Detection of mineralized zones at an igneous intrusion in the Koutala islet, Lavreotiki, Greece using Sentinel-2 satellite data and mineralogical analysis

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Introduction and Objectives

The Lavreotiki area (Attica, Greece) has been famous for mining since the 5th century BC producing silver and lead contributing to the economic development of ancient Athens during the classic era (Voudouris et al., 2021). The geology and metallogeny of the Lavreotiki area (Attica, Greece) were studied by Marinos and Petrascheck (1956), Skarpelis et al. (2008), Voudouris et al. (2021) among others, including the petrology and emplacement of magmatic intrusions (granitoids). These igneous rocks in SE Attica are the most westerly occurrence of a series of Middle to Late Miocene plutons in the Attic–Cycladic belt that were emplaced following the widespread extension of the Cyclades area (located in the back-arc area of the Hellenic Subduction) and the exhumation of high-pressure rocks (blueschists). A west-dipping major detachment fault has been mapped by Skarpelis et al. (2008) and Scheffer et al. (2016) a few km west of the city of Lavrio with a N-S orientation. In this paper, we present the findings of a joint remote-sensing and laboratory examination of the mineralization zones induced by the intrusion of an igneous body onshore the islet of “Koutala” (Fig.1a) about 5 km NNE of the city of Lavrio. The islet has a form of a rocky promontory, forming a characteristic tombolo feature with the mainland (in geomorphologic terms). Its size is about 240 m in E-W by 40-60 N-S direction. Our objective was to investigate the potential of Sentinel-2 to detect and map minerals which were detected from the laboratory analysis of samples collected in-situ and that they could be linked to Fe-Mn mineralization.

Data and analysis

During a field campaign conducted in 18/7/2022, 18 GPS measurements were collected at the eastern part of the islet in order to delineate the contact between the granitoid and the schists. Furthermore, four samples were collected and analyzed in the laboratory using the XRD method, one of schist, two of granitoid and one of Fe-Mn mineralization identified at the granitoid/schist contact. The XRD analysis detected, among other minerals, the presence of hydrothermal alteration minerals in all samples. In particular, micas and chlorite were found in the granitoid and schist samples while goethite Mn-oxide/hydroxides and micas, were identified in the ore sample. Mn-oxide/hydroxides were also identified in the schist sample (Fig. 1b).

Following the mineralogical study, four minerals, that could be related to this type of alteration, were selected, namely muscovite, chlorite, goethite and Mn-oxides/hydroxides for the spectral study of the Sentinel-2 image. Their spectral signatures were retrieved from the USGS Spectral Library (average grain size 30-70μm) convolved to the Sentinel-2 spectral bands (named hereafter as reference minerals and/or spectral signatures). A Sentinel-2 satellite image was retrieved, acquired in 19/7/2022. The image was georeferenced, atmospherically corrected and subset to the study area. The output reflectance image (pixel values [0,1]) consists of 12 spectral bands, resampled to 10m spatial resolution. Two distinct methods were then applied: (i) band ratios and (ii) absorption feature analysis. Concerning the former, two spectral indices (SIs) were calculated that detect the presence of iron-bearing minerals, namely the ferric iron SI (b4/b3) and the ferrous iron SI [(b12+b8)+(b3/b4)] (van der Meer et al., 2014). In Fig. 2(a,b), the corresponding maps SI maps are shown. Concerning the second method, the center wavelength(s) of diagnostic absorption feature(s) of each reference mineral was identified in its continuum removed spectrum (Clark, 1999). The analysis showed that each one of the reference minerals presented a diagnostic absorption feature that does not exist in the corresponding signatures of all detected minerals in the study area. This feature is centered at 490nm (band 2) for goethite, at 560nm (band 3) for Mn-oxides/hydroxides, at 783nm (band 7) for muscovite and at 865nm (band 8A) for chlorite. We then produced the corresponding absorption maps. In each map, pixels presenting an absorption greater than 0.01 (0 indicates no absorption and 1 indicates full absorption) were retained while the others were masked (Fig. 2c,d,e and f) indicating thus the spatial distribution of the specific mineral on the islet.

Discussion and Conclusions

XRD analyses and both methods of reflectance spectroscopy applied on the Sentinel-2 satellite image were consistent. They both showed significant mineralization due to the igneous intrusion. Hydrothermal alteration to a different degree is observed on both schists and the granitoid on the entire surface of the island. However, it seems that alteration is stronger at the center of eastern part of the islet where the granitoid/schist contact is located.
Figure 1. (a) Location of the study area on the true color composition of the Sentinel-2 image (19/7/2022) (yellow frame). The yellow cross shows the location of the oxides sample collection; (b) XRD plot of the oxides sample.

Figure 2. Mineral thematic maps issued from Sentinel-2 satellite image. (a) Normalized SI ferric iron (goethite); (b) normalized SI ferrous iron (micas, chlorite); (c) absorption map centered at 783nm (muscovite); (d) absorption map centered at 865nm (chlorite); (e) absorption map centered at 490nm (goethite); (f) absorption map centered at 560nm (Mn-oxides/hydroxides). The background image is the true color composite of the Sentinel 2A image used in this study.

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References