HYPERSPECTRAL IMAGING FOR SYLVINITE MINING

Lithological mapping for potassium chloride mining

NOVEMBER 2023

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Sylvite is a mineral primarily mined as a source of potassium chloride (KCl) and extracted through underground or solution mining. The extracted sylvite is typically crushed and processed to remove impurities to increase the concentration of KCl. The product is used as fertilizer, for the production of glass and to manufacture chemicals such as potassium carbonate and other compounds. It is also used in the food industry as a salt substitute and as a feed supplement for livestock. Carnallite, a hydrated K-Mg-Chloride mineral, can affect the mining of sylvite and create operational challenges during the extraction and processing of the ore. Both sylvite and carnallite deposits are often found in association and with other evaporite minerals such as halite, anhydrite or gypsum. The presented case study showcases the potential of mineral classification in such deposits and a semi-quantification of chloride content in sylvinite mining operations [1].

For this test, half-core samples were scanned using the visible-to-near infrared (VNIR) and shortwave infrared (SWIR) spectral ranges. The imaging was done from a scanning distance of 100 cm, resulting in 0.16 mm and 0.77 mm pixels in the VNIR and SWIR, respectively. Figure 1 shows the scanning setup with the HySpex classic VNIR (blue) and SWIR (red) cameras mounted side by side. The data is corrected to absolute reflectance using a reference grey panel, also visible in the image.

Figure 1: Scanning of the samples using the HySpex lab setup with both VNIR and SWIR cameras.

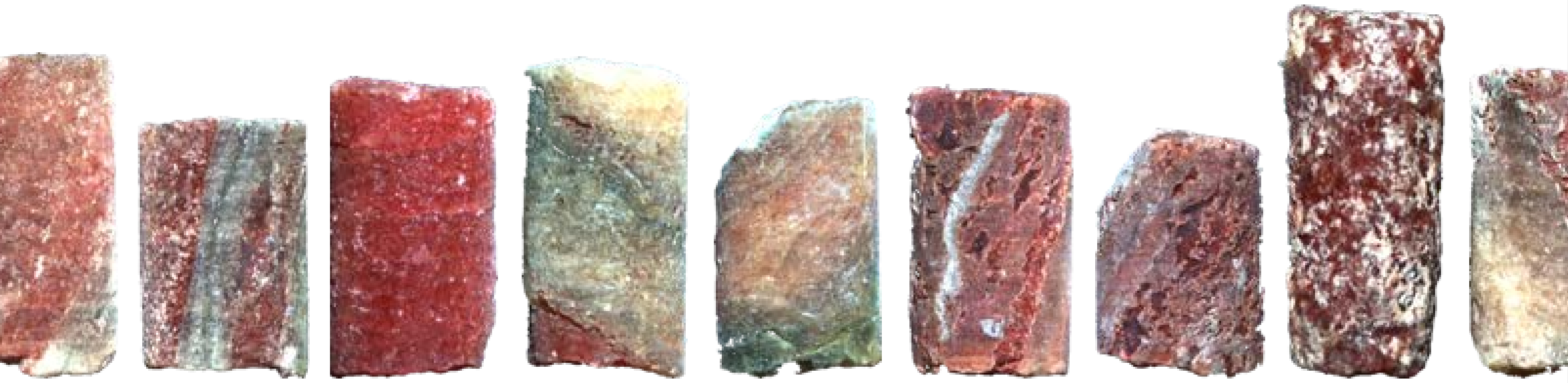
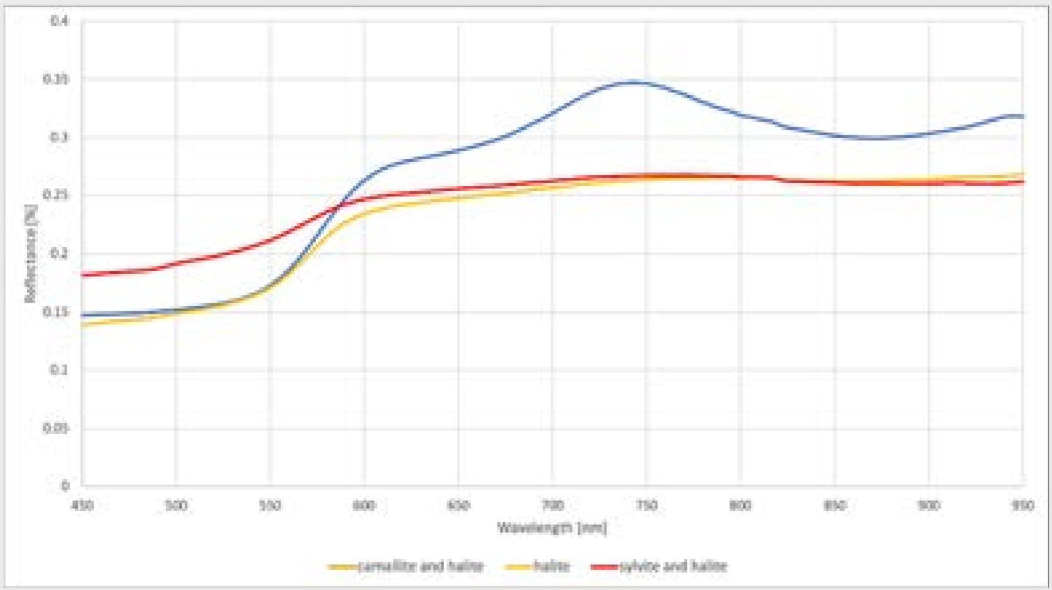


Figure 2: Silvinite, Carnallite and Halite cores

The samples were scanned using the **HySpex VNIR-1800 and SWIR-384 hyperspectral cameras** and a broadband halogen illumination source. The cameras covers the spectral region of 400-2500nm. Featuring low background noise, high dynamic range, and superior signal-to-noise ratio, these state-of-the-art cameras guarantee high-quality image data and the reliability needed for consistent lithology mapping in operational mining environments.

In this project, sylvinite rock is the main KCl source. Here, the mineral sylvite co-exists intimately with halite and carnallite (Figure 2). Of the 113 samples, 83 represent the sylvite-halite category (sylvinite), whereas 17 represented halite and 13 carnallite-halite lithologies. The samples are not mono-mineralic and the samples' lithology label is provided by the operators on site, including the determined KCl, $MgCl_2$ and Ca^{2+} grades. In the 113 samples, KCl% grades differed between 0.0% - 97.8% with a median grade of 36.5%. The reported average grade of the mine of 26% KCl is not represented in the provided sample set, instead, a wide range of variability was introduced to cover the full range of possible expected KCl grades in smaller samples. The sylvite-halite lithology is the main source of KCl, carnallite-halite represents a median KCl content with a high $MgCl_2$ content of up to 33%.

As the KCl is linked to the sylvinite, a classification model was set up to define the areas occupied by the sylvite-halite lithology. The spectra of sylvite-halite show a sufficient though subtle spectral difference compared to carnallite-halite and halite lithologies (Figure 3).



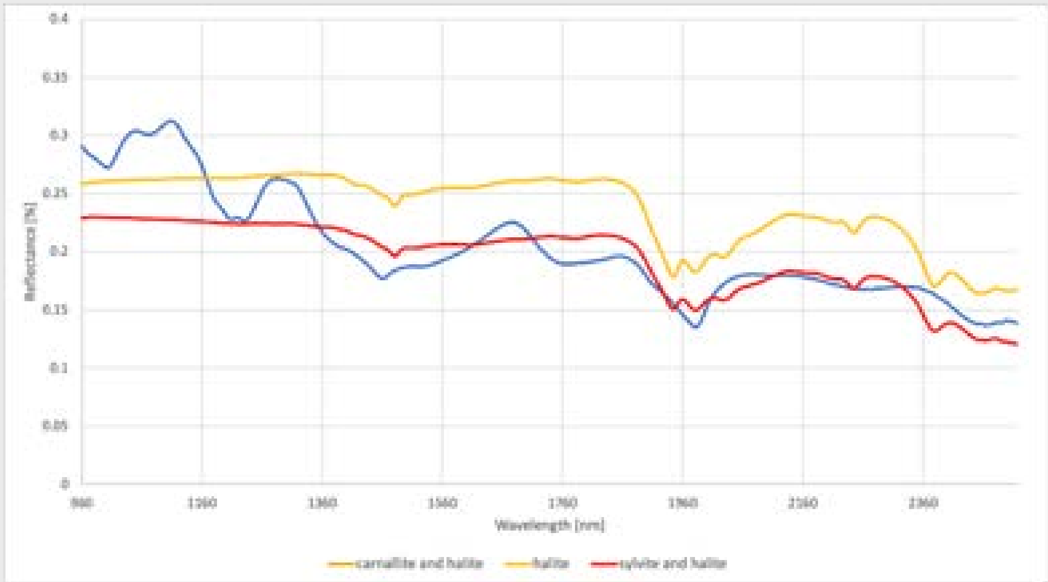


Figure 3: Top: VNIR, Bottom: SWIR spectral plot of the three main lithologies

To achieve a lithology classification a PLS-DA model was trained in Prediktera's Breeze software. As the samples are distinctly heterogeneous, the classification model was trained based on the full sample average spectrum. Of the 113 samples, 91 were used for training and 22 for testing. The SWIR classification shows good classification results, where 87% of the training set can be classified correctly and 85% of the test set. The per-pixel classification shows the heterogeneity of the sample, i.e. by classifying "halite" in the areas visible as "white-grey" in the sample (Figure 4).

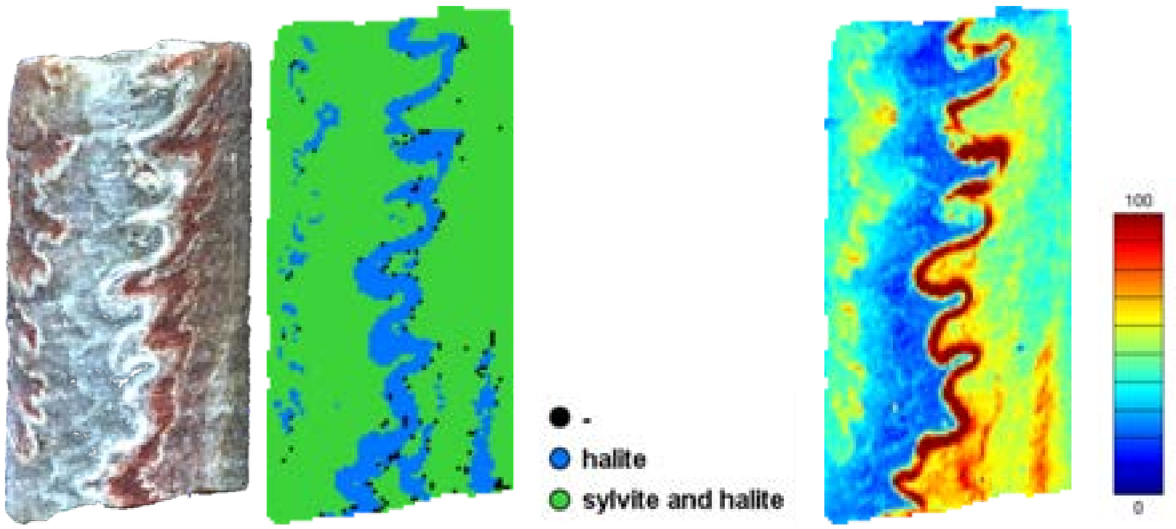


Figure 4: Left: VNIR, true colour RGB; Centre and right: SWIR analysis based on a sample representing sylvite-halite. Centre: SWIR-based classification of Lithologies. Black pixels represent unclassified pixels; Right: SWIR-based KCl% content prediction per pixel.

For semi-quantification, a PLS model was trained based on the provided geochemistry. Different modelling approaches were tested within the breeze software and the best results were found to be achieved when training different univariate models based on each parameter (MgCl2, KCl and Ca2+) and each lithology separately. The KCl prediction based on the SWIR data of one sample is shown in Figure 4.

This feasibility study shows the capability of modelling the different lithologies spectrally and classifying the occurrence of the minerals and the extent of their spatial distribution using HySpex hyperspectral cameras. Based on this, an online or offline classification model can be developed further and implemented for onsite, real-time classification. This way hyperspectral imaging cameras can enable continuous monitoring and notify operators about undesired changes in lithology in the feed.

[1] Maerz, N.H., Richardson, R.J., Krukowski, S.T. (2017). Potash Deposits, Processing, Properties, and Uses. In: Kogel, J.E., Trivedi, N.C., Barker, J.M., Krukowski, S.T. (Eds.), Industrial Minerals and Rocks: Commodities, Markets, and Uses, 8th Edition, pp. 765-782. Society for Mining, Metallurgy, and Exploration, Inc. (SME).