



Gold Potential Mapping using Remote Sensing and GIS at the Prestea Concession of Golden Star Bogoso/Prestea Ltd, Ghana

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Abstract:

Remote sensing and data integration techniques using Geographic Information Systems (GIS) offers a less expensive and attractive strategy in mineral exploration, notably for identification of target areas in the screening phase of a new mineral exploration project. Exploration companies in Ghana have not embraced and explored this powerful tool. The research aimed at integrating remote sensing data and field data through a knowledge driven approach in a Geographic Information System (GIS) environment to map areas of potential gold mineralization at 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 to highlight the hydrothermal alterations relevant to gold mineralization within the study area, as well as extraction of lineaments using the automatic extraction method. The alterations and lineaments, together with geological structures mapped during field mapping, soil geochemical data, and the lithologies were reclassified into a common suitability scale and the results integrated through weight overlay in a model built using ArcGIS's model builder tool to produce the gold potential map of the study area. A total of 995 known gold deposits were used for validation. The gold potential map outlined an area of 39.40 km² which represented 33.94% of the total area as having high potential or favorability for gold mineralisation. The results of the study indicate that the best predictor for gold mineralisation within the study area is geological structures followed by hydrothermal alterations.

Keywords: Ghana, GIS, Gold Potential Mapping, Prestea, Remote Sensing

1. INTRODUCTION

A company that implements mineral prospection or exploration programs usually carries out work at many different scales (from small to large) with the objective to release barren and to retain potentially mineralized areas, out of initially acquired exploration areas, until areas worthy enough for drilling are discovered. During these mineral exploration programs, abundant data of different types is generated. Various datasets from geological, geochemical, geophysical surveys, different remote sensing (RS) data (including satellite images and aerial photographs) topographic data, have to be managed and integrated to define target areas. In the past, such integration of multiple datasets was done via analogical methods, overlapping different layers of information by means of transparencies in an attempt to discover relationship between layers. Today this integration of datasets can be done digitally using a Geographic Information System (GIS). The use of GIS and remote sensing in mineral exploration has the following advantages over the conventional method: Exploration works can cover large areas at a reduced cost and a fast rate when using remote sensing and GIS as compared to the conventional method. Various exploration datasets from geological, geochemical, geophysical survey as well as data from remotely sensed images can be combined readily when using remote sensing and GIS as compared to the conventional method.

A. Previous Work on Mineral Exploration

Various authors have researched into the usage of GIS and Remote Sensing in the field of mineral exploration. Kwang *et al.*, [1] used remote sensing methods and geographic data

analysis through GIS in a mineral exploration context to identify gold-rich potential areas in the Birim North District of the Eastern Region of Ghana and established that the best predictors were the geochemical, geophysical factors and lineament, while alteration is the least predictor. The gold potential map delineated 158 km² as gold potential area, representing 32% of the entire area of 497 km² as favorable for the occurrences of gold deposits. Chandrasekar *et al.*, [2] used multispectral satellite data to map out the heavy mineral deposits in South Tamil Nadu Coast of India. Minerals which show much variation in reflectance at different spectral bands mapped out. This has opened up new areas for inland heavy mineral exploitation and leads to eco-friendly mining of natural resources along the study area. It also showed the high potential of multispectral satellite data for exploration and mapping of mineral resources. Xianfeng *et al.*, [3] in their work mapped lithologies related to gold deposit in the South Chocolate Mountains area, California using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) radiance data and then compared different methods for extracting mineralogical information from ASTER data. Andrada-de-Palomera, [4] used Landsat ETM+ and ASTER image to delineate the potential gold areas in the Deseado Massif, Southern Argentina; followed by extracting the mineralogical indicative features from the ASTER data and the indicative hydrothermal alteration from Landsat data. These data were combined with other geologic data like lineaments. It was apprehended that, the weight of evidence approach was successful to produce mineral predictive maps necessary to investigate the spatial association of Low Sulfidation Epithermal Deposit (LSED) with lithology, structures and hydrothermal alterations as well as to deduce some information

related to the genesis of LSED in the Deseado Massif. He also concluded that Simple band ratios (5/7 for Landsat and 4/6 for ASTER) proved to be more suitable methods than principal component analytical techniques to map clay alteration at regional to district scale using Landsat and ASTER data. According to him, a great advantage of using ASTER over Landsat data is the ability to map silica abundance, which is an important indicator for LSED in the Deseado Massif.

B. Knowledge Driven Approach

Knowledge-driven approach in mineral potential mapping is a more subjective approach and relies on the modeler's input, or expert opinion or knowledge concerning mineralisation to provide the relative weightings assigned to the different evidential themes. These methods may be more appropriate for lesser to unexplored landscapes (Greenfield areas) where there are few known deposits of the type sought [5]. Examples of knowledge-driven model types include; Fuzzy Logic, Boolean overlay and Weight overlay.

C. Weight Overlay

A group of methodologies applied in optimal site selection or suitability modeling is referred to as overlay analysis. It is an approach for assigning a common scale of values to varied and dissimilar inputs to create an integrated analysis. Suitability models define the best or most preferred locations for a specific phenomenon. Overlay analysis most often entails the examination of many different factors. For instance, selecting a site suitable for gold mineralisation means assessing parameters relevant to gold mineralisation within the locality such parameters may include lithology, hydrothermal alterations, and geological structures among others. These data exist in different rasters with different value scales. A raster of hydrothermal alterations (DNs) cannot be added to a raster of distance to geological structures (meters) and obtain a meaningful result. More so, the factors in the analysis may not have equal importance. It may be that hydrothermal alteration has good correlation to gold mineralisation than the distance to geological structures. The importance of these parameters are determined by the modeler and shown as weights which sum up to 100% or 1.

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° N and longitude 2.1401° 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.

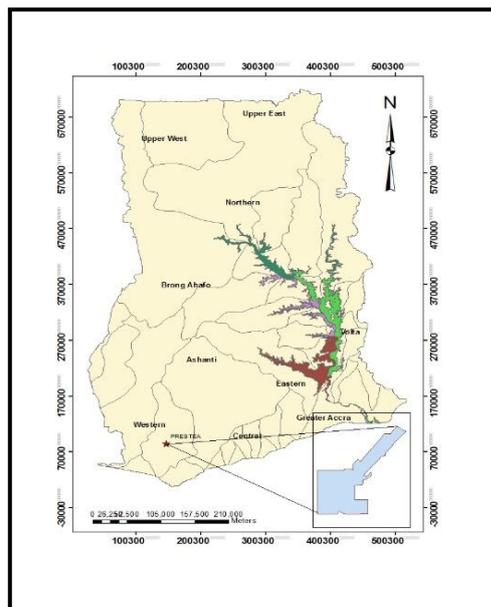


Figure.1. Location of the study area

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 syn-volcanic 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.

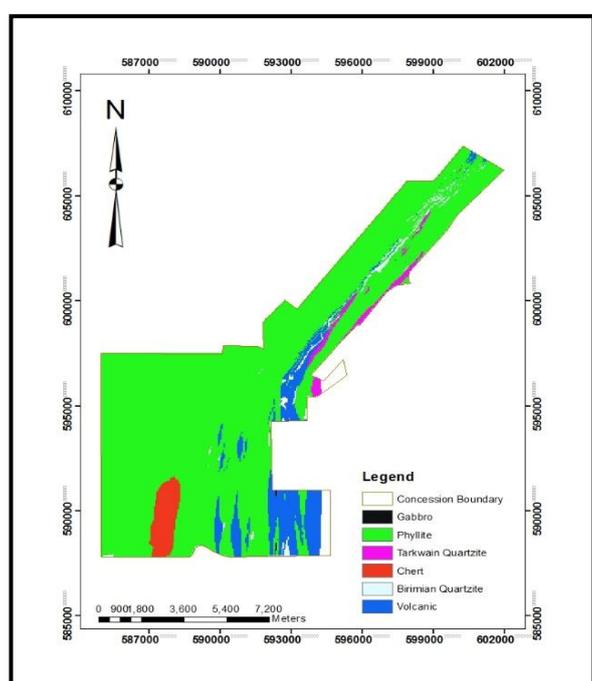


Figure .2. Major rock types within the study area

C. Exploration Model of the Prestea Area

The exploration model (prediction criteria) for mesothermal gold deposits within the study area includes; alterations, lithology, and geological structures. These features serve as guides or evidence to gold mineralization within the Prestea concession. These features together with the gold in soil geochemical data were used as evidential themes in the prediction of areas favourable for gold mineralisation within the Prestea concession of Golden Star.

D. Materials

The materials used in this research work are listed below.

1. Gold occurrence points used for validation
2. Geochemical data of the Prestea concession
3. Geological structural data of the Prestea concession
4. Geological map of the Prestea concession
5. 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)

E. Software

This study made use of ESRI ArcGIS version 10.4.1. The ESRI ArcGIS Spatial Analyst extensions were used to run most of the analysis (IDW interpolation, calculation of euclidean distances, reclassification among others). The core geological predictions were made using weight overlay tool under the spatial analyst extension. The ENVI 4.7 software was used in the image processing. PC1 Geomatica software was also used in the extraction of lineaments from the satellite image.

F. Method

The flowchart of the method used in this research work is illustrated in Fig.3. Georeferencing was performed on the geological map of the study area because of difference in coordinate system between the geological map and the image, the map was then digitized to form the vector layer. Pre-image processes such as stacking and subsetting were performed on the ETM+ image to obtain the image of the study area. Some 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 alteration and lineaments, and this formed the raster layer. The point soil geochemical data of the study area was converted into a continuous surface representation using the inverse distance weighting interpolation in ArcGIS 10.4. Geological structural data obtained through field mapping was also processed on ArcGIS 10.4 to obtain the proximity to geological structures. The lineaments extracted were also processed to obtain the distances to lineaments. The vector layer, the raster layers, the geochemical data, and the distances to geological structures were all reclassified into a common suitability scale. By using the weight overlay tool, the reclassified data were combined, with their respective weights attached to them to produce the gold potential map of the study area using the model builder in ArcGIS 10.4 as illustrated in Fig.4. The gold potential map was validated with known gold occurrence points of the type sought. A total of 995 known gold occurrence points were used for validation.



Figure .3. Flowchart of methodology

G. Weighting of Evidential Themes

The weights were determined after a thorough literature review on gold mineralisation within the study area. Furthermore, consultations with mine and exploration geologists with Golden Star Bogoso/ Prestea Ltd. on exploring for gold in the study area resulted in the weighting in Table 1.

Table.1. Summary of weights attached to the evidential themes.

Evidence	% of influence	Weight
Structures	50	0.5
Hydrothermal alterations	25	0.25
Lithology	10	0.1
Geochemistry	15	0.15

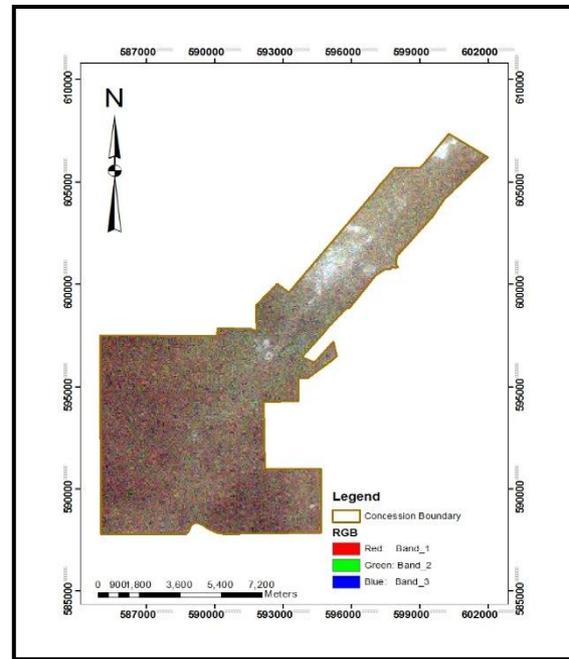


Figure.5. Landsat 7 ETM + image of the study area in RGB combination

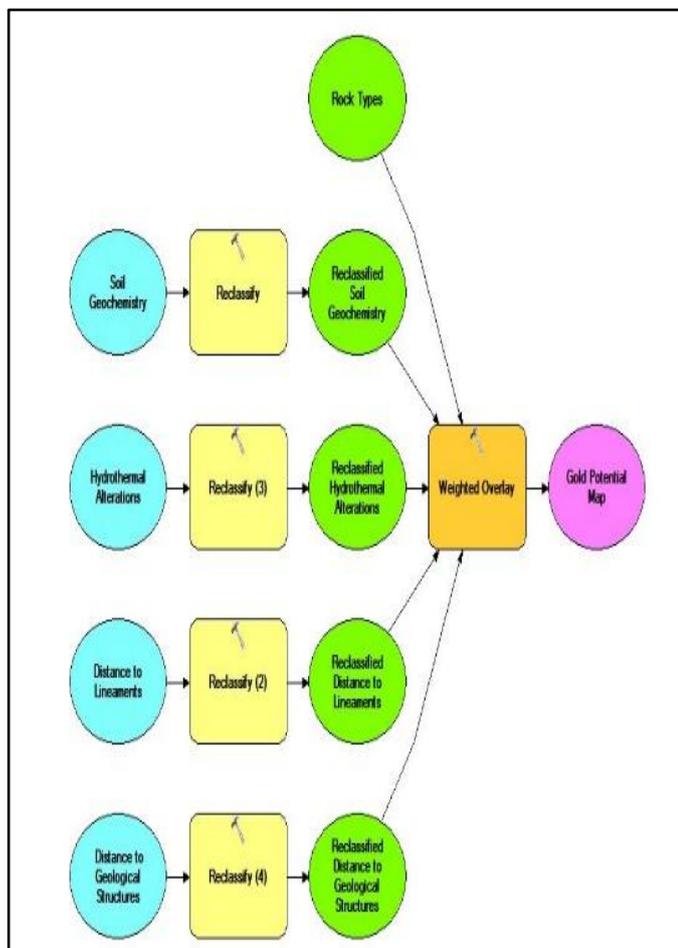


Figure.4. Model for deriving the gold potential map

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 subsetting

The Figure 5 shows the results of layer stacking and subsetting of the Landsat ETM+ image to obtain the image of the study area.

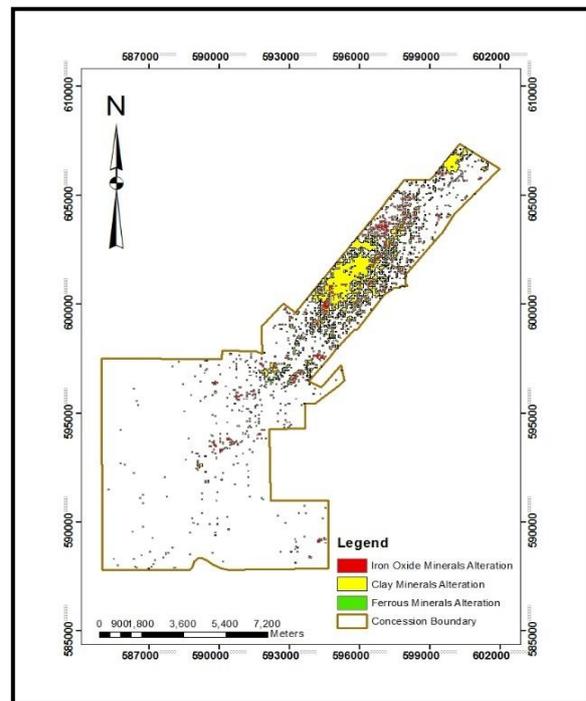


Figure.6. Alteration map of the Prestea concession

Figure 6, 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, the green colour shows the ferrous mineral alterations. From Figure 6, 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 are highly concentrated at the NE portion of the study area

B. Results of the Lineament Extraction and Processing of Geological Structures

Figure 7, shows the lineament map of the Prestea concession. Lineaments are mappable linear or curvilinear feature of a surface whose parts align in a straight or slightly curving relationship. They may be an expression of faults, joints, lithological contacts, fractures and others. From Figure6, the

linear feature striking in NE-SW and dipping to the NW may reflect the main fault known as the Ashanti fault which occurs at the contact between the met sedimentary and met volcanic rocks and hosts numerous hydrothermal gold deposits. Figure7, shows the straight line distances to the lineaments. Areas closer to this feature have significant correlation with gold mineralisation than areas farther away. Figure 8, shows the spatial distribution of mapped geological structures within the study area. The geological structures include quartz veins, shear zones, faults and foliation. These structural features represent zones of weakness favorable for trapping and accumulation of hydrothermal fluids resulting in localization of ore deposits

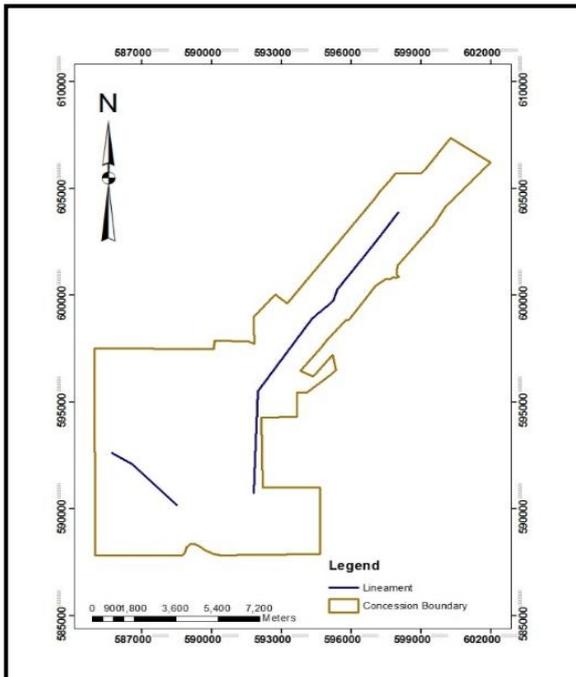


Figure.6. Lineament map of the Prestea concession

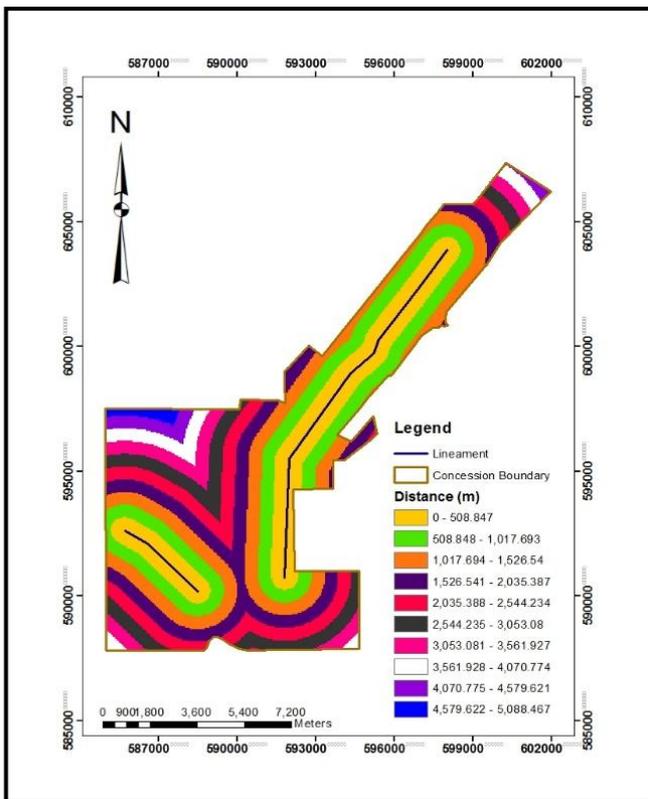


Figure.7. Distances to lineaments

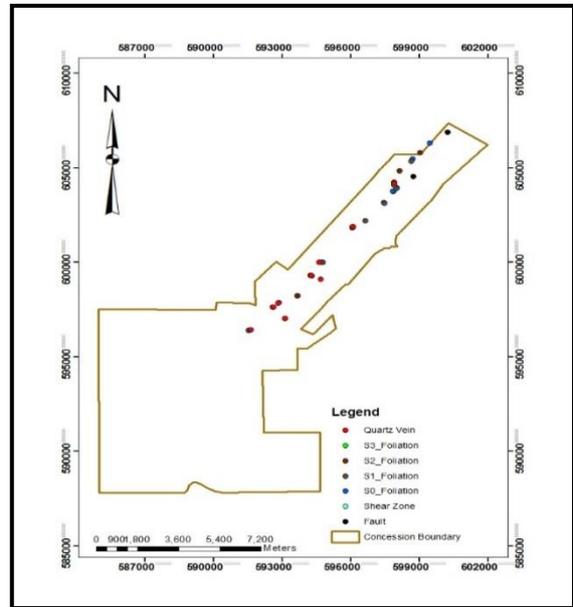


Figure.8. Spatial distribution of geological structures mapped in the Prestea concession

Figure.9. illustrates the proximity to geological structures in the Prestea concession. Distances close to structural features have good correlation with gold mineralisation than distances farther away hence distances closer to structural feature are favourable for gold mineralisation. This is because during the deposition of hydrothermal fluids, some of the fluids move through the host rock via diffusion or the pore spaces within the rocks, making areas closer to point of deposition having anomalous abundance of ore elements, with a logarithm reduction away from the points of deposition.

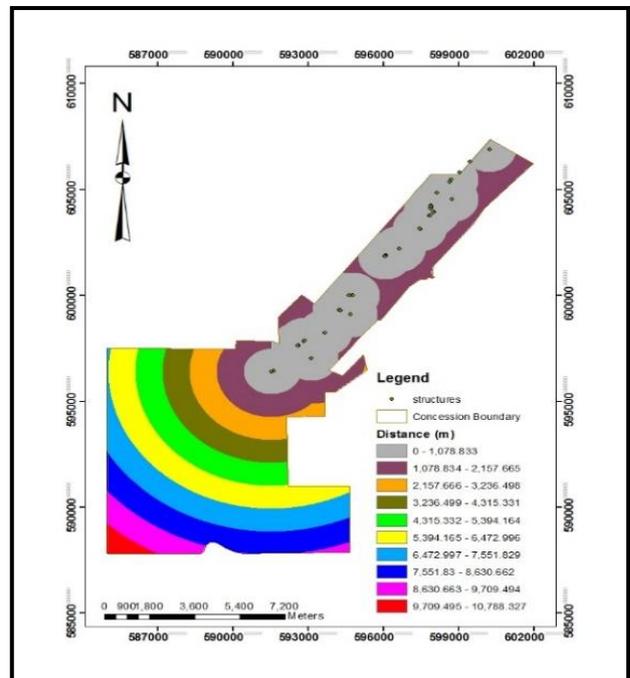


Figure.9. Proximity to geological structures

C. Results of the Inverse Distance Interpolation of the Geochemical Data

Figure 10, shows the results of the interpolation of the gold in soil geochemical anomalies using the inverse distance weighting tool under spatial analyst in ArcGIS. Inverse distance weighting (IDW) interpolation explicitly makes the assumption that things that are close to one another are more

alike than those that are farther apart. To predict a value for any unmeasured location, IDW uses the measured values surrounding the prediction location. The measured values closest to the prediction location have more influence on the predicted value than those farther away. From Figure 10, areas denoted by red color zone have high concentration of gold, followed by those areas denoted by yellow color whereas areas denoted by green color have low gold concentration. Geochemical data is very important in exploration because it's a direct method which measures the exact amount of the mineral sought for.

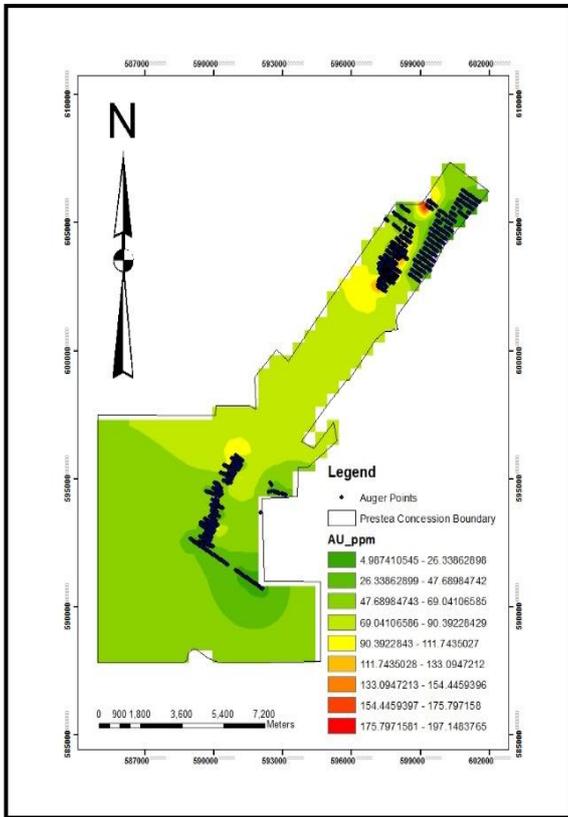


Figure 10. Gold in soil concentrations of the Prestea concession

D. Result of Weighting and Combining Dataset

Weights were assigned to various evidential themes for prediction of areas with high potential for gold mineralisation. The results is as shown in Fig. 11. From the gold potential map shown in Figure 11, areas with low ranking values, 1, 2, 3 and 4, have low potential for gold mineralization. These areas may not be favourable for gold exploration and hence need no further work. Areas with high ranking values, 5 and 6, are areas which are mapped to have high potential for gold mineralization. These areas are shown on the map with colours blue and yellow respectively. The gold potential map demarcates an area of 39.40 km² out of the total area of 116.08 km² to be highly favourable for gold mineralization which represents 33.94% of the total area of Prestea concession. The gold potential map provides more spatial information on gold occurrence within the study area. This would help the mine to widen their scope of search within the concession to areas where they have not explored at a reduced cost in an effective and efficient way. This gold potential map would also enable management of GSR to visualize the extent of gold occurrence and plan the mine in relation to building of bungalows and offices, plants installation, construction of haul roads among others.

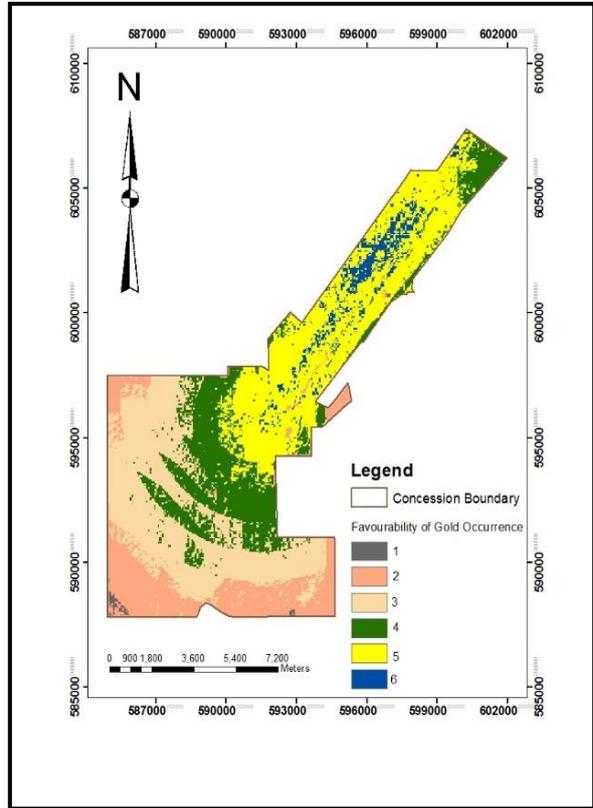


Figure 11. Gold potential map of the Prestea concession

E. Validation of the Gold Potential Map

The gold potential map of the Prestea concession was validated with 995 known gold occurrence points and the results is illustrated in figure 12. From figure 12, it can be observed that most of the validating points falls within area predicted to have high potential for gold mineralisation shown on the map with colours blue and yellow with few falling within the area shown in green colour. The results of the validation confirms the usefulness and effectiveness of applying remote sensing and GIS in gold exploration.

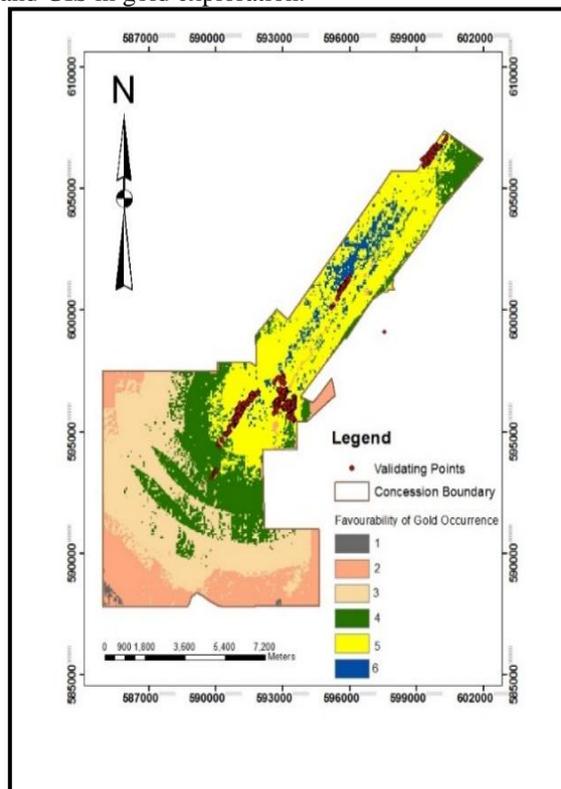


Figure 12. Validation of the gold potential map

IV. CONCLUSION

Based on the results and analysis, a gold potential map of the Prestea concession has been produced through the application of Remote Sensing and GIS. This demonstrates the usefulness and effectiveness of the application of Remote Sensing and GIS in the exploration for gold. The study indicates that the best predictor for gold mineralisation within the study area is the geological structures followed by the hydrothermal alterations. The gold potential map of the Prestea concession outlines an area of 39.40 km² which represents 33.94% of the total area as highly favourable for gold mineralisation. The phyllite rocks are highly deformed due to presence of geological structures and may be very receptive for hosting the gold mineralisation. The use of Landsat ETM+ as the source of information for recognition parameters such as hydrothermal alteration and lineaments was very successful. Remote sensing and GIS are powerful exploratory tools which can be applied in the initial stages of mineral exploration to narrow our search to areas of potentials high mineralisation, hence government agencies in charge of mineral exploration as well as mining and exploration companies in Ghana should embrace this technology since it is less expensive, effective and efficient, environmental friendly and most of the resources required are open source. Also, gold potential maps should be produced for all the districts in Ghana to enable the government use them as documents to attract more investors into the exploration and mining industry. This technique should be applied to the exploration of other minerals such as iron, copper, uranium among others. Golden Star Exploration should carry out more detailed exploration at places that are predicted to have high potential for gold mineralisation but are out of their current working zones.

V. REFERENCES

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