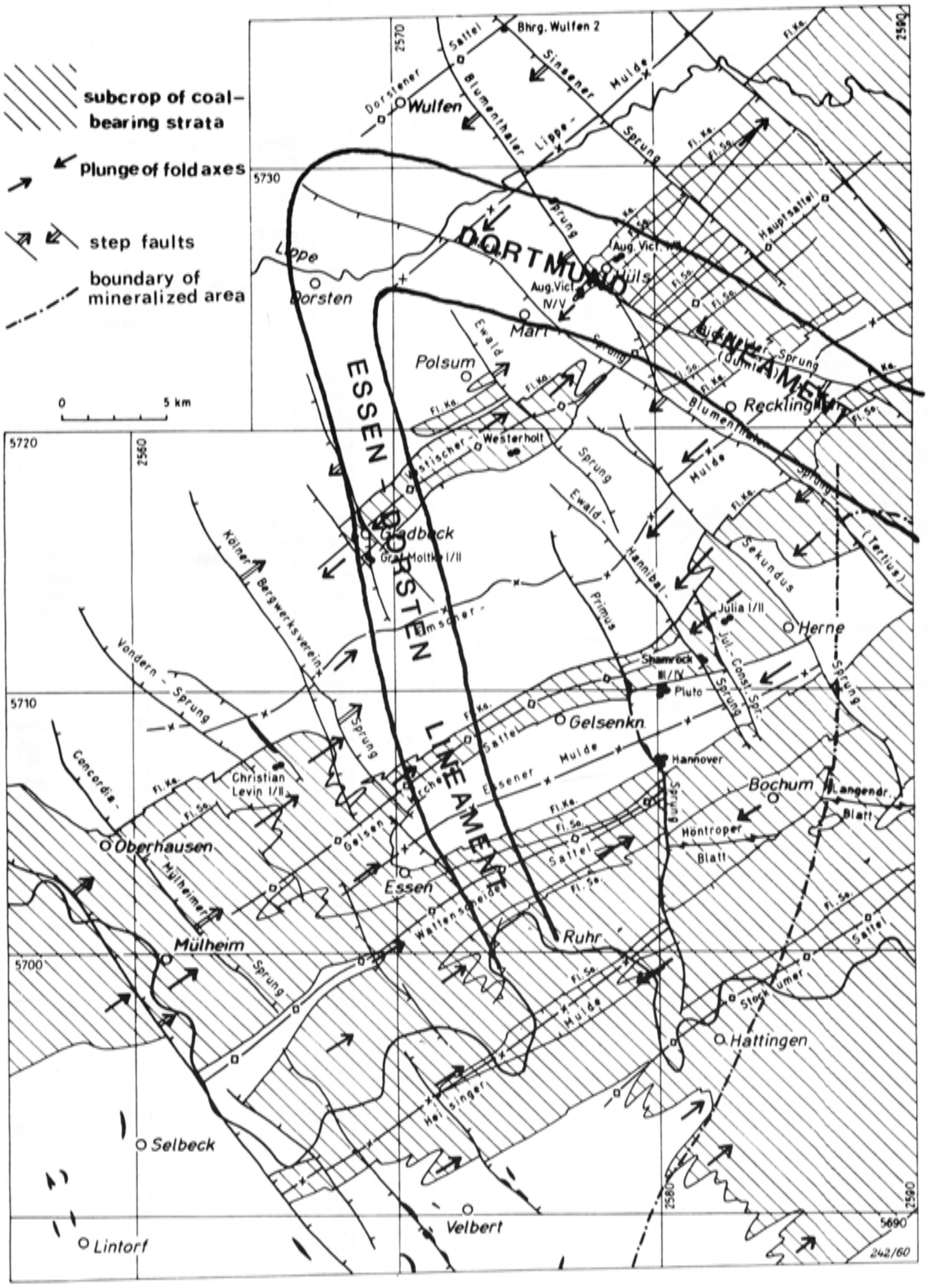


Figure 2 Map of structures in the Carboniferous rocks of the mineralized part of the Ruhr area. Post-Carboniferous rocks removed (after Pilger, 1961).

4. Wrench faults developed in a WNW direction, diagonal to the folds. This movement caused reopening of the veins and gave rise to slickensiding and brecciation of earlier fillings. This was followed by a second generation of mineralization. (The fluids exploited both the cross and wrench faults during their development).

As an example, the vein mineralization in the Auguste Victoria colliery is shown in Figure 3. Here the vein mineralization is situated in an anticline on the Tertius Fault. The different phases of mineralization were caused by cross and wrench faults (Pilger et al., 1961). The two orebodies, separated by a 70-200m thick zone of barren rock, strike 135°, parallel to the Tertius fault zone; they dip 60-70°SW into the axial depression zone. The two orebodies extend for about 1000m in strike and up to 57m thick; they have been mined over a vertical interval of about 500m, from 480m to 1000m below the surface.

Mineralization

It has been shown that mineralization is associated with zones of axial depression accompanied by cross faults with vertical displacement, and a high grade of coalification

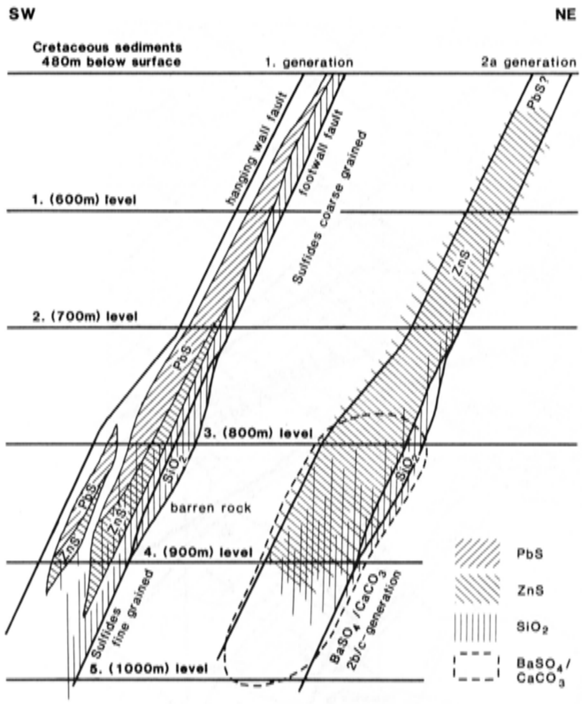


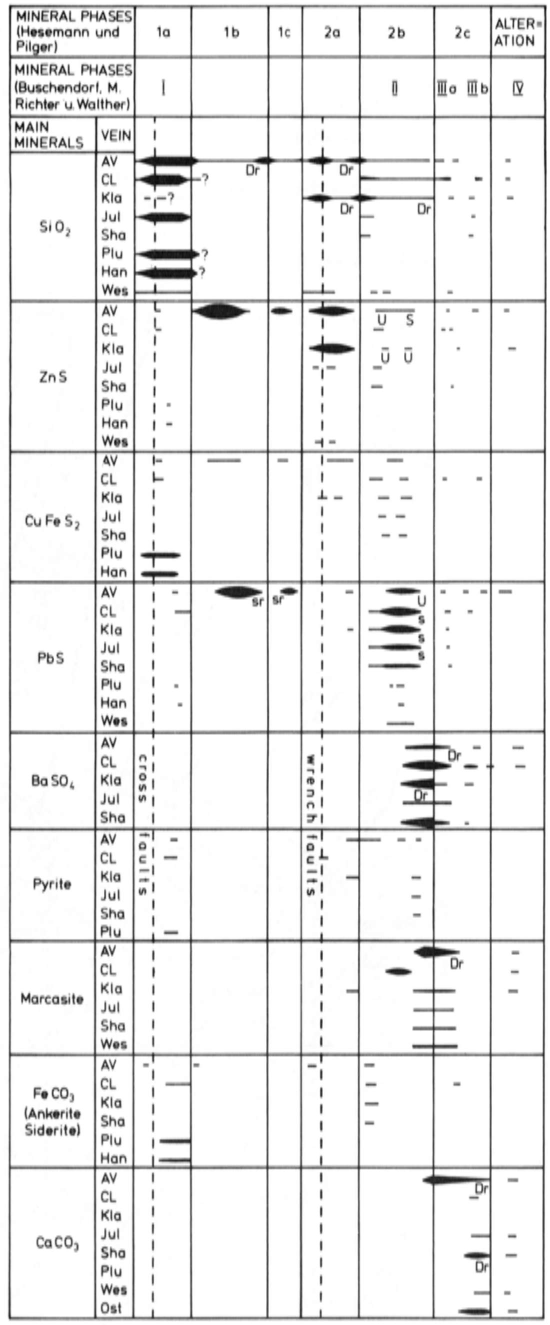
Figure 3. Vertical section showing the Auguste Victoria orebodies (after Pilger, 1961).

(Teichmüller, 1949). The nature of the mineralization suggests (Pilger et al., 1961) two clearly distinct phases which are closely related to different tectonic events. Tectonic movement and mineralization took place contemporaneously, whereby the faults which were dilating served as depositional sites. Pilger et al. (1961) suggested the following model: during transverse movements, the veins were opened up by hydraulic pressure provided by the mineralizing fluids whereby the first generation of minerals were precipitated (Fig. 4) viz. quartz, siderite-ankerite, sphalerite, a little chalcopyrite, pyrite and galena. The grain size of the various minerals in the vein increases towards the upper parts of the vein where crystals up to 2cm long occur. (Plate 1).

Transcurrent movements resulted in the re-opening of the wrench faults allowing fresh mineralizing solutions to rise and precipitate a second generation of minerals: quartz, ankerite, sphalerite, chalcopyrite, pyrite, barite, calcite and kaolin. Brecciated ore textures predominate in which fragments of host rocks consisting of sandy shale, coal and gangue minerals are cemented by ore minerals (Plate 2). Mineralized joints also occur, but only few fissure veins; the latter are mainly filled with quartz and barite. There are no banded ores.

Considering the metal distribution in the Ruhr district, it is clear that in the area of the Primus Fault, which coincides with the axial depression zone, the ore paragenesis is quartz-siderite/ankerite-chalcopyrite-pyrite-galena-sphalerite. Laterally, away from the axial depression, the mineralization shows the paragenesis sphalerite-galena-barite-calcite.

These parageneses suggest that there is a metal zonation in the district with chalcopyrite in the centre of the axial depression, and sphalerite, galena and barite laterally around it. The metal zonation suggests that the mineralization developed under a decreasing thermal gradient.



AV	Auguste Victoria 2a,3,3a. level			Jul	Julia 7. level
CL	Christian Levin			Sh	Shamrock 3/4,4. level
Kla	Klara-vein (Gladbeck), 4. level			Plu	Pluto
Han	Hannover	U	alteration	sr	silverrich
Wes	Westerholt	S	Schalenblende	s	silverpoor
Ost	Osterfeld	Dr	Geode		

Figure 4. Sample diagram of parageneses of various veins in the Ruhr area (after Pilger, 1961).

Metallogenetic considerations

A. Ascending hydrothermal solutions

Concentric lateral zoning with chalcopyrite in the axial depression and galena and barite in the outer zones led Pilger et al. [1961) to the conclusion that the mineralization

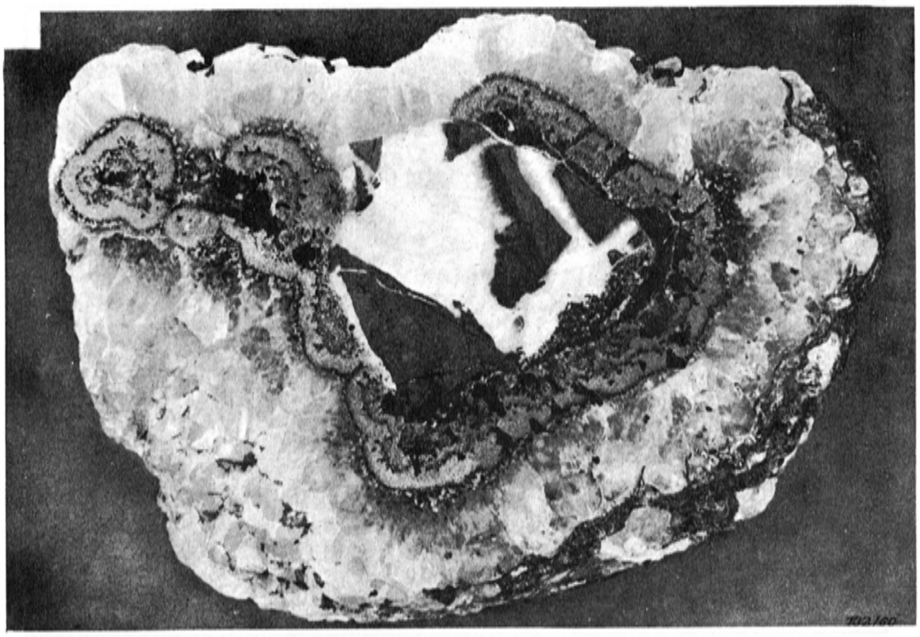


Plate 1. Brecciated sphalerite crystals (dark) of generation two in white matrix of quartz (generation one). Scale 1:1.

Plate 2. Silicified sandstone breccia with large crystals of sphalerite on top and barite (white) on left. Scale 1:1.

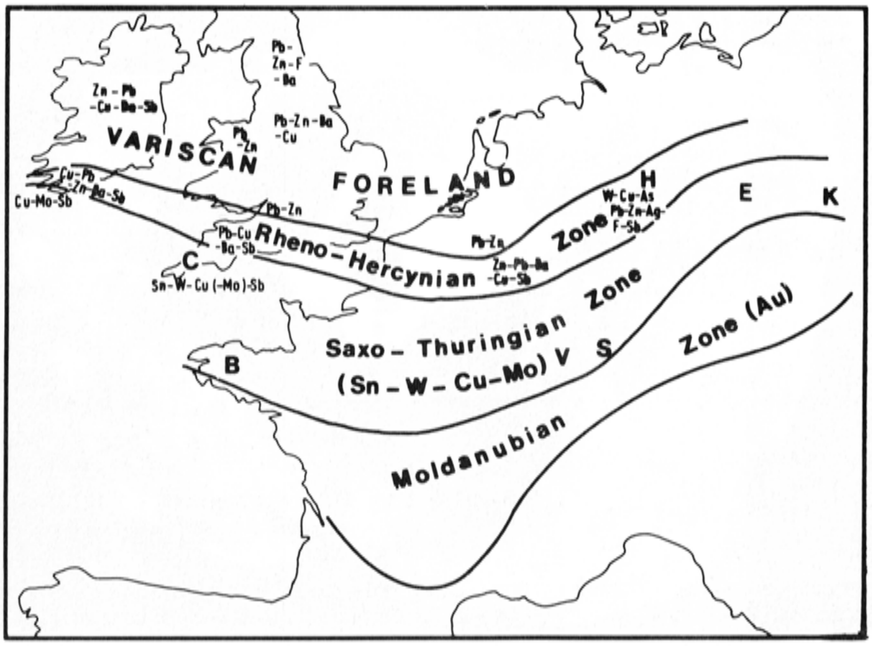


Figure 5. Metallogenic provinces in Europe (after Sattran and Cadek, 1967).

was temperature controlled and ranged from about 250°C to below 100°C. They further suggested that mineralizing solutions ascended from a deep-seated pluton at least 4km below the surface, and that mineralization initiated with the opening of the veins. It is difficult to support this model for the following reasons:

1. The veins are restricted to Westphalian A strata and do not continue in depth,
2. The existence of a pluton has not been proven,
3. There is a scarcity of volatile bearing minerals which comply with the magmatic-hydrothermal-solution model.

B. Descending brines from Permian rocks

Seeliger (1950) suggested that the metals were leached from the Kupferschiefer by Zechstein brines and were precipitated in veins. This model can hardly be supported on the evidence of the ore textures present. Moreover there is a lateral metal zonation which is hard to reconcile with descending brines from Permian rocks.

C. Brines expelled from a sedimentary basin

According to this model (Jackson and Beales, 1967), it can be postulated that metal chloride complexes remained trapped in intermediate (Devonian?) reservoirs until widespread fracturing took place during the Asturic tectonic event. Compaction pressure and an appropriate thermal gradient caused the metal chloride complexes to be expelled from a deeply buried basin along a network of faults into Westphalian A strata. Precipitation resulted from mixing of the metal chloride complexes with reduced sulphur and organic matter, both of which were present in the coal. Repetition of the paragenetic sequence was caused by repeated fault movements. This model suggests that the temperature of crystallization of the ores was between 95°C and 140°C. The earliest minerals, after the crystallization of ankerite, include quartz and chalcopyrite; this phase is followed by sphalerite, galena and barite. Calcite is usually a late mineral. This paragenetic sequence agrees with research done by Buschendorf et al. (1957) at the Christian Levin colliery. This model however requires further research on isotope geochemistry and fluid inclusions.

Comparative reflections

Sattran and Cadek (1967) divided western and central Europe into a number of metallogenic provinces with different types of mineralization (Fig 5).

1. The Variscan Foreland with Pb-Zn-Ba-F-Cu.
2. The Rheno-Hercynian Zone with Pb-Zn-Ba-Cu-Sb.
3. The Saxo-Thuringian Zone with Sn-W-Cu-Mo.
4. The Moldanubian Zone with Au.

It is clear from the foregoing that the Pb-Zn veins in the Ruhr are at present of little economic importance, but they seem very significant as a type deposit of "coal-hosted Pb-Zn mineralization". Similar mineralization also occurs in the English Pennines in three seperate orefields, Alston and Askrigg in the north, and the Peak District in the south.

There are no similarities between vein mineralization in the Ruhr and in Ireland since strata of corresponding age and lithology are poorly developed or absent in Ireland.

Zn mineralization has also been reported in the Westphalian strata of the Illinois coal basin (Hatch et al., 1976). Here it has been demonstrated that sphalerite is associated with minor vertical fractures which provided channels in the coal along which the mineralizing solutions could move. The zinc content is as high as 5300ppm and cadmium as high as 65ppm. Both metals can be removed from the coal by washing. It is therefore suggested that base-metal mineralization should be carefully considered when coal mining is being planned.

Summary and conclusions

The distribution of the mineralization in the Ruhr is closely related to the structure of the district. It is believed that mineralization took place during and shortly after the younger phase (Asturic) of the Hercynian orogeny. It is probable that ore-forming solutions were expelled as connate brines from sedimentary basins and were precipitated under low temperature conditions in a network of faults in Westphalian A strata. The mineralization of the Ruhr district shows a paragenesis of quartz-chalcopyrite-sphalerite-galena-barite.

The Pb-Zn veins in the Ruhr can be considered to be a type example of "coal-hosted Pb-Zn mineralization". Similar mineralization also occurs in three separate orefields of the English Pennines. This type deposit does not occur in Ireland since strata of corresponding age are poorly developed or absent. Zn mineralization has also been reported in the Illinois coal basin. It is suggested that coal might be further investigated as a potential for base metals.

Acknowledgement

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