INTEGRATION AND ANALYSIS OF REMOTE SENSING AND GIS DATA FOR MAPPING OF OCCURRENCE OF GOSSANS IN THE ANTIFORM SERRA DOS PEDROSAS REGION, PORONGOS COMPLEX, SUL-RIOGRANDENSE SHIELD

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1. INTRODUCTION

Remote sensing applied to mineral exploration constitutes the preliminary phase of the process of discovering areas with potential mineral deposits, which may become mineral reserves. Several studies using the multispectral sensor ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) of the Japanese satellite TERRA have successfully defined areas with mineral potential through the extraction of spectral information using digital image processing techniques (*e.g.*, MORADI *et al.*, 2015; MEKONNEN *et al.*, 2021). The spectral information is analyzed and compared with reflectance and wavelength data of the minerals of interest (GUPTA, 2018). Despite the great advance represented by this set of tools, in southern Brazil its application is insufficient.

The study region is in the southern portion of Brazil, southwestern region of Rio Grande do Sul, in the Porongos Complex geological context. The Porongos Complex (PC) is around 170 km long and 15 to 30 km wide and includes rocks structurally conditioned by a complex system of regional geological structures (faults, folds and shear zones) formed by the Paleoproterozoic basement and supracrustal successions (SAALMANN *et al.,* 2006). The PC comprises four regional antiforms (Godinho, Santana, Capané and Serra dos Pedrosas) (SAALMANN *et al.,* 2006; TAKEHARA & LAUX, 2019). The geology of the Serra dos Pedrosas Antiform region (Figure 1a) is constituted principally by metavolcanic and metasedimentary rocks, gneiss, granitoids. In this area mineral resources were identified in inactive mines (tin) and several occurrences (lead, copper, tin, iron, molybdenum, pyrite, thorium and tungsten) (TAKEHARA & LAUX, 2019). In the Serra dos Pedrosas region, the occurrence of lead mineralization denominate Martelo Perdido was identified and described (JOST, 1981; DRUMMOND, 1986). This mineralization is associated with graphite schist, which generally have an oxidized cover consisting of gossans (DRUMMOND, 1986).

Gossans are materials resulting from oxidation due to the process of weathering and leaching of sulphide minerals, and they occur on the surface indicating the possibility of supergenic mineral deposits (*e.g.*,VELASCO *et al.*, 2013). The gossan's formation requires the evaluation of: (i) topography and slope of the terrain; (ii) vegetation and surface cover exposure; (iii) climate; and (iv) lithology. These variables are important, as they condition and intensify the mechanisms responsible for the formation of gossans, which are the erosive, weather and supergenic processes.

The main goal of this work is to identify areas in the Antiform Serra dos Pedrosas region that have potential for the occurrence of gossans, through the integrated analysis of remote sensing data from the sensor ASTER (band combination), topography, geology and mineral resources through a geographic information system (GIS).

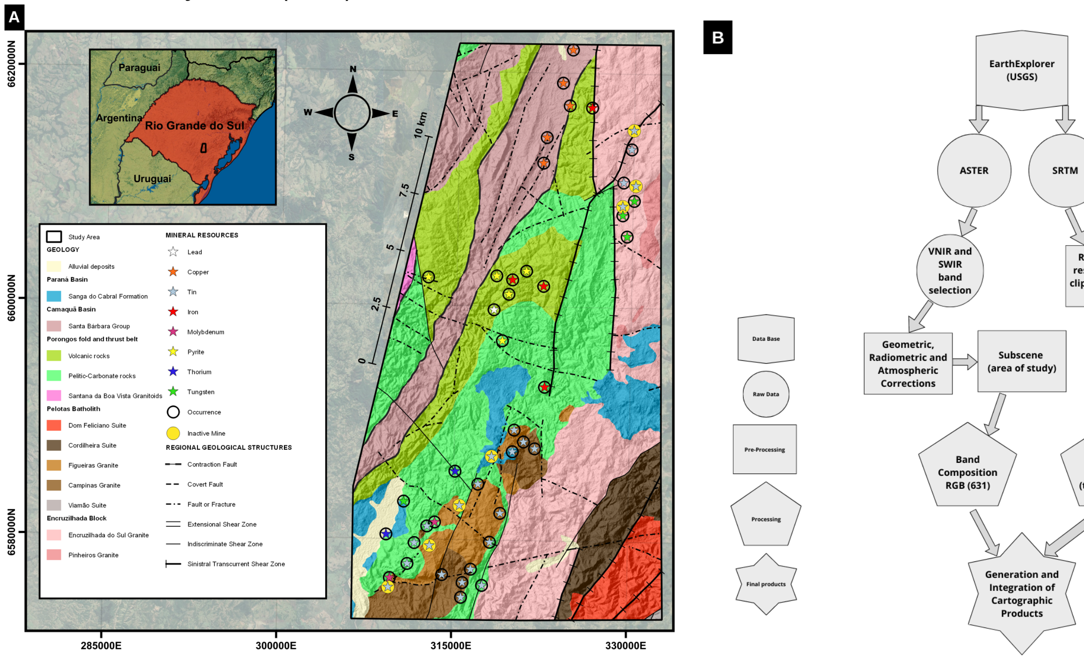

Figure 1: (a) Geological-mineral map and location of the study area; (b) Methodological flowchart. (Source: (a) adapted from TAKEHARA & LAUX, 2019; and (b) the author.)

2. METHODOLOGY

The methodology (Figure 1b), was performed using QGIS software version 3.16 and comprise the topics: i) Database and raw data: the data were obtained through the EarthExplorer platform of the United States Geological Survey (USGS). The two distinct satellite scenes an ASTER sensor scene with partial cloud coverage of 10%, where 3 bands with the following resolutions of the electromagnetic spectrum were selected, bands 1 [spectral range (μm) from 0.52-0.60] and 3 [spectral range (μm) from 0.78-0.86] of the visible and near infrared (VNIR) with 15 meters of spatial resolution, and band 6 (spectral range (μm) from 2.185-2.225) of the short wave infrared (SWIR) with a spatial resolution of 30 meters. And also a scene from the Shuttle Radar Topography Mission (SRTM) sensor with a spatial resolution of 30 meters; ii) Pre-processing: for the ASTER sensor scene, geometric corrections were performed (co-registration, reprojection, resampling of the SWIR spatial resolution to 15 meters), radiometric corrections (conversion of Digital Numbers to Exoatmosphere Reflectance as in ABRAMS; YAMAGUCHI, 1999) and atmospheric [i.e., obtaining Surface pseudo-Reflectance through the empirical Dark Object Subtraction algorithm of CHAVEZ, 1996], and for the SRTM sensor scene, reprojection and resampling to 12,5 meters were performed, in both scenes were applied clips for the study area; iii) Processing: generation of the band composition with the ASTER sensor bands being the RGB triplet, band 6 (SWIR) for red (R), band 3 (VNIR) for green (G) and band 1 (VNIR) for blue (B), and for the SRTM sensor scene the false-color gradient was applied to enhance the topography; iv) Final products: band composition map RGB (631), and digital elevation model (DEM).

The band composition in item III aims to enhance features of the earth's surface through the reflection and absorption of the electromagnetic spectrum of the following materials: (a) band 6 (SWIR) for gossans (also known as iron hats); (b) band 3 (VNIR) for vegetation; and (c) band 1 (VNIR) for host rocks (MORADI *et al.*, 2015; MEKONNEN *et al.*, 2021).

3. RESULTS AND DISCUSSION

The results are displayed in Figure 2, and consist of: (a) band composition map RGB (631); (b) digital elevation model map (topography); (c) geological-mineral map (Figure 1a); and (d) band composition map RGB (631) with suggested areas for mapping.

Figure 2a shows a band composition map RGB (631); band 6 is red represent gossans or hematites (iron oxides), band 3 for green colors represent vegetation and band 1 is blue for host rocks (mafic or volcanic), lighter colors (*e.g.*, white) indicate felsic material. Band 6 of the ASTER sensor has the spectral length correlated with the mineral spectrum of oxidized materials such as the occurrence of gossan, for this reason the pink color has a high sensitivity in the image contrast.

The geomorphology presents hill tops with gentle slopes (Figure 2b), around 80% in the region have a unhealthy vegetation cover, in addition the subtropical temperate climate (high thermal amplitude, humid and with a high degree of precipitation) favors the exposure of geological structures and materials (*e.g.*, gossans).

Figure 2c shows the geological-mineral map of the study area on the layer of the band combination (631). In this map it is possible to observe the correlation between the volcanic rocks of the Porongos Complex with the pink colors of the band combination (Figure 2a). In these rocks it is also possible to identify several associated mineralizations, such as lead, copper, iron, pyrite, molybdenum.

The observed characteristics imply the contribution of processes formed by gossans, corroborating the leaching and chemical weathering. The target areas (Figure 2d) were defined by analyzing the characteristics that were described together, in areas that have volcanic and mafic rocks, where minerals undergo the weathering process in a more intensified way, and also with typical occurrences of lead, copper, iron, pyrite, molybdenum.

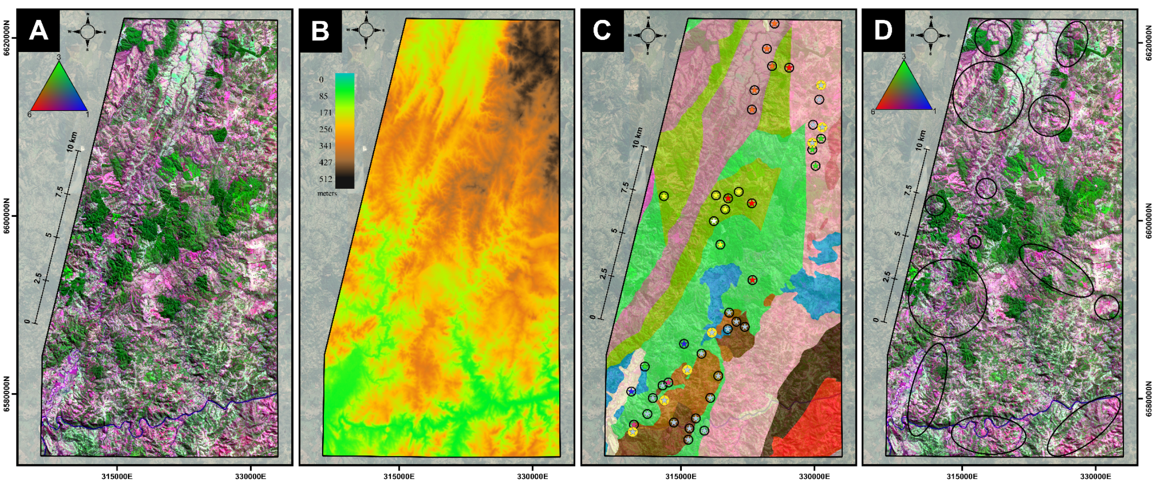

Figure 2: (a) Fe-oxide band composition map (631); (b) digital elevation model map; (c) geological-mineral map on the layer of the band combination (631); (d) Fe-oxide band composition map (631) with suggested areas.

4. CONCLUSIONS

Based on the applied methodology and the results integration , it is possible to conclude that: (1) to suggest, according to the integrated analysis of the geological features; areas with possible occurrences of gossans, associated with mafic and volcanic rocks and occurrences of lead, copper, iron, pyrite, molybdenum of Serra dos Pedrosas region; (2) the band composition (631) is a useful product that can be applied and tested in regions similar to Serra dos Pedrosas, as an auxiliary tool for geological mapping, mainly for the identification of gossans; (3) unpublished cartographic products were developed, which can be improved with additional geochemical and geophysical data, for data analysis more robust; (4) for future studies, field surveys will be carried out in the target areas to validate the results and identify the correlation of the geological materials with cartographic products.

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