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Reflectance spectra and LIBS data of 16 iron-bearing surface samples from Rammelsberg – a non-ferrous metal mine in the Harz Mountains near Goslar, Germany

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Reflectance spectra and LIBS data of 16 iron-bearing surface samples from Rammelsberg – a non-ferrous metal mine in the Harz Mountains near Goslar, Germany

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Abstract

This Technical Report presents data from a solaroptical spectral investigation in the area of the Rammelsberg non-ferrous metal mine in the Harz Mountains near the city of Goslar. The investigation refers to the local communion stone quarry ("Kommunionssteinbruch") above the former mining area. As this is a nature conservation zone, all measurements were carried out in-situ without any physical sampling action. The field measurements were carried out in June 2019 in cooperation with Bergbau Goslar GmbH and the German Research Centre for Geosciences (GFZ). The data were collected within the research project ReMon (Remote Monitoring of Tailings Using Satellites and Drones, https://www.gfz-potsdam.de/en/section/remote-sensing-and-geoinformatics/projects/remon/) which aims at developing a prototypical monitoring system for mine tailings by using different sensors scaling from satellite- to drone-based. The data were analysed in the unpublished B.Sc. thesis of Constantin Hildebrand (Hildebrand, 2019). Sixteen different surface materials were determined and examined on-site. Point and imaging hyperspectral data were acquired (with the spectroradiometer PSR+ 3500 operating in the range of 350 - 2500 nm and with the Cubert FireflEYEUHD-185 hyperspectral camera with a range of 450 - 950 nm, respectively), both data sets are presented as spectral libraries. Chemical analyses of the samples were performed by using Laser-Induced Breakdown Spectroscopy (LIBS). LIBS data were collected using a handheld LIBS analyzer, the SciAps Z-300. In this report the different in-situ measurements are presented for each of the sixteen samples. Detailed information about the analysed material, the area of spectral sampling and geochemical analyses are explained in this report and can also be found in the additional Excel® sheet provided with the data.

Keywords: Hyperspectral Imagery, Imaging spectroscopy, Mineral mapping, 3D reconstruction, non-ferrous metals

1. Introduction

1.1. Study area

The study area is a former non-ferrous metal mine in the Harz Mountains in Germany. It is located near the city of Goslar (Figure 1). The location of the outcrop can be specified with the following coordinates: N51° 53.328' E10° 25.500'. The outcrop consists of several tailing piles with formerly mined material from underground workings. Since the closure of the mine in 1988, these tailings have escaped anthropogenic influences.

Figure 1: *Location of the "Kommunionssteinbruch" in the "Blockschutthalden am Rammelsberg" nature reserve (Top, in red outline) and the location of the investigated outcrop (Bottom, blue outline). Source: "Rammelsberg Mine", N51° 53.328' E10° 25.500', GOOGLE EARTH, Image capture date for top image: 23rd of Aug. 2017, for bottom image: 24th of Aug. 2017.*

1.2. 3D Visualisation

For a detailed visualisation of the outcrop, a 3D model was created from Nikon RGB images. The number of images and the size of the 3D model exceed the capacity of this data publication and cannot be provided. However, for an overview of the study area, images of the result are shown here (Figure 2 and 3). The 3D model was created with the software *AgiSoft PhotoScan Professional v1.3.2.* The 3D models originate from the unpublished B.Sc. thesis of Constantin Hildebrand (Hildebrand, 2019).

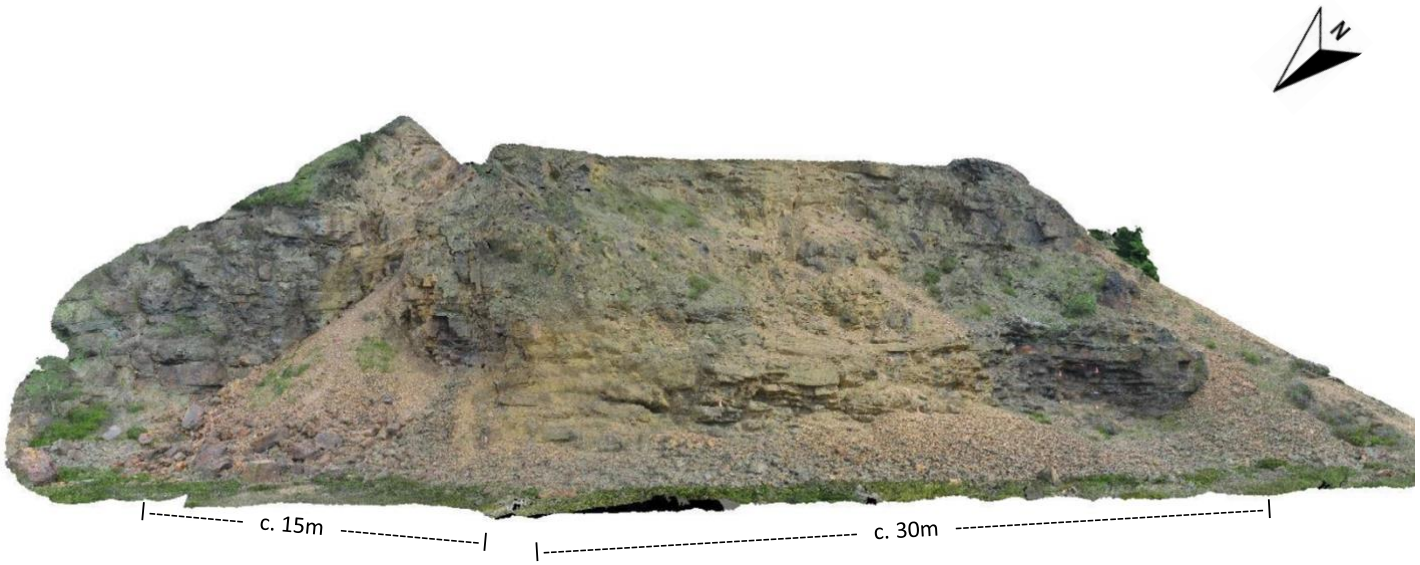


Figure 2: *Front view of the outcrop, view from NW towards SE. Scale bars and a north arrow were added.*

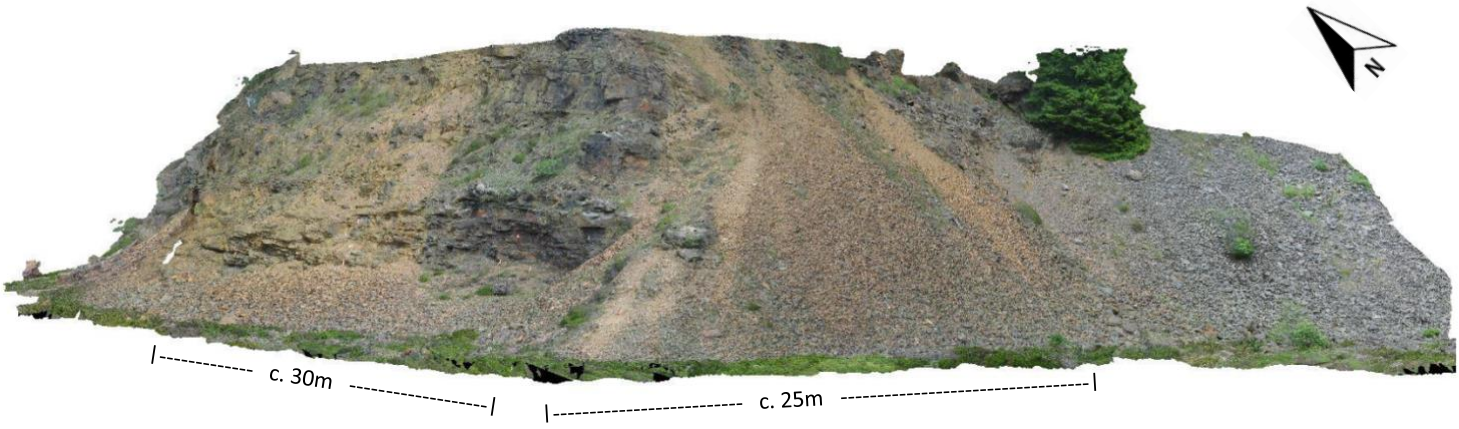


Figure 3: *View from SWS. Scale bars and a north arrow were added.*

2. Data Acquisition

2.1. Samples

The measurement campaign in the non-ferrous metal mine Rammelsberg in June 2019 was carried out as part of the ReMon project and the data were analysed in the unpublished B.Sc. thesis of Constantin Hildebrand (Hildebrand, 2019). Sixteen macroscopically distinguishable surface materials were identified. As this site is part of a protected area, no physical samples were taken. All measurements in the field were carried out at the specified sample locations with non- or minimal invasive techniques. The position of the analysed surface materials was marked by cones, the sample locations are shown in Figure . The data were acquired with a hyperspectral VNIR imaging camera (Cubert UHD-185), a handheld point spectroradiometer (PSR+ 3500) and a minimal-invasive, mobile LIBS (SciAps Z-300). Table 1 lists the identified surface materials (samples), the sample locations, a short sample description, a greyscale image showing the area covered by the image cubes of the hyperspectral camera, sample photos with the area of spectral sampling highlighted in red circles and plots of the corresponding reflectance spectra and the averaged spectra of the LIBS analyses. For each sample 64 LIB spectra were taken over a 8x8 pulse grid in the red circled area which was also used for the hyperspectral investigations to obtain the reflectance spectrum. The resulting Cubert and PSR+ reflectance data were collected in spectral libraries. A mean LIB spectrum per sample was calculated from the individual measurements.

Figure 4: *Rammelsberg mine sample locations marked with cones.*

Table 1: ***Overview of the Rammelsberg mine samples included in this publication.***

(1) ***Sample locality****: 51.88… = decimal latitude, 10.42… = decimal longitude;* *(2) the area of spectral sampling for both reflectance and emission retrieval is highlighted in red;*

(3) highly resolved greyscale image showing the area covered by the hyperspectral image cube, the position of the sample is highlighted in green.

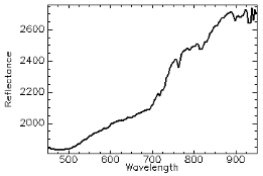
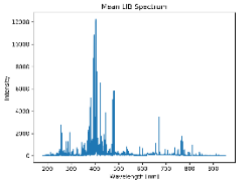
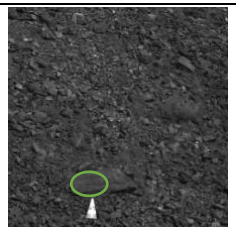
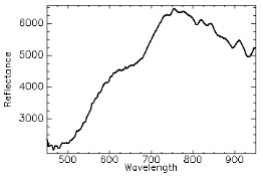
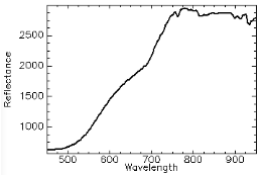
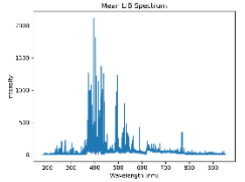
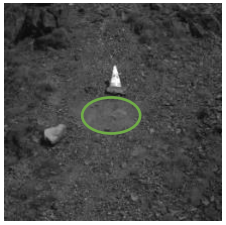
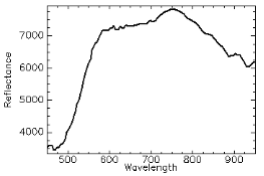
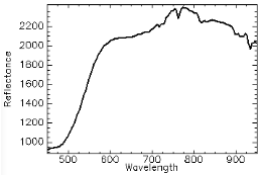
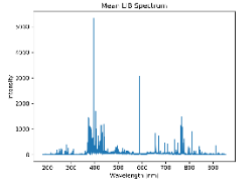
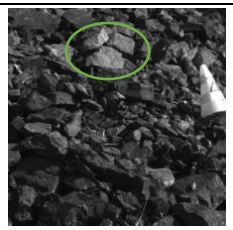
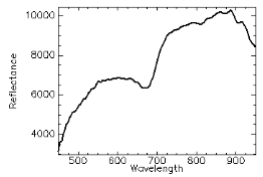
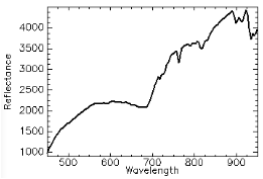
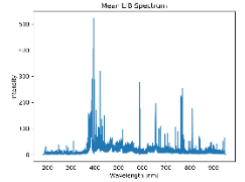
Sample ID	Sample locality (1)	Sample description	Photo of sample (2)	Cubert greyscale image (3)	Cubert reflectance spectrum	PSR+ reflectance spectrum	SciApps Z-300 emission spectrum
01_RAM	51.88876 10.42467	grey-black clay schist		not available	not available		
02_RAM	51.88883 10.42464	lichen, red					
03_RAM	51.88889 10.42470	ochre sand					
04_RAM	51.88894 10.42479	lichen, green					

Table 1 (continued)

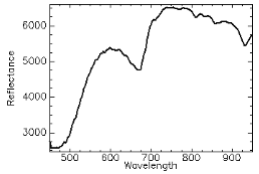
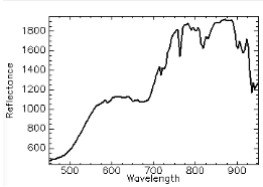
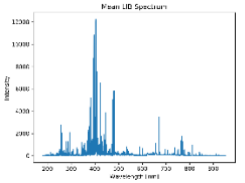
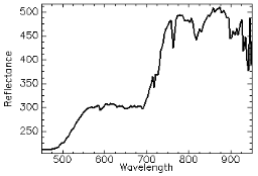
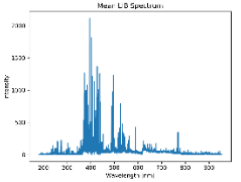
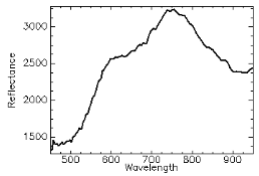
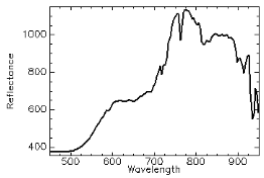
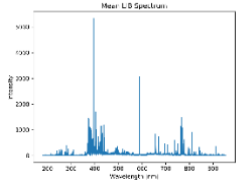
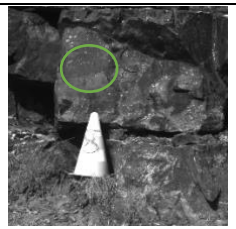
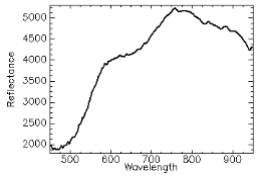
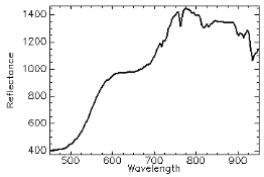
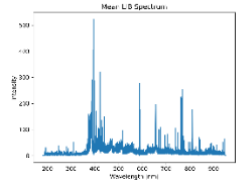
Sample ID	Sample locality [1]	Sample description	Photo of sample [2]	Cubert greyscale image [3]	Cubert reflectance spectrum	PSR+ reflectance spectrum	SciApps Z-300 emission spectrum
05_RAM	51.88892 10.42485	ochre					
06_RAM	51.88892 10.42489	black-dark green		not available	not available		
07_RAM	51.88892 10.42487	band with weathered pyrite					
08_RAM	51.88896 10.42489	dark brown					

Table 1 (continued)

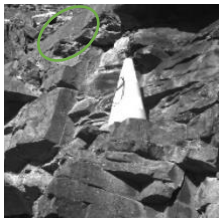
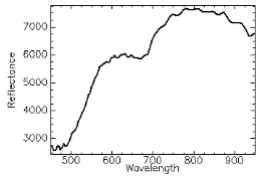
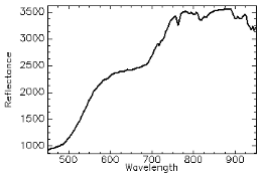
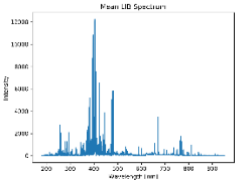
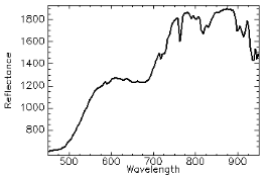
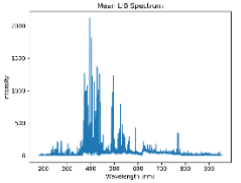
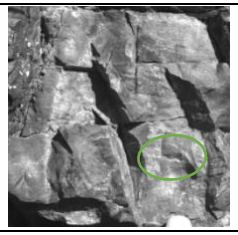
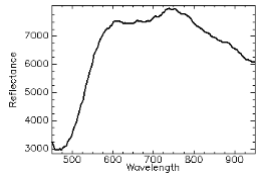
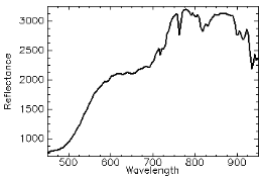
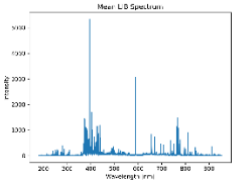
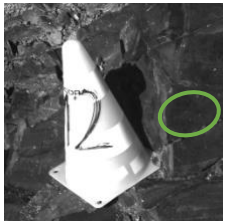
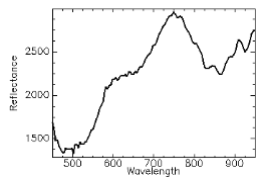
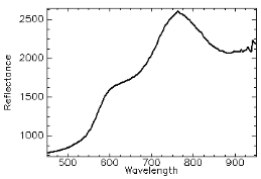
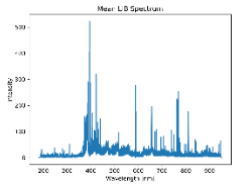
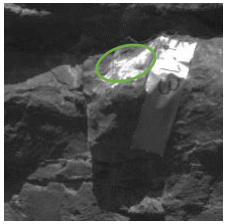
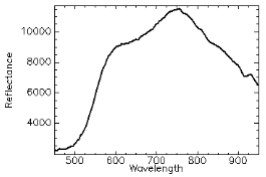
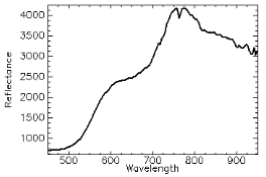
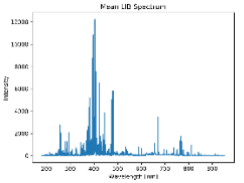
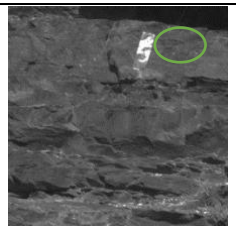
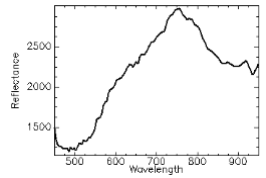
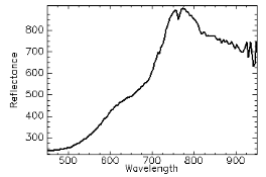
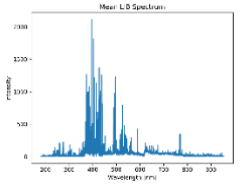
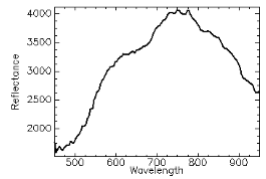
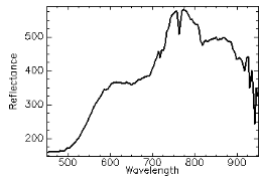
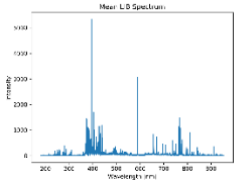
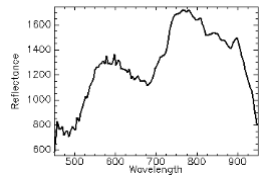
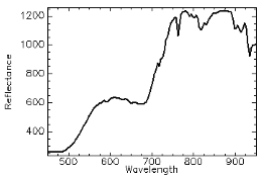
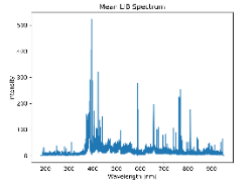
Sample ID	Sample locality [1]	Sample description	Photo of sample [2]	Cubert greyscale image [3]	Cubert reflectance spectrum	PSR+ reflectance spectrum	SciApps Z-300 emission spectrum
09_RAM	51.88896 10.42496	yellow-brown					
10_RAM	51.88897 10.42493	green-grey, slight growth of green lichen		not available	not available		
11_RAM	51.88903 10.42501	yellowish weathering like sample RAM_16					
12_RAM	51.88910 10.42507	dark brown-red					

Table 1 (continued)

Sample ID	Sample locality [1]	Sample description	Photo of sample [2]	Cubert greyscale image [3]	Cubert reflectance spectrum	PSR+ reflectance spectrum	SciApps Z-300 emission spectrum
13_RAM	51.88890 10.42486	orange					
14_RAM	51.88891 10.42487	hematite					
15_RAM	51.88889 10.42485	dark brown like sample RAM_08					
16_RAM	51.88895 10.42493	yellowish					

2.2. Hyperspectral field measurements

2.2.1. Imaging Spectroscopy: Cubert UHD-185

The hyperspectral data in the field were acquired with the UHD-185 camera from Cubert GmbH, from here on referred to as “Cubert camera”. With a size of 195 x 67 x 60 cm and a weight of 470 g, the Cubert camera can be used in a field setting and ground-based measurements but can also be utilized mounted on an UAV. The Cubert camera is equipped with a CCD full-frame sensor, which utilized the so-called ‘SnapShot’ technology (Weber, Kneer and Jenal, 2015) to capture 2D imagery with a focal length of 23mm and 11° field of view (FOV). Each spatial pixel of the captured image represents a hyperspectral spectrum (Aasen et al., 2014). The sensor records in a wavelength range from 450 to 950 nm in 126 individual bands (with a sampling interval of 4 nm). A single image has a spatial resolution of 50x50 pixels (12-bit depth). Each image is additionally recorded as a grayscale image with a spatial resolution of 1 megapixel (1000x1000 pixels) (Aasen et al., 2014). For the measurements, the position of the samples was marked with cones and the outcrop’s surface was recorded by taking single overlapping images. The distance between sensor and surface varied from image to image. After data acquisition, the reflectance for each data cube was calculated on the basis of the dark current measurement and white reference panel measurement performed before image acquisition.

For a three-dimensional reconstruction of the entire outcrop, a large number of images were taken. In this data publication one hyperspectral image (50x50 pixels, reflectance data) and one highly resolved greyscale image (1000x1000 px) is provided for 13 sample areas. Table 2 lists the specifications and settings of the Cubert camera for the field measurements. Table 3 lists the samples, the names of the provided images covering the measured sample areas, a greyscale image showing the area covered by the corresponding image cubes, the estimated pixel sizes of the hyperspectral image cubes and the measurement parameters. The image file names refer to the hyperspectral reflectance data cube (“.cue”) and the high-resolution greyscale image (“.jpg”). The changing distance between sensor and the measured sample surfaces results in a different size of the area represented by each image. The area represented by a pixel in the image can be estimated roughly by taking the cones (25 cm height) as a reference in relation to the total image size. The estimated pixel size is listed in Table 3. The samples 01_RAM, 06_RAM and 10_RAM are not available as Cubert images. The reasons are commented on in Table 3. When checking the hyperspectral data cubes, be aware that all images are rotated by 180 degrees. For each sample, except samples 01_RAM, 06_RAM and 10_RAM, a reflectance spectrum of one pixel in the associated hyperspectral image cubes was collected in a spectral library.

Table 2: Specifications and settings of the Cubert camera for the field measurements.

Cubert settings	
Light source	Sunlight
Distance: sensor to sample	Varying between 1 to 10 meters
Sensor arrangement	30mm, 11° FOV
Wavelength range	450 to 950 nm
Sensor type	VNIR
Shots to Average	12 bit
Radiometric resolution	12 bit
Integration time [ms]	(see single file description)
White reference (WR) for calibration	(see single file description)

Table 3**: **Overview of the provided Cubert images included in this publication.
***(1) Cubert image filenames**: … .cue = hyperspectral reflectance image cube, … .jpg = corresponding greyscale image; **(2)** highly resolved greyscale image showing the area covered by the hyperspectral image cube, in which the Cubert reflectance spectra where retrieved, **(3) Cubert image cube pixel (px) size**: "-" = no estimation due to missing cone in the image; **(4)** used white reference (WR) for reflectance retrieval / exposure time.*

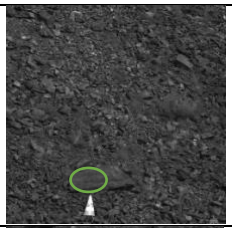
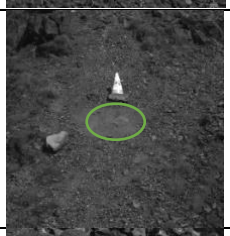
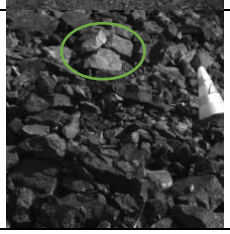
Sample ID	**Cubert image filenames (1)**	**Cubert greyscale image (2)**	**Cubert image cube pixel (px) size (3)**	**Measurement parameters (4)**
01_RAM	no image available			
02_RAM	02_RAM_Cubert_ref.cue 02_RAM_Cubert.jpg		1 px ~ 5x5 cm	WR 20% / 2 ms
03_RAM	03_RAM_Cubert_ref.cue 03_RAM_Cubert.jpg		1 px ~ 5x5 cm	WR 20% / 2 ms
04_RAM	04_RAM_Cubert_ref.cue 04_RAM_Cubert.jpg		1 px ~ 2.27x2.27 cm	WR 20% / 3 ms

Table 3 (continued)

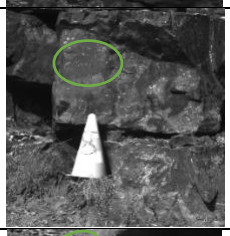
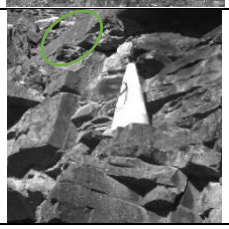
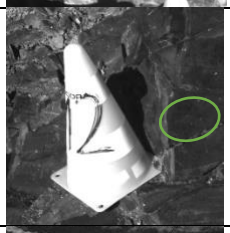
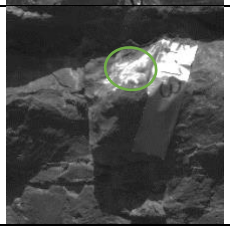
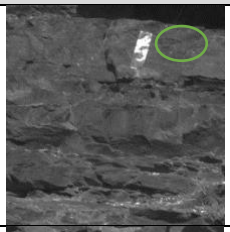
Sample ID	Cubert image filenames (1)	Cubert greyscale image (2)	Cubert image cube pixel (px) size (3)	Measurement parameters (4)
05_RAM	05_RAM_Cubert_ref.cue 05_RAM_Cubert.jpg		1 px ~ 0.9x0.9 cm	WR 20% / 3 ms
06_RAM	area completely covered with shadows			
07_RAM	07_RAM_Cubert_ref.cue 07_RAM_Cubert.jpg		1 px ~ 2.3x2.3 cm	WR 20% / 3 ms
08_RAM	08_RAM_Cubert_ref.cue 08_RAM_Cubert.jpg		1 px ~ 1.8x1.8 cm	WR 20% / 3 ms
09_RAM	09_RAM_Cubert_ref.cue 09_RAM_Cubertjpg		1 px ~ 1.4x1.4 cm	WR 20% / 3 ms
10_RAM	image not available			
11_RAM	11_RAM_Cubert_ref.cue 11_RAM_Cubert.jpg		_	WR 20% / 3 ms
12_RAM	12_RAM_Cubert_ref.cue 12_RAM_Cubert.jpg		1 px ~ 0.7x0.7 cm	WR 20% / 3 ms
13_RAM	13_RAM_Cubert_ref.cue 13_RAM_Cubert.jpg		_	WR 20% / 3 ms

Table 3 (continued)

Sample ID	Cubert image filenames (1)	Cubert greyscale image (2)	Cubert image cube pixel (px) size (3)	Measurement parameters (4)
14_RAM	14_RAM_Cubert_ref.cue 14_RAM_Cubert.jpg		_	WR 20% / 3 ms
15_RAM	15_RAM_Cubert_ref.cue 15_RAM_Cubert.jpg		_	WR 20% / 3 ms
16_RAM	16_RAM_Cubert_ref.cue 16_RAM_Cubert.jpg		_	WR 20% / 2 ms

2.2.2. Point Spectroscopy: PSR+ 3500 Spectroradiometer

The PSR+ 3500 is a portable spectroradiometer from the company Spectral Evolution and covers a spectral range of 350 - 2500 nm. The measurements were taken with an 8° pre-optic from a distance of 1.5 meters to the sample surface. The size of the measured area can be estimated to a circular spot with a diameter of ca. 21 cm. Before the measurement, the system was normalized to a white reference panel calibrated to 50 % reflection. Every spectrum collected represents an average of 30 individual measurements. The weather was alternately sunny and overcast. To compare both spectral libraries provided in this technical report, the PSR+ spectral library was resampled to the spectral characteristics of the Cubert camera (450 - 950 nm in 126 bands). Both spectral libraries can be used for further comparison-based classification of the Cubert image cubes which are also provided in this publication.

2.3. Geochemical Measurements

Laser-Induced Breakdown Spectroscopy (LIBS) is an analytical technique used for the determination of the elemental composition of materials. A focused, pulsed laser beam is directed at a sample surface, where laser energy absorption and material ablation produces high-temperature microplasma. Small amounts of the measured material are dissociated and ionized at the point of laser focus. During cooling atomic/ionic emissions in the plasma are generated. The integrated detector is used to

spectrally/temporally resolve the signals from the plasma and records the emission lines of all elements present in the material. The resulting LIBS spectrum represents the complete chemical composition of the analysed material (Miziolek et al., 2006). In this study LIBS data were collected using the SciAps Z-300 with a wavelength range of 190 – 950 nm. The 50 Hz laser shots with 5-6 mJ due every pulse and analyses every element in the periodic table table (available at: (https://sciaps.com/libs-handheld-laser-analyzers/z-300, 2022). The LIBS measurements were taken over an 8x8 pulse grid by using the Geochem Pro (Mining) App, resulting in 64 individual measurements per sample. The acquisition settings are listed in Table 4. For these 64 single shots, outliers and negative values were removed and the data were averaged to a mean spectrum for each sample.

Table 4: ***Acquisition settings of the SciAps Z-300 handheld analyzer in Geochem Pro mode.***

Acquisition settings	
Test Rate	10 Hz
Test Locations	1 Locations
Cleaning Pulses Per Location	2 Shots
Data Pulses per Location	4 Shots
Argon Preflush Time	300 ms
Shots to Average	1

3. File Description

The data are organised in three folders “Cubert-images”, “hyperspectral-libraries”, and “LIBS-data”. The additional Excel™ file “Rammelsberg_samples_measurement_parameters.xlsx” provides a full overview of the samples and the parameters of all measurements.

3.1. Excel® file “Rammelsberg_samples_measurement_parameters.xlsx”

The Excel® file “Rammelsberg_samples_measurement_parameters.xlsx” lists the samples and descriptions and the measurement parameters of all measurements. The Excel® file header is described in Table 5.

Table 5: ***Explanation of the header of "Rammelsberg_samples_measurement_parameters.xlsx".***

Header of Excel™ file	Explanation
Samples	General sample information
Sample ID	Sample name
Decimal Latitude	Latitude location of the sample
Decimal Longitude	Longitude location of the sample
Sample description	Description of visible alteration, type of material and colour of the samples
Field photo	Field photo showing the location of the sample in the outcrop
Close-up with highlighted area of spectra retrieval	Close-up field image showing the location on the sample for Cubert, PSR+ and LIB spectrum retrieval
Cubert measurements	Measurement parameters and names of the provided data files of the Cubert analyses
Cubert reflectance image cube name	Name of the Cubert reflectance image cube
Cubert image cube pixel (px) size	Estimated pixel size of the Cubert image cube based on the height of the imaged cone
Cubert greyscale image name	Name of the Cubert high-resolution greyscale image
Cubert greyscale image with highlighted area of spectrum retrieval	Cubert greyscale image showing the location of Cubert spectrum retrieval in the corresponding Cubert image cube
Cubert spectrum name	Name of the Cubert reflectance spectrum
WR (%)	White reference standard used
Integration time (ms)	Light exposure on Cubert camera
PSR+ measurements	Information related to the PSR+ analyses
PSR+ spectrum name	Name of the PSR+ reflectance spectrum
Weather condition during measurement	Plot with hyperspectral profile
LIBS measurements	Information related to the LIBS analyses
Lib spectrum name	Name of the LIB mean spectrum

3.2. Folder „Cubert-images“

The hyperspectral image cubes of the Cubert camera are provided as reflectance data. For each sample, except samples 01_RAM, 06_RAM and 10_RAM, an individual reflectance image cube following the syntax “Sample ID_Cubert_ref.cue” with its associated header file “Sample ID_Cubert_ref.hdr” is provided. The corresponding high-resolution greyscale image is provided as an individual JPG file following the syntax “Sample ID_Cubert.jpg”.

3.3. Folder “hyperspectral-libraries”

The Cubert reflectance spectra of the samples, except samples 01_RAM, 06_RAM and 10_RAM, are presented in an ENVI® Spectral Library file format “GFZ_Cubert_RAM”, associated header file “GFZ_Cubert_RAM.hdr” and a text file format “GFZ_Cubert_RAM.txt”. The spectral library can be visualized in ENVI® as seen in Figure 5. Figure 6 shows a section of the text file presenting the wavelength in column 1 and the reflectance values of the samples from column 2 onwards.

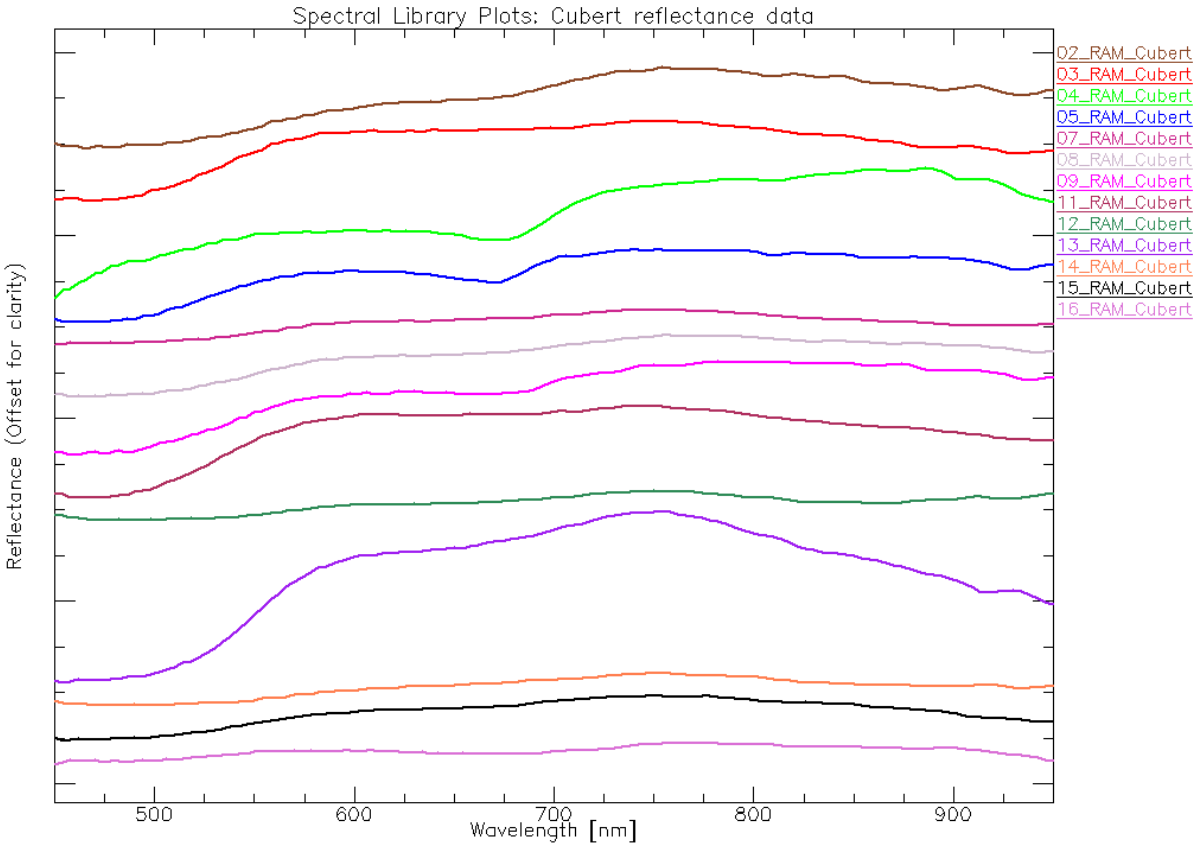


Figure 5: Spectral library plot of the Rammelsberg mine samples analysed with the Cubert UHD-185.

```
ENVI ASCII Plot File [Thu Jan 06 12:04:37 2022]
Column 1: Wavelength [nm]
Column 2: 02_RAM_Cubert~~47
Column 3: 03_RAM_Cubert~~2
Column 4: 04_RAM_Cubert~~3
Column 5: 05_RAM_Cubert~~4
Column 6: 07_RAM_Cubert~~5
Column 7: 08_RAM_Cubert~~6
Column 8: 09_RAM_Cubert~~7
Column 9: 11_RAM_Cubert~~8
Column 10: 12_RAM_Cubert~~9
Column 11: 13_RAM_Cubert~~10
Column 12: 14_RAM_Cubert~~11
Column 13: 15_RAM_Cubert~~12
Column 14: 16_RAM_Cubert~~13
  450.000000   2362.000000   3548.000000   3140.000000   2772.000000   1326.000000   2000.000000
  454.000000   2142.000000   3578.000000   3610.000000   2564.000000   1320.000000   1968.000000
  458.000000   2166.000000   3592.000000   3678.000000   2572.000000   1462.000000   1878.000000
  462.000000   2160.000000   3576.000000   4018.000000   2562.000000   1406.000000   1902.000000
  466.000000   2010.000000   3444.000000   4214.000000   2580.000000   1414.000000   1868.000000
  470.000000   2158.000000   3448.000000   4512.000000   2566.000000   1378.000000   1896.000000
  474.000000   2138.000000   3532.000000   4570.000000   2594.000000   1406.000000   1874.000000
  478.000000   2062.000000   3514.000000   4880.000000   2624.000000   1430.000000   1974.000000
  482.000000   2104.000000   3610.000000   4984.000000   2664.000000   1406.000000   1910.000000
  486.000000   2256.000000   3646.000000   5134.000000   2752.000000   1426.000000   1978.000000
```

Figure 6: Detail of the ASCII file from the ENVI® spectral library of the Cubert measurements.

The PSR+ reflectance spectra of the samples are presented in an ENVI® Spectral Library file format "GFZ_PSR+_RAM", associated header file "GFZ_PSR+_RAM.hdr" and a text file format "GFZ_PSR+_RAM.txt". The spectral library can be visualized in ENVI® as seen in Figure 7. Figure 8 shows a section of the text file presenting the wavelength in column 1 and the reflectance values of the samples from column 2 onwards.

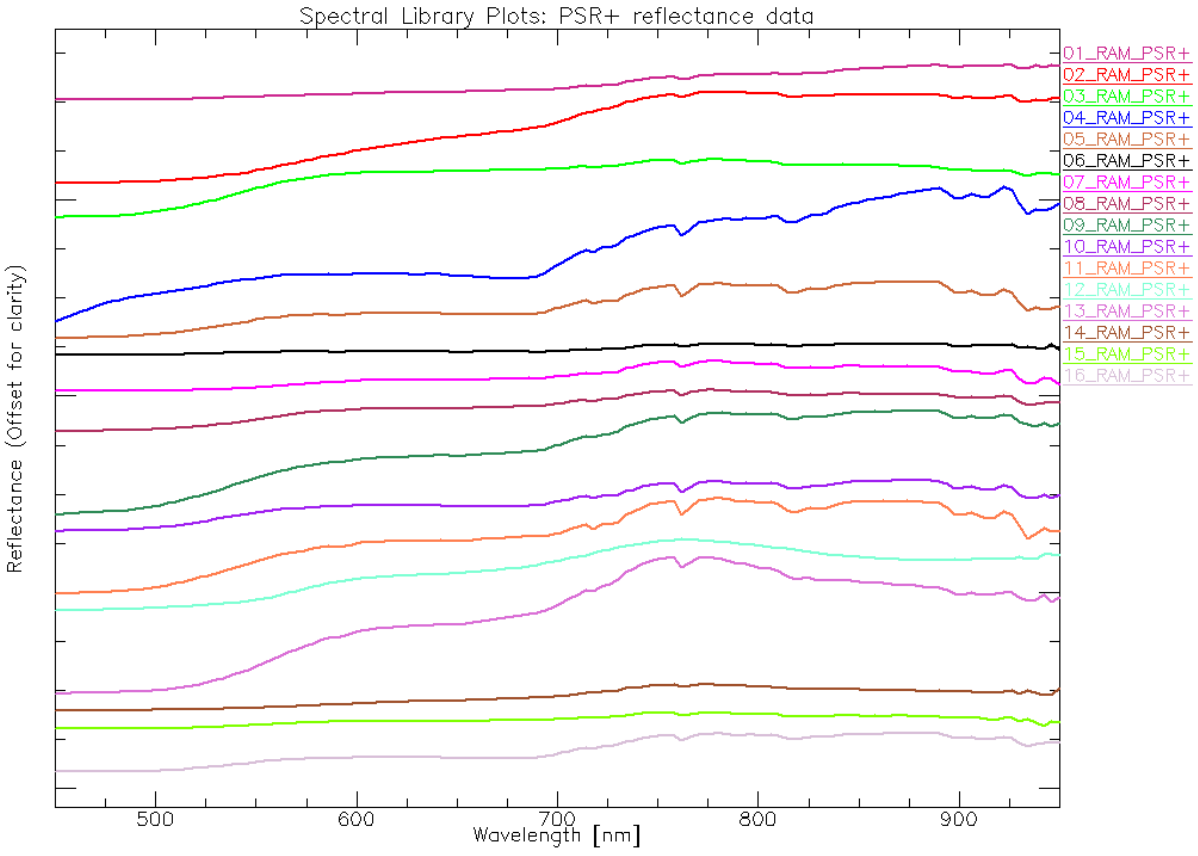


Figure 7: Spectral library plot of the Rammelsberg mine samples analysed with the PSR+ 3500.

```
ENVI ASCII Plot File [Thu Jan 06 12:31:53 2022]
Column 1: Wavelength
Column 2: 01_RAM_PSR+~~1
Column 3: 02_RAM_PSR+~~2
Column 4: 03_RAM_PSR+~~3
Column 5: 04_RAM_PSR+~~4
Column 6: 05_RAM_PSR+~~5
Column 7: 06_RAM_PSR+~~6
Column 8: 07_RAM_PSR+~~7
Column 9: 08_RAM_PSR+~~8
Column 10: 09_RAM_PSR+~~9
Column 11: 10_RAM_PSR+~~10
Column 12: 11_RAM_PSR+~~11
Column 13: 12_RAM_PSR+~~12
Column 14: 13_RAM_PSR+~~13
Column 15: 14_RAM_PSR+~~14
Column 16: 15_RAM_PSR+~~15
Column 17: 16_RAM_PSR+~~16
  450.000000  1841.800064   617.499985   918.899998   983.700007   467.600003   210.900009
  454.000000  1840.700060   620.400012   930.100009  1068.999991   476.499982   211.900007
  458.000000  1838.999987   622.900017   936.100036  1152.599975   483.799987   211.299993
  462.000000  1836.300045   624.600016   939.600021  1235.999987   488.599986   211.299993
  466.000000  1834.899932   626.600012   943.399966  1311.199963   494.000018   211.999994
  470.000000  1832.900047   627.899989   946.500003  1380.199939   498.800017   211.599991
  474.000000  1832.900047   632.599965   951.900035  1444.199979   505.300015   212.500002
  478.000000  1829.299927   633.699968   954.499990  1504.900008   510.200001   212.600008
  482.000000  1832.299978   637.700036   966.200009  1553.499997   518.699996   215.000007
  486.000000  1832.299978   643.400028   982.299969  1594.700068   529.399998   216.000006
```

Figure 8: Detail of the ASCII file from the ENVI® spectral library of the PSR+ measurements.

3.4. Folder “LIBS-data”

The results of the LIBS analyses are given as an averaged mean spectrum per sample. The averaged LIB spectra are provided as individual CSV files following the syntax “Sample ID_mean_spectrum.csv”. Figure 9 shows a section of a CSV file presenting wavelength and intensity separated by comma.

```
wavelength,intensity
180.0,0.0
180.1,0.0
180.2,0.0
180.3,0.0
180.4,0.0
180.5,0.0
180.6,0.0
180.7,0.0
180.79999999999995,0.0
180.89999999999995,0.0
180.99999999999997,0.0
181.09999999999997,0.0
181.19999999999996,0.0
181.29999999999995,0.0
181.39999999999992,0.0
181.49999999999991,0.0
181.59999999999994,0.0
181.69999999999993,0.0
181.79999999999993,0.0
181.89999999999992,0.0
181.99999999999991,0.0
182.09999999999988,0.0
182.19999999999987,0.0
```

Figure 9: Detail of a CSV file from LIBS analyses.

4. Acknowledgements

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5. References

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