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Remote Sensing-based Mapping of Zn-Pb-Carbonate Hosted Ore Deposits Using Sentinel-2 and PRISMA Satellite Imagery: The Jabali Test Site (Western Yemen)

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In this study, we have developed an integrated methodology, based on hyperspectral and multispectral imagery, for mapping the spatial distribution of the hydrothermal and supergene alteration associated with the Zn-Pb(-Ag) Jabali deposit (Yemen). The Jabali deposit is located in a desert area northeast to the capital of Yemen, Sana'a, along the western NW-SE-trending margin of the Sab'atayn basin. The Zn-Pb mineralization consists mainly of nonsulfides of supergene origin, mainly represented by smithsonite, minor hydrozincite, and hemimorphite (+ acanthite and greenockite in small amounts). The nonsulfide ore is hosted by a partly hydrothermally dolomitized Jurassic limestone. The supergene ore derived from oxidation of the primary sulfide mineralization (sphalerite, pyrite, and galena) that has been interpreted as a Mississippi Valley Type deposit emplaced via fluid migrations in extensional tectonic regime. Satellite data enabled the identification of the hydrothermal dolomitization, as well as the outlining of the gossans and secondary mineralized products, which extensively outcrop in the test area. The area was analysed by means of Sentinel-2 multispectral (European Space Agency) and PRISMA* hyperspectral (Italian Space Agency) imagery. These two missions provide to the scientific community and to other users free-of-charge data and were chosen for sensing the different materials' spectral responses in the visible near infrared (VNIR) and the shortwave infrared (SWIR) regions, respectively. PRISMA provides images at a spectral resolution of 12 nm in a continuum of 240 bands in the VNIR to SWIR wavelength region of the electromagnetic spectrum (400-2,505 nm). This satellite imagery allows the clear distinction between dolomite and limestone in the SWIR region by enhancing the spectral differences between these two carbonate phases in bands 148 and 150 (2,320 and 2,335 nm, respectively). The distribution of gossans and alteration products, instead, was tested on 10-m resampled Sentinel-2 products, which offer a full set of 12 bands, with several bands in the VNIR region (B2, B4, B6, B7, and B8A) covering the Fe-bearing minerals spectral features. Spectral signatures of representative host-rock samples and Fe- and Zn-bearing mineralized alteration products were collected and validated via XRD analyses in order to build up a spectral library needed for image classification, which has been produced with the support of band combinations, spectral indices, and statistical analyses. Despite the great number of bands provided by PRISMA, a prompt visualization of the known Fe and alteration minerals outcrops with the 30-m spatial resolution was not achieved yet. However, the availability of multiple bands in the SWIR region and the hyperspectral resolution make PRISMA a suitable tool for mapping the dolomitization footprint, while the use of multispectral, Sentinel-2 "easy-to-handle" products suits best for the identification of the gossan outcrops associated with the Jabali ore type.

This work proves that an integrated satellite-ground-based mapping approach using multiple sources of spectral data with different spectral resolution is a promising exploration strategy for the Jabali ore type at regional scale in the Sab'atayn basin of Yemen, transferable to other sedimentary basins worldwide.