Technical Report: Mineral reflectance spectra and chemistry of 20 copper-bearing minerals

(http://doi.org/10.5880/GFZ.1.4.2019.003)

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2. License

3. Citation

When using the data please cite:

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The data are supplementary to:

Koerting, F., Koellner, N., Kuras, A., Boesche, N. K., Rogass, C., Mielke, C., Elger, K., Altenberger, U. (2020). A Solar Optical Spectral Library of rare earth-bearing minerals, rare earth oxide powders, copper-bearing minerals and Apliki mine surface samples, Earth System Science Data Discussion, https://doi.org/10.5194/essd-2019-228

The spectral library presented here is part of a larger collection of spectral libraries including samples from rare-earth minerals, rare-earth-oxides and field samples from a copper-gold-pyrite mine in the Republic of Cyprus:

Koerting, F.; Herrmann, S.; Boesche, N. K.; Rogass, C.; Mielke, C.; Koellner, N.; Altenberger, U. (2019a). Mineral reflectance spectra and chemistry of 29 rare earth-bearing minerals and rare earth oxide powders including niobium- and tantalum-oxide. V. 2.0. GFZ Data Services, http://doi.org/10.5880/GFZ.1.4.2019.004

Koerting, F., Rogass, C., Koellner, N., Horning, M. and Altenberger, U. (2019b). Mineral reflectance spectra and chemistry of 37 copper-bearing surface samples from Apliki copper-gold-pyrite mine in the Republic of Cyprus. V. 2.0. GFZ Data Services, http://doi.org/10.5880/GFZ.1.4.2019.005

4. Version history

Version 2.0 (14 December 2020): completely restructured Technical Report and data files according to the review recommendations of the related article in Earth System Science Data (ESSD). Details:

- New title of the data publication
- addition of spectra names in the table that lists the sample info
- change of file names and titles according to reviewer's comments as followed:
    1. Spectral library "GFZ_HySpex_copper_minerals"
        - → correction of the spectral name for the unknown spectrum from "?" to "unknown" in the ENVI-standard + .hdr file and the .txt file
        - → splitting up the plot in two parts to make it easier to comprehend
    2. file "copper_bearing_minerals_hyperspectral_parameters.xlsx"
        - → change to "copper-bearing", change of filename and title
    3. file "copper_bearing_minerals_geochemistry.PDF"
        - → change to "copper-bearing", change of filename and title, removal of "H2O missing" comment
    4. file "copper_bearing_minerals_EPMA_oxides.txt"
        - → change to "copper-bearing" and changes of EMPA to EPMA changed in the file name and the table header as requested by the reviewer.
    5. file "copper_bearing_minerals_mount_SEM_EPMA.png"
        - → change of photo labels for a better understanding
    6. file "copper_bearing_minerals_EPMA_elements.txt"
        - → file name and table header changed to "EPMA_elements" instead of "EMPA_ore" as requested by the reviewer. Only the file name changed.

5. Abstract

The data set contains mineral-chemical analyses of 20 copper-bearing minerals and their corresponding hyperspectral reflectance spectra. The hyperspectral data were acquired with the HySpex system in a range of 414 – 2498 nm and are presented in a spectral library. Detailed information about the mineral specimen, sample area and mineral chemistry is presented in the data sheets below. The spectral library presented here is part of a larger collection of spectral libraries including samples from rare-earth minerals, rare-earth-oxides (Koerting et al., 2019a) and field surface samples from a copper-gold-pyrite mine in the Republic of Cyprus (Koerting et al., 2019b) and are fully described in (Koerting et al., 2020). These libraries aim to give a spectral overview of important resources and ore mineralization.

6. Samples

Twenty samples from the collection of the University of Potsdam (UP) and the Federal Institute for Geosciences and Natural Resources (BGR) were hyperspectrally measured and mineral-chemically analysed by using a scanning electron microscope (SEM) and electron probe microanalyzer (EPMA). A description of the HySpex system can be found in (Koerting et al., 2020). The samples were acquired for the unpublished B.Sc. thesis by Marcel Horning (Horning, 2018).

The copper-bearing mineral samples were measured without prior sample preparation as the surface of the minerals and the influence of the mineral structure were of interest (Figure 1). Figure 1 shows one HySpex scan of four minerals (L1_Linarite, C5_Chalcopyrite, A1_Azurite, K1_Copper) displayed as a true color RGB image in order to show the untreated samples and the white reflectance (WR) panel needed for the hyperspectral measurements (WR 20%). Table 1 lists the copper-bearing sulphide and native copper samples, their original collection, their original sample name, the sample locations, a description of visible alterations, a general mineral formula, sample photos with the area of sampling for mineral-chemical analyses in the yellow circles, the corresponding spectra names presented in the spectral library and the averaged results of the EPMA analyses. For each sample the yellow circled area was also used to obtain the reflectance spectrum, averaging (AVG) over a 5 by 5-pixel window (see also Koerting et al., 2020). Table 2 lists the copper-bearing silicate, carbonate and sulphate samples with the same header as Table 1.

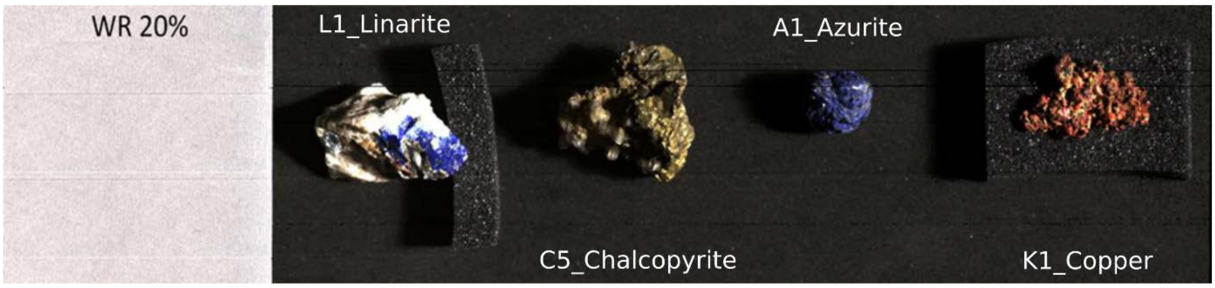


Figure 1: The HySpex scan, displayed as a true color RGB image, shows the lack of sample preparation. The scan includes 4 samples and a white reflectance panel of 20% reflectance.

Table 1: ***Overview of copper-bearing sulphides and native copper included in this publication****.*
[(1)] ***Collection****: UP = University of Potsdam, BGR = Federal Institute for Geosciences and Natural Resources, Spandau;* *[(2)]* *the area of sampling for SEM/EPMA analyses and spectrum retrieval is highlighted in yellow;* *[(3)]* ***Spectra names*** *are following the syntax "Sample_Collection-Original sample name [pixel averaging]".*

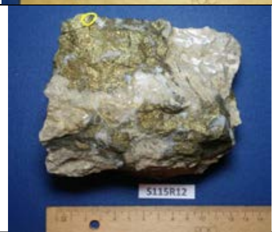
Sample	Collection[(1)]	Original sample name	Sample locality	Visible alteration	Mineral formula	Photo of sample [(2)]	Spectrum name [(3)]	Geochemical composition (EPMA mean, wt.%)
C1_Chalcopyrite	BGR	S55L16 C	Füsseberg Mine, Siegerland, Germany	strongly altered	$CuFeS_2$		C1_Chalcopyrite_BGR-S55L16-C [5x5 AVG]	S: 34.94; Fe: 30.09; Cu: 34.09
C2_Chalcopyrite	BGR	S115R12	Erzgebirge, Slovakia	slightly altered	$CuFeS_2$		C2_Chalcopyrite_BGR-S115R12 [5x5 AVG]	S: 34.90; Fe: 30.07; Cu: 33.95
C3_Chalcopyrite	BGR	S131L5 C	Henderson Mine, Clear Creek Country, USA	tarnished	$CuFeS_2$		C3_Chalcopyrite_BGR-S131L5-C [5x5 AVG]	S: 35.04; Fe: 30.11; Cu: 33.97
C4_Chalcopyrite	UP	7534	Cornwall, England, GB	slightly altered	$CuFeS_2$		C4_Chalcopyrite_UP-7534 [5x5 AVG]	S: 35.01; Fe: 30.16; Cu: 34.04

Table 1 (continued)

Sample	Collection[(1)]	Original sample name	Sample locality	Visible alteration	Mineral formula	Photo of sample [(2)]	Spectrum name [(3)]	Geochemical composition (EPMA mean, wt.%)
C5_Chalcopyrite	UP	7526	Clausthal, Harz, Germany	altered	$CuFeS_2$		C5_Chalcopyrite_UP-7526 [5x5 AVG]	S: 35.05; Fe: 30.01; Cu: 34.18
K1_Copper	UP	600-1	Furnace, Lübeck, Germany	slightly altered	Cu		K1_Copper_UP-600-1 [5x5 AVG]	Cu: 98.58

Table 2: Overview of copper-bearing silicates, carbonates and sulphates included in this publication.

*(1) **Collection**: UP = University of Potsdam, BGR = Federal Institute for Geosciences and Natural Resources, Spandau; (2) the area of sampling for SEM/EPMA analyses and spectrum retrieval is highlighted in yellow; (3) **Spectra names** are following the syntax "Sample_Collection-Original sample name [pixel averaging]".*

Sample	Collection[(1)]	Original sample name	Sample locality	Visible alteration	Mineral formula	Photo of sample [(2)]	Spectrum name [(3)]	Geochemical composition (EPMA mean, wt.%)
A1_Azurite	UP	2458	Cheroy near Lyon, France	altered, nodular	$Cu_3(CO_3)_2(OH)_2$		A1_Azurite_UP-2458 [5x5 AVG]	CuO: 65.34; HgO: 0.09

Table 2 (continued)

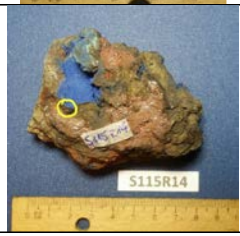
Sample	Collec-tion[1]	Original sample name	Sample locality	Visible alteration	Mineral formula	Photo of sample [2]	Spectrum name [3]	Geochemical composition (EPMA mean, wt.%)
A2_Azurite	UP	2437	Tsumeb near Otavi, Namibia	altered	$Cu_3(CO_3)_2(OH)_2$		A2_Azurite_UP-2437 [5x5 AVG]	CuO: 65.19
A3_Azurite	BGR	S101L7	Cornberg by Fulda, Germany	strongly altered	$Cu_3(CO_3)_2(OH)_2$		A3_Azurite_BGR-S101L7 [5x5 AVG]	CuO: 63.87; SO_3: 0.13; FeO: 0.18
B1_Brochantite	BGR	S115R3	Altenberg, Slovakia	slightly altered, powdered	$Cu_4[(OH)_6\|(SO_4)]$		B1_Brochantite_BGR-S115R3 [5x5 AVG]	Al_2O_3: 0.18; SiO_2: 0.07; SO3: 16.26; CuO: 80.33
F1_Unknown	BGR	S115R14	Kotterbach near Witkow, Poland	slightly altered	-		F1_Unknown_BGR-S115R14 [5x5 AVG]	SiO2: 2.59; FeO: 69.04; CuO: 0.25; SO3: 0.16; MnO 0.29

Table 2 (continued)

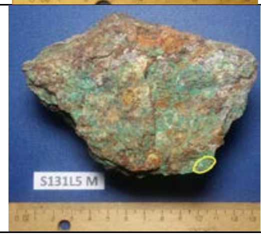
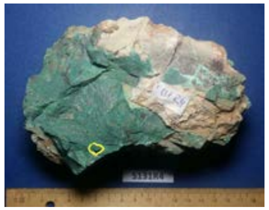
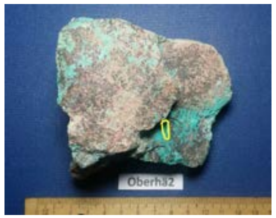
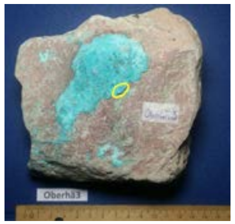
Sample	**Collection**[(1)]	**Original sample name**	**Sample locality**	**Visible alteration**	**Mineral formula**	**Photo of sample** [(2)]	**Spectrum name** [(3)]	**Geochemical composition (EPMA mean, wt.%)**
L1_Linarite	UP	9542	Unknown location	slightly altered, acicular	$PbCu[(OH)_2 \vert SO_4]$		L1_Linarite_UP-9542 [5x5 AVG]	SO_3: 64.18; CuO: 24.18; HgO: 0.44
M1_Malachite	BGR	S134R8	L'Etoile du Congo Mine, Katanga, Kongo	altered, nodular	$Cu_2[(OH)_2 \vert CO_3]$		M1_Malachite_BGR-S134R8 [5x5 AVG]	CuO: 67.61
M2_Malachite	BGR	S131L5 M	Henderson Mine, Clear Creek Country, USA	strongly altered	$Cu_2[(OH)_2 \vert CO_3]$		M2_Malachite_BGR-S131L5-M [5x5 AVG]	CuO: 66.92
M3_ Malachite	BGR	S131R4	Tsumeb near Otavi, Namibia	altered	$\mathrm{Cu2[(OH)2 \vert CO3]}$		M3_Malachite_BGR-S131R4 [5x5 AVG]	CuO: 65.18; SO3: 0.46

Table 2 (continued)

Sample	Collec-tion[(1)]	Original sample name	Sample locality	Visible alteration	Mineral formula	Photo of sample [(2)]	Spectrum name [(3)]	Geochemical composition (EPMA mean, wt.%)
M4_ Malachite	BGR	S132L2	Ogonja Mine in Okahandja, Namibia	strongly altered	$Cu_2[(OH)_2\|CO_3]$		M4_Malachite_BGR -S132L2 [5x5 AVG]	CuO: 67.05
M5_ Malachite	BGR	S55L16 M	Siegen, Germany	slightly altered, acicular	$Cu_2[(OH)_2\|CO_3]$		M5_Malachite_BGR -S55L16-M [5x5 AVG]	CuO: 67.89
P1_Plancheite	UP	Oberhä	Jordan	slightly altered	$Cu_8Si_8O_{22}(OH)_4$• (H_2O)		P1_Plancheite_UP-Oberhä [5x5 AVG]	Al_2O_3: 2.95; SiO_2: 42.08; CuO: 51.78; SO_3: 0.06; MnO: 0.24
P2_Plancheite	UP	Oberhä2	Jordan	slightly altered	Cu8Si8O22(OH) 4• (H2O)		P2_Plancheite_UP-Oberhä2 [5x5 AVG]	Al2O3: 3.73; SiO2: 44.12; CuO: 48.90; SO3: 0.28; MnO: 0.25
P3_Plancheite	UP	Oberhä3	Jordan	slightly altered	Cu8Si8O22(OH) 4• (H2O)		P3_Plancheite_UP-Oberhä3 [5x5 AVG]	Al2O3: 2.74; SiO2: 43.25; CuO: 51.37; SO3: 0.27; MnO: 0.09

7. Hyperspectral measurements

The HySpex VNIR-1600 and SWIR-320m-e (available at: (hyspex.no/products/disc.php, 2019)) are two line-scanning cameras that are mounted in parallel. They cover the range of the visible to near infrared (VNIR, 414 – 1000 nm) region and the short-wave infrared (SWIR, 1000 – 2498 nm) region and record an array-line of 1600 pixels (VNIR) and 320 pixels (SWIR) (push-broom scanning). Every pixel contains a spectrum with a total spectral sampling number of 408 bands in total.

In laboratory mode, the HySpex cameras are combined with a trigger pulse moving sleigh (translation stage) of definable frame period (depending on the integration time of every array-line acquisition). The configuration of the translation stage framework, the cameras and the light source (45° illumination angle) are fixed, while the sleigh and the samples are moving through the focal plane (Rogass et al., 2017). Detailed descriptions of the hyperspectral measurements and parameters can be found in (Koerting et al., 2020).

8. Mineral-chemical measurements

For mineral-chemical analyses a small piece of each sample (yellow circled area in Table 1 and 2) was prepared on a 1-inch mount (25 mm in diameter). Afterwards the mount's planar surface was highly polished and coated with a thin layer of carbon. Figure 2 shows the mount after preparing the samples on it. For the mineral-chemical analyses the mount was fitted into a suitable sample holder.

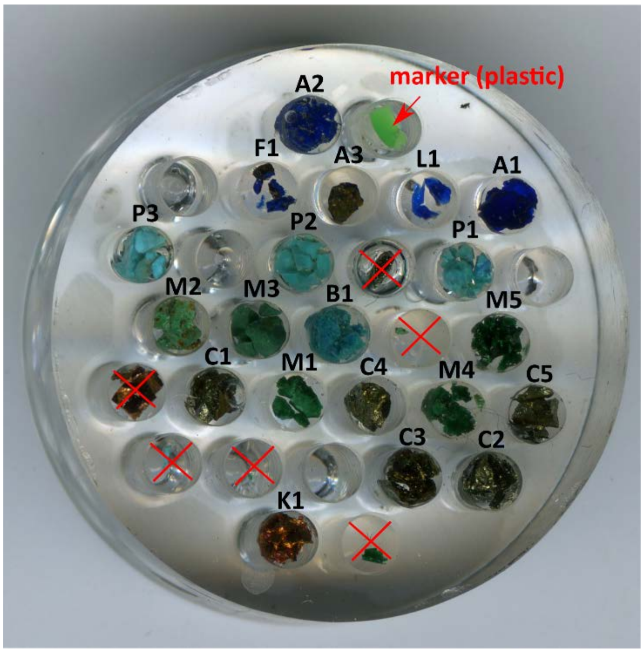


Figure 2: 1-inch mount, hosting small pieces of native copper and copper-bearing minerals, for SEM and EPMA analyses.

In order to obtain general information about the chemical composition, zonation and internal fabrics of the copper samples a fully automated JEOL JSM-6510 scanning electron microscope (SEM, 20kV acceleration voltage) at the Institute of Geosciences of the University of Potsdam, was used. A back-scattered electron detector displays compositional variation in the imaging area based on the mean atomic number of the pixel. An energy dispersive X-ray spectrometer (EDX, Oxford Instruments INCAxact) attached to the instrument provides quantitative elemental analysis of single spots. After calibrating with pure copper, a wide spectrum of elements can be identified. Based on previous results, divergences of up to 5 wt.% can be expected, which for quantitative analyses is considered acceptable. All measurements were normalised to 100 wt.% so the H_2O content for minerals with OH groups in the crystal structure is not included.

The results of the SEM analysis for C3_Chalcopyrite, A1_Azurite, A3_Azurite, B1_Brochantite, L1_Linarite, M2_Malachite and P3_Plancheite indicate that the minerals of interest in the sample are accompanied by other mineral phases. This will affect the hyperspectral spectra of these minerals, resulting in spectral mixtures. The spectra of the samples C3_Chalcopyrite, A1_Azurite, A3_Azurite, B1_Brochantite, L1_Linarite, M2_Malachite and P3_Plancheite do not represent pure mineral phases. All identified mineral phases of each sample are presented and marked in the backscatter electron images in Table 3 and Table 4.

To approximate the values for copper a JEOL JXA-8200 electron probe microanalyzer (EPMA) at the Institute of Geosciences of the University of Potsdam was used. The EPMA is equipped with five wavelength-dispersive X-ray spectrometers (WDX) and operates with a 20-kV accelerating voltage, a 20 nA current, and a beam diameter of 2 µm. The analytical counting times were 20/10 s for the element peak and 10/5 s for background positions. Analyses were standardized against silicates/sulphides obtained from the Smithsonian Institution and Astimex Standards Ltd. For each sample up to three point measurements within the yellow circled areas (see Table 1 and 2) were performed. The measurements were averaged for each sample and the mean values can be read in Table 3 and Table 4. A more detailed description can be found in Koerting et al. (2020). Table 3 and 4 list the copper-bearing sulphide and native copper as well as the copper-bearing silicate, carbonate and sulphate samples, SEM backscatter electron images with labelled accompanying minerals if necessary, the mineral names and the results of SEM and EPMA analyses. The results of the EPMA analyses are given as averaged values.

Table 3: ***Results of the mineral-chemical analyses for copper-bearing sulphides and native copper included in this publication****.*

(1) *identified mineral and corresponding general mineral formula*

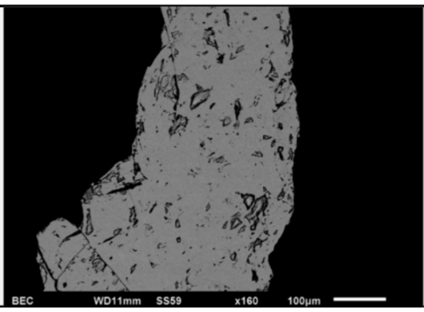
Copper-bearing sulphides and native copper			
Chalcopyrite $CuFe^{2+}S_2$			***(1)***
Bornite $Cu_5Fe^{2+}S_4$			
Sample	**backscatter electron image (SEM)**	**Mineral**	**Chemical Analyses**
C1_Chalcopyrite			SEM Analysis (Σ = 100 wt.%)
		Chalcopyrite	S: 38.7 ; Fe: 28.7 ; Cu: 32.57
			EPMA Analysis (wt.%, mean of 3 measurements)
		Chalcopyrite	S: 34.94 ; Fe: 30.09 ; Cu: 34.09

Table 3 (continued)

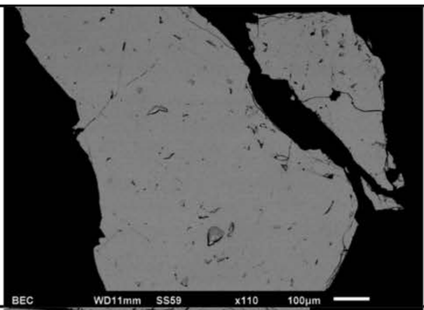
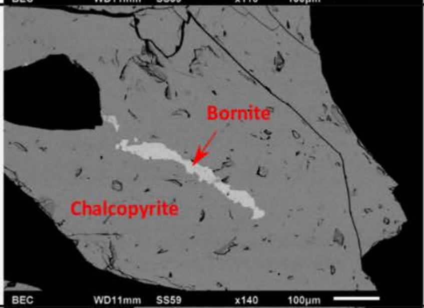
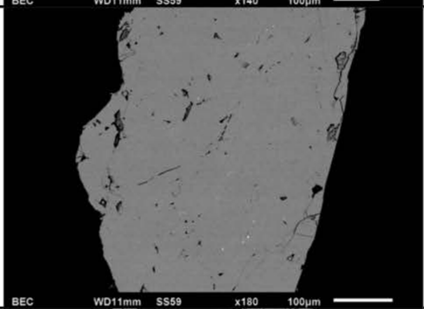
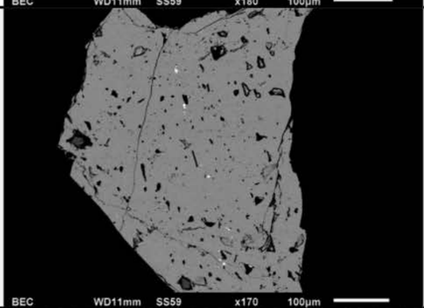
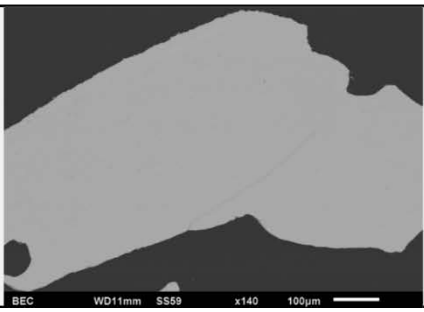
Chalcopyrite CuFe^{2+}S$_2$ ***Bornite Cu$_5$Fe^{2+}S$_4$***			***(1)***
Sample	**backscatter electron image (SEM)**	**Mineral**	**Chemical Analyses**
C2_Chalcopyrite			SEM Analysis (Σ = 100 wt.%)
		Chalcopyrite	S: 39.13 ; Fe: 28.96 ; Cu: 31.91
			EPMA Analysis (wt.%, mean of 3 measurements)
		Chalcopyrite	S: 34.90 ; Fe: 30.07 ; Cu: 33.95
C3_Chalcopyrite			SEM Analysis (Σ = 100 wt.%)
		Chalcopyrite	S: 39.64 ; Fe: 28.73 ; Cu: 31.62
		Bornite	S: 29.35 ; Fe: 11.23 ; Cu: 59.42
			EPMA Analysis (wt.%, mean of 3 measurements)
		Chalcopyrite	S: 35.04 ; Fe: 30.11 ; Cu: 33.97
C4_Chalcopyrite			SEM Analysis (Σ = 100 wt.%)
		Chalcopyrite	S: 39.38 ; Fe: 29.27 ; Cu: 31.35
			EPMA Analysis (wt.%, mean of 3 measurements)
		Chalcopyrite	S: 35.01 ; Fe: 30.16 ; Cu: 34.04
C5_Chalcopyrite			SEM Analysis (Σ = 100 wt.%)
		Chalcopyrite	S: 39.64 ; Fe: 28.73 ; Cu: 31.62
			EPMA Analysis (wt.%, mean of 3 measurements)
		Chalcopyrite	S: 35.05 ; Fe: 30.01 ; Cu: 34.18
Copper Cu			***(1)***
Sample	**backscatter electron image (SEM)**	**Mineral**	**Chemical Analyses**
K1_Copper			SEM Analysis (Σ = 100 wt.%)
		Copper	Cu: 100
			EPMA Analysis (wt.%, mean of 3 measurements)
		Copper	Cu: 98.58

Table 4: ***Results of the mineral-chemical analyses for copper-bearing silicates, carbonates and sulphates included in this publication***.

[(1)] identified mineral and corresponding general mineral formula

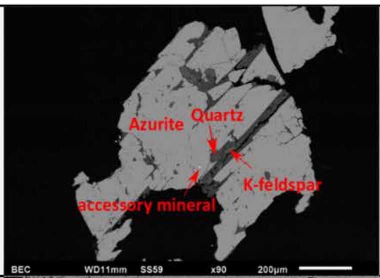
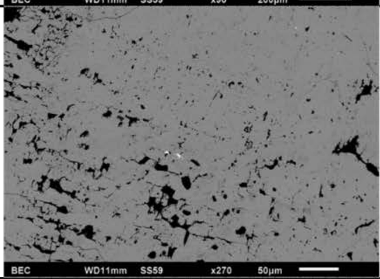
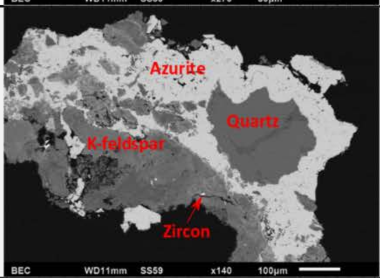
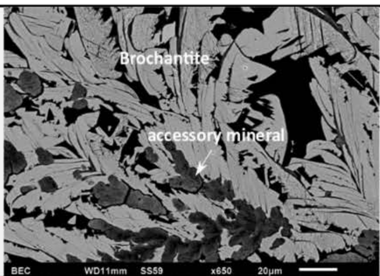
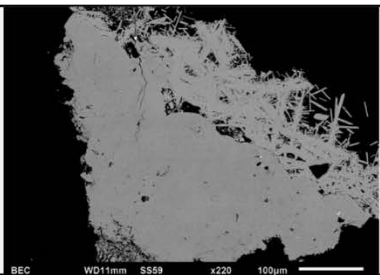
<table>
<tr><th colspan="4">Copper-bearing silicates, carbonates and sulphates</th></tr>
<tr><td colspan="4">Azurite $Cu_3(CO_3)_2(OH)_2$ [(1)]</td></tr>
<tr><th>Sample</th><th>backscatter electron image (SEM)</th><th>Mineral</th><th>Chemical Analyses</th></tr>
<tr><td rowspan="5">A1_Azurite</td><td rowspan="5">
</td><td></td><td>SEM Analysis (Σ = 100 wt.%)</td></tr>
<tr><td>Azurite</td><td>CO_2: 53.26 ; CuO: 46.74</td></tr>
<tr><td>accessory mineral</td><td>S: 50.48 ; Fe: 30.09 ; Cu: 19.43 possibly mixed analysis</td></tr>
<tr><td></td><td>EPMA Analysis (wt.%, mean of 3 measurements)</td></tr>
<tr><td>Azurite</td><td>CuO: 65.34 ; HgO: 0.09 ; Balance: 34.54 (CO_2 + H_2O)</td></tr>
<tr><td rowspan="4">A2_Azurite</td><td rowspan="4">
</td><td></td><td>SEM Analysis (Σ = 100 wt.%)</td></tr>
<tr><td>Azurite</td><td>CO_2: 53.85 ; CuO: 46.15</td></tr>
<tr><td></td><td>EPMA Analysis (wt.%, mean of 3 measurements)</td></tr>
<tr><td>Azurite</td><td>CuO: 65.19 ; Balance: 34.69 (CO_2 + H_2O)</td></tr>
<tr><td rowspan="4">A3_Azurite</td><td rowspan="4">
</td><td></td><td>SEM Analysis (Σ = 100 wt.%)</td></tr>
<tr><td>Azurite</td><td>CO_2: 54.43 ; CuO: 45.57</td></tr>
<tr><td></td><td>EPMA Analysis (wt.%, mean of 3 measurements)</td></tr>
<tr><td>Azurite</td><td>CuO: 63.87 ; SO_3: 0.13 ; FeO: 0.18 ; Balance: 34.38 (CO_2 + H_2O)</td></tr>
<tr><td colspan="4">Brochantite $Cu_4(SO_4)(OH)_6$ [(1)]</td></tr>
<tr><th>Sample</th><th>backscatter electron image (SEM)</th><th>Mineral</th><th>Chemical Analyses</th></tr>
<tr><td rowspan="5">B1_Brochantite</td><td rowspan="5">
</td><td></td><td>SEM Analysis (Σ = 100 wt.%)</td></tr>
<tr><td>Brochantite</td><td>SO_3: 22.43 ; CuO: 77.57</td></tr>
<tr><td>accessory mineral</td><td>Al_2O_3: 3.19 ; SiO_2: 0.54 ; SO_3: 16.13 ; CuO: 80.15</td></tr>
<tr><td></td><td>EPMA Analysis (wt.%, mean of 3 measurements)</td></tr>
<tr><td>Brochantite</td><td>Al_2O_3: 0.18 ; SiO_2: 0.07 ; SO_3: 16.26 ; CuO: 80.33 ;
Balance: 3.15 (H_2O)</td></tr>
<tr><td colspan="4">Linarite $PbCu(SO_4)(OH)_2$
Anglesite $Pb(SO_4)$ [(1)]</td></tr>
<tr><th>Sample</th><th>backscatter electron image (SEM)</th><th>Mineral</th><th>Chemical Analyses</th></tr>
<tr><td rowspan="4">F1_Unknown</td><td rowspan="4">
</td><td></td><td>SEM Analysis (Σ = 100 wt.%)</td></tr>
<tr><td>Unknown</td><td>SiO_2: 4.53 ; FeO: 95.47</td></tr>
<tr><td></td><td>EPMA Analysis (wt.%, mean of 3 measurements)</td></tr>
<tr><td>Unknown</td><td>SiO_2: 2.59 ; FeO: 69.04 ; CuO: 0.25 ; SO_3: 0.16 ; MnO: 0.29 ;
Balance: 27.33</td></tr>
</table>

Table 4 (continued)

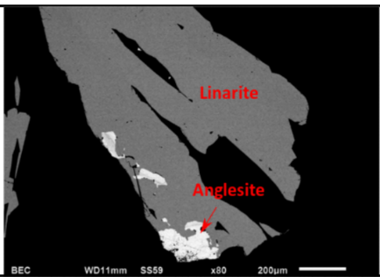
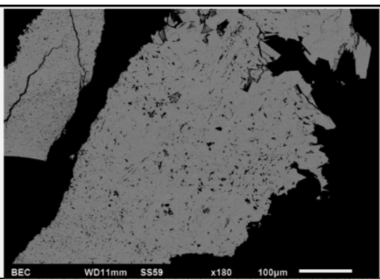
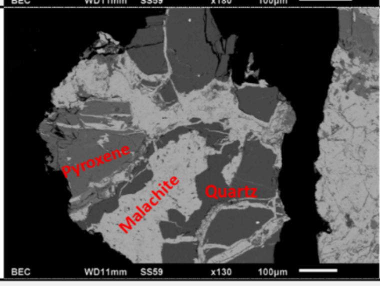
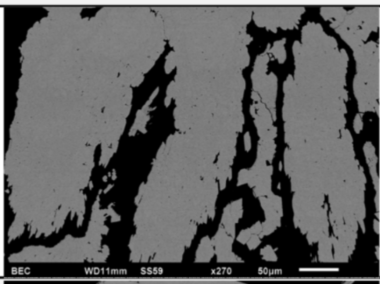
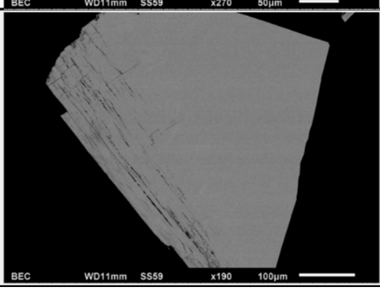
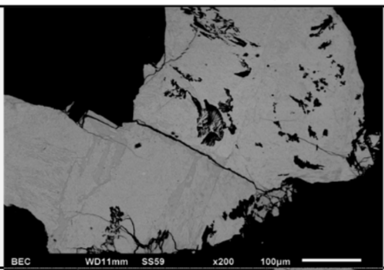
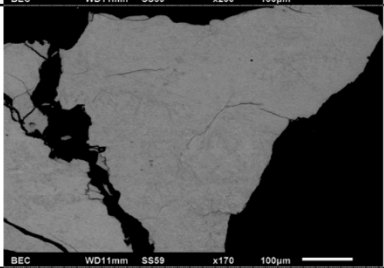
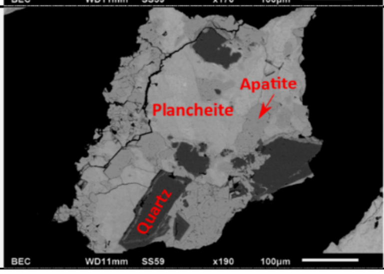
Sample	backscatter electron image (SEM)	Mineral	Chemical Analyses
Linarite PbCu(SO $_4$)(OH) $_2$ ***Anglesite Pb(SO $_4$)***			*(1)*
Sample	**backscatter electron image (SEM)**	**Mineral**	**Chemical Analyses**
L1_Linarite			SEM Analysis (Σ = 100 wt.%)
		Linarite	SO_3: 22.28 ; CuO: 19.49 ; PbO: 58.24
		Anglesite	SO_3: 28.25 ; PbO: 71.75
			EPMA Analysis (wt.%, mean of 3 measurements)
		Linarite	SO_3: 64.18 ; CuO: 24.18 ; HgO: 0.44 ; Balance: 11.20 (PbO + H_2O)
Malachite Cu $_2$(CO $_3$)(OH) $_2$			*(1)*
Sample	**backscatter electron image (SEM)**	**Mineral**	**Chemical Analyses**
M1_Malachite			SEM Analysis (Σ = 100 wt.%)
		Malachite	CO_2: 51.78 ; CuO: 48.22
			EPMA Analysis (wt.%, mean of 3 measurements)
		Malachite	CuO: 67.61 ; Balance: 31.83 (CO_2 + H_2O)
M2_Malachite			SEM Analysis (Σ = 100 wt.%)
		Malachite	CO_2: 46.98 ; CuO: 53.02
			EPMA Analysis (wt.%, mean of 3 measurements)
		Malachite	CuO: 66.92 ; Balance: 32.83 (CO_2 + H_2O)
M3_Malachite	image missing		SEM Analysis (Σ = 100 wt.%)
		Malachite	CO_2: 53.84 ; CuO: 43.27 ; ZnO: 3.56
			EPMA Analysis (wt.%, mean of 3 measurements)
		Malachite	CuO: 65.18; SO_3: 0.46 ; Balance: 34.07 (CO_2 + H_2O)
M4_Malachite			SEM Analysis (Σ = 100 wt.%)
		Malachite	CO_2: 48.84 ; CuO: 51.16
			EPMA Analysis (wt.%, mean of 2 measurements)
		Malachite	CuO: 67.05 ; Balance: 32.85 (CO_2 + H_2O)
M5_Malachite			SEM Analysis (Σ = 100 wt.%)
		Malachite	CO_2: 58.25 ; CuO: 41.74
			EPMA Analysis (wt.%, mean of 2 measurements)
		Malachite	CuO: 67.89 ; Balance: 32.15 (CO_2 + H_2O)

Table 4 (continued)

Plancheite $Cu_8Si_8O_{22}(OH)_4\bullet(H_2O)$			*(1)*
Sample	**backscatter electron image (SEM)**	**Mineral**	**Chemical Analyses**
P1_Plancheite			SEM Analysis (Σ = 100 wt.%)
		Plancheite	Al_2O_3: 2.52 ; SiO_2: 42.64 ; CaO: 0.76 ; CuO: 54.08
			EPMA Analysis (wt.%, mean of 3 measurements)
		Plancheite	Al_2O_3: 2.95 ; SiO_2: 42.08 ; CuO: 51.78 ; SO_3: 0.06 ; MnO: 0.24 ; Balance: 2.68 (H_2O)
P2_Plancheite			SEM Analysis (Σ = 100 wt.%)
		Plancheite	Al_2O_3: 2.74 ; SiO_2: 42.88 ; CaO: 0.82 ; CuO: 53.06
			EPMA Analysis (wt.%, mean of 3 measurements)
		Plancheite	Al_2O_3: 3.73 ; SiO_2: 44.12 ; CuO: 48.90 ; SO_3: 0.28 ; MnO: 0.25 ; Balance: 2.65 (H_2O)
P3_Plancheite			SEM Analysis (Σ = 100 wt.%)
		Plancheite	Al_2O_3: 2.88 ; SiO_2: 42.87 ; CaO: 0.97 ; CuO: 53.28
			EPMA Analysis (wt.%, mean of 3 measurements)
		Plancheite	Al_2O_3: 2.74 ; SiO_2: 43.25 ; CuO: 51.37 ; SO_3: 0.27 ; MnO: 0.09 ; Balance: 2.28 (H_2O)

9. File description

The data are organised in two folders “hyperspectral-libraries” and “mineral-chemistry”.

9.1. Folder “hyperspectral-libraries”

The spectra of the copper-bearing minerals are presented in an ENVI® Spectral Library file format “GFZ_HySpex_copper_minerals”, associated header file “GFZ_HySpex_copper_minerals.hdr” and a text file format “GFZ_HySpex_copper_minerals.txt”. The spectral library can be visualized in ENVI® as seen in Figure 3a and 3b.

The additional file “copper_bearing_minerals_hyperspectral_parameters.xlsx” provides a full overview of the samples, their descriptions and the measurement parameters of the HySpex measurements. The Excel™ file header is described in Table 5.

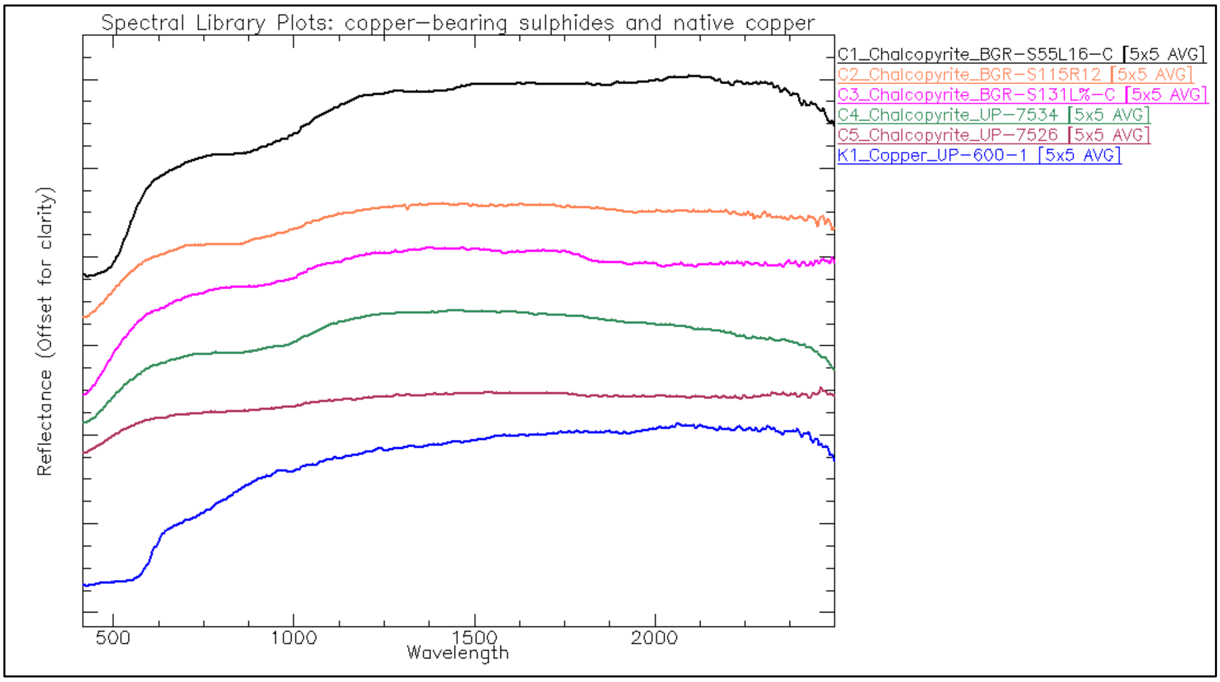


Figure 3a: Spectral library plot of the analysed copper-bearing sulphides and native copper.

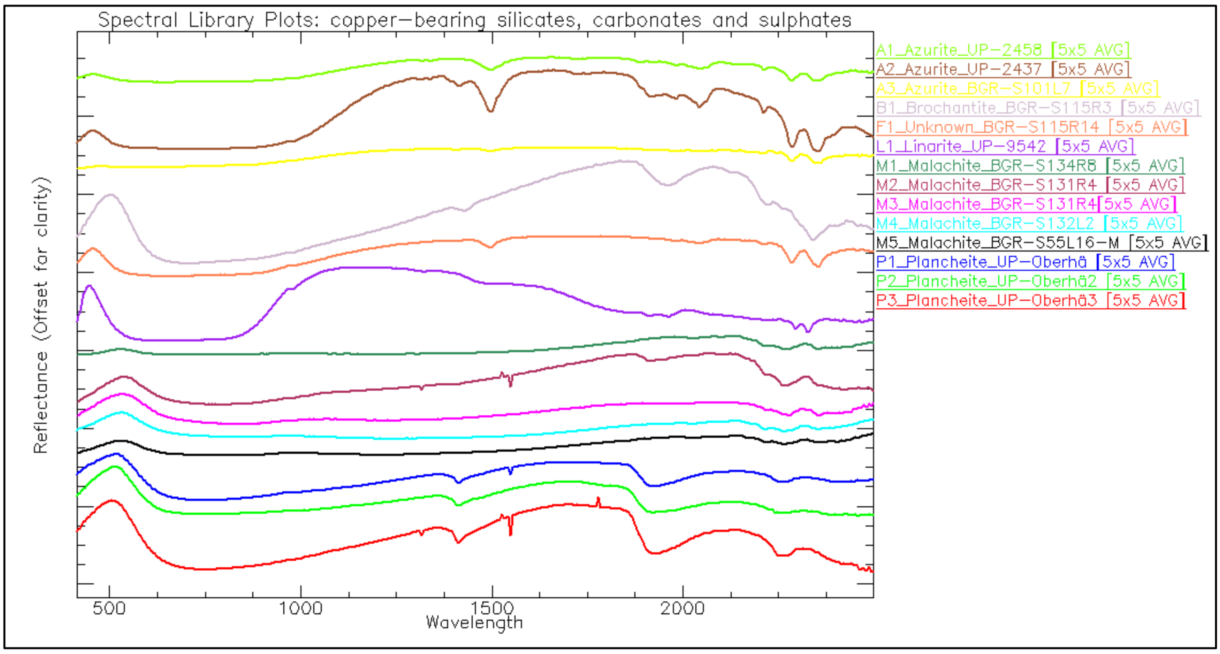


Figure 3b: Spectral library plot of the analysed copper-bearing silicates, carbonates and sulphates.

Table. 5 Explanation of the header of "copper_bearing_minerals_hyperspectral_parameters.xlsx"

Header of Excel™ file	**Explanation**
Sample	Sample name
Collection	Name of host institution of the sample Collection analysed in this study
Original sample name	Original sample name from the collection
Sample locality	Origin of the sample
Degree of weathering	description of alteration grade and style of mineralization
Mineral	Name of the analysed mineral
Formula	General mineral formula of the analysed mineral
Photo with spectrum and sampling location	Showing the location on the sample for EPMA analysis and spectrum retrieval over a 5 x 5-pixel average window
Spectrum name	Name of the spectrum, averaged over a window of 5 x 5-pixel
VNIR integration time (us)	Light exposure on VNIR sensor
VNIR frame period (us)	Time per line that the sensor allows data acquisition
VNIR frames	Number of frames measured
VNIR lens	VNIR lens used
SWIR integration time (us)	Light exposure on SWIR sensor
SWIR frame period (us)	Time per line that the sensor allows data acquisition
SWIR frames	Number of frames measured
SWIR lens	SWIR lens used
WR (%)	White reference standard used
SNR frame averaging	Number of frames that are averaged per measured frame
Temperature (°C)	Room temperature
Pressure (hPa)	Room pressure
Humidity (%)	Room humidity

9.2. Folder “mineral-chemistry”

The results of the EPMA analyses are presented as two ASCII tables (txt). Each sample was measured three times at different measurement points. The file “copper_bearing _minerals_EPMA_sulphides-copper.txt” shows the element composition of the sulphides and native copper (in wt.%); “copper_bearing_minerals_EPMA_silicates-carbonates-sulphates.txt” provides the composition of the copper-bearing silicates, carbonates and sulphates reported as element oxides (in wt.%).

10. Acknowledgements

We would like to thank the Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences for providing the infrastructure and personnel support to conduct our research. Our gratitude also goes to the support by the University of Potsdam and the Spandau branch of the Federal Institute for Geosciences and Natural Resources (BGR) for supplying the mineral samples.

11. References

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