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The application of threshold gold values based on geochemical exploration in complex regolith terrains: A case study at Lawra Greenstone Belt of Northwest Ghana

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ABSTRACT

Interpreting surface gold geochemical data to define anomalous sites in complex regolith terrains is generally very challenging. Working around the challenges in geochemical data interpretation to avoid defining 'positive false anomalies' as 'positive true anomalies' require the application of multiple thresholds that account for the regolith environment in the analysis. 367 regolith samples were collected from four different regolith regimes namely-ferruginous (F), relict (R), erosional (E) and depositional (D) regolith respectively. Q-Q Probability method was applied on the gold data obtained from the regolith regimes to determine populations in the data distributions to detect anomalies. The first natural breaks from probability Q-Q plots defined the thresholds for the respective ferrugninous, relict erosional and depositional FRED regimes. These were 40 ppb for F, 30 ppb for R, 70 ppb for E and 25 ppb for D. The gold geochemical responses in the different regolith regimes were extracted and normalized using the different thresholds separately in the 6000 historical soil data. An anomaly maps showing enrichment factors of gold were plotted. The gold concentrations in the regolith were reclassified into the four regolith regimes. Gold thresholds were then estimated for each of the regolith regimes as the regolith-landform modification at each regolith will be different. Each estimated threshold value is likely to define gold anomaly in the regolith regime it was calculated from. This will provide equal weight of all gold anomalies relating to bedrock mineralization if thresholds-based-on regolith environment is applied on geochemical data during interpretation. A single threshold of 34 that had no unit was later defined from a combined normalized data obtained for all the regimes. Using an Indictor Krigging in GIS environment and applying 34 as the threshold, an enhanced prospectivity map outlining and prioritizing anomalies at a scale of '0' to '1', where '1' is the most likely anomaly to host mineralization and '0' lack of mineralization area were defined. This data interpretation approach using different thresholds based on regolith environments confirmed some defined anomalies that were drill-tested to host potential bedrock mineralization. The use of the technique is practically feasible and its application is recommended in complex regolith environments in the savannah of northern Ghana and other similar terrains dominated by complicated regolith in the West African Sub-Saharan Region and globally.

Keywords: *Regolith, Geochemistry, Gold, Exploration, Anomaly, Mineralization.*

INTRODUCTION

The trend of gold discoveries in known prospective provinces with long histories in the past several decades has been towards fewer or no new findings of major deposits (Schodde, 2011; McKeith et al., 2010). The causes have been unclear whether it is the depletion of ore deposits or that the exploration tactics are unsuitable to define mineral anomalies. Anand et al. (2003) and Arhin and Nude, (2009) believe the incorporation of regolith information during surface geochemical data interpretation can lead to identification of concealed anomalies despite the changing climate that affect the regolith environments. Confirmation of regolith-landform units to influence surface gold geochemistry was identified by Arhin et al. (2015). They noted environments with simple weathering histories to have surface Au geochemistry relating to underlying rocks and mineralization whilst complex weathering history environments generally have anomalies with challenging relationship to underlying substrates. The savannah regions of northern Ghana have complex regolith characteristics (Arhin and Nude, 2009) with reports on gold occurrences (Griffis et al., 2002) but with no published reports on productive gold mining operations. However, gold mining dates back centuries but all these activities were situated in southern Ghana where the regolith were normally homogeneous except the alluvial flats of the major rivers and streams. Known gold occurrence areas in northern Ghana with similar geology to that of southern Ghana with prospective mining activities (Griffis et al., 2002) only have physiographic differences. The climate in the north has influence on the regolith-landform units, vegetation and weathering types, hence affecting the surface materials sampled for surface gold geochemistry. There are some isolated occurrences of strongly weathered regolith in parts of these areas but with extensive transported and laterite covers depicting the entire area as a mosaic of different regolith units. However, unlike southern Ghana with tropical rainforest climate, much of the regolith is residual and consists of intensely weathered bedrock, though there are overlying component of transported material, itself weathered to varying degrees at some places. The challenge in detecting true anomalies in surface samples in humid tropical climate like southern Ghana may be much easier in contrast to the challenges in the savannah regions. Surface materials sampled for gold signatures in savannah regions with heterogeneous regolith may produce variable values because of:

1. The sample media variability (from ferruginous, relict, erosional and depositional units) across the landscape. The variability may be due to the regolith-landform modifications that inadvertently give rise to modifications of geochemical parameters. This phenomenon in the surface environment affects the general procedures for geochemical exploration if not factored into the exploration protocols.

2. The complex characteristics of the regolith materials due to regolith-landform evolution that influence the gold distributions in sediments and laterites as well as the residual regolith thus makes it difficulty in selecting the correct sample media for exploration.

The lack of understanding the regolith environment leads to gross and simplified assumption that the surface regolith materials are homogeneous everywhere and thus do not require distinguishing the various regolith units for separate application of threshold gold values for anomaly definitions relative to regolith-types.

Any of these listed factors can influence the surface geochemical gold data interpretations and can render true-positive-anomaly-delineation challenging. It thus implies that geochemical explorations in savannah regions that aim at defining potential anomalies require regolith distinctions. In that case and as noted by

Anand et al. (2001) and Arhin et al. (2015), the geochemical data interpretation can be done in the context of the regolith.

In the past, thresholds were defined by values > 2 standard deviations from the mean as anomalous (Hawkes and Webb, 1962). This threshold estimation has been found to be somewhat arbitrary (Grunsky et al. 2010), because geochemical data rarely fit a normal distribution. In reality distributions in geochemical data are usually skewed, have outliers and these originate from more than one process. This observation by Grunsky et al. (2010), has serious consequences for statistical treatment of geochemical data as most widely used statistical methods are all based on the assumption that the studied data show a normal or lognormal distribution. Reimann and Filzmoser (2000) realized that neglecting that geochemical data show neither a normal or lognormal distribution will lead to biased or faulty results when such techniques are used. In addressing the non-normally distribution in geochemical data, Reimann et al. (2005) suggested the use of other statistical methods to assess the nature of distribution in the data in order to identify presence of outliers. Following the approach of Reimann et al. (2005), Q-Q plots and frequency-histogram plots were constructed for the determination of threshold values for each of the FRED regolith regimes. The authors consented to Reimann et al. (2005) suggestion by using Q-Q plot in estimating the thresholds but finalized the choice with Stanley and Sinclair (1989) experiential and model-based subjective threshold estimation technique. This paper highlights the significance of establishing different thresholds based on regolith environment characteristics and demonstrates the importance of applying different thresholds to the surface soil geochemical data to develop an enhanced prospectivity map of the Lawra Greenstone Belt.

MATERIALS AND METHODS

The investigated area forms part of the Lawra Birimian Belt (Figure 1). It is located in Nadowli in northwest Ghana ~700 km northwest of Accra, the national capital. By road the study area can be accessed via a first class highway through Kumasi, Ghana’s second city to Wa, the regional capital of Upper West region. 80 Km northwest of Wa along a second class road leads to the study area.

The climate at the area is semi-arid with annual rainfall ranging between 600-1200 mm (Webber, 1996). The rain pattern is mono-modal (Figure 2) but starts slowly from March and peaks in August after which there is a sharp decrease after October (Kranjac-Bersaljevic et al., 1998). Temperatures are consistently high and averages 28.6^{o}C. However, monthly averages range from 26.4^{o}C at the peak of the rainy season in August to a maximum of 32.1^{o}C in April (Dickson and Benneh, 1995). As is common for the tropics, diurnal temperature changes exceed monthly variations (Dickson and Benneh, 1995). The total evaporation rate of 2050 mm (Figure 2) exceeds the annual rainfall more than two fold. These conditions are favourable for lateritization processes to form laterites (Freyssinet et al., 2005, Butt and Zeegers, 1992).

Regolith

The regolith contains weathered *in situ* and transported materials with widespread buried and sub-cropping laterites. The transported materials are from diverse sources and are made up of generally unconsolidated landform units with some marked secondary cementation and re-cementation by Fe-oxides, Fe-hydroxides and clay minerals. These footprints recognized in the transported materials have been characterized by Taylor and Eggleton (2001) to represent past and present regolith-landforms of depositional regolith.

Also present are Fe-coated surface crusts referred to as laterites and these constitutes the ferruginous regolith regime. These are widespread and are formed mainly in depositional and stable landform terrains. The environments of formation, the characteristics of the matrix materials and the general framework of the laterites have led to two classes of laterite-types. These are ferruginous and lateritic duricrusts formed at the depositional and stable landform terrains respectively. The ferruginous duricrust occupies low lying terrains whilst the lateritic duricrust normally are found at the summits of isolated hills. The common distinguishing feature between the two laterite-types is the matrix materials. Uniform matrix materials characterizes lateritic duricrust whereas polymictic matrix materials dominate the ferruginous duricrust. The ferruginous duricrust generally sub-crop in low-lying terrains and can cover extensive land space but there are some that occupies relief inversion landscapes (Arhin and Nude, 2009). Typifying these laterite–types are the unique smooth sub-rounded lithic and quartz pebbles cemented together by clay minerals and Fe-oxide (Figure 4). Overlying the landforms considered stable in the study area are the relict regolith.

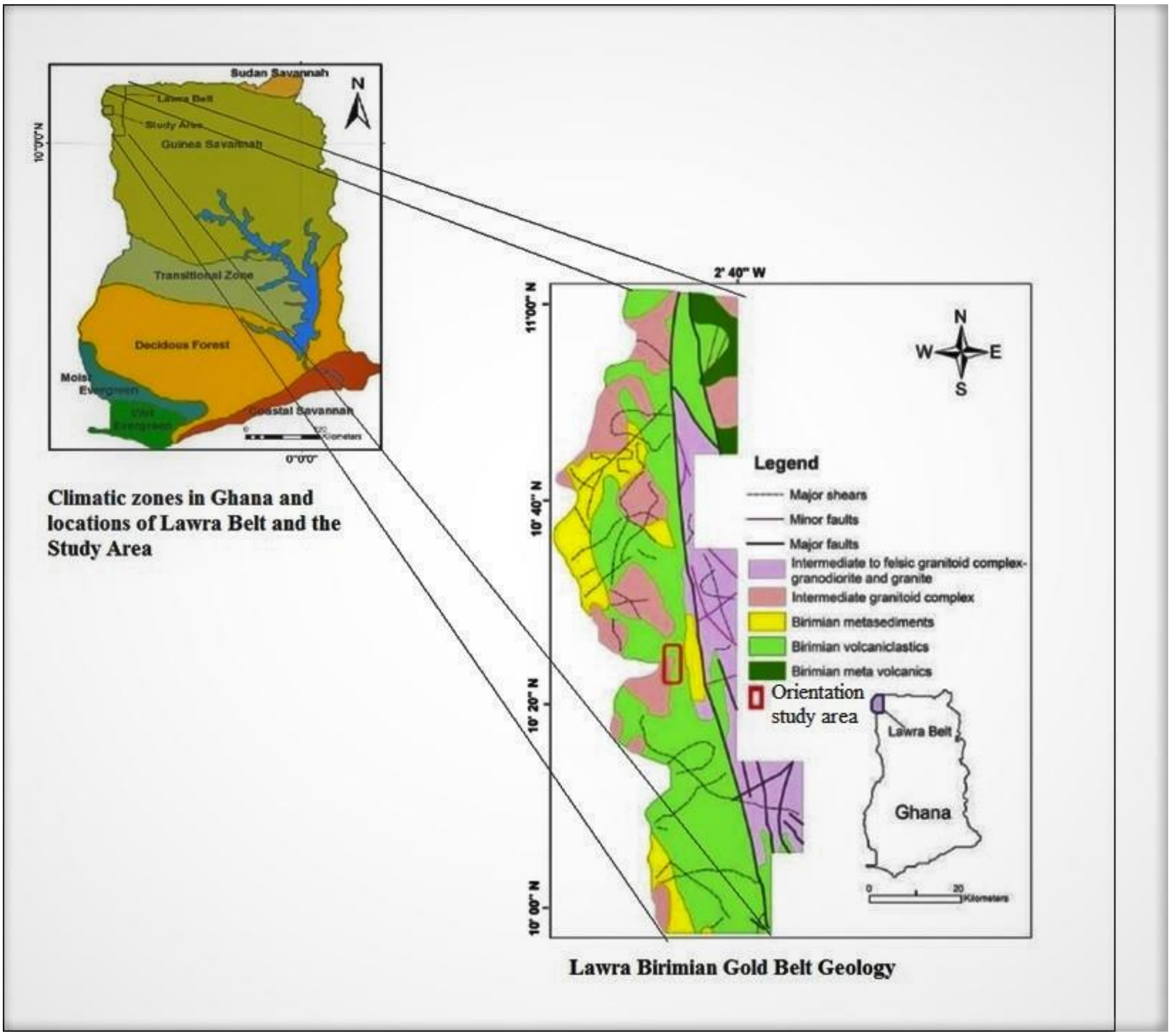

FIGURE 1**. Regional Geology**

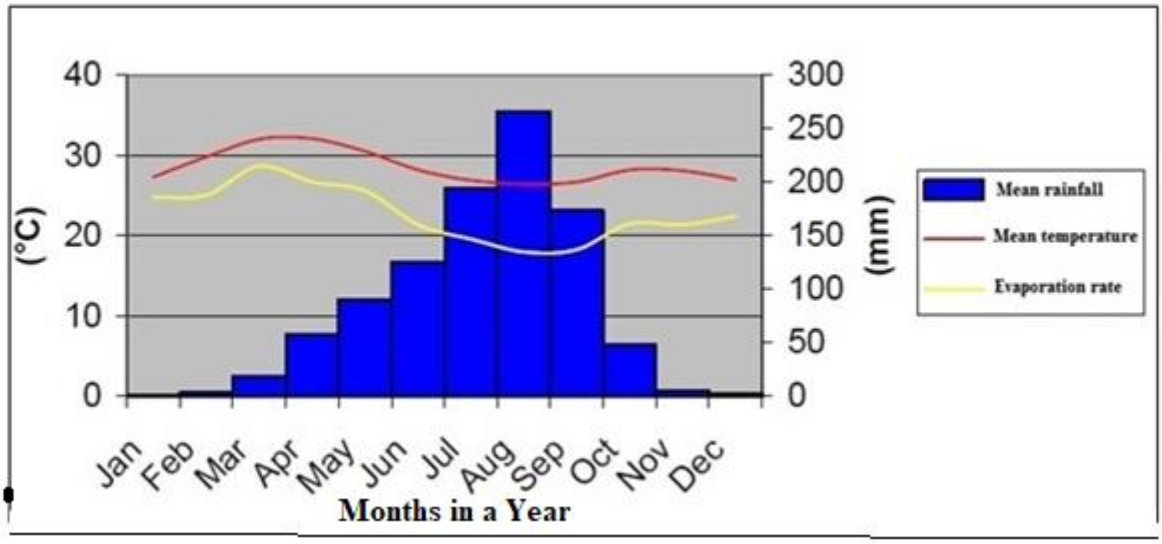

FIGURE 2. **The climate of the Nadowli area (Ghana Meteorological Service 2012)**

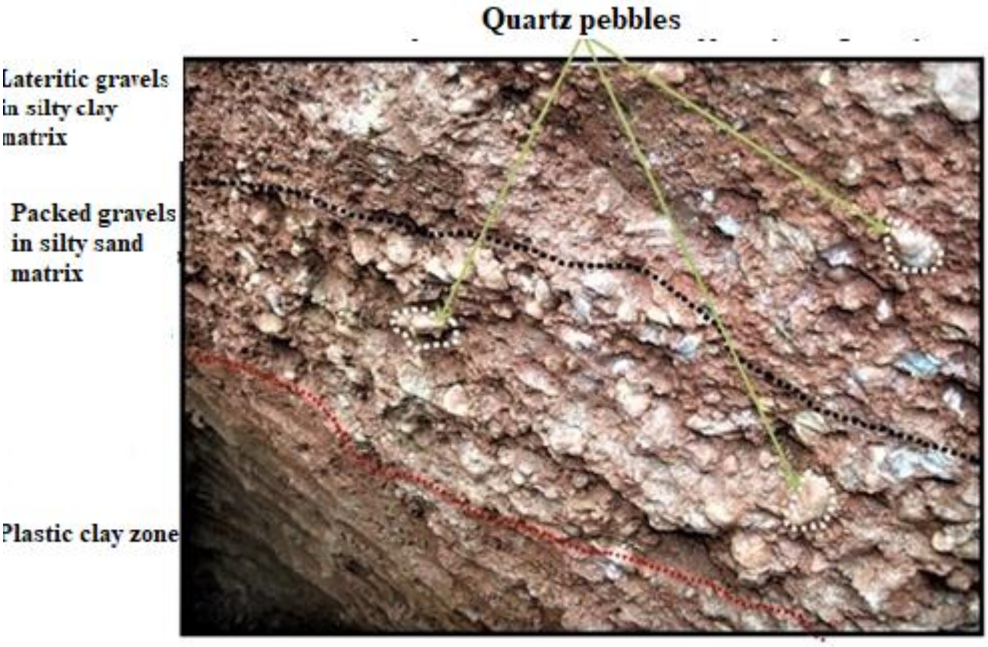

FIGURE 4. **EXAMPLE OF FERRUGINOUS PROFILE** ***(pebbles are generally surrounded and rounded depicting long distance of travel)***

This regolith-type contains some relics of weathered primary minerals of the parent rock within a predominantly secondary mineral assemblage above the coherent bedrock. The relict regolith contains sub angular to angular lithic units and the angularity or sphericity of the lithic and quartz fragments defines the degree of their lateral displacements (Arhin et al. 2015). The erosional regolith landscapes are uncommon. However, areas where physical erosion exceeds bedrock weathering, isolated erosional surfaces or bedrock knobs (e.g. inselbergs) that often punctuate otherwise smooth pediments of homogeneous basement lithology develop.

Most erosional surfaces occurred at hilltops and at the highly jointed morphologically complex areas along most of the steep-slopes >250 m. Modified erosional surfaces were found at the low-lying areas. These areas are characterized by thin veneer of present surface of about 30 cm overlying the truncated pre-existing surfaces.

Geology

The geology of the area comprises metavolcanic and metasedimentary rocks intruded by granitoid (Figure 2, Kesse, 1985). The metavolcanic rocks contain basalts, andesite and rhyolites, with dolerite and gabbroic intrusive (Feybesse et al., 2006; Egal et al. 2002; Oberthuer et al., 1998). Intruding the metavolcanic rocks are the Belt-type granitoids, which include biotite and hornblende-rich granitoids varieties. These intrusive rocks are discrete and discordant and are distinctly mafic. Conversely, the metasedimentary rocks contain phyllite, sericite-schist and metagreywacke that are intruded locally by felsic and mafic dykes. In addition to the dykes are the Basin-type granitoids. They are large felsic, concordant and syntectonic batholiths generally banded and foliated. Unlike the Belt granitoids, these Basin granitoids are two-mica-rich types, containing both biotite and muscovite, with biotite being the dominant mineral (Baratoux et al., 2011; De Kock et al., 2011).

Known gold mineralisation in the area

The occurrence of gold in the area was first reported in 1935 (Junner, 1945) and systematically explored by Ashanti AGEM Alliance from 1996-1998. Their soil geochemical survey work revealed the gold potential in the area (Figure 3). But these occurrences have not been developed into a productive mine (Griffis et al., 2002). The only reported gold extraction activities are the artisanal mining operations found at several places, along the strike of the Greenstone belt in the area (Griffis et al., 2002; Kesse, 1985). Authenticating the gold occurrence in the area is the recent discovery of 750,000 oz. Au, at an average grade of 1.94 g/t (Franey et al., 2012) by Azumah Resources Limited (Amponsah et al., 2015). The discovered mineralisation is reported to be hosted in the volcanoclastic rock units and occurs in a variety of styles and settings (Amponsah et al., 2015; Griffis et al., 2002; Dzigbodi-Adjimah 1993) similar to many discoveries in southern Ghana. The major recognizable styles are:

(i) The quartz-vein mineralisation style: this has gold occurring in deformed quartz veins, principally associated with pyrite or tourmaline.
(ii) The disseminated mineralisation style: this has gold occurring as disseminated particles with association with sulphides within the alteration halo of undeformed veins of quartz ± albite ± carbonates.
(iii) Shear related gold mineralization type also occurs in shear zones of the metasedimentary and the volcano-sedimentary rock units.

The undeformed quartz veins in the disseminated mineralisation style-type normally contain little or no gold. The disseminated mineralisation has lower grades but much higher tonnage and occurs in highly carbonatized and albitized rocks or pure albitites. The quartz-vein and disseminated mineralisation styles represent variations due to local heterogeneity of the host lithologies, the mineralising fluids and precipitation mechanisms. The gold geochemical signature from the mineralised bodies at the surface environment has been influenced by the regolith and landform evolution thereby making anomaly delineation from surface geochemical data extremely difficult to detect.

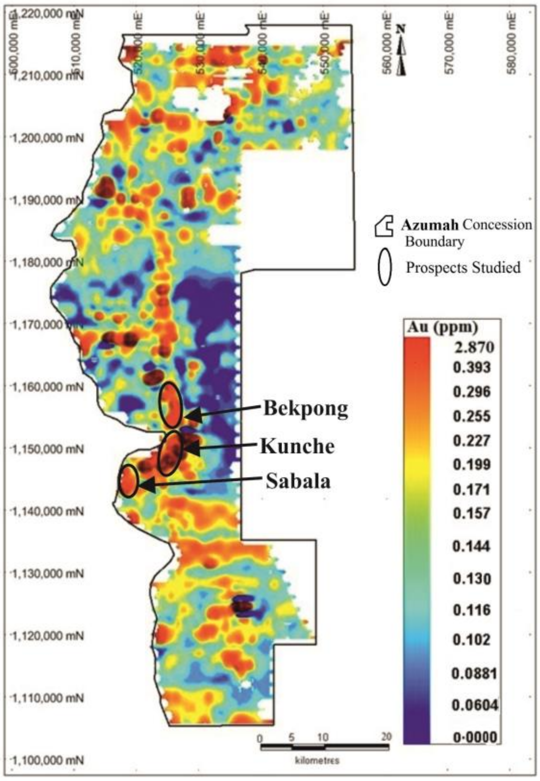

FIGURE 3. **Historical gold results plot by Ashanti Agem Alliance**

This study uses the regolith classification scheme detailed by Arhin et al. (2015), which comprises ferruginous (F), relict (R), erosional (E) and depositional (D) regimes to distinguish the regolith types. The existing regolith map of the area developed by Arhin et al. (2015) was used as the base map and was juxtaposed onto the same scaled replotted soil geochemistry gold map produced from historical soil gold data by Ashanti-AGEM Alliance exploration company (Franey et al., 2012). The surface gold geochemistry results were re-interpreted by incorporating the regolith information extracted from the regolith base map. Four sub-geochemical data placed in regolith context were created for ferruginous, relict, erosional and depositional regimes. Separate thresholds were obtained for the different regolith regimes using gold geochemical results obtained from 367 new regolith samples collected from three known mineralized areas: Kunche, Bekpong and Sabala in the current study. Out of the 367 samples collected, 267 samples were from a ferruginous regolith environment, 15 from relict, 62 from erosional, and 51 from a depositional regolith domain. The predominance of ferruginous materials among the sampled materials is attributed to climate destabilizing and exposing soils to direct impact of occasional heavy sheet wash from heavy rainfall and frequent strong winds resulting in an increased rate of erosion, particularly on unconsolidated surface horizons, exposing indurated lower horizon such as the lateritic and ferruginous duricrust. These samples were sieved to <125 µm size fraction just as were done in the previous soil geochemical survey. A nominal size of 50 g weight of sieved samples were sent for gold analysis using Au-AA24 Fire Assay method at ALS-Chemex laboratory in Ghana.

Normal probability plots or Q-Q probability plots (i.e. involving cumulative frequency plotted on a probability scale) were performed separately on the data for the four 'FRED' spatial regions to establish the most appropriate thresholds for each regolith regime. The thresholds were estimated from the first natural breaks of the multiple population distributions for the various regimes. These different defined thresholds were used to normalize the gold data reclassified based on regolith environments into indicators. Using an inverse distance weighting (IDW) gridding method, the indicators or the normalized data were plotted in a GIS environment to produce gold anomaly maps. The IDW method uses exact and smooth surfaces and shows the gradational changes of the assay values by its distance from the sample point or grid node being interpolated. Images created by this method using the reclassified surface historical geochemical data for each regolith regimes normalized to the estimated thresholds defined from the Q-Q plots, outlined geospatially the gold concentration patterns in each regolith regimes. Despite the recognition of the spatial anomalous patterns in the respective regolith-landform units; further transformation on the combined normalized geochemical data of all the four regolith regimes was carried out. This transformation on the combined data created a probability anomaly map that prioritises the most prospective anomalies on a scale of 0 to 1. The anomaly with the highest chance of hosting mineralisation is rank 1 and the least anomalous areas are ranked 0. A new non-dimensional factor was estimated as the second derived threshold from the combined data. From the Q-Q plot, the value of the first natural break was chosen as the second derived threshold to represent all four regolith regimes. The new non-dimensional threshold was used in Indicator Krigging gridding to produce enhanced prospectivity map to outline and define potential anomalous areas,

RESULTS

The normal probability plots show multiple populations indicating distinct groupings in the frequency distribution of the data set of which each distribution may have an association with an anomaly. The multiple populations observed in the 367 soil gold results plots for the individual regolith regimes confirm McQueen's (2009) assertion that geochemical data sets seldom represent single populations because of the many controls on metal transport in the regolith-landform units. Figure 5 represents frequency-histogram and normal probability plots of gold in soil data in the ferruginous and relict regimes whereas Figure 6 shows the erosional and depositional environments. The red dots on the Q-Q plots represent the chosen threshold values for the individual regimes. The thresholds for the FRED classes are 40 ppb, 30 ppb, 100 ppb and 25 ppb respectively. The defined thresholds were used in Indicator Krigging (IK) gridding to produce anomaly maps.

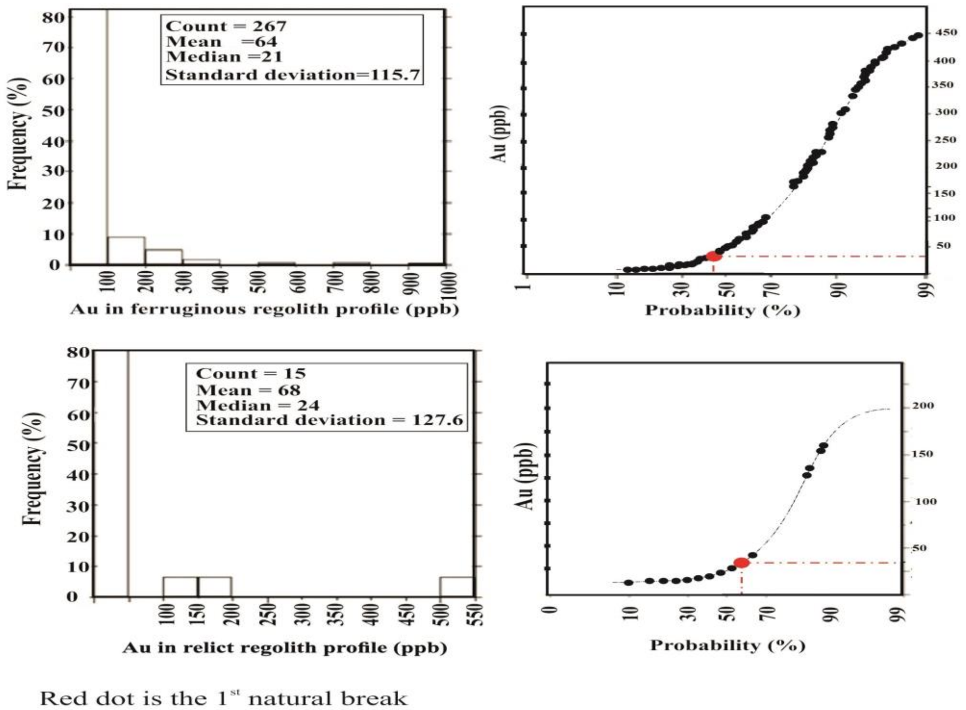

FIGURE 5: **Threshold Gold Values Estimation for Ferruginous and Relict Regimes**

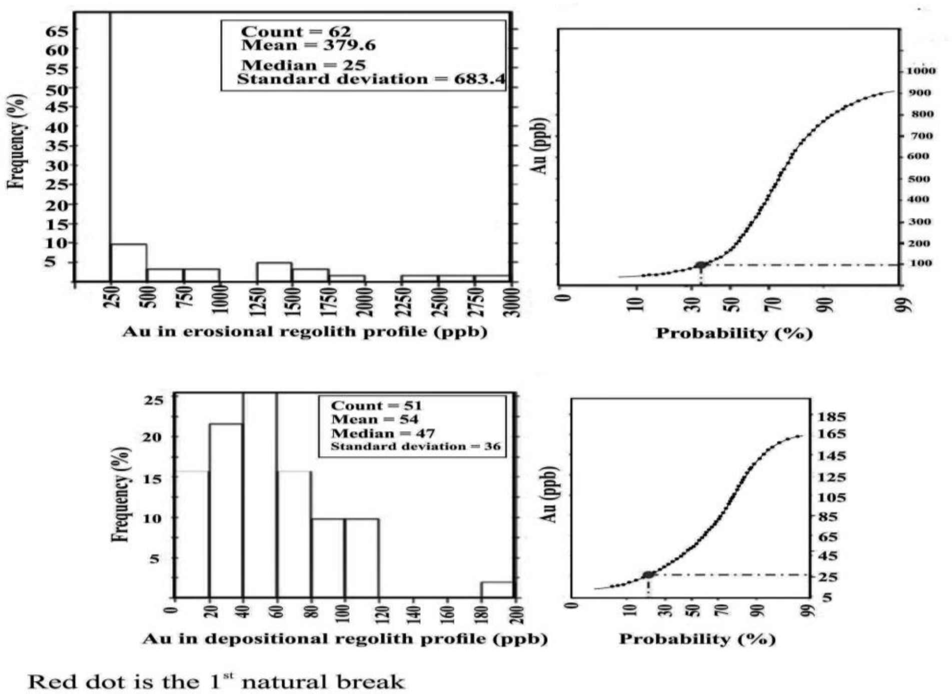

FIGURE 6. **Threshold Gold Values Estimation for Erosional and Depositional Regimes**

Figures 7-10 represent probability anomaly maps for ferruginous, relict, erosional and depositional regolith regimes respectively. The geochemical data in each of the regime were normalized using the defined thresholds and later combined into a single database.

The multiple populations in the new transformed data distributions was examined using probability plot. At this stage the regolith environment was considered to be uniform and applying Stanley and Sinclair (1989) experiential and model-based subjective threshold estimation, the first natural break value of 34 was selected as the second derived threshold.

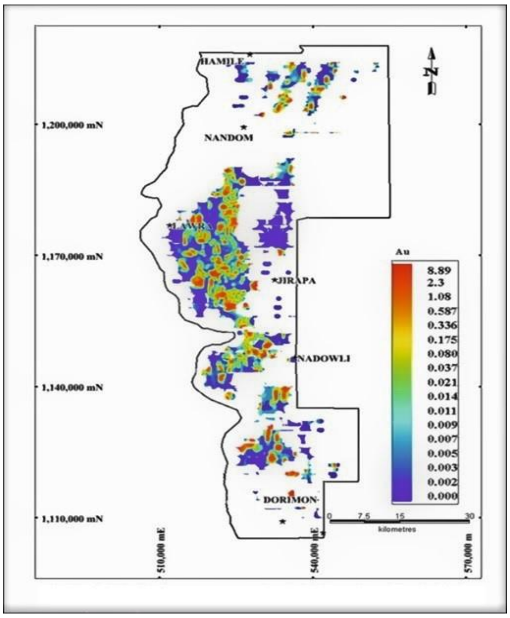

FIGURE 7. **Gold in Ferruginous Regolith Regime**

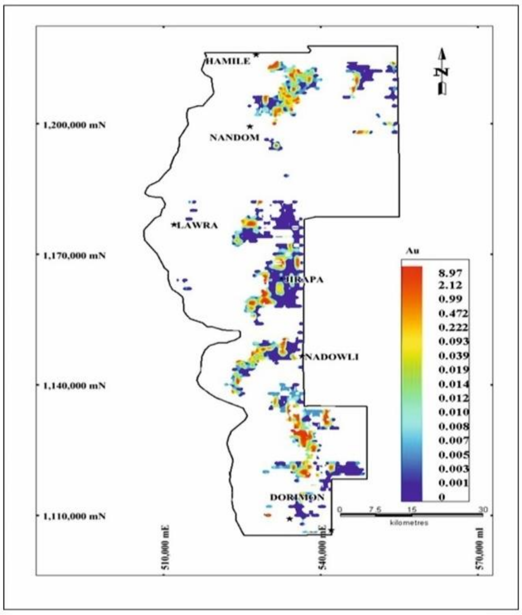

FIGURE 8. **Gold in Relict Regolith Regime**

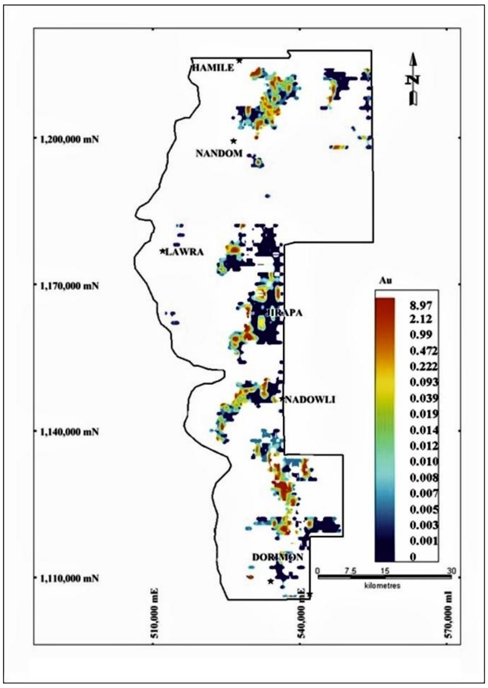

FIGURE 9. **Gold in Erosional Regolith Regime**

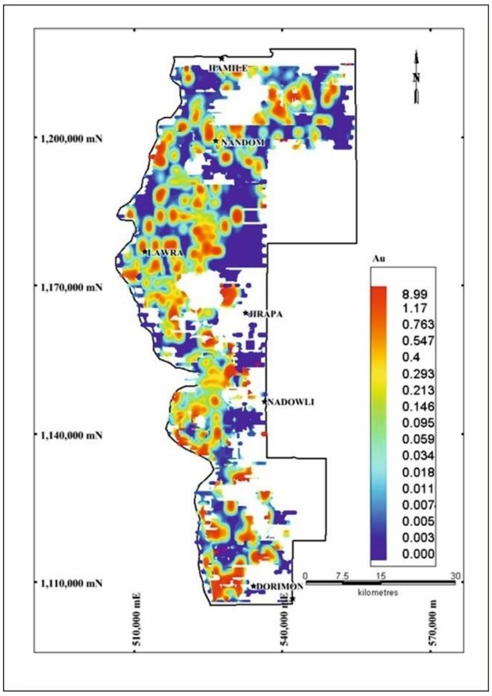

FIGURE 10. **Gold in Depositional Regolith Regime**

By applying 34 as the new threshold for

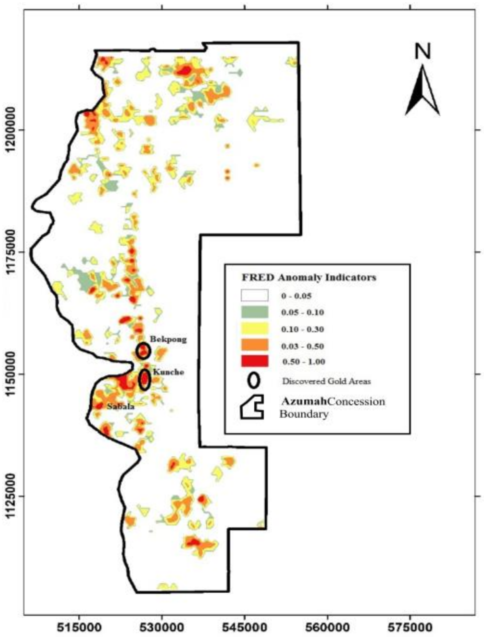

FIGURE 11. **Probability Anomaly Map**

the combined transformed data obtained from the historical data using the Indicator Krigging, an enhanced anomaly-map, outlining areas that require further exploration were defined (Figure 11).

DISCUSSION

The multiple populations identified in the data suggest different thresholds are needed to identify true anomalies for gold anomalies. This confirms McQueen's (2009) assertion that geochemical data sets seldom represent single populations. Therefore the use of single threshold for anomaly delineation may be fraught with challenges particularly in regolith-dominated terrains. The present and past regolith-landform evolutional events identified in this area (Arhin et al. 2015) further explain the mix gold geochemistry (Figure 3) reported by Griffis et al. (2002) for the area. The regolith-landform modifications thus have control on metal transport and consequently could lead to anomalies being false positive, false negative, true negative and true positive. However, referring to McQueen's (2009), all regolith materials can host and hide true positive anomalies and non-accounting of regolith environments in surface geochemical data interpretation can lead to challenging anomaly detections (Arhin and Nude, 2009). Revelations by Arhin et al. (2015) and Anand et al. (2001) suggest the environment of formation of the various regolith landform units have impact on metal residence in surface environment and also in distributions and concentrations of elements. Example in relict and erosional regolith regimes the geochemical expressions relate to bedrock mineralisation. On the contrary, the geochemical expressions in ferruginous and depositional regolith can hide the expressions of bedrock mineralisation because of the regolith-landform evolution process and may not relate easily to bedrock mineralisation. Thus, the landscape evolution process can enhance or dilute bedrock mineralisation signatures unless regolith factors are incorporated during geochemical data interpretations. On the basis of these, distinguishing regolith types and attempting to identify anomalies in different regolith regimes may be the best way of defining true positive anomalies.

In all analysis of geochemical data for true positive anomaly delineation, it is valuable to make initial assessment of the nature of distribution of gold values and presence of outliers. At an environment where regolith materials are considered homogeneous, the distribution may appear near normal and often be a single distribution with some outliers. However, this may be different for heterogeneous regolith environments. Multiple populations may be indicated by distinct groupings in the frequency distribution of the data. As often the case populations with the highest values may be chosen to represent anomalies but there may be potential anomalies that could be defined by relatively lower distribution groupings. Most companies that worked in the area used 20 ppb threshold to define anomalies. But many of the anomalies defined from the single threshold value of 20 ppb resulted in false positives and true negatives follow ups (Griffis et al. 2002). No distinctions were made for the different regolith regimes because the entire area was considered generally as overlain by homogeneous regolith. The consequence were that some high and low gold values could be due to the regolith-landform processes. Therefore for a successful exploration in such terrains, it is valuable to distinguish the different regolith types to guide in ascertaining the source of the anomalies.

Traditionally geochemical anomalies have been identified by setting threshold values which mark the upper and lower limits of normal variation for a particular population of data (McQueen, 2009). So by applying different thresholds to the data for each regolith-landform units, an enhanced prospectivity map of spatial locations hosting true positive anomalies have a chance of being detected for further exploration. Multiple thresholds dependent on regolith environments could detect concealed anomalies due to detrital gold encrustation by Fe-oxide and clay minerals in ferruginous regolith regime (Arhin and Nude 2009, Butt and Zeegers, 1992) because the detrital gold coatings effect on geochemical expressions had been factored in the regime threshold estimations. Conventionally and particularly in this area, lateritic and ferruginous duricrust samples collected during soil surveys are sieved and this often results in the removal of the coated detrital gold as they are considered part of the oversize materials, which are discarded and thrown away. The gold geochemistry in such samples recovered after chemical analysis represent just a portion of the true gold in the area. Therefore a single threshold used if the choice was decided on high gold assays, then anomalies in ferruginous and depositional areas that suffer gold coatings dismissal as oversize materials and anomaly dilution due to gold-poor sediments deposition may go undetected.

From the current investigation, it was recognized that geochemical plot of surface gold geochemistry where the regolith constraints were not considered in anomaly delineation (e.g. Figure 3) has a maximum Au assay of 2.87 ppm in all samples. It is thus challenging to know the source of this high value. With no regolith studies to understand the geochemical survey environment and unsure of the regolith-landform unit-type the source of the high gold assay will be unknown. But with the wholesale adoption of exploration protocols in homogeneous regolith environment, the inclination to follow the high assay gold value up will be high. Recounting the notions of Butt (2004), Butt et al. (2000) and Smith (1996), there are differences in gold geochemical responses at areas with variable regolith thicknesses even in a known mineralized terrains. Thus, in depositional regimes; a sample collected over a 10 m thick sediments overlying bedrock mineralization will have different geochemical response if the sediment thickness is much shallower. So with the lack of understanding the characteristics of regolith units resulting in the 2.87 ppm assay value, follow up survey based on the high assay may either lead to the definition of positive-true-anomaly or positive-false-anomaly. Meticulous examination of spatial gold geochemical responses in the miscellany of regolith units (Figure 3) suggests the entire area is anomalous based on 20 ppb threshold used (Griffis et al. 2002). This resulted in the earlier explorers following up high assays and employing single thresholds with no considerations to the regolith environments Griffis et al 2002). This however yielded numerous false-positive, false-negative, true-negative and a few true-positive-anomalies resulting in general unsuccessful exploration surveys in the area (Griffis et al. 2002).

In a case where 171 ppb (spatial patterns limit edged yellow, Figure 3) is used as a threshold disregarding the regolith environment, broad geochemical anomalies will still be defined but these may be less extensive in strike and slimmer in width compared to the application of the 20 ppb threshold. If 171 ppb threshold is used, from Fig 5, the second natural break of the data distributions in the ferruginous and erosional regimes would have been the thresholds to use. The threshold for relict would have been chosen from the third break and 171 ppb would have been outside the distributions in the depositional environment. The implication of the use of single and higher assays as thresholds normally lead to many potential anomalies gone undetected. Similarly the spot-high-gold anomalies may not necessarily relate to bedrock mineralisation because spot-high-gold areas can occur in either residual or transported regolith environments. The gold geochemical responses in surface samples from the historical geochemical data ranges from 5 ppb to 2870 ppb. It is therefore imperative that definition of true-positive-anomalies require the distinctions between residual and transported regolith with subsequent treatment of anomalies using different thresholds according to the regolith class.

The veracity of different thresholds defining potential anomalies based on the incorporation of regolith factors is verified in this study and shown in figures 6-9. The anomaly-definitions in each of the regolith-types has equal chance and merit to relate to bedrock mineralisation. As seen in figures. 7-10, the enrichment factors normalized with the defined thresholds irrespective of the regolith-regime-types produced values such as of 8.89 in ferruginous regolith, 8.97 in relict 8.97, 8.97 in erosional and 8.99 in depositional regolith. These values appear to be about 9-folds implying the anomalies defined in figurs 7-10 all have an equal chance for anomalies, in all the regolith regimes to host mineralization despite the variations of concentration differences. The anomalies defined in the different regolith regimes in figures (7-10) may relate to the same mineralized source in the primary environment. But the fractions of mineralised body haloes, expressed in soils in the secondary environment may be modified in anomaly concentrations and distributions due to the regolith-landscape modifications and local activities. The four identified regolith regimes (FRED) co-exist on the landscape. This makes the transformation of the four normalized data from the four regimes to determine the population that can define potential anomalies; a varied approach in gold exploration in regolith-dominated terrains. From figure 11 areas that have high probability of hosting bedrock mineralization has a value of upto 1. Two of such areas defined by the probability Krigging technique defined Kunche and Bekpong anomaly (Figure 11). The recent discovery of 750,000 oz. Au, at an average grade of 1.94 g/t by Azumah Resources Limited (Amponsah et al. 2015, Franey *et al.*, 2012) at the same locations defined and prioritized using the techniques employed in the study suggest other potential anomalous regions defined in the enhanced prospectivity map along the north-south trend and others outside the main north-south trend can be prioritized for further exploration.

CONCLUSION

The findings from the investigation suggests distinguishing the regolith into regimes based on environment of formation. It further recognized true gold anomaly- identifications with the use of different threshold values centred on regolith environment and suggest that to be one of the sure way to address the challenges of following false positive-anomalies. This method has successfully identified and ranked anomaly potentials of a region in a prospectivity map and demonstrates the ability of all regolith regimes to have equal chance of detecting anomalies that can host mineralisation. The method self-eliminate the challenges introduced in surface geochemical gold data analysis from regolith evolution because it accounts for the effects of regolith on gold migration and dispersions. The probability map showed discretely the potential anomalies across all regolith types and ranked the anomalies between 0 and 1 in terms of prospectivity

In conclusion, the ratings of the individual anomalies at different regimes presented in the enhanced prospectivity map for all regolith regimes can be assessed and prioritised on the probability map, scaled 0-1 where 1 is the most likely anomaly to host mineralisation and 0 depicting lack of mineralisation area. This innovative approach of interpreting geochemical data in a complex regolith environment has been promising in confirming some gold discoveries by Azumah Resources Ltd exploring for gold in the study area and therefore recommended for all exploration surveys in complex regolith-dominated terrains.

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