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Automated Quantitative Mapping of Ore Minerals by Multispectral Reflected-light Microscopy

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ABSTRACT

An innovative multispectral reflected-light microscopy system is able to automatically identify ore minerals by measuring their specular reflectance with non-polarized light in a number of spectral bands, and comparing the values obtained with a reference database. In this way it can provide quantitative mineralogical mapping comparable to that obtained from automated mineralogy systems based on SEM-EDS (Scanning Electron Microscopy with Energy-Dispersive X-Ray Spectroscopy), at a fraction of the cost and with less stringent environmental and operational requirements.

The new system, called AMCO (for Automated Microscopic Characterization of Ores), consists of an instrument and two proprietary software applications: *amcoCapture*, to acquire multispectral images of a polished section prepared from an ore sample, and *amcoAnalysis*, to process these images and extract different types of mineralogical information from them.

SYSTEM DESCRIPTION

The instrument (Figure 1) is based on a fully motorized reflected-light microscope, incorporating several auxiliary elements (halogen lamp light source with custom hot mirror, filter wheel with many bandpass filters, monochrome video camera sensitive to a wide spectral range, XY scanning stage) linked to a control unit, to allow acquisition of multispectral images beyond the visible spectrum.

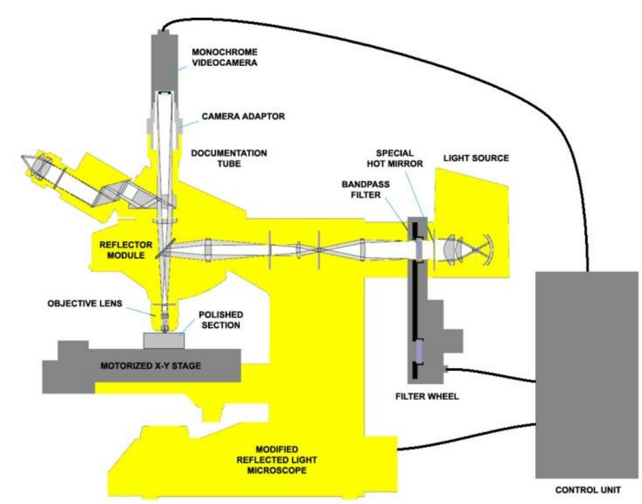

Figure 1. Scheme of the AMCO instrument. AMCO System running *amcoCapture* software

As for the software, *amcoCapture* runs on the control unit (Figure 1), where it manages the instrument elements while acquiring images manually or by automated scans of polished sections. It implements calibration procedures with geometric and high and low specular reflectance standards in order to ensure accuracy and repeatability of reflectance measurements and a precise registration between image bands. The basic system acquires multispectral images composed of up to 20 reflectance bands spanning the VNIR (visible and near infrared) range of the spectrum (between 350 and 1000 nm), plus an optional fluorescence band to help discriminate fluorescein-dyed resin from gangue in polished thin sections prepared from milled ore samples [1]. An advanced version of the system uses a second camera to capture additional reflectance bands in the SWIR (short-wave infrared) range (between 1100 and 1700 nm) to improve discrimination between some minerals.

amcoAnalysis can be run on any computer, and allows to process the acquired multispectral images either manually or automatically. In manual image analysis (Figure 2), the operator can interactively delineate polygonal zones (shown outlined in bright colors) on mineral grains, in which the average multispectral specular reflectance of the mineral is determined. These mean multispectral values and the curve passing through them are plotted in a graph in the upper right corner. The mineral of a zone can be identified by comparing its mean values with the multispectral specular reflectance database of ore minerals, which is integrated in the system software. This database includes about 100 ore minerals of industrial or economic interest, and can be expanded by users by placing measurements of additional minerals in a customized auxiliary database. The minerals in the database that best match the mean values of the active zone are listed in the lower left corner, sorted by increasing distance (i.e. from highest to lowest likelihood). The operator can assign a mineral to the active zone by simply clicking on its name.

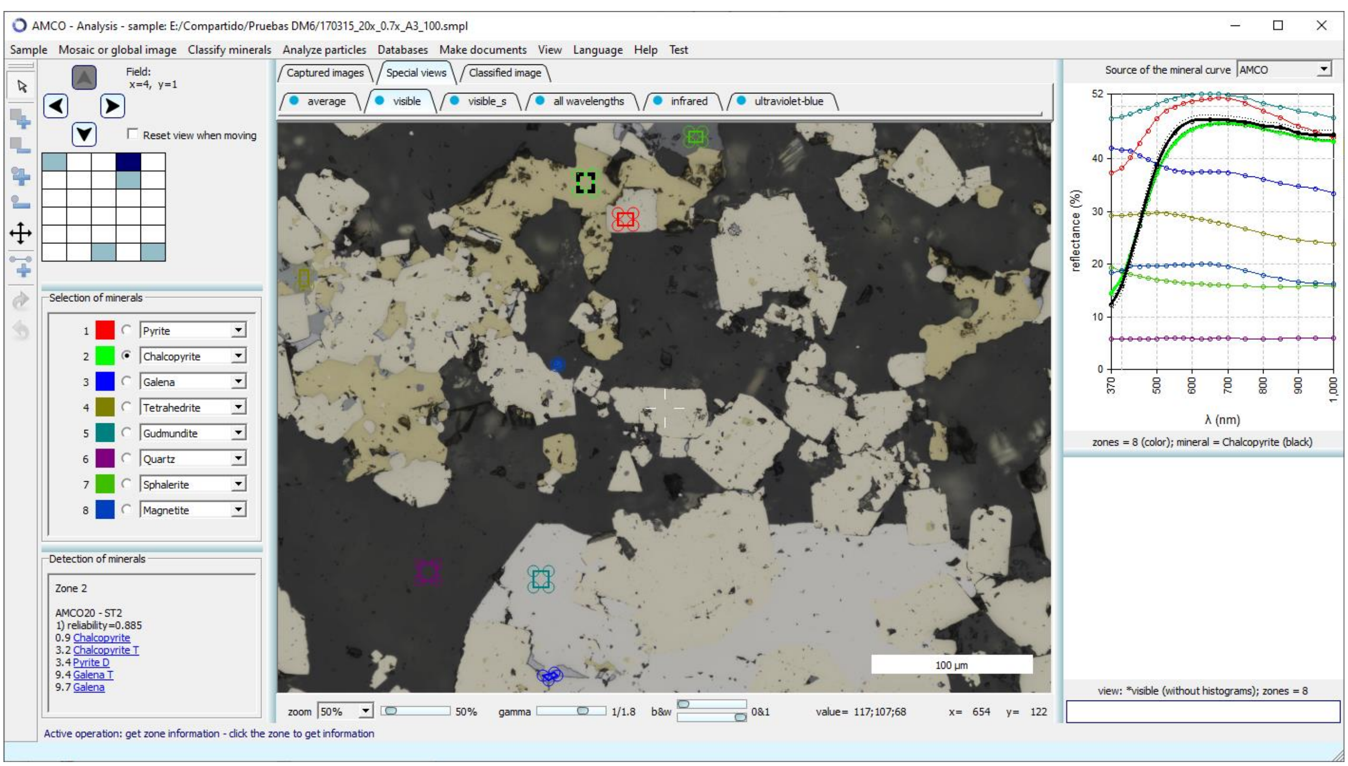

Figure 2. Capture of *amcoAnalysis* software while doing manual analysis of an image series

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In automatic image analysis, each image pixel is assigned to a mineral class by comparing its actual multispectral specular reflectance values with the multispectral specular reflectance database of ore minerals [2], producing a classified image that maps the distribution of mineral phases in the field. If the fluorescence band is available, its value is compared with a threshold to discriminate resin pixels. The modal analysis of the field (in volume %) is obtained simultaneously (Figure 3).

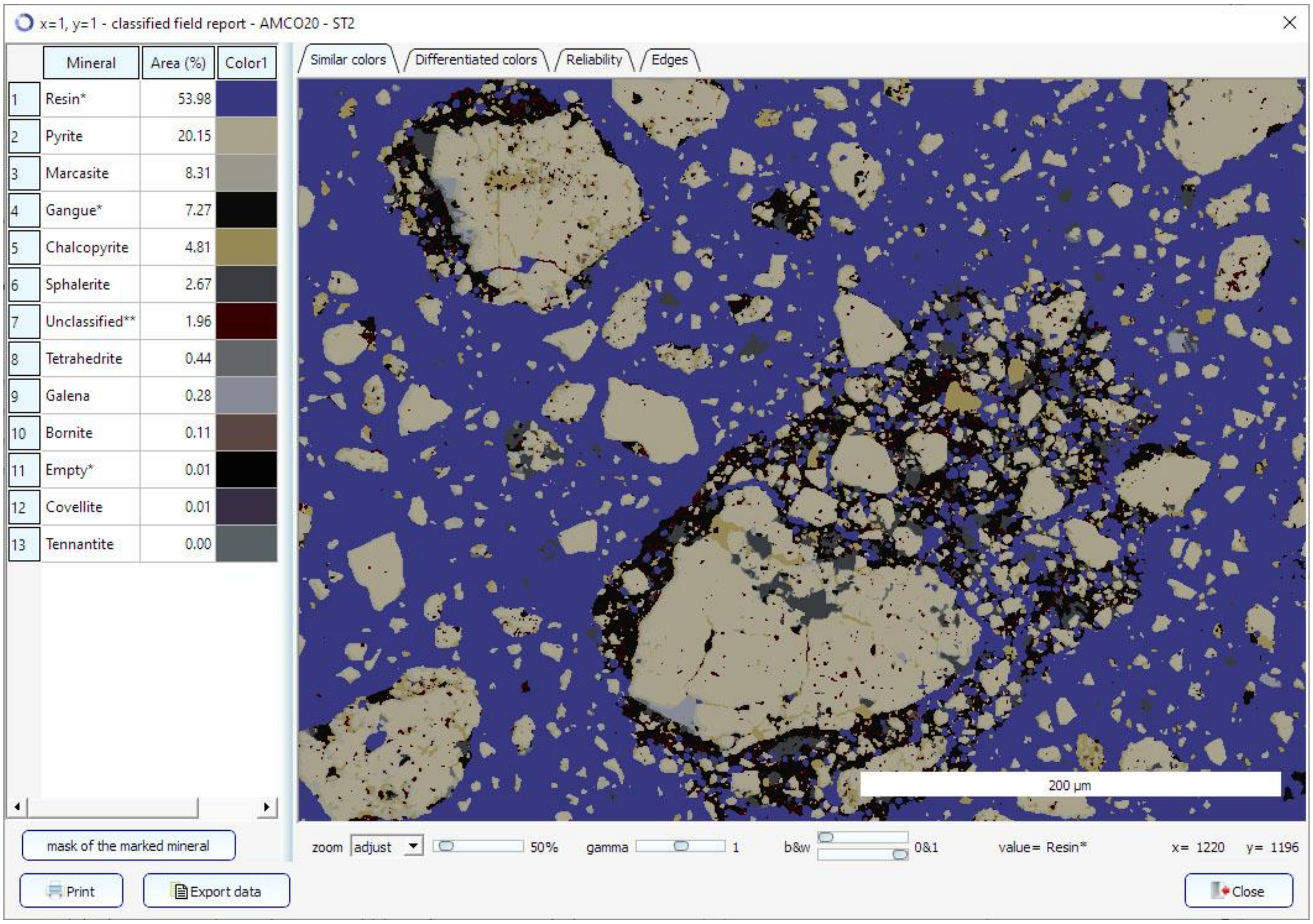

Figure 3. Capture of the automated classification of the image of a field by *amcoAnalysis*

The overall modal analysis of the entire sample is computed by adding up the modal analyses of all the fields of the image series, discarding pixels assigned to resin. To compute the modal analysis in weight %, pixels assigned to the empty or unclassified classes are also discarded, and remaining pixel counts are weighted by the density of each mineral.

SYSTEM VALIDATION

AMCO System validation was performed by comparing its results with the results obtained from an Automated Mineralogy system based on SEM-EDS, when processing the same set of polished thin sections [3]. First, image series were acquired at LMA-UPM using *amcoCapture* to perform automated scans of 18 polished thin sections with a scanning step size of 1500 µm, providing an effective coverage of 8 % of the polished section area. Each one was processed with *amcoAnalysis* to obtain its overall modal analysis. Afterwards, the sections were sent to Université de Liège, where they were carbon coated and analyzed with a ZEISS Mineralogic Mining system, using mapping mode with 100 µm step size and 50 ms dwell time. Modal analysis results from both systems were reasonably similar, taking into account the completely different sampling method used by each system and the expected statistical variation for the minority minerals.

The main advantages of AMCO over systems based on SEM-EDS are:

- Much lower cost and infrastructure requirements
- Does not require specialized personnel for its operation
- Can reliably identify polymorphs and mineral phases having very similar composition that cannot be distinguished by SEM-EDS (e.g., pyrite/marcasite, enargite/tennantite/luzonite, digenite/chalcocite/djurleite, magnetite/hematite, graphite, etc.)
- Lower percentage of unclassified pixels
- Analyzes more pixels in a given time

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