Geoscience Canada

Kupferschiefer and Other Sediment-Hosted Deposits in Central Europe: Field Trip Review

Holly L. O. Huyck

Volume 13, numéro 4, december 1986

URI : https://id.erudit.org/iderudit/geocan13_4con03

Aller au sommaire du numéro

Éditeur(s)

The Geological Association of Canada

ISSN

0315-0941 (imprimé)
1911-4850 (numérique)

Découvrir la revue

Citer cet article

Huyck, H. L. O. (1986). Kupferschiefer and Other Sediment-Hosted Deposits in Central Europe: Field Trip Review. *Geoscience Canada*, *13*(4), 263–265.

Résumé de l'article

The "Kupferschiefer and Other Sediment-Hosted Deposits in Central Europe" field trip(22 May-1 June 1986), which focussed uponthe stratiform copper shale (Kupferschiefer)deposits of West Germany and Poland, was amajor success. Trip leaders effectively com-municated the stratigraphy associated withthese deposits, the sulphide zonation, andthe controls of mineralization (particularly lo-cation with respect to hematitic alterationzones — "Rote Fàule" — and to paleo-topography). Replacement textures by ox-ides and copper sulphides and cross-cuttingrelationships of ore zones with respect tolithologies indicate diagenetic to epigeneticemplacement of ore. While many crucialquestions have been answered, severalremain.

Kupferschiefer and Other Sediment-Hosted Deposits in Central Europe: Field Trip Review

Dr. Holly L.O. Huyck
Department of Geology
University of Cincinnati
Cincinnati, Ohio USA 45221-0013

Summary
The "Kupferschiefer and Other Sediment-Hosted Deposits in Central Europe" field trip (22 May-1 June 1986), which focussed upon the stratiform copper shale (Kupferschiefer) deposits of West Germany and Poland, was a major success. Trip leaders effectively communicated the stratigraphy associated with these deposits, the sulphide zonation, and the controls of mineralization (particularly location with respect to hematitic alteration zones — "Rote Fäule" — and to paleotopography). Replacement textures by oxides and copper sulphides and cross-cutting relationships of ore zones with respect to lithologies indicate diagenetic to epigenetic emplacement of ore. While many crucial questions have been answered, several remain.

Introduction
Kupferschiefer, or copper shale, deposits are stratiform deposits associated with Permian sediments covering approximately 600,000 km^2 of Europe, from northern Great Britain to western Russia, and are mined today in East Germany and Poland. After being mined for copper for almost 800 years, the Kupferschiefer continues to produce new deposits; in southwestern Poland, recently discovered mines contain estimated reserves of at least one billion tonnes of 1.5-2.0% copper and approximately 30 g/tonne silver (White, 1986).

The Kupferschiefer is a thin, carbonaceous shale or marl which lies at the base of the Upper Permian, or Zechstein sediments. This shale overlies Lower Permian terrestrial, red-coloured sandstones and conglomerates (Rotliegendes) and transitional white-to-grey sandstones (Weissliegendes), which in turn overlie older Paleozoic volcanics and sediments (locally metamorphosed during the Variscan orogeny). The Kupferschiefer forms the base of the lowest of three to five marine-evaporite cycles in the Zechstein sediments.

Mineralization occurs in the Kupferschiefer and its adjacent sediments (Zechstein limestone above, and Weissliegendes below). Highest metal grades occur adjacent to Rote Fäule, a hematitic alteration of Rotliegendes and Zechstein sediments. Moving away from Rote Fäule (generally basinward), typical metal zonation is: chalcocite, bornite, chalcopyrite, galena, sphalerite and pyrite/marcasite. Silver, an important by-product in Kupferschiefer mines, is associated with copper; other metals (including cobalt, gold and platinum) are also enriched in these deposits, but are not currently recovered.

Models of ore genesis in these deposits have ranged widely over time: (1) epigenetic emplacement of metals by hydrothemal solution, (2) syngenetic precipitation of metals in an euxinic, saline basin; (3) early diagenetic precipitation of metals from groundwater ascending via evaporation in overlying sabkhas. Papers presented at the Symposium on Sediment-Hosted Stratiform Copper Deposits, at Ottawa, Canada, in May 1986, suggest that several workers have returned to a diagenetic or epigenetic model of Kupferschiefer mineralization related to convecting hydrothermal fluids.

Kupferschiefer Field Trip
The "Kupferschiefer and Other Sediment-Hosted Deposits in Central Europe" field trip (22 May - 1 June 1986), presented in association with the symposium, provided a rare opportunity to view the Permian sediments and Kupferschiefer deposits of both West Germany and Poland. The trip was organized into three parts: the German Kupferschiefer excursion (I), the German Sedimentary exhalative excursion (II), and the Polish Kupferschiefer excursion (III). The sedimentary-exhalative portion of the trip included tours of the Marsberg and Rammelsberg copper deposits. While fascinating in their own right, these deposits will not be discussed in this summary. Also, several stops in Germany and Poland which are not essential to this summary have been excluded.

This field trip was very well organized and led by Canadian, German and Polish geologists. The participants are indebted to the organizers and to the host countries for making this an excellent trip. The guidebook (Jowett, 1986) is similarly well organized and is recommended to the reader. This review will focus on observations and questions raised by the actual field experience. The excursion's purpose, "to view the continental volcanic and clastic rocks of the Rotliegendes and the marine carbonates and evaporites of the Zechstein, and the relationship of ore mineralization to facies, paleogeography and paleotopography" (Jowett, 1986) was fully accomplished.

Part I: German Kupferschiefer. During the first segment of the field trip, participants observed portions of the Rotliegendes clastics and volcanics, and the overlying Zechstein marine sediments. Participants spent the first field day (23 May) in the Saar-Nahe basin, a northeast-trending basin located southwest of Frankfurt where the largest continuous exposures of Rotliegendes occur, and where the Rotliegendes reaches a maximum thickness of 5000 metres. The upper half of the lower Rotliegendes, viewed near Oderheim, contains lacustrine siltstones, locally containing as much as 5000 ppm copper and lesser amounts of lead and zinc. Overlying sediments grade upward into a deltaic sequence of alternating sandstones and mudstones followed by massive sandstones. Thin coal beds scattered throughout the deltaic sediments locally contain anomalous copper or uranium.

Portions of the upper Rotliegendes were viewed in Waldbockelheim, including andesitic volcanics, interbedded sandstones, lapilli-bearing conglomerates and rhyolitic tuffs. These are overlain by a rhyolitic conglomerate and a thick sequence of massive latitic flows.

The Saar-Pfalz rhyolite, seen near Bad Kreuznach, is an alkalic rhyolite which intruded the Rotliegendes sediments. It is one of a series of alkalic intrusions which indicates rift-related igneous activity during Permian deposition.

On the second field day, near the former mining district of Richelsdorf, we observed the uppermost Rotliegendes, the Cornberg sandstone, and the first cycle of Zechstein sediments (including the Kupferschiefer). Uppermost Rotliegendes is a thick sequence of non-marine sandstones, pebble conglomerates and lesser shales, with a characteristic reddish matrix. This portion of Rotliegendes was visible at both the Schuchard Sandstone Quarry in Cornberg and the Münden Barite Mine.

Cornberg Sandstone, an equivalent of Weissliegendes, was seen only at the Schuchard Quarry. This cross-bedded white sandstone of disputed origin (eolian, fluviatile or shallow marine) has an undulating surface which is in sharp contact with Kupferschiefer. The laminated shale thickens to 85 cm in the sandstone troughs and almost pinches out over crests. Organic carbon, copper (averaging 1%), lead and zinc are concentrated in the lower portions of the shale.

At the Münden barite mine, Kupferschiefer rests directly upon a relatively flat surface of bleached Rotliegendes (Grauliegendes). Metals — dominantly zinc in this area — are again concentrated in the lower, organic-rich portion of the shale. As is characteristic throughout the Kupferschiefer, copper is most concentrated at the base, lead in the middle, and zinc in the upper part of the mineralized zone. This sequence is repeated whether it occurs within tens of centimetres of shale, or tens of metres of various sediments.

Above the Kupferschiefer lies the Zechsteinkalk, a marly limestone with a bioturbated base and anhydrite nodules near the top. Overlying the Zechsteinkalk at the Münden barite mine, Anhydritknotenschiefer (with the interbedded anhydrite layers now dissolved out) and Shale Breccia (solution breccia of Lower Werra Anhydrite) complete the first cycle of the Zechstein.

At the Münden mine and in drill core seen in Cornberg, the Rotliegendes is bleached to a greenish-grey or yellowish-grey colour for several metres below the Zechstein contact. Such alteration in colour, due to reduction of iron oxides, was called "Grauliegendes" by miners. This form of bleaching has also developed locally in Weissliegendes and, where Rotliegendes is quite thin, in the underlying schists or sediments. The Grauliegendes consistently underlies the Zechstein sediments. Causes of these lenses of reduction are disputed; proposed reasons range form pre-Zechstein weathering to sabkha formation or to reduction during Zechstein sedimentation. Grauliegendes may contain anomalous copper concentrations — locally appearing to be associated with downward movement of metals from the Kupferschiefer at the Münden mine. However, the copper-rich zone in the Grauliegendes also may be separated from the Kupferschiefer by a copper-poor zone. The cause of such zoning is unclear.

One critical type of alteration introduced to us on the second day was the Rote Fäule, a zone of oxidation characterized by development of hematitic patches. Rote Fäule generally occurs near paleotopographic highs in Zechstein seas; it is never adjacent to Grauliegendes; but it forms in sediments ranging from Rotliegendes to anhydrite in the Zechstein; and it is generally barren, but consistently occurs adjacent to the highest-grade mineralization. The classic basinward zonation, found throughout Europe is: hematite → chalcocite → bornite → chalcopyrite → galena → sphalerite → pyrite. To emphasize the importance of this zonation with respect to Rote Fäule, the German trip leaders noted a drillhole in which Rote Fäule was found stratigraphically high in the section. Here, the vertical zoning mentioned above was reversed; copper was highest on top, with chalcocite on top and chalcopyrite at the base of the copper zone, and lead and zinc *below* the copper. Thus, location of Rote Fäule and not lithology, appears to control metal zonation. For all its importance, however, Rote Fäule is not well-understood. Enigmas of Rote Fäule and Grauliegendes provided lively discussion among participants.

Participants also viewed sections where the Rotliegendes is only five metres thick. The grade of Kupferschiefer mineralization is *not* dependent upon the thickness of Rotliegendes.

The third field day was mainly devoted to observing basin-edge Zechstein deposits in quarries near Dorfitter, where the Kupferschiefer equivalent is Kupfermergel ("copper marl"), or a thin sequence of interbedded limestones and copper-bearing marls. No Rotliegendes occurs in this area. However, a thin limestone, Productuskalk or Mutterkalk, locally occurs between the Kupfermergel and underlying Carboniferous/ Devonian shales or greywackes. The Kupfermergel is overlain by Zechstein limestone, and by RandKarbonat — the facies equivalent of the Anhydritknotenschiefer. Copper mineralization is strongest adjacent to Rote Fäule, which has developed in the Productuskalk through the Zechsteinkalk.

Observations and discussion with leaders of the German segment of the field trip have answered several questions about the formation of these deposits, and have raised new questions. First, it is obvious from the trip leaders' presentations that a great deal of effort has been made to define the Zechstein and underlying stratigraphy, and to characterize the Kupferschiefer in detail. This author now has a sense of the types of rocks and the spatial variations of specific facies in the Rotliegendes and Zechstein. However, terms such as "Grauliegendes", and even "Weissliegendes", which evolved from miners' terminology, appear to encompass a bewildering variety of lithologies or alteration types. Characterization of these terms would be most helpful. Second, mineralization in the Zechstein sediments is controlled by basin depth, type of basin (some seem to be more copper-rich, others more zinc-rich), and location with respect to Rote Fäule. The strong relationship of metal content and zoning with Rote Fäule, and not as closely with lithology, and the crosscutting of Rote Fäule means that at least the most recent mobilization of metals must have significantly post-dated sedimentation.

Part III: Polish Kupferschiefer. The first day in Poland (27 May) was mainly spent underground at the Konrad mine near Legnica, SW Poland. This deposit occurs on the northeast edge of the North Sudetic Basin, which is bounded to the northeast by the Fore-Sudetic Block, an Alpine-age uplifted block and site of a topographic high during Late Permian times. At the 550 metre level, participants observed the Rotliegendes, Ore Series (including Basal Limestone and Kupfermergel), and Zechstein Limestone. The Rotliegendes, which is approximately 500 m thick in this area, consists of red and banded red-and-grey sandstone to pebble conglomerate. Crossbeds of sandstone alternate red and grey in colour. Within the red beds, dark, volcanic(?) clasts are surrounded by grey reduction halos. Locally, zones of grey colour vertically cut across massive red zones — apparently ascending solutions have reduced the iron oxides in the Rotliegendes.

The Ore Series in the Konrad mine includes Basal Limestone and Kupfermergel. The Basal Limestone forms a sharp contact with underlying Weissliegendes (which is locally present) or Rotliegendes. The Kupfermergel (averaging 2.7 m thickness) includes the Spotted Marl, a grey marl commonly coloured by large hematitic spots (Rote Fäule), and the Copper-Bearing Shale, a dark grey, fissile marl, averaging 0.8%-1.1% copper in the mine. The Zechstein Limestone, overlying the Kupfermergel, includes a lower unit, the Lead-Bearing Marl, and an upper dolomitic limestone to dolomite. (Please note: these are stratigraphic units, as defined by marker beds — see editor's note in Oszczepalski *et al.*, 1986.) Rote Fäule is developed in Basal Limestone, Spotted Marl, and lower Copper-Bearing Marl, while copper is concentrated in the upper Copper-Bearing Marl and lower Lead-Bearing Marl. Silver is associated with the copper. At the Konrad mine, only copper and silver are recovered. Anhydrite is also mined from one of the near-surface members of the Upper Zechstein.

The Rudna mine, toured on 28 May, occurs in the Fore-Sudetic Monocline, which is bounded on the southwest by the Fore-Sudetic Block. Along with the Lubin and Polkowice mines, the Rudna exploits a northwest-trending, continuously mineralized zone (the Lubin district) covering approximately 600 km^2. Farther northwest on this same trend lies the Sieroszowice deposit, which is currently being developed.

Stratigraphy within Rudna is quite similar to that found in Konrad, with a few notable exceptions. Weissliegendes sand waves, ranging between 5 and 43 metres in thickness, occur throughout the deposit; the Border Dolomite ($\leq$ 15 cm thick) is the equivalent of the Basal Limestone seen at Konrad; and the Kupferschiefer is a black, laminated shale here, not a marl. This shale can be as thick as 90 cm, but locally pinches out over crests of Weissliegendes sand waves.

Copper mineralization is present in the Weissliegendes, Kupferschiefer and/or Lower Zechstein limestone. Within the Kupferschiefer, rich copper ore (5-15% Cu) occurs as disseminations, and beddingparallel and near-vertical veinlets. Within the Weissliegendes, copper contents, ranging 0-15% Cu, tend to be highest in sand wave crests. Where anhydrite cement occurs in the sandstone crests, however, *no* copper is present and only minor pyrite, galena and sphalerite may occur. Copper ore zones can be as thick as 20 metres. One startling observation was the presence of repeated ore bands (defined by high chalcocite at the base to low chalcocite at the top), $\leq$ 2 cm thick, within the rich Weissliegendes ore. Exact mineralogy and reasons for this banding are unclear at the moment. The lower portions of Zechstein Limestone may be copper-rich, but copper content decreases upward, while lead and zinc increase. Zoning of sulphide minerals relative to Rote Fäule (which is located in the western edge of the deposit), is the same sequence as noted in Germany. Silver is most strongly associated with chalcocite and bornite. At Rudna, as opposed to Konrad, all the base metals and silver are recovered. Petrographically, the sulphides reflect the regional zonation. Framboidal pyrite is the earliest sulphide to form, and is consistently replaced by copper sulphides. Hematite prevalently replaces copper sulphides.

On the eighth field day, the shoreward facies of Zechstein sediments in southwestern Poland, and the interaction of Rote Fäule with mineralized zones were examined. The Nowy Kosciol quarry and Lena open-pit mine occur in nearshore facies equivalents of the Konrad mine within the North-Sudetic Basin. The stratigraphy of these two deposits is very similar to that at Konrad except that the marls are increasingly carbonate-rich toward the paleoshoreline. Copper mineralization occurs stratigraphically higher near the Lena mine; it is almost entirely within the Lead-Bearing Marl, whereas in the Nowy Kosciol quarry, it is dominantly in the Copper-Bearing Marl. At Nowy Kosciol, where an overlap of copper mineralization and Rote Fäule of approximately one metre occurs, hematitic spots have halos of sulphides — the opposite of the usual trend. The complex relations of oxides and sulphides suggest possible oscillation of redox zones in this area.

The Polish geologists' understanding of paleogeographic settings, metal zonations, relations of mineralization to stratigraphy and Rote Fäule, and sedimentary environments of deposition are impressive. Discussions with Polish geologists and synthesis of the group's observations have provided an understanding of the essential characteristics of the Polish Kupferschiefer deposits. Copper mineralization cuts across stratigraphy at a low angle, and is strongly associated with the boundaries of Rote Fäule; the richest ore parallels Rote Fäule boundaries, which are at a slight angle to the Zechstein's paleoshoreline. District-wide ore grades or metal contents are *not* correlated with thickness of either Zechstein or Rotliegendes sediments. Zoning of mineral sulphides with respect to Rote Fäule is consistent; copper sulphides consistently replace early pyrite, usually in the order of mineral zonation, and hematite generally (but perhaps not always) replaces copper sulfides. Iron content of Rote Fäule and pyritic zones are roughly equal, however organic carbon content increases from 0% in Rote Fäule to 10% in the pyrite zone.

Several ambiguities, in addition to those noted with specific reference to Germany, still remain regarding the Kupferschiefer deposits. First, Polish geologists suggested that, on a regional scale, copper mineralization is generally associated with a calcite-rich zone which also cross-cuts stratigraphy at a low angle. This is not obvious in the stratigraphic sections, and the limestone *versus* dolomite distribution was unclear from our observations. If a relationship between mineralization and calcite is present, it may reflect mineralizing processes. This topic is being investigated (Oszczepalski, in press). One question is whether any similar relationship is observed in the German Zechstein sediments.

Second, there is some discussion as to whether the Kupfermergel of Poland is truly equivalent to the Kupferschiefer; certain characteristics suggest that it more closely resembles part of the Zechsteinkalk. One way to answer this question is to perform detailed studies of the Kupferschiefer and Kupfermergel in Poland to see whether the detailed stratigraphy described by Kulick *et al.* (1984) is present in the Polish "equivalents".

Third, the importance of the Rote Fäule has been well-established on a regional scale, and some petrographic work (Oszczepalski and Rydzewski, 1983; Rydzewski, 1978) has been done. This author believes, however, that further study of Rote Fäule, and particularly of the 50-80 cm thick transition zone to chalcocite, whould shed important light on the questions of mechanisms of ore depostion. Rydzewski has observed three types of hematite in these sediments: disseminated hematite in pore fillings with no suggestion of replacing sulphides; hematite gradually replacing individual sulphide grains; and hematite-rich spots (e.g., in the Spotted Marl) forming a splotchy appearance. The question of which type of hematite truly represents the Rote Fäule deserves more study.

The final question, the goal of studying Kupferschiefer deposits, is to understand how they form. The experience of this field trip has convinced the author that metal zonation must be related to diagenetic/epigenetic processes associated with formation of the the Rote Fäule. Two major theories seem to be surfacing at the moment: (1) the metals were leached from Rotliegendes sediments and transported through Zechstein sediments during diagenesis via convective flow of oxidized brine (Jowett *in* Jowett, 1986a, p. 42-52); and (2) metal deposits resulted from the interaction of two brines, an ascending, hot, metal-rich brine associated with Rote Fäule formation, and descending, cold, alkaline brine (Kucha and Pawlikowski, 1986). The first theory includes two variations: Jowett (*op. cit.*) argues strongly that mineralization occurred during late diagenesis; Oszczepalski (in press) believes that copper mineralization mainly occurred during early diagenesis and was remobilized during late diagenesis. The cursory nature of one field trip does not permit confidence in choosing between the two mechanisms which currently seem to be most sensible. Furthermore, it is unclear to the author how one would differentiate between metals introduced by late diagenetic influx of brines, and simply remobilized metals. Perhaps the continued work on stable isotopes, fluid flow paths, fluid chemistry and fluid/rock reactions will shed light on this. The author's main conclusion from the Kupferschiefer field trip is that much important work has been accomplished toward understanding these deposits, but new questions are have resulted.

Acknowledgements
The author wishes to express her gratitude to the leaders of the field trip, J. Kulick, D. Leifeld and A.-K. Theuerjahr (Part I); B. Stribrny, H. Sperling, G. Herget and E. Walcher (Part II); W. Ryka, A. Rydzewski, S. Oszczepalski, T.M. Peryt, C. Skowronek (Konrad), L. Biela, J. Blaszczyk (Rudna), and K. Dubinski (Part III); to G. Burchart (translator in Poland), to W.W. Hutchison, President of IUGS, and especially to E.C. Jowett (overall leader, co-ordinator, and text editor) for providing an excellent field trip and forum for exchanging ideas. The individuals, their sponsoring organizations, and the host countries each contributed to making this trip a major success. The author also thanks the several trip participants and leaders who read this manuscript and made valuable criticisms. The final manuscript, however, is entirely the author's responsibility.

References

Jowett, E.C., 1986, editor, Kupferschiefer and Other Sediment-Hosted Deposits in Central Europe: Geological Association of Canada—Mineralogical Association of Canada, Joint Annual Meeting, Ottawa '86, Field Trip 12 Guidebook, 79 p.

Jung, W. and Knitzschke, G., 1976, Kupferschiefer in the German Democratic Republic (GDR) with Special Reference to the Kupferschiefer Deposit in the Kupferschiefer Deposit in the Southeastern Harz Foreland, *in* Wolf, K.H., editor, Handbook of Strata-Bound and Stratiform Ore Deposits, v. 6: Elsevier Scientific Publishing Company, Amsterdam, ch. 7, p. 353-402.

Kucha, H. and Pawlikowski, M., 1986, Two-brine model of the genesis of strata-bound Zechstein deposits (Kupferschiefer type), Poland: Mineralium Deposita, v. 21, p. 70-80.

Kulick, J., *et al.*, 1984, Petrofazielle und chemische Erkundung des Kupferschiefers der Hessichen Senke und des Harz-Westrandes: Geologisches Jahrbuch, v. 68, p. 223.

Oszczepalski, S., and Rydzewski, A., 1983, Copper-bearing Permian rocks in areas adjoining the Lubin-Sieroszowice deposit (in Polish, English abstract): Przeglad Geologiczny, v. 31, p. 437-444.

Oszczepalski, S., *et al.*, 1986, Polish Kupferschiefer excursion, *in* Jowett, E.C., editor, Kupferschiefer and Other Sediment-Hosted Deposits in Central Europe: Geological Association of Canada—Mineralogical Association of Canada, Joint Annual Meeting, Ottawa '86, Field Trip 12 Guidebook, p. 53-71.

Rydzewski, A., 1978, Oxidated facies of the copper-bearing Zechstein shale in the Fore-Sudetic Monocline (in Polish, English abstract): Przeglad Geologiczny, v. 26, p. 102-108.

White, L., 1986, Polish copper: engineering and Mining Journal, v. 187, p. 26-30.

Accepted 18 August 1986.