Close-Range Hyperspectral Sensing of Mineralized Outcrops in Open-Pit Mines: Analysis of the Lithocaps of the Allumiere-Tolfa Epithermal System (Central Italy)

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This study aims to demonstrate how the new generation of portable spectral cameras can significantly enhance geological mapping, enabling rapid acquisition of detailed mineralogical information directly in the field. We showcase the Allumiere-Tolfa mining district (central Italy), where lithocaps associated with a high-sulfidation epithermal system are characterized by alunite and polymetallic mineralizations in addition to a widespread, structurally-controlled and zoned hydrolytic alteration of the hosting volcanic rocks.

High spatial and spectral resolution reflectance VNIR-SWIR imaging was acquired on four outcrops in two open-pit mines using tripod-mounted Headwall Photonics cameras, covering the 400-2500 nm spectral range, with 270 (VNIR) to 166 (SWIR) spectral bands. These spectral images were complemented with 3D modelling obtained via drone imagery and Structure from Motion reconstruction. Hyperspectral data were validated through laboratory spectroscopy and mineralogical analysis on twenty-nine ground samples. Identification and characterization of optically active minerals were performed using minimum wavelength mapping and band ratios. Distinct hydrothermal alteration zones were mapped by using absorption features of smectites, kaolin-group, and alunite-group minerals at ~2160, 2200, and 2290 nm in the SWIR range. Kaolinite polytypes and alunite composition were investigated through the wavelength position of the 1400 nm doublet and sulfate-related absorptions between 1400-1800 nm, enabling estimation of the physicochemical conditions under which the hydrothermal alteration developed. The Fe-oxy-hydroxides signature at ~900 nm allowed mapping the supergene alteration. The hyperspectral images of the Allumiere quarry were finally draped onto a 300-m wide 3D model, for improving the spatial visualization of the alteration facies and their relationship in 3D with tectonic structures and other geological features.

This high-resolution, multi-scale approach, combined with 3D modelling, provided key insights into the geometry of alteration mineral assemblages, serving as a powerful tool for rapid, cost-effective, detailed characterization of exposed vertical wall-rocks, applicable to other active and/or inactive mining areas.