ISSN XXXX XXXX © 2018 IJESC

Research Article Volume 8 Issue No.1

Hydrothermal Alteration mapping using Remote Sensing and GIS at the Prestea Concession of Golden Star Bogoso/Prestea Ltd, Ghana

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Abstract:
Exploration for gold involves identification and mapping of predictive features which have spatial relationship with the type of gold deposit sought for. Hydrothermal alterations are one of such features that control the mesothermal gold mineralisation within the Prestea area in the Western region of Ghana. Remote sensing and reprocessing techniques using Geographic Information Systems (GIS) offers an attractive strategy tomap this hydrothermal alteration which provides evidence of gold mineralisation within the study area. The research aimed at mapping hydrothermal alterations within the Prestea concession of Golden Star Bogoso/Prestea Ltd, in the Prestea Huni Valley District of the Western Region of Ghana. Landsat 7 ETM + data were processed through band ratioing and principal component analysis to highlight the hydrothermal alterations relevant to gold mineralisation within the study area. The TM band ratios 5/7, 3/1 and 5/4 were used to highlight clay mineral, iron oxide and ferrous oxide mineral alterations respectively. The results of the image analysis in ENVI software was integrated in the ArcGIS environment and geoprocessed to obtain the alteration map of the Prestea concession. The mineral alterations mapped using the TM band ratio 5/7 is the most abundant alteration mineral within the Prestea concession.

Keywords: Ghana, GIS, Hydrothermal Alterations Mapping, Image Processing, Prestea, Remote Sensing

I. INTRODUCTION

Hydrothermal alterations refer to mineralogical, textural, and compositional and colour changes in rocks resulting from interaction of the rocks with high temperature, chemically potent ascending fluids. This process leads to the formation of mineral deposits, replacement of existing minerals and even realignment of mineral grains. Alterations have a spatial temporal relationship with mineral deposits and are very good guides to mineralization in exploration. Mineral deposits are usually associated with hydrothermal alteration of the neighboring rocks, the extent and style of the alteration depicts the type of mineral deposit [1].

Laboratory studies of the near-infrared spectral characteristics of the minerals and rocks show that mineral species associated with hydrothermally altered rocks can be identified [2-4]. Host rocks of hydrothermal mineral deposits invariably indicate the results of their chemical interactions with hydrothermal fluids that resulted in mineral deposition [5].

Alteration of this sort commonly results in the formation of a halo around the mineralisation, giving an exploration target considerably larger than the deposit itself. The characterization and delineation of hydrothermal alteration can therefore be of important value in mineral exploration and assessment of new targets. In locating the main outflow zones of hydrothermal systems, which may lead to the recognition of mineral deposit, the spatial distribution of hydrothermally altered rocks is key [1].

According to Rajesh [1], the colour of the rock is a good guide to the identification of these minerals. The presence of iron oxides rocks usually gives red, brown, and orange or yellow colour and the presence of clay minerals usually gives pale colour (yellow, violet, green, and beige). Landsat TM images are suitable for hydrothermal mineral identification because of the presence of mid- infrared bands in which the characteristic spectral features of most hydrothermal minerals are present.

II. MATERIALS AND METHODS

A. Study Area

The Prestea concession is cited in the Western Region of Ghana about 200 km from the capital Accra and 50 Km from the coast of the Gulf of Guinea with latitude 5.4373^0 N and longitude 2.1401^0 W. Bogoso and Prestea comprise of a collection of connecting mining concessions that together cover a 40 km section of the Ashanti gold district in the central eastern section of the Western Region of Ghana. Entry to the Prestea concession by road is a six-hour drive from Accra through the port city of Takoradi.

The road linking Accra to Prestea is paved. There are airports at Kumasi and Takoradi, providing daily services to the international airport situated at Accra. Kumasi is situated about a three and half hour drive from Prestea. Road surfaces in the area vary from poor (on the section between Bogoso and Prestea) to good (Accra to Bogoso). The topography of the area within which the Prestea concession is located generally slopes in a northern direction towards the Ankobra River. It can be described as gently rolling, punctuated by a number of low hills and rises. Series of NE-SW trending sub-parallel ridges, approximately 2 km wide, dominates the eastern part of the Prestea concession. These ridges range in height from 150 m to 195 m. The western part has lower hills generally ranging in height between 70 m and 110 m.

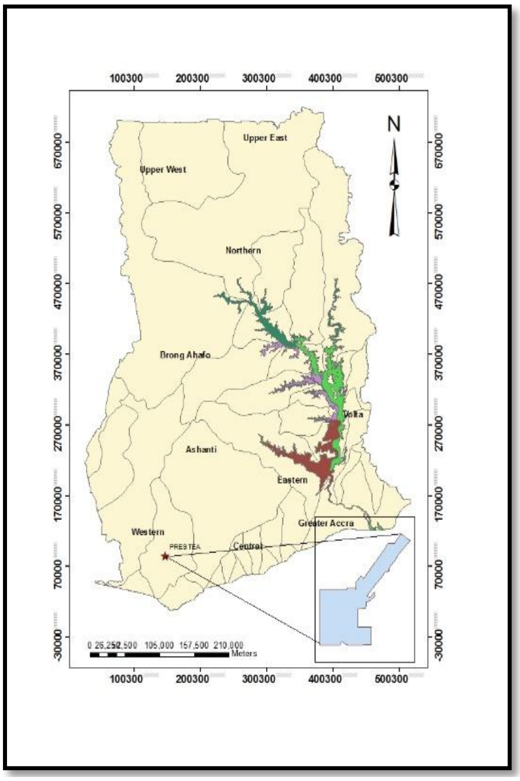

Figure.1. Location of the study area

B. Geology of the study Area

The Prestea concession lies within the southern portion of the Ashanti Greenstone Belt along the western margin of the belt. Rock assemblages from the southern area of the Ashanti Belt were formed between a period spanning from 2,080 to 2,240 Ma, with the Sefwi Group being the oldest rock package and the Tarkwa sediments being the youngest. The Ashanti Belt is host to numerous gold occurrences, which are believed to be related to various stages of the Eoeburnean and Eburnean deformational events.The geology of the Prestea concession is divided into three main litho-structural assemblages, which are fault bounded and steeply dipping to the west. This suggests that the contacts are structurally controlled and that the litho-structural assemblages are unconformable. From the eastern footwall to the western hanging wall, these packages are represented by the Tarkwaian litho-structural assemblage, the tectonic breccia assemblage, composed of sheared graphitic sediments and volcanic flows, and the last assemblage is composed of undeformed sedimentary units of the Kumasi Basin, which is located to the west of the Ashanti fault zone. The Tarkwaian litho-structural assemblage to the east is mostly composed of sandstone, pebbly sandstone, and narrow conglomerate units. Bedding and sedimentary textures have been observed sporadically, and in most cases they have been obliterated by hydrothermal alteration and deformation at the proximity of the Ashanti fault. The litho-structural assemblage overlying the Tarkwaian sediments is a tectonic breccia bounded to the west by the Kumasi sedimentary basin. The tectonic breccia is a polygenic assemblage, composed of various rock types such as volcanic rocks, volcanoclastics, sediments of the Birimian Supergroup, and sparse Tarkwaian sedimentary slivers. Volcanic lenses have been divided into two units based on their alteration pattern: weakly altered mafic volcanic rocks are characterized by a distal chlorite/calcite alteration pattern, while strongly altered mafic volcanic rocks are characterized by proximal silica/ sericite/ Fe-Mg carbonates alteration pattern. These strongly altered mafic volcanic lenses are generally located at proximity to the Main Reef Fault or bounded by second order footwall faults. The tectonic breccia assemblage is believed to have been the focal point of the post thrusting Eburnean deformational events (syn-D3 to syn-D5), therefore, primary textures, whether synvolcanic or syn-sedimentary, have only been locally preserved. Volcanic lenses are intercalated with sheared graphitic sedimentary horizons which represent strained and brecciated sequences of siltstones, mudstones and greywacke units affected by pervasive graphitic alteration. Primary textures are generally overprinted and obliterated by deformation, but bedding has locally been preserved. The most western litho-structural assemblage underlying the Prestea concession consists of relatively unreformed to weakly strained sedimentary rocks of the Kumasi basin. The assemblage is composed of a series of flyschoid sequences where the most common units found are argillites, mudstones, siltstones and greywackes, which are all commonly referred to as phyllite in Ghana. Several syn-sedimentary textures have been observed such as bedding planes, graded bedding and cross-bedding. Chert horizons are locally intercalated within the flysch sequence, but appear to lack lateral continuity. The major lithologies are illustrated in Figure 2.

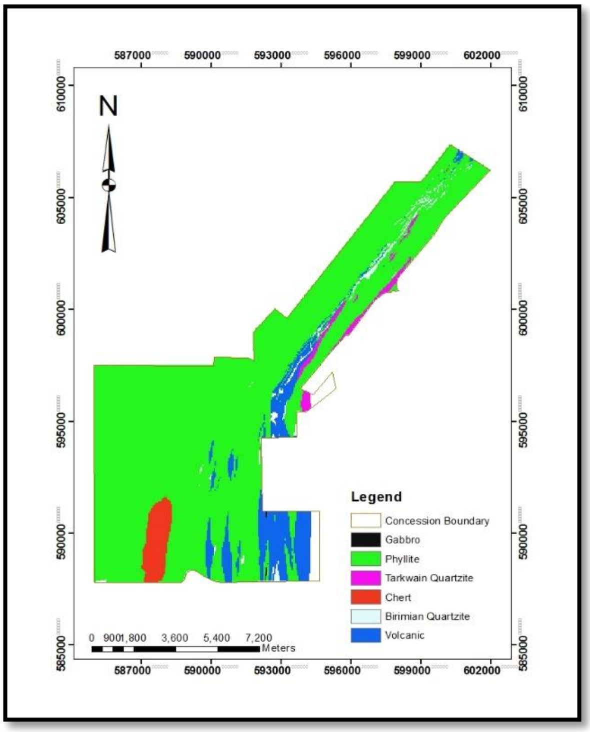

Figure.2. Major Rock types within the study area

C. Materials

The materials used in this research work are listed below.

1. Remote sensing image (Landsat 7 ETM +) of the study area. (The image was acquired on January 15, 2002. The image has WRS path of 196 and WRS row of 56)

D. Software

This study made use of ESRI ArcGIS version 10.4.1. And ENVI 4.7 software

E. Method

Pre-image processes such as stacking and subseting were performed on the ETM+ image to obtain the image of the study area. Image enhancement techniques such as band combination, band ratioing, and principal component analysis were performed on the image of the study area for the extraction of hydrothermal alterations relevant to gold mineralisation within the study area. The first step in the extraction of the alterations was to use the software defoliant technique to enhance the spectral signatures of these alteration minerals using band ratioing. Clay minerals alterations were generated using the TM band ratio 5/7. TM band ratio 5/4 was used to highlight alteration patterns for ferrous minerals whiles TM band ratio 3/1 was used to highlight iron oxide mineral alterations within the study area. The ENVI software was used for the band ratioing. The pixel values of the individual band ratios were resample as a geotif grayscale image to enhance data representation. The individual band ratio image files were stacked together to obtain a single image file of alteration patterns. The various alteration anomalies or signatures were extracted as shape file using density slicing tool in ENVI software. The extracted alteration signatures or anomalies were imported into ArcMap software and processed to obtain the alteration map of the study area.

III. RESULTS AND DISCUSSION

The results obtained from the various image processing and geoprocessing techniques are presented in this sub-section.

A. Results of Layer Stacking and Subseting

The Figure3 shows the results of layer stacking and subseting of the Landsat ETM+ image to obtain the image of the study area.

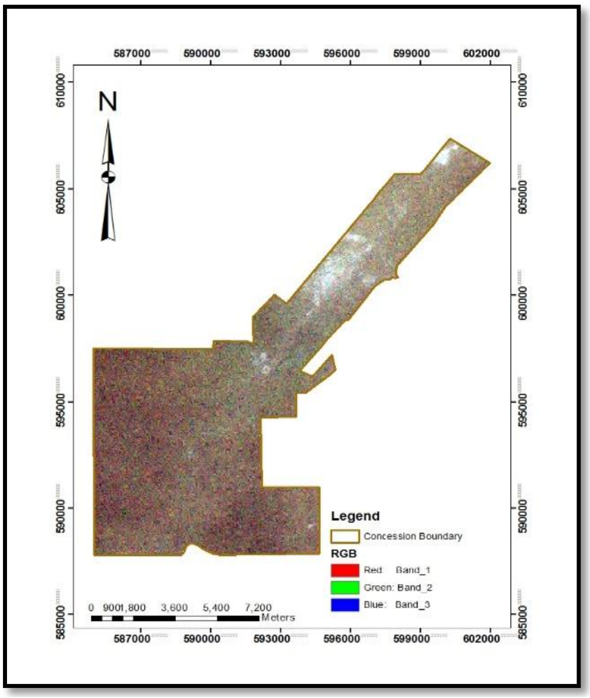

Figure.3. Landsat 7 ETM + image of the study area in RGB combination

B. Results of the image enhancement techniques to map the hydrothermal alterations in the study area

Figures 6, 7, and 8 are the outcome of the various band combinations and ratioing of the Landsat ETM+ image of the study area to map the hydrothermal alteration signatures for ferrous minerals, clay minerals and iron oxide minerals respectively.

C. Clay minerals alteration

Figure4 shows the TM 5/7 image ratio of the Prestea concession, highlighting clay mineral alteration. Areas with high DN values denoted by bright tones indicate clay mineral alterations which correlate to altered rocks. The clay minerals may be illite, montmorillonite and kaolinite. These minerals show high reflection in TM band 5 and very high absorption in TM band 7. The clay minerals indicate the presence of rocks with lot of clay minerals within the study area. From Figure. 2, it can be observed that, the most abundant rock within the study area is phyllite, the phyllite rocks have illite as part of theminerals making up the rock. Also, the parent rock of phyllite (shale) is clay-rich in composition hence high abundance of clay minerals within the study area. The clay minerals have spatial relationship with hydrothermal gold deposits. According to [6-8], the TM band ratio 5/7 also highlights carbonate minerals (calcite and dolomite), Fe-OH bearing minerals (epidote), and Mg-OH bearing phyllosilicate minerals (chlorite, talc, and serpentine). In view of this, the area with bright tone in Figure 4 may not indicate only clay minerals but also carbonate minerals, chlorites, epidote, talc and serpentine.

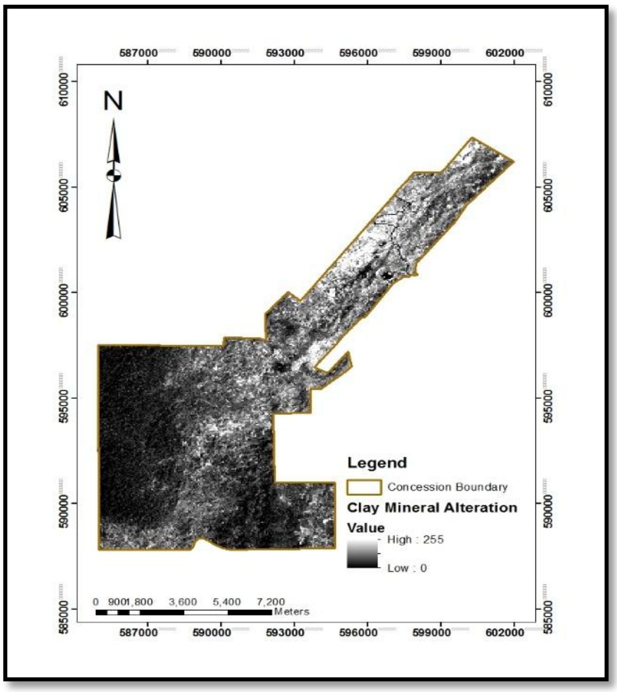

Figure.4.Clay minerals alteration highlighted by dividing band 5 by band 7

D. Iron oxide mineral alteration

A Landsat TM 3/1 ratio was used to highlight areas that have absorption in Landsat band 1 (blue wavelengths) relative to band 3 (red wavelengths) as shown in Fig. 7 to map Iron Oxide minerals alteration. Iron oxide minerals have high absorption in TM band 1 and higher reflectance in TM band 3. Iron-stained hydrothermally rocks are shown by areas having higher Digital Numbers (DNs) as shown in the TM 3/1 ratio image (Figure 5). The areas with high DN values are shown in bright tones and they correlate to altered rocks. The iron oxide minerals as indicated by areas of brighter tones in Figure5 may be hematite alteration, jarosite alteration and goethite alteration. These minerals are formed by the oxidation of sulphide minerals (pyrite, chalcopyrite) within the rock units in the area. The abundance of these mineral alterations as indicated in Figure5 may correlate with the presence of pyrites and chalcopyrite within the rock units in the area. These alteration minerals may havespatial relation with gold mineralisation within the area. Also, according to Rockwell [9], the TM 3/1 ratio is analogous to the ASTER 2/1 ratio and is normally used to highlight iron oxide minerals. Jarosite normally have deeper absorption at band 1 compared to goethite. Most hematite show less band 1 absorption compared with jarosite.

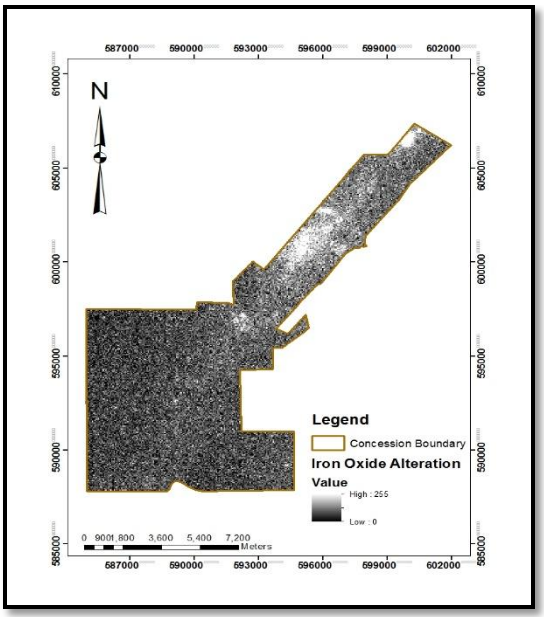

Figure.5. Iron oxide minerals alteration highlighted by dividing band 3 by band 1

E. Ferrous mineral alteration

Ferrous minerals produce a broad VNIR absorption at Landsat band 4 relative to 5. A Landsat TM **5**/**4** ratio was used to highlight areas with ferrous mineral alteration as shown in Figure 6. Areas with high DN values indicated with bright tones in Figure 8 highlights ferrous mineral alteration and therefore correlate with altered rocks. Rockwell [9], indicated that, the TM 5/4 is analogous to the ASTER (**1**+**4**)/(**2**+**3**) ratio. The TM 5/4 ratio also highlights concentrations of coarse grained iron oxides that are typically distinguished by deep crystal-field absorption in band 4 relative to band 5.

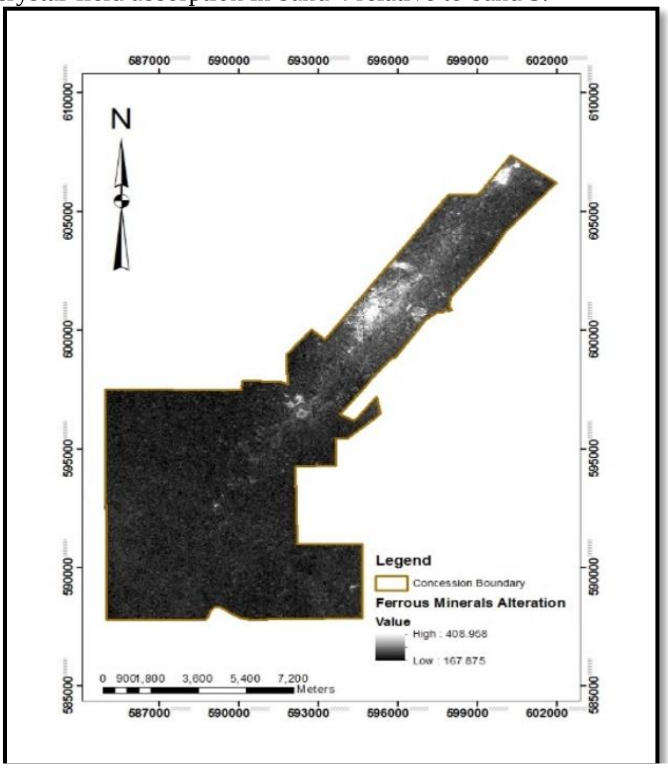

Figure.6. Ferrous mineral alteration highlighted by dividing band 5 by band 4

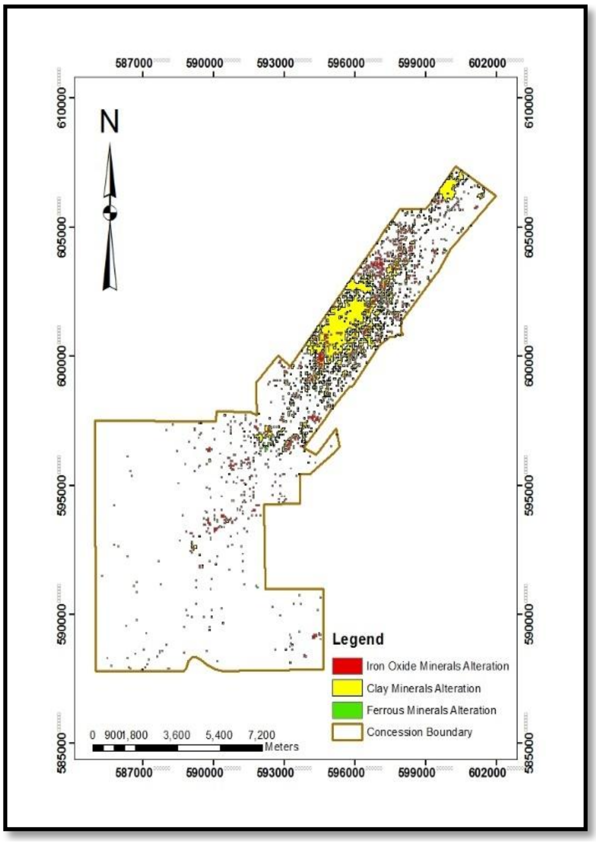

Figure.7. Alteration map of the Prestea concession

Figure 7 shows the combined alterations mapped within the study area. The red colour denotes iron oxide alterations, yellow colour indicates clay mineral alterations as well as carbonate minerals and chlorite alterations, and the green colour shows the ferrous mineral alterations. From Figure 7, it can be observed that clay mineral alterations are the abundant alteration patterns within the study area. Also, most of the alteration patterns associated with gold mineralisation is highly concentrated at the NE portion of the study area

IV. CONCLUSION

Based on the results and analysis, an alteration map of the Prestea concession has been produced through the application of Remote Sensing and GIS. The study outlines the clay mineral alterations, carbonate and chlorite alterations which were mapped using the TM ratio 5/7 to be the most abundant alteration mineral within the study area. This demonstrates the usefulness and effectiveness of the application of Remote Sensing and GIS in mapping of predictive evidence for mineral exploration. The use of Landsat ETM+ as the source of information for mapping the hydrothermal alteration was very successful.

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