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Terrestrial long-wave infrared hyperspectral imaging for geological mapping: a case study

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Mapping lithology and geological structures accurately remains a challenge in difficult terrain or in active mining areas. Visible to near-infrared (VNIR) and short-wave infrared (SWIR) hyperspectral data has been proven successful for mapping of alteration minerals under such demanding logistical circumstances. However, many rock-forming silicates are indistinct in this spectral range. In this regard, hyperspectral long-wave infrared (LWIR) imaging adds a promising complement to hyperspectral VNIR and SWIR data in the field of mineral mapping, since the molecular vibrations of many rock-forming minerals have characteristic resonant frequencies in the LWIR part of the electromagnetic spectrum. In this contribution, we demonstrate the use of hyperspectral LWIR data for mineral mapping of vertical geological outcrops on the example of the Naundorf gravel quarry in Saxony (Germany), which features sulfide-rich hydrothermal zones in a granitoid host. We describe an integrated workflow to produce a geometrically and spectrally accurate combination of a Structure-from-Motion point cloud and a hyperspectral LWIR datacube. The data are processed using spectroscopic (e.g., feature matching) and machine learning (e.g., Random Forests) algorithms to generate meaningful 2.5 D maps. These provide a basis for mapping of lithological contacts and tectonic structures in the outcrop. We validate the remote sensing data with laboratory X-ray diffraction and thin section analysis as well as FTIR point spectrometer data. In combination with ground- or drone-based photogrammetric and hyperspectral VNIR and SWIR data, LWIR imaging provides a powerful tool for safer and more efficient ground surveys as well as a better, mathematically sound, sampling strategy for further structural, geochemical and petrological investigations.