THE "COPPER SHALE" OF MANSFIELD, GERMANY

—— A complex deposit of syngenetic and hydrothermal origin ——

A. Schüller

(*Academy of Sciences of Germany*)

Since about 1300 the Mansfield copper deposits have been the most productive copper-field in central Europe (Fig. 2). To give you a quantitative idea about its importance I give in the following the production of metals per one million tons of handpicked ore in 1941:

16,000 tons Cu	92 tons Ag	18 tons Se
1,300 tons Pb	91 tons Ni	0.5 tons Re
3,400 tons Zn	11 tons Cd	0.3 g/ton Au
200 tons Mo	39 tons V	

The mining district covers an area of 140 km² of which 120 km² have already been mined out. By the research of the Geological Commission (Survey) of the Democratic Republic of Germany, we have discovered a number of new fields of nearly 100 km² and the studies have not yet been completed. The deposit mainly contains three metals approximately in the proportion of Cu: Zn: Pb $\cong > 3\%$ (5%): $< 3\%$: $< 3\%$. That is, this deposit contains nearly as much Cu as Pb and Zn combined. As comparing this figure with the above production data, you will notice that most of Pb and Zn are not recovered because of inadequate technique.

If one estimates roughly the total quantity of metals which are concentrated in this deposit, one will get the enormous figures as follows: 50 million tons of Cu, 25 million tons of Pb and 25 million tons of Zn.

If any one wants to discover new mining districts, one must answer the question, Why is ore? Where it is?

First of all, one must know the origin of the deposit. All kinds of ideas about the origin of our deposits that one can think of have already been published. But none is founded on modern, thorough investigation.

Next, if one wants to get more metals by technical processes, one must know the quality of the ore, i. e. the nature of the chemical compounds—the minerals, the grain size of the ore particles, the chemistry of gangue, the intergrowth of ore and gangue minerals, the proportions of the different minerals, etc.

In this connection, our Mansfield deposits are as poorly known as most of other old mineral deposits of the world. Therefore our Government has charged me to study this deposit, especially its numerous bore-cores, in cooperation with other geologists by means of the ore microscope, X-ray diffraction, and chemical analysis.

I am going to give a brief account of the results of our work.

(I) *Stratigraphy* (Figs. 1,3)

Firstly the name "Copper Shale" is wrong. The ores are embedded in a slightly sandy or a platy, pure bituminous black limestone. If the limestone becomes dolomitic, ore is missing. In some instances, PbS may travel into the overlying porous dolomite and be stored in its pores, but this is a secondary process. No shales at all exist here. Very often ore begins already 0.2 m below the "Copper Shale" in sandstones and conglomeratic sandstones. These sandstones belong either to the Permain red beds or represent the transgressive conglomerate of the marine Zechstein. The black "Copper Shale" proper, i. e., the platy black beds, has a thickness of 0.2—0.4 m and changes gradually into a gray massive limestone which sometimes contains thick nodules of ore, but is mostly free of it. So the whole productive series amounts to 0.4—0.8 m. Then follow dolomitic limestons, dolomites and anhydrites of the Zechstein. The overlying beds are the famous mighty Salts of Germany.

(II) *Palaeogeography* (Figs. 3,4)

This series of marine sediments was deposited in a lagoon between the Variscian peneplained trunk of Saxony and the Rhenian mountains. The shoreline is well known in most parts, but we have recently corrected it pitiably at the eastern side. The outcrops of the black platy limestone (Kupferschiefer) were lifted up by fracture-folding of the Mesozoic Germano-type and forms a ribbon around the Variscian rocks and horsts.

The productive beds are in general situated only in the center of this lagoon. One may conclude that this part may represent a continuing sinking region during the following sedimentation of Zechstein-chalk, which reaches the great thickness of 10 m here. Near the shoreline the productive beds were mostly destroyed as we could establish during the immediately succeeding sedimentation and redeposited only to a small extent in the younger "Muttenfloz" toward the land.

(III) *Structural behavior* (Fig. 2)

Besides the palaeogeographic relations as mentioned above, there evidently exist structural features in this area which are of great importance to the formation of the deposit. That is, the lineage of the great tectonic lines of late Variscian fracturing. If one extends the fracture-zones of the hydrothermal veins of the Erzgebirge from SE to NW, one will reach the mining districts of the copper deposits, namely:

1. the Ilmenau field, which was finally mined by Geothe, poet and Minister of Geology in Weimar; and the field of western Germany which was mined until 1953;
2. from Schneeberg to Saugerhausen;
3. from Freiberg to Mansfield;
4. the recently investigated field of Edderitz;
5. the newly discovered field of Spaemberg.

It is a remarkable fact that in the copper districts, the Variscian chains become bended when crossing these fractures on the flanks of the "Middle German Swell" of mica schist, which is the main structure underlying the Zechstein. It is at the intersections of these structural lines where we find workable metal concentrations.

And now we want to ask: Why is ore and where it is?

(IV) *Mineralogy and Paragenesis of the Ore.*

(1) Sanderz

Now let us first consider the lowest part of the metalliferous beds, the sandstones. We see under the ore microscope that both large and fine grains are coated mainly by yellow chalcopyrite and in the finer cement, the pores are filled with chalcopyrite, sphalerite, galena and in certain places covellite. Very often the whole grains are replaced by ore; pyrite is found in all places.

It was a great surprise when I found also grains of a partly silicified porphyry and relics of vein-filled gangue with disseminated intergrown copper-lead-zinc ores. Very often small druses in the silicified porphyry are lined with well formed quartz crystals along the walls and filled with complex ores in the center, indicating that silicification was followed by mineralization. It may be concluded therefore that these grains may be the detritus of primary hydrothermal veins belonging to the older Variscian (Carboniferous and Permian) hydrothermal mineralization. The detritus may have been transported into the transgressing Zechstein Sea, but not very far from its source, since the fragments have angular shape and the sulfide ore is quite fresh.

(2) "Kupferschiefer"

In the platy black limestone, i. e. the so-called "Copper Shale", mostly 15—20 cm thick, we find as minerals mainly bornite and chalcopyrite, galena and sphalerite. Very rare are covellite and chalcocite, and still rarer are pyrite and marcasite in the productive parts. The ore is very fine grained and disseminated. In the rich parts these ore grains join closely to form "lineals" of 20 cm long or more and 0.1 to 5 mm thick with 15—20% Cu.

Under the microscope one can see that the ore is regularly connected with small balls of calcite, which may be interpreted from their sections as globular algae. Sometimes the algae are not only coated but also totally replaced by the ores of Cu, Pb, and Zn. Streaks of ore are lying between them. In beds rich in bitumen their forms are elongated and deformed and give a very confused picture under the microscope.

If one studies the balls in oil with high magnification, one can find that the crusts consist mostly of finely intergrown Cu, Pb, and Zn-sulfides, often with ZnS as the only mineral. They often form fine porous networks, perhaps copying deformed algae or other organic structures. The sulfides are growing in well developed crystals into the calcite balls. In certain parts of the mining district, also Foraminifera are impregnated with ore. Spores of higher plants (Coniferas) occurring only in the overlying massive limestone are very often found with Foraminifera. Both are also surrounded mostly by pyrite and marcasite. It may be concluded from the microscopic studies that the Cu-Pb-Zn sulfides were precipitated by organisms, mainly microplants and their remains. Very often are found fossil fish coated with Cu ore and even their brain may be repalced by chalcopyrite and other ore minerals. They probably died in the midst of living and rottening algae. It is believed that the metals are derived from Variscian and older Permain primary and oxidized deposits and were transported into the Zechstein Sea by both surface and underground waters. Therefore, they have the same source as the detritus type of ore.

(3) The copper beds are sometimes crossed by numerous microfractures and

fractures. These fractures are partly filled by massive chalcocite and the metal content of this type of ore amounts to 60 to less than 100 kg per ton. Besides, these beds are also impregnated with chalcocite and bornite.

Only in this type of ore we find chalcocite nearly always associated with massive silver plates. It is remarkable that the chalcocite has a very white color with such a high reflecting power that one might mistake it for galena. By spectroscopic analysis we have proved that it is a mixed crystal of $(Ag, Cu)_2S$, perhaps a new mineral. The paragenesis begins with bismuth, nickel arsenides as niccolite, maucherite, rammelsbergite. It is a pleasure to study this beautiful mineral association.

The most interesting minerals are pitchblende and tucholith. Bote are in company with molybdenite in an uncommon manner and rhenium glanze (ReS_2?), a new but not yet sufficiently studied mineral.

Some of the photomicrographs of the minerals in reflecting light are shown at the end of the paper (Pls. I & II).

The youngest ore minerals of these hydrothermal veins are PbS and ZnS. Tthe last one is a new Pb-Cu sulfide which belongs to the systematic group of Kupfer-spiessglanze and is difficult to distinguish from emplektite ($CuBiS_2$) or wittichenite ($Cu_6Bi_2S_6$). I have named it "Betechtinite", Cu_{10} (Pb, Fe)S_6, in honor of Academician Betechtin of Moscow.

(V) *Genssis*

If we are now asked at the end of this paper about the genesis of the deposits, it would be difficult to answer, since the deposits are a very complex one and not all the events that must have happened during their geological history have been presented here.

I think that when one wants to know the genesis of any deposit, one must distinguish three steps of its development:

a) differentiation,

b) concentration, and

c) the available room ("Speichenung").

The order is very rigorously followed. If one step is missing, no deposit could form.

In Mansfield there must have happened 5 events which appear to be responsible for the formation of the deposits:

1. Variscian hydrothermal veins and porphyry copper deposits were formed;
2. (a) They were eroded on the Middle German Swell and preserved in the Sanderz;

(b) Their solutions were captured by the transgressing Zechstein Sea;

3. The ore solutions were precipitated by bitumen producing algae in the platy "black beds";
4. Hydrothermal veins with Cu, Ag, Bi, Ni, Mo, and U ores formed.
5. The preservation of the ore loading sediments in the continuing sinking central part of the Zechstein lagoon.

(1) and (2) are processes of differentiation, (1), (3) and (4) are processes of concentration, and (4) and (5) are the warehouse where the metals are stored up.

(VI) *Conclusion*

It is clear that the Mansfield deposits were formed by a series of processes and have a complex origin as both a syngenetic sedimentary and hydrothermal deposit. This has not become evident until our recent study, mainly because the mineralogical features were not well known previously.

The formation of the thoughts of the paper and the translation of it from German into English and then into Chinese were helped by my friend Dr. C. J. Peng of Peking. I am obliged to thank him for his help and will always remember the pleasant and fruitful hours of our cooperation.

Fig. 1. Pitchblende drops overgrown by hard rhenium glanze(ReS_2?)and molybdenite.

圖 1. 瀝青鈾矿小点被一种含錸的新矿物(ReS_2?)(环狀)和輝鉬矿(白色毛髮狀)所包圍。

Fig. 2. Rosette characteristic of rhenium glanze and molybdenite.

圖 2. 含錸硫化物和輝鉬矿所成的特有的玫瑰花結構。

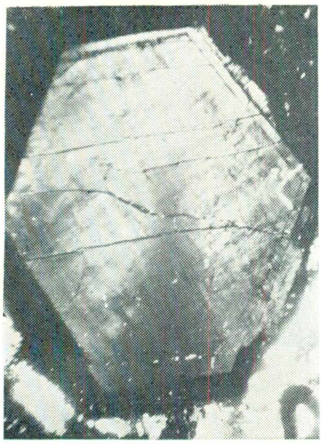

Fig. 3. Pitchblende forming crusts during the growth of trigonal quartz crystals, causing pleochroic halos in the latter.

圖 3. 当石英晶体生長时，瀝青鈾矿在其中造成皮壳結構，致使石英發生多色的色暈

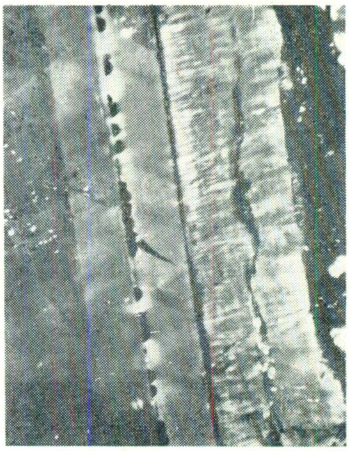

Fig. 4. Same as Fig. 3, but showing an enlarged portion.

圖 4. 同 Fig. 3，但表示一放大部份。

Fig. 1. Pitchblende impregnations on fractures in rammelsbergite.

圖 1. 瀝青鈾矿浸染於淺紅鎳矿(rammelsbergite)的裂縫上。

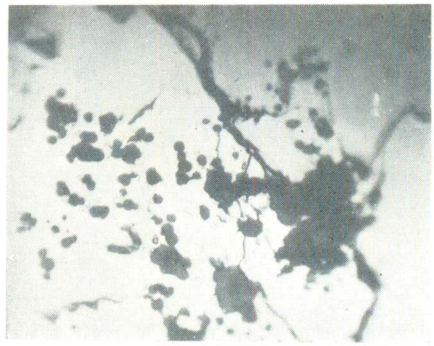

Fig. 2. Molybdenite and rammelsbergite in chalcocite in a large calcite rhombohedron.

圖 2. 輝鉬矿及淺紅鎳矿与輝銅矿共生於方解石菱面体中。

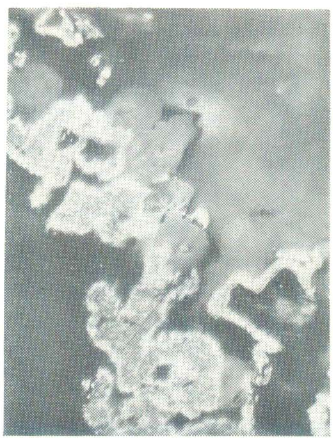

Fig. 3. Thucholite, an uraniferous asphalt, with molybdenite.

圖 3. 含鈾瀝青和輝鉬矿(白色毛髮狀)。