Integration of Satellite Remote Sensing Data for Gold Prospecting in Tropical Regions

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This study presents a remote sensing approach for geological mapping aimed at the detection of hydrothermal alteration minerals and structural features for initial stages of gold exploration in tropical environments. The identification of hydrothermal alteration zones and geological structures using remote sensing data are widely and successfully used for initial stages of mineral deposits exploration in arid and semi-arid regions. However, remote sensing study for mineral deposits exploration in tropical environments is not completely implemented due to constraints imposed by tropical climate, including dense to complete vegetation cover, limited bedrock exposures and the persistent cloud coverage. A recent challenge is to utilize the most suitable recent generation of remote sensing data and innovative image-processing approaches for detecting hydrothermal alteration zones and structural features associated with epithermal and polymetallic vein-type mineralization in tropical environments. In this investigation, two gold mining districts in Malaysia were selected as case studies, namely the Bau gold mining district in the State of Sarawak, East Malaysia, on the island of Borneo and Penjom goldfield in the state of Pahang, Peninsular Malaysia. The climate of both study regions is tropical with persistent cloud coverage and very dense vegetation cover. Gold mineralization in these areas is structurally controlled and associated with hydrothermal mineral assemblages. Various types of remote sensing data were tested for hydrothermal alteration mapping and structural analysis associated with gold mineralization in the study areas. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Landsat Enhanced Thematic Mapper$^+$ (ETM^+), Hyperion and Phased Array type L-band Synthetic Aperture Radar (PALSAR) data sets were used in this study. The data sets were processed using the ENVI (Environment for Visualizing Images) version 4.8 software package. A field reconnaissance was also conducted in the both gold mining districts. Preprocessing of the remote sensing data was applied to eliminate the spectral effects of water vapor and aerosols for optical data and speckel suppression for radar data. Atmospheric correction was applied to the ASTER, ETM^+ and Hyperion data sets using FLAASH algorithm. Speckel suppression was implemented to PALSAR data using adaptive filtering. Processing of the image data was performed using some developed methods that could reduce or remove the spectral effects of vegetation to detect alteration mineral zones and geological structures associated with gold mineralization in the study areas. Vegetation, mineral and lithological spectral indices have been applied to ASTER bands. Directed principal components (DPC) analysis was implemented to four special band ratio images of ETM^+, including 3/1, 4/3, 5/7 and 5/4. Linear spectral unmixing (LSU) was applied to visible and near-infrared radiation (VNIR) and shortwave infrared (SWIR) bands of Hyperion. Directional filters were applied to PALSAR data. N-S, E-W, NE-SW and NW-SE principal directional filters with a 7*7 kernel were used.

In the present investigation, it is observed that the integration of satellite data could provide comprehensive geological information for initial stages of gold exploration in tropical environments. Despite the spectral effects of vegetation on lithologic and mineral indices, they were capable in lithological and alteration mapping using ASTER bands in tropical environments. Results of the DPC analysis of four appropriate ETM^+ band ratios produced DPC images, allowing the removal of spectral effects of vegetation from ETM^+ data and the detection of iron-oxide-rich rocks or gossan and clay-rich zones. Results derived from VNIR and SWIR bands of Hyperion represented iron oxide/ hydroxide and clay-rich zones using LSU technique.

Numerous tectonic lineaments with consistent variations in trend, length and density associated with different litological units outcropping in the study areas were detected using PALSAR data. Geological tectonic structures such as faults, fractures and anticline were detected in the PALSAR resultant image derived from directional filters (N-S, NE-SW, and NW-SE). Structural features associated with fault-related rocks and hydrothermal alteration zones were identified as highly potential areas for prospecting gold mineralization. Of particular importance to exploration are the intersection of ENE and NNE structure element in the Bau area and N-S, NE-SW, NNW-SSE and ESE-WNW mineralized trends in the Penjom region, respectively. Results of this study demonstrate the applicability of integrated satellite remote sensing data to assist more feasible gold exploration plans in the study regions and reduction of exploration costs for epithermal or polymetallic vein-type mineralization in tropical environments.