Hydrothermal mineral mapping using Landsat 7 ETM$^+$ Bands and GIS techniques in Banyo, Adamawa-Cameroon.

13th GEOMUNDUS CONFERENCE

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Abstract. The purpose of this research paper is to delineate several hydrothermal mineral deposits in Banyo area using remotely sensed data and techniques. To achieve the best results in this research, false color composite, PCA, and BR techniques are used. To clearly distinguish the lithologies of SE Banyo area, Landsat 7 ETM+ image processing algorithms such as false color composite (4, 7, and 2), Crosta PCA (PC b4 and PC b5), Abrams (5/7, 3/2, and 4/5 in RGB), Kaufman (7/4, 4/3, and 5/7 in RGB), and Chica-olma (5/7, 5/4, and 3/1 in RGB) band ratios techniques for hydrothermal alteration mineral mapping.

Keywords. Remote sensing, Landsat 7 ETM+, hydrothermal alteration.

1. Introduction

Remote Sensing for geological and mineral prospections, is primarily concerned with mapping of lithological features and mineral deposits. It is a cost-efficient, time-efficient, and efficient means of gathering satellite and airplane data from difficult locations such as hilly, forest, and rough terrains observed in dry and semi-arid countries where field work is scarce (Sabins, 1997; El Kati, 2018). Remote sensing has become increasingly important in identifying rock contacts and structures, with the availability of high-quality spectral and high resolution data enabling researchers to make more detailed and interpretable images.

Various valuable metal deposits, according to Eugster (1985) and Sillitoe (1996), are geographically, chronologically, and genetically linked with diverse forms of granitoids. The majority of wolfram, tin, and rare-earth metal deposits (Nb, Be, Zr, Ta, Li, Ga), as well as about 10% of iron, gold, zinc, lead, silver, and uranium deposits, have been linked to granitoids (Sillitoe, 1996). Ghodsi et al. (2016) and Fozing et al. (2021) showed that calco-alkaline i-type lavas may carry and accumulate valuable minerals such as gold, copper, iron and molybdenum, whereas s-type lavas include aqueous fluids including tin, wolfram, and precious minerals. Deposits of rare-earth elements, uranium, and molybdenum are ore systems linked to A-type granitoids. (Pirajno, 2009).

2. Geology of the research area and lithological context

The research area (Fig. 1) belongs to the Western Cameroonian domain of the CAFB, precisely in the edge of the NE-SW Tchollire-Banyo fault zone. The earliest geological investigations conducted by Koch (1953) recognized in the Banyo area: (i) syn-to late-tectonic hornblende-biotite granites (HBG); (ii) Charnorckites, syenites and monzonites; (iii) Hornblende biotite±garnet (HBGrt) orthogneisses; and (iv) Migmatitic gneiss of hornblende biotite ± garnet having layers of garnet kyanite-biotite metapelites, and garnet-(cpx/opx)-plagioclase metabasites (Fig. 1).

The research region (Figs. 1) comprises HBG intruded in pre-Pan-African HB orthogneiss basement. HBG outcrops as flagstones and/or bowls in Banyo and Ndjé localities. It contains decametric to metric size enclave of HB orthogneiss. It’s grey in color; average to coarse-grained, containing HB, Bt, Pl, and Qtz in a porphyry texture. Zircon, and oxides are rock-forming mineral (regularly included in hornblende). HB orthogneiss forms mostly the common petrographical units of the study region. It appears as flagstone displaying grey to dark grey hue, granoblastic structure, and preferred mineral orientation. It is made up of HB, Bt, Pl, Qtz, and K-Feldspars while oxides constitute commonly the auxiliary phase.

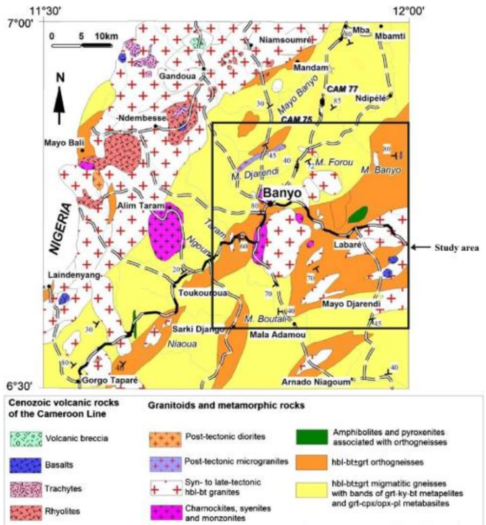

Figure 1: Geologic sketch map of research area in the North Cameroonian Domain adapted from Koch, P. (1953) reconnaissance geologic map.

3. Materials and Methods

3.1. Materials

For this investigation, Landsat 7 ETM+ imageries (path 185, row 55, acquisition date 17th November 2020) of Banyo area were chosen and downloaded under favourable climatic conditions from the USGS and NASA official website. Geometric and radiometric corrections adjustments were applied to the Landsat 7 ETM+ imageries.

3.2. Methodology

The primary goal of employing remote sensing techniques was to restrict the search region, therefore reducing fieldwork time and costs. Fig. 2 summarizes the approach flowchart of the image processing algorithms. Geometric corrections and sub setting of Landsat 7 ETM+ images were done to improve the visual interpretation using ENVI 4.7. The digital image processing techniques (including false color composite enhancement, PCA and band ratio) for Landsat 7 ETM+ images were processed using ENVI 4.7 to differentiate among the rock natures and identify hydrothermal minerals inside the research region.

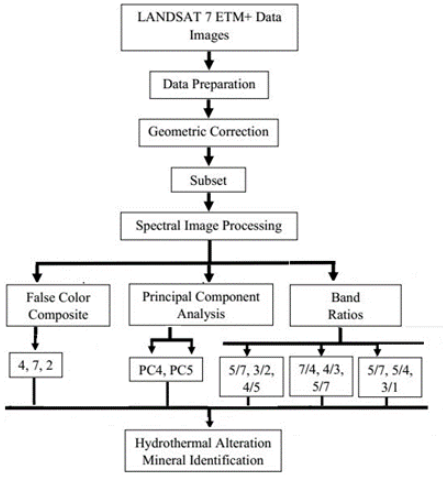

Figure 2: Methodology flowchart.

3.2.1. Alteration Mineral mapping

The CC, PCA (Crosta method), and BR approaches were utilized to target hydrothermal alteration regions and altered minerals. The approaches were chosen because some minerals linked to hydrothermal process, like hydroxyl containing minerals (clays, micas), ferrous oxide and iron bearing minerals (haematite, goethite, jarosite), exhibit diagnostic spectrum characteristics which permit their recognition (Clark et al., 1990; Fraser, 1991).

To define the hydrothermal alteration regions, the CC method was used by integrating bands in the visible and infrared radiations and utilizing RGB colors (Crosta and Moore, 1989). The Crosta approach (feature-oriented principal component selection) was employed to detect the diagnostic characteristics of hydroxide, iron and carbonate bearing metals (Aydal et al., 2007; Liu et al., 2011).

4. Result and Discussion

A remote sensing method combined with GIS was utilized in this work to map the mineral composition of the Banyo area using multi-spectral imageries with medium to high spatial resolution.

Several studies have demonstrated the possibility of mapping hydrothermally changed zones using remote sensing methods (CC, PCA and BR). Hydroxide and ferrous metals can be seen on LANDSAT7 ETM+ PC band (excluding B6; Rejith and Sundararajan, 2019). Figure 3 illustrated hydrothermal alteration areas displaying green color FCC of Landsat 7 ETM+ b4, 7 and 2 in RGB.

Landsat 7 ETM+'s PC 4 band exhibit greater factor loading than B5 and 7, however in the negative sign (Table 1); enhancing hydroxide metals and displaying bright pixel (Fig. 4a). PC5 band of Landsat 7 ETM+ possesses greater factor loading than B1 and 3; as a result, it accentuates ferrous metals, displaying a dark pixel in the greyscale image (Fig. 4b).

BR imageries are well-known for enhancing spectral differences between bands included as in ratios operations, and they've been effectively used in the identification of alterations zones (Segal, 1983). Ferrous and clay metals are recognised once the Abram, Kaufman, and chica-olma ratios are applied to LANDSAT7 ETM+ bands (Mia & Fujimitsu, 2012). In this study, the Abram ratios 5/7, 3/2, and 4/5 in RGB were used to depict the hydrothermally changed ferrous oxide as greenish (Fig. 5a) and clay metals as purple. By using the Kaufman ratios 7/4, 4/3, and 5/7, metals including ferric ions, vegetation areas, and hydroxide metals display RGB colors, respectively (Fig. 5b). The changed clay metals appear as reddish, ferric ions as greenish, and Iron oxide as blue, with Chica-olma ratios 5/7, 5/4, and 3/1 in RGB respectively (Fig. 5c).

Table 1: Landsat 7 ETM+ bands PCs eigenvectors and eigenvalues loadings.

Eigenvector	Band1	Band2	Band3	Band4	Band5	Band7	Eigenvalues	Variance %
PC1	0.385555	0.315252	0.304661	0.560376	0.508766	0.293736	2349.462	93.77
PC2	-0.405306	-0.214327	0.054578	-0.436069	0.627569	0.450349	93.930099	3.75
PC3	0.517975	0.344933	0.343504	-0.677176	-0.140243	0.128425	43.094645	1.72
PC4	0.471490	-0.066356	-0.673020	-0.165117	0.445923	-0.306965	12.616784	0.50
PC5	0.252902	-0.215767	-0.410311	0.094436	-0.357604	0.764416	4.729980	0.19
PC6	0.364025	-0.827492	0.406076	0.032775	0.030308	-0.125910	1.650596	0.07

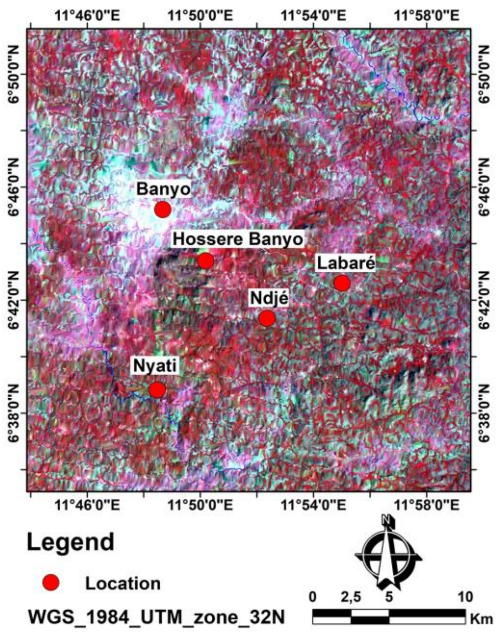

Figure 3: Landsat 7 ETM+ FCC imageries (4, 7, & 2) in RGB showing hydrothermal alteration zones (green color) of the study area.

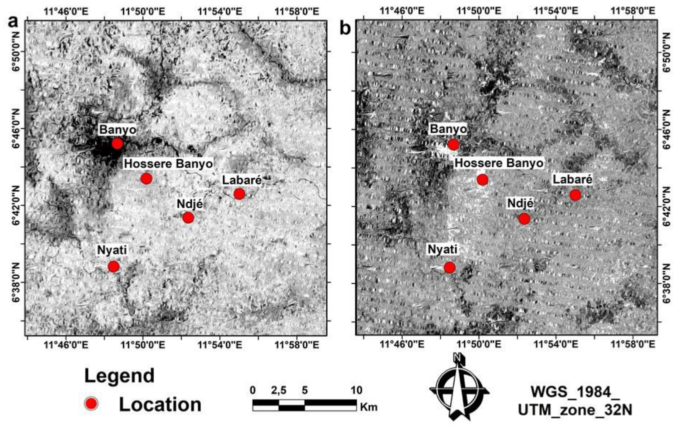

Figure 4: (a) Landsat 7 ETM+ PC 4 band showing the hydroxyl minerals (bright pixels). (b) Landsat 7 ETM+ PC 5 band representing the iron oxide minerals (darker pixels).

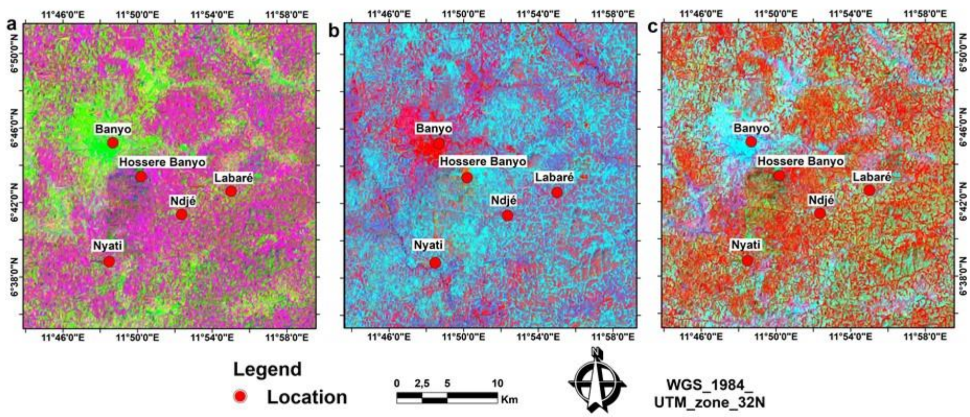

Figure 5: (a) Abram band ratios (5/7, 3/2, and 4/5 in RGB). (b) Kaufman band ratios (7/4, 4/3, & 5/7 in RGB). (c) Chica-olma ratios (5/7, 5/4, & 3/1) in RGB of Landsat 7 ETM+ for analyzed altered mineral deposits of the research area.

5. Conclusion

This study focuses on using remote sensing techniques like FCC, PCA, and BR for hydrothermal mineral identification of the research area. The following conclusions were drawn:

(a) Field data, false color composite (4, 7 & 2) and rand ratio images of Landsat 7 ETM+ (5/7, 3/2 & 4/5, 7/4, 4/3, & 5/7 and 5/7, 5/4, & 3/1 in RGB) enable to differentiate hydrothermal minerals.

(b) Analysis of eigenvalues obtained from PCA conducted on Landsat 7 ETM+ data shows that, hydroxide, and ferrous metals are observed in PC band 4 and 5 respectively.

This work demonstrates that, Landsat 7 ETM+ combined with field informations are suitable to differentiate between different lithologies that provides an important basis for mineral exploration.

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