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## LOW TEMPERATURE ORE MINERALS ASSOCIATIONS IN THE KUPFERSCHIEFER TYPE DEPOSIT, LUBIN–SIEROSZOWICE MINING DISTRICT, SW POLAND

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The low temperature ore minerals associations in the Kupferschiefer type deposit of Lubin–Sieroszowice mining district (south-western part of Poland) are described.

*Key words:* mineralogy, low temperature ore mineralization, Kupferschiefer type deposits, Poland.

The copper-silver deposit lies on SW corner of the Fore-Sudetic Monocline (fig. 1) and is located within the Permian sediments, which covered 56 % of the Polish territory. The southern border of deposit is a tectonic limit of Permian strata close to the tectonic border of the Fore-Sudetic Block. The other borders were documented following the contour set on last positive drill holes characterized with an accumulation index of 50 kg/m<sup>2</sup> and 0,7 % Cu as a cut of.

Kupferschiefer type copper deposit was discovered in 1957 in the Lubin ore district and mining started in 1968. The Lubin–Sieroszowice mining district is owned by the public mining company KGHM Polska Miedź S. A., since 2012 an international, that owned also some deposits and tenements in South and North America. During 50 years of mining operation, over one billion tons of ore grading 1,1–2,0 % of copper and 45–60 ppm of silver were extracted. The recent mining area is 400 km<sup>2</sup>, but the geological deposit stretches over 1 000 km<sup>2</sup> of the Fore-Sudetic Monocline (see fig. 1). Although gold and PGM's were discovered by Kucha (1973), however an economic concentrations were first reported in 1994 during routine mineralogical sampling and described in [26]. Rote Fäule (RF) was described in the time of deposit documentation. The RF is recognized as syndimentary and early diagenetic oxide facies controlled by fine dispersed hematite in the Kupferschiefer and Werra limestone strata [31]. The polymetallic, an economic ore mineral association is related to the geochemical redox barrier represented by the Kupferschiefer unit overlying the white sandstone strata. The secondary oxidation system (SOS), responsible for the second association of precious metals enrichment, was studied by Piestrzyński et al. [26]. SOS is younger in comparison to the RF [26].

**Outline geology.** The ore horizon is close to the Lower–Upper Permian strata composed of white sandstone (Weissliegend), boundary dolomite, the Kupferschiefer and dolomite (fig. 2). In the mining area, the average thickness of the Weissliegend sandstone is close to 18 m, however it is ranging from several up to 35 m. Copper content in the sandstone ore is ranging from 0,7 % in dispersed type of ores up to 30 % in massive type of ore, with an average thickness close to 1,8 m. In some places related to the elevations of the Weissliegend sandstone developed

during Zechstein see transgression, nests and lenses anhydrite cemented sandstone are common. Anhydrite cemented sandstone is usually barren with minor pyrite, marcasite, galena, sphalerite and covellite. Close to the anhydrite cemented bodies massive chalcocite, covellite ores are present. Boundary dolomite (BD) is a next lithological unit containing ore mineralization. It is developed in the eastern part of the deposit as a continuous solid layer and in the western wing occurring only locally in a lensoidal forms.

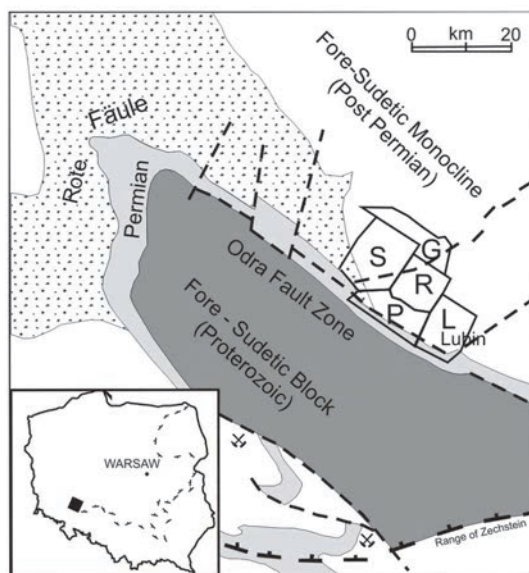


Fig. 1. Simplified map of the Lubin-Sieroszowice IOCG deposit, SW Poland (without Cenozoic strata), after J. Pieczonka, A. Piestrzyński, 2011:

L – Lubin Mine, P – Polkowice Mine, R – Rudna Mine, S – Sieroszowice Mine, G – Głogów Industrial field.

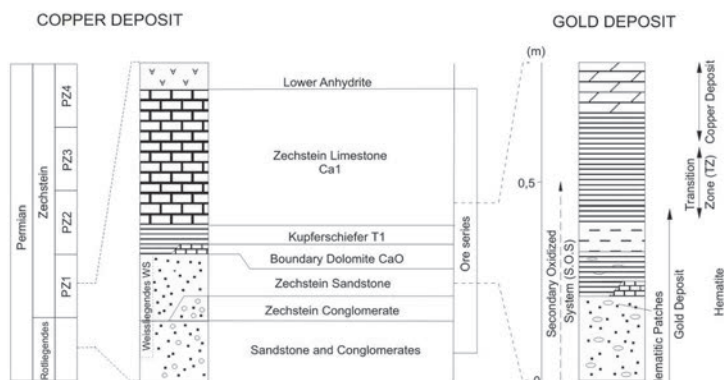


Fig. 2. Stratigraphic column of typical copper deposit (modified after [19]) and section containing gold ore (after [26]).

The Kupferschiefer (KS), that is follow the BD is typical metal-bearing shale, black in color, micro laminated sediment composed of illite, mixed-layer clays, dolomite, organic matter (7,34 %), sulphides, calcite, and minor phosphates, gypsum, anhydrite, and clastic materials e.g. quartz, feldspar, different types of mica and titanium oxides (fig. 3, 4). In this unit pitchy shale (clay-organic), clay-dolomite, dolomite-clay, and clay-calcareous varieties have been recognized. The KS thickness varies from 0 up to 0,7 m in the mining area with an average 0,27 m. An average content copper is close to 10 % however it's ranging from several up to 35 %. Some section of KS are oxidized and discolored to the maroon tint [26]. Carbonate type of ores (Zechsteinkalk – Z1, Ca1 – Werra) overly the KS are fine crystalline dolomite that is characterized with the high variability of its thickness ranging from zero up to several meters. Copper content in this ores is ranging from 0,7 % up to several percent.

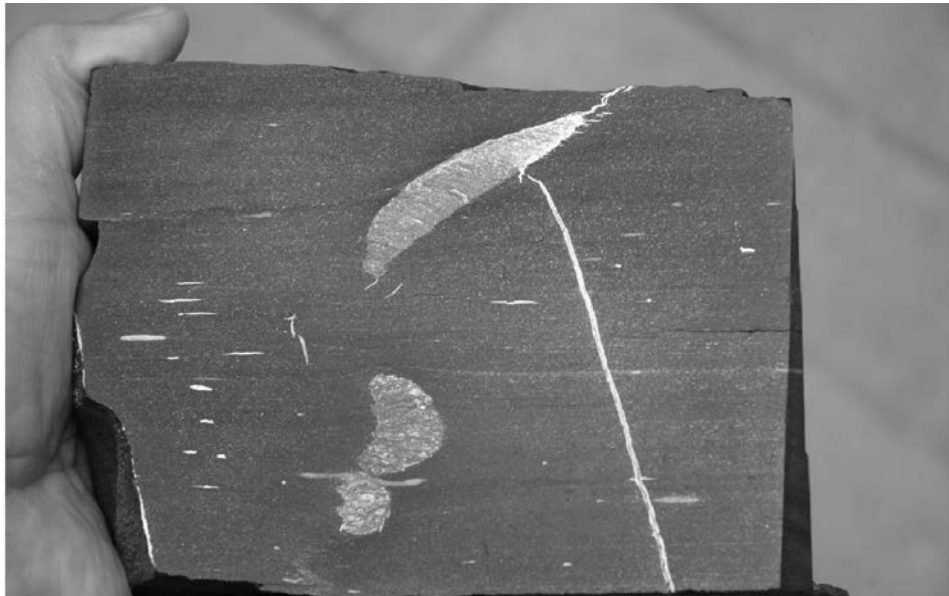


Fig. 3. Typical Kupferschiefer rich ore, Rudna Mine, 12 × 10 cm.

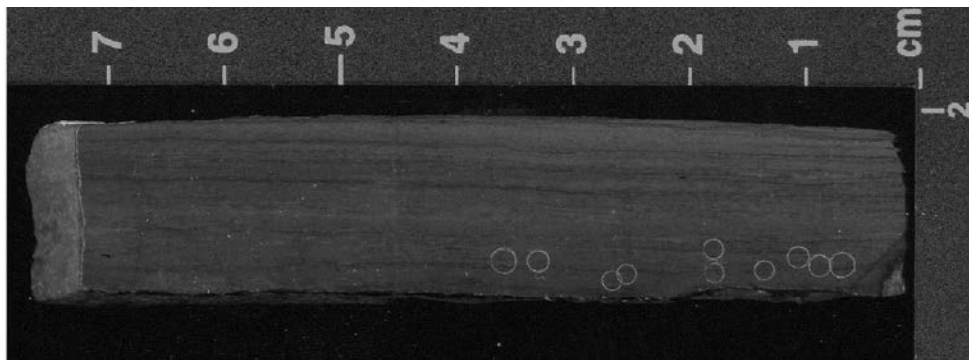


Fig. 4. Red variety of the Kupferschiefer containing fine grains of gold (in circles), Polkowice Mine.

**Mineralogy.** During 50 years of study following minerals have been distinguished: chalcocite, digenite, bornite, lilac bornite  $[(\text{Cu}, \text{Ag})_3\text{FeS}_4]$  chalcopyrite, covellite, pyrite, marcasite, sphalerite, galena, tenorite, cuprite, native Ag and Cu, stromeyerite, stromeyerite Cu and tennantite, tetrahedrite, enargite, cobaltite, julukulite  $(\text{Co}, \text{Ni})\text{AsS}$ , skutterudite  $(\text{Co}, \text{Ni}, \text{Fe})\text{As}_3$ , smaltine  $(\text{Co}, \text{Ni})\text{As}_3$ , bravoite  $(\text{Fe}, \text{Ni}, \text{Co})\text{S}_2$ , vaesite  $\text{NiS}_2$ , rammelsbergite, parammelsbergite, nicollite, maucherite, safflorite, bietiechtinite [5]. In the next years: famatynite, chloantite, pitchblende, luzonite, jalpaite, argyrodite, siegenite  $(\text{Co}, \text{Ni})_3\text{S}_4$ , castaingite  $\text{CuMo}_2\text{S}_{4,85}$ , djurleite, Co-löllingite, acanthite, clausenthalite and wittichenite, azurite, malachite, cerusite, smitsonite, annabergite, erythrite [7], electrum [8], morozewiczyt, polkowiczyt [6], mackinstryite  $\text{Cu}_{0,8}\text{Ag}_{1,2}\text{S}$ , kongsbergite  $\text{AgHg}$  and tiemannite [28], gersdorffite [9], thucholite [1], brannerite [15], anilite [10], molybdenite, jordisite [29], villamaninite [18], half-bornite, quarter-bornite [30], mooihokite, haycockite [11], native Pb, Pt-gold, Pb-gold, native Pd, sobolevskite, vinctentite, eugenite  $\text{Ag}_{11}\text{Hg}_2$ , kolymite  $\text{Cu}_7\text{Hg}_6$  [13], uraninite [21], chlorargyrite and platnerite [14], tetraauricupride, spionkopite and yarrowite [24], native Bi, bismuthinite, pavonite [17], carrolite, lautite and linneite [17].

Based on microprobe and EDS analyses next tens of new chemical phases have been detected:  $\text{Pb}_5\text{As}_4$ ,  $\text{Cu}_{21}\text{PbS}_{16}$ ,  $\text{CuMoS}_3$ ,  $\text{Pd}_5\text{As}_2$ ,  $\text{PdAs}_2$ ,  $\text{Pd}_3\text{As}_2$ ,  $\text{Cu}_6\text{FeS}_5$ ,  $\text{Cu}_9\text{MoS}_9$ ,  $\text{Cu}_8\text{MoS}_9$ ,  $\text{Ag}_7\text{Hg}_2$ ,  $\text{Ag}_{10}\text{Hg}_2$ ;  $\text{Cu}_4\text{Ag}_2\text{S}_3$ ,  $\text{Cu}(\text{Fe}, \text{Ag})\text{S}_2$ ,  $(\text{Fe}, \text{Cu})\text{Cu}_2(\text{Ag}, \text{Cu})_3\text{S}_4$ ,  $\text{FeCu}_3\text{Ag}_6\text{S}_7$ ,  $\text{Cu}_{5,28}\text{Fe}_{0,55}\text{Ag}_{1,17}\text{S}_4$ ,  $\text{FeCu}(\text{Ag}, \text{Cu})_2\text{S}_5$ ,  $\text{FeCu}_2\text{Ag}_3\text{S}_4$ ;  $\text{Pd}_3\text{As}_5$ ,  $(\text{Ni}, \text{Pd})_3\text{As}_4$ ,  $\text{Pd}_4\text{As}_3$ ,  $\text{PdCu}(\text{As}, \text{S})_6$ ,  $\text{Pd}_8\text{As}_2\text{S}$ ,  $\text{Pd}_8\text{As}_6\text{S}_3$  [12];  $\text{Cu}_6\text{Ag}_2\text{S}_5$  [28];  $(\text{Cu}, \text{Fe})_{22}\text{PbS}_{14}$ , Pb-castaingite, K-castaingite [14];  $\text{Ag}_{14}\text{Hg}_1$ ,  $\text{Ag}_6\text{Hg}_1$  [25];  $\text{Pd}_2\text{AsO}_4$ , PbBi,  $(\text{Cu}, \text{Pb}, \text{Fe}, \text{K})_2(\text{Mo}, \text{As})_6\text{S}_8$ ,  $\text{Pb}_4\text{Hg}$ ,  $(\text{Cu}, \text{Fe})_4\text{Bi}_2\text{S}_7$ ,  $\text{Cu}_7\text{Bi}_2\text{S}_7$ ,  $\text{Cu}_4\text{BiS}_4$  [17];  $\text{PdAs}_7$ ,  $\text{Pd}_2\text{As}$ ,  $\text{Pd}_4\text{As}$ ,  $\text{Pd}_9\text{As}_2$ ,  $\text{Pd}_5\text{As}$ ,  $\text{Me}_{13}\text{As}_2$  ( $\text{Me} - \text{Pd}, \text{Pt}, \text{Au}, \text{Ag}$ );  $\text{Me}_8\text{As}_3$  ( $\text{Me} - \text{Pd}, \text{Ag}$  and  $\text{Pt}$ );  $\text{Pd}(\text{Ni}, \text{Fe})_2\text{As}_3\text{S}_{0,5}$  or  $\text{Me}_4\text{As}_7\text{S}$ ,  $(\text{Pd}, \text{Pt}, \text{Ni})\text{As}_7$ ,  $(\text{Pd}, \text{Ni})\text{As}_7$ ,  $(\text{Pd}, \text{Au}, \text{Ni})_3\text{As}$  and  $\text{PdAs}_3$  [20].

In atomic proportions showed following new faces like:  $\text{Me}_3\text{Se}_2(\text{Te}, \text{As})_1$ ,  $\text{Me}_2(\text{Se}, \text{Te})_1$ ,  $\text{Me}_5\text{Se}_4(\text{Te}, \text{As})_1$ ,  $\text{Me}_2(\text{Se}, \text{Te}, \text{As})_1$ ,  $\text{Me}_3(\text{Se}, \text{Te}, \text{As})_2$ , where  $\text{Me} - (\text{Ag} + \text{Au} + \text{Pb} + \text{Bi})$ ;  $\text{Pd}_{9,1588}\text{Pt}_{1,1020}(\text{Au}_{2,2148}\text{Ag}_{0,5694})\text{As}_{2,0000}$ , (11,70 % Pt) [20]; naumannite, characterized by instable chemical composition [20], Au-naumannite, Au-Pb-naumannite, Pb-naumannite, Au-Rh-naumannite, Au-clausenthalite, Au-Ag-clausenthalite and phase with composition of  $\text{AgSe}_2$  [20, 26]; montroseite  $\text{VO}(\text{OH})$ , roscoelite  $\text{KV}_2[\text{AlSi}_3\text{O}_{10}(\text{OH})_2]$  [2].

In general two ore mineral association and thirteen paragenetic groups were described [22], however the deposit was developed in five stages [26]. The first two stages are related to the sedimentation and early digenesis of the Zechstein strata; accumulation of base metals was on the level of  $n0-n00$  ppm. The last stage is related to the secondary oxidation system that was responsible for Cu deposit oxidation and precipitation of a noble metal association [20, 26].

The first association is composed of an economic accumulation of polymetallic minerals. The second association contains a great number of noble metals association accompanied with some not fully identified Se, Te, Hg, Bi phases, which are probably a new minerals. Total in the deposit over 140 minerals have been recognized. Both association and all described above minerals were precipitated in low temperature. The upper limit of temperature is restricted to the two factors, the upper limit of low-chalcocite stability ( $103,5 \pm 1,5$  °C [27]) and reflectivity of vitrinite. Chalcocite and vitrinite are major components of ores. Existing geochemical environments are confirmed by presence of low temperature phases like thiosulphates which are common metastable minerals (fig. 5–7).

Copper minerals occur in dispersions (fig. 8), nests (fig. 9) and veinlets.

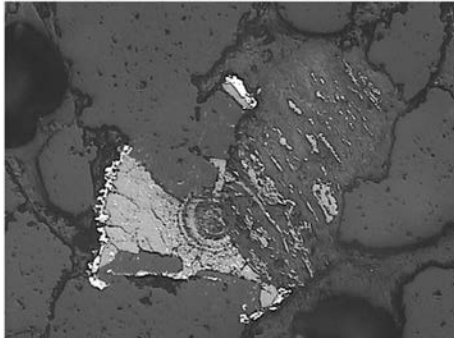


Fig. 5. Botroidal structures of thiosulphates – digenite with pyrite rim, Rudna Mine. Reflected light,  $\times 600$ .

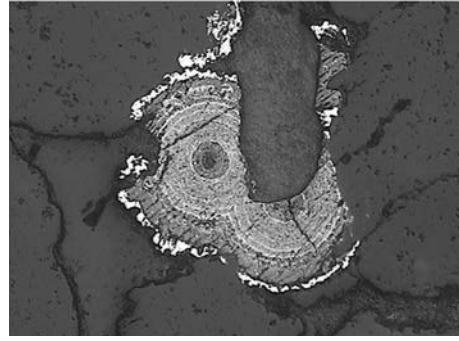


Fig. 6. Botroidal structures of thiosulphates – covellite with pyrite rim, Rudna Mine. Reflected light,  $\times 600$ .

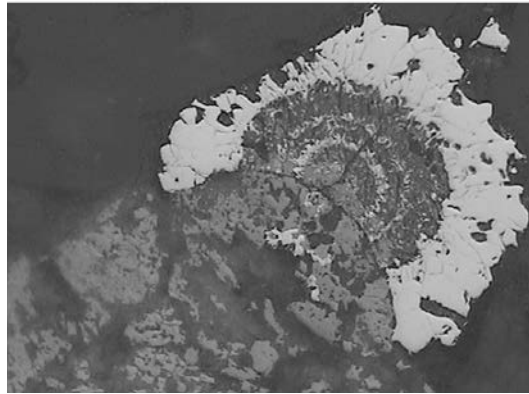


Fig. 7. Botroidal structures of thiosulphates – covellite with pyrite rim, Rudna Mine. Reflected light,  $\times 600$ .

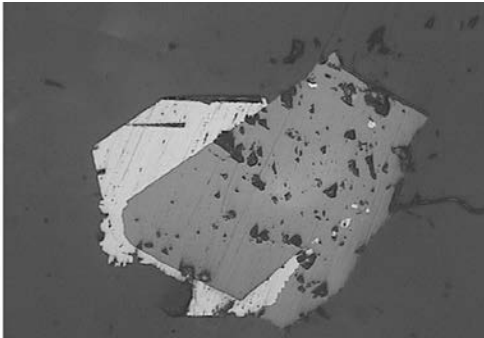


Fig 8. Chalcocite framboides in carbonate matrix, Rudna Mine. Reflected light,  $\times 1\ 200$ .



Fig. 9. Low temperature intergrowth of sphalerite (grey) with galena (white) and chalcopyrite in dolomite sparite, Rudna Mine. Reflected light,  $\times 600$ .

There is a long list of evidences of pseudomorphs and replacement (fig. 10) represented by different paragenetic groups and mineral association. These minerals contain sulphur on different stages of oxidation at the same phase [16].

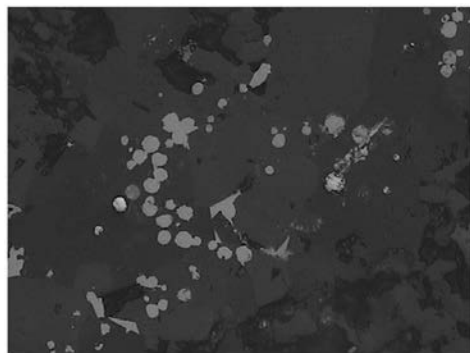


Fig. 10. Chalcocite pseudomorph after foraminifera skeleton, Rudna Mine. Reflected light,  $\times 1200$ .

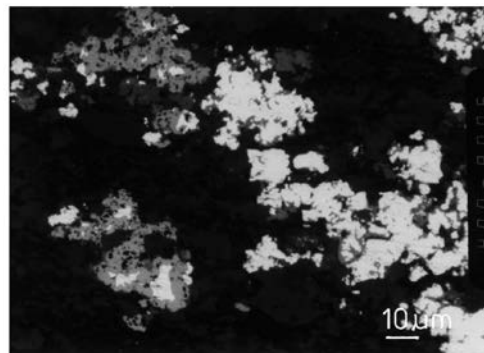


Fig. 11. Gold-hematite intergrowth (blue – covellite), Polkowice Mine. Reflected light.

Gold (fig. 11) and others noble metal alloys are a major phases accompanied by the secondary, coarse grain hematite and minor tellurides, selenides and arsenides [20].

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## **АСОЦІАЦІЇ НИЗЬКОТЕМПЕРАТУРНИХ РУДНИХ МІНЕРАЛІВ НА РОДОВИЩІ ТИПУ КУПФЕРШІФЕР, РУДНИЙ РАЙОН ЛЮБІН–СЄРОШОВИЦЕ, ПІВДЕННО-ЗАХІДНА ПОЛЬЩА**

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Описано низькотемпературні асоціації рудних мінералів на родовищі типу Купфершіфер рудного району Любін–Сєрошовице (південно-західна частина Польщі).

*Ключові слова:* мінералогія, низькотемпературна рудна мінералізація, родовища типу Купфершіфер, Польща.

## **АССОЦИАЦИИ НИЗКОТЕМПЕРАТУРНЫХ РУДНЫХ МИНЕРАЛОВ НА МЕСТОРОЖДЕНИИ ТИПА КУПФЕРШИФЕР, РУДНЫЙ РАЙОН ЛЮБИН–СЄРОШОВИЦЕ, ЮГО-ЗАПАДНАЯ ПОЛЬША**

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Описаны низкотемпературные ассоциации рудных минералов на месторождении типа Купфершифер рудного района Любін–Сєрошовице (юго-западная часть Польши).

*Ключевые слова:* мінералогія, низькотемпературна рудна мінералізація, месторождения типа Купфершифер, Польща.