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Lack of Exploration Success in Northern Ghana: Problems and Solutions

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Abstract: The aim of this research is to investigate reasons for the lack of exploration success in the savannah regions of Northern Ghana and offer some remediation. The failure of exploration expedition could be traced from scores of unsuccessful and abandoned grassroots explorations programmes since 1935. More recently the discontinuous exploration activities in Northern Ghana, even in the midst of the gold boom and favorable commodity prices have been regrettable. Also, for about 78 years now that gold occurrence was reported in these northern Ghana, none had been developed to a prospective mine. The problem is attributed to the lack of understanding the regolith distribution and characteristics of gold deposits as well as poor exploration practices. Application of enhanced exploration methods such as the use of regolith mapping and characterization, remote sensing and study into landform modifications and variabilities in Northern Ghana could help reveal patchy and false anomalies. Again, resulting dispositional overburden as well as thick ferruginous enrichment which tend to mask anomalous signatures could be unraveled by enhanced exploration techniques. The solution to these unsuccessful exploration expeditions therefore require the understanding of the regolith environment, mineral hosts for gold and trace metals along with regolith map that aids in interpreting geochemical signatures could assist to unravel potential mineralization under cover.

Keywords: Birimian, dispersion pattern, exploration, landform modification, northern Ghana, regolith

INTRODUCTION

The use of regolith geochemistry plays an important role in mineral exploration as observed by the successful application in deeply weathered regions of Australia such as the Yilgarn Craton (Anand and de Broekert, 2005; Butt and Zeegers, 1992). The anomalies variabilities in these areas are due to the different background and gold values from different regolith units. Savanna regions of West Africa in general have a mix of residual and transported regolith and thus regolith geochemical anomalies may not necessarily reflect buried mineralization. The subdued relief hosts flood and sheet wash deposits in addition to Aeolian input from the adjacent Sahara. These surficial deposits result in a complex, heterogeneous regolith across the landscape. Geochemical anomalies from surface regolith materials may therefore not reflect the underlying obscured mineralization and for effective interpretation of regolith geochemical data. There is a need to study and integrate regolith-landform units with surface geochemistry of the West African Craton. In view of the active exploration work being conducted by some Australian Exploration Companies in Ghana and also in the West African Craton as a whole, even with their efforts and knowledge in exploration have seen little success in discovering new deposits.

It appears the discovering of potential gold mineralization in the complex regolith needs better knowledge of the regolith architecture and metal transfers in the regolith structure. This study looks of why many of the gold exploration companies had at work without any exploration success in Northern Ghana. It tries to ascertain the problems and difficulties associated with this unique gold deposit and propose an exploration strategy that outlines methods that could assist to unravel the hidden mineralization (Griffis *et al*., 2002; Nude and Arhin, 2009).

LOCATION AND GEOLOGY

The study area falls within the Birimian gold bearing belts of northern Ghana in West Africa sub-region (Kesse, 1985) (Fig. 1). This area is located in the Lawra gold belt, 700 km northwest of Accra. The area therefore is underlain by meta-volcanic, pyroclastic and meta-sedimentary rocks. The meta-volcanic rocks are basaltic and gabbroic in compositions and most of them have been altered into various schist. The meta-sedimentary rocks consist of phyllites, tuffaceous and carbonaceous phyllites, sandstones, siltstones, tuff, cherts and manganiferous sediments. Intruding the meta-volcanic and meta-sedimentary rocks are magmatic bodies and porphyritic granitoids that have generally been classified into two broad categories.

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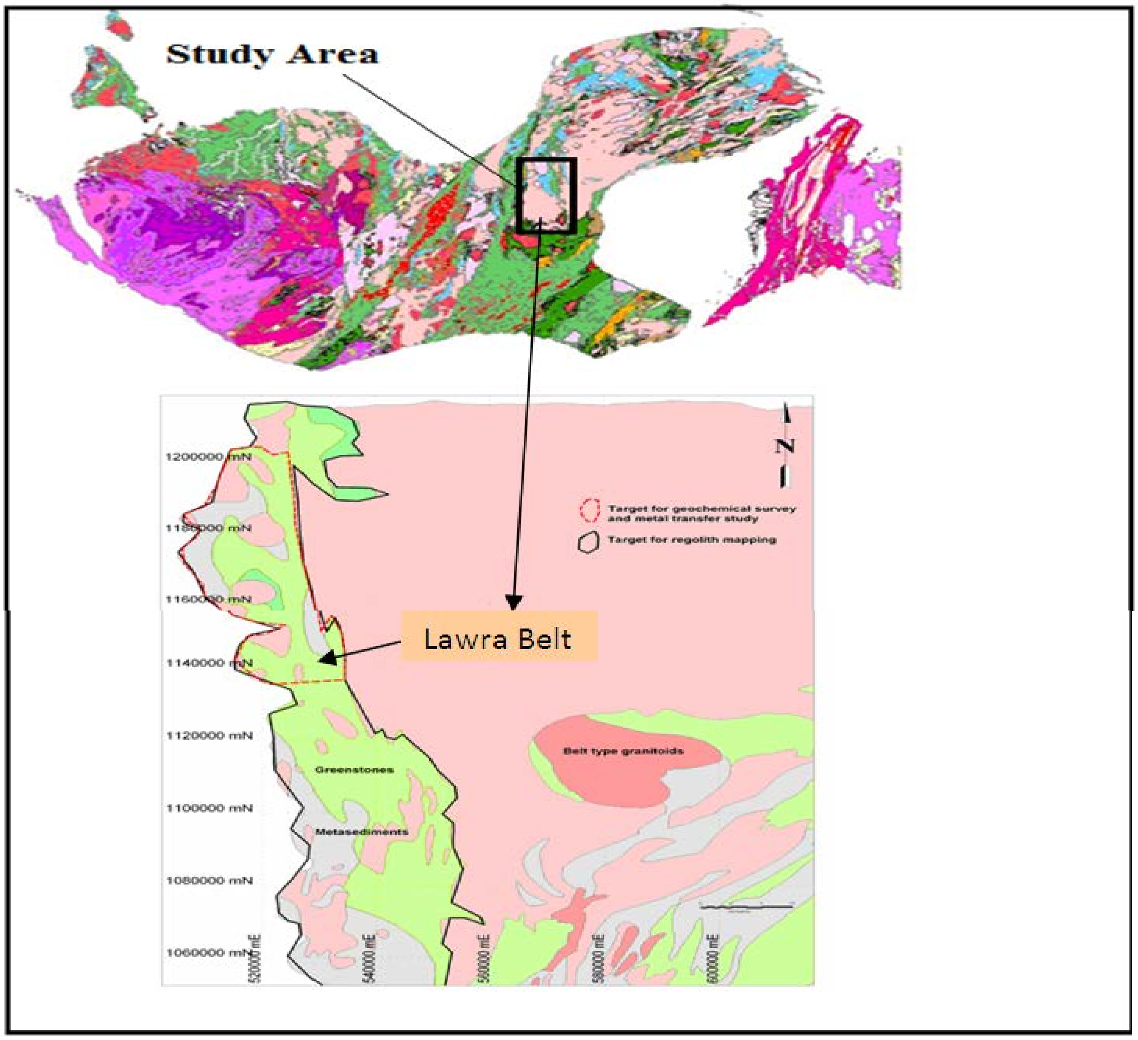

Fig. 1: Geology and location of study area (modified after Arhin and Nude (2009))

These are:

- Hornblende-rich varieties that are closely associated with the volcanic rocks and known locally as "Dixcove" or "belt" type.
- Mica-rich varieties which tend to border the volcanic belt or greenstones and are found in the meta-sediment units and referred to as "Cape Coast" or "basin" type granitoids (Leube *et al*., 1990).

Exploration difficulties: The majority of Brownfield mineral exploration in the West African Shield is confined adjacent to known mineral deposits with the objective of delineating new targets in the vicinity of the existing deposits. Companies that have chopped some successes using this approach are conducting Greenfield exploration in this region. It would be expected that with the current gold price many companies would have been in the Greenfields but this activity appears limited. On the contrary, many exploration companies have closed down their exploration wings in charge of Greenfield target in Northern part of Ghana because of the lack of discovering potential targets. These regional groups often define surficial anomalous targets but the follow-up normally render negative results because of the lack of understanding of the regolith environments and its geochemical signatures. Many of the anomalous targets defined from soil geochemical surveys tend to be associated with transported regolith and are representative of false anomalies (Fig. 2a to d). The findings of isolated high metal concentration values were either associated with false mineralization or poor regolith characteristics. As noted by Butt and Zeegers (1992) the mineralization is often not related to proper residual soils.

Residual regolith usually had good gold response underneath, whereas those associated with transported regolith had nothing below. Again, Bolster (1999) had also indicated that many exploration companies exploring in the West African Shield do not follow

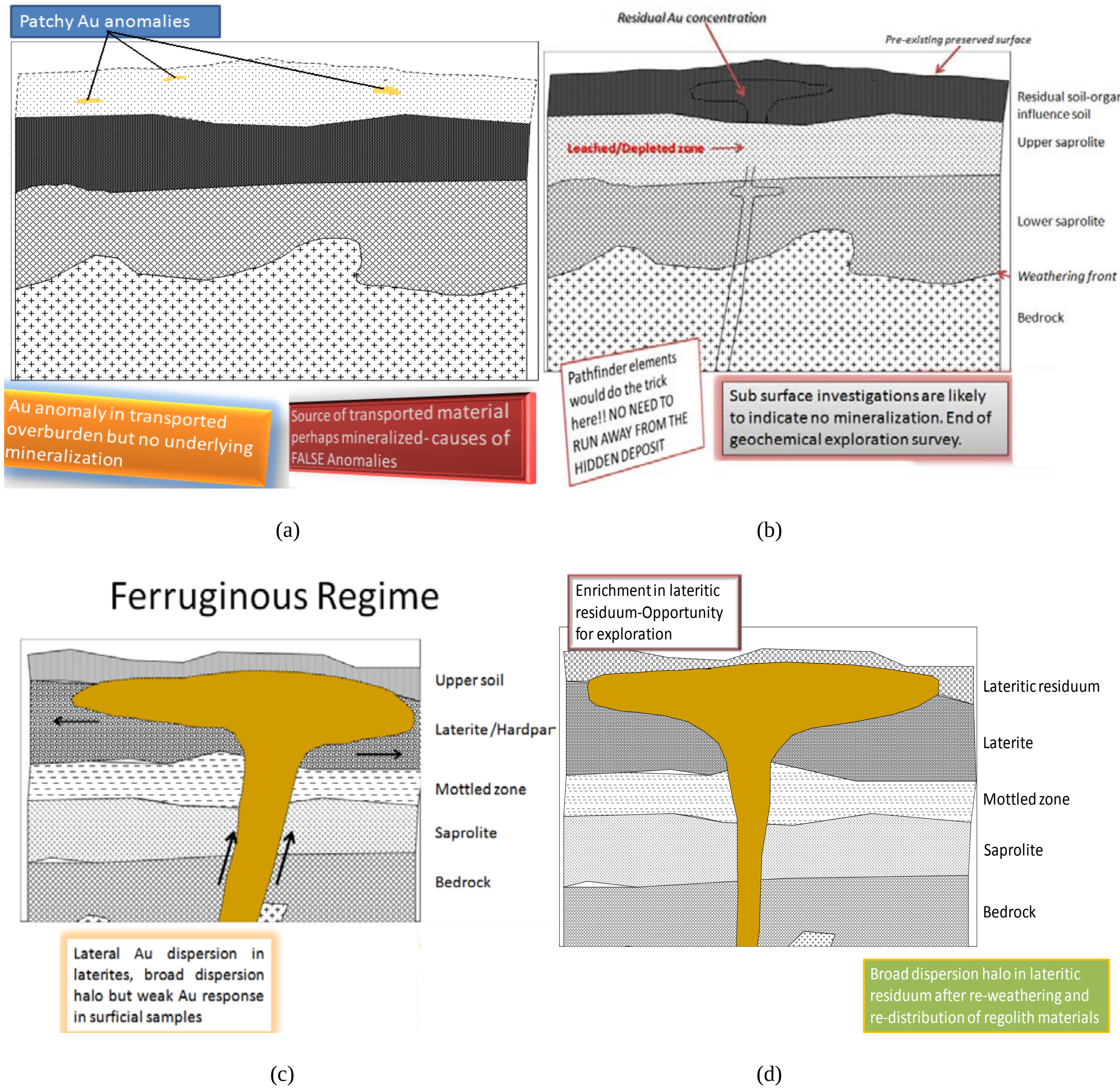

Fig. 2: Patchy and false anomalies resulting dispositional overburden or thick ferruginous enrichment

these anomalies because they do not understand the nature and genesis of the regolith and assume that if there is any mineral association it may not be big enough for economic exploitation. The resultant effect is the difficulty in delineating the blind deposits overlain by the complex regolith. The present research has envisaged the difficulties in discovering new gold deposits especially in northern Ghana due to the lack of understanding the regolith distribution and characteristics (Fig. 3). Understanding exploration issues, the characteristics of gold deposits and the exploration practices in the north without factoring in the regolith complexities therefore may not yield the desired results. Some details of the problems are as presented below.

REGOLITH OF THE STUDY AREA

The complex regolith: The study area is associated with low topographical terrains where most areas retain relicts of lateritic weathering profiles. The upper surficial profiles generally have a thin veneer of pisoliths and sheet wash deposit cover in the low lying areas. The spatial distributions of the regolith materials consist of residual regolith, commonly preserved at ridge tops and high pediments and proximal transported materials or colluviums which are found at the base of ridges and often at moderate elevated terrains. These materials are preserved on the landscapes generally as colluvial soils, screes/talus. There are also residual laterites or duricrust, which occurs at the topographic highs and are preserved as equi-granular groundmass.

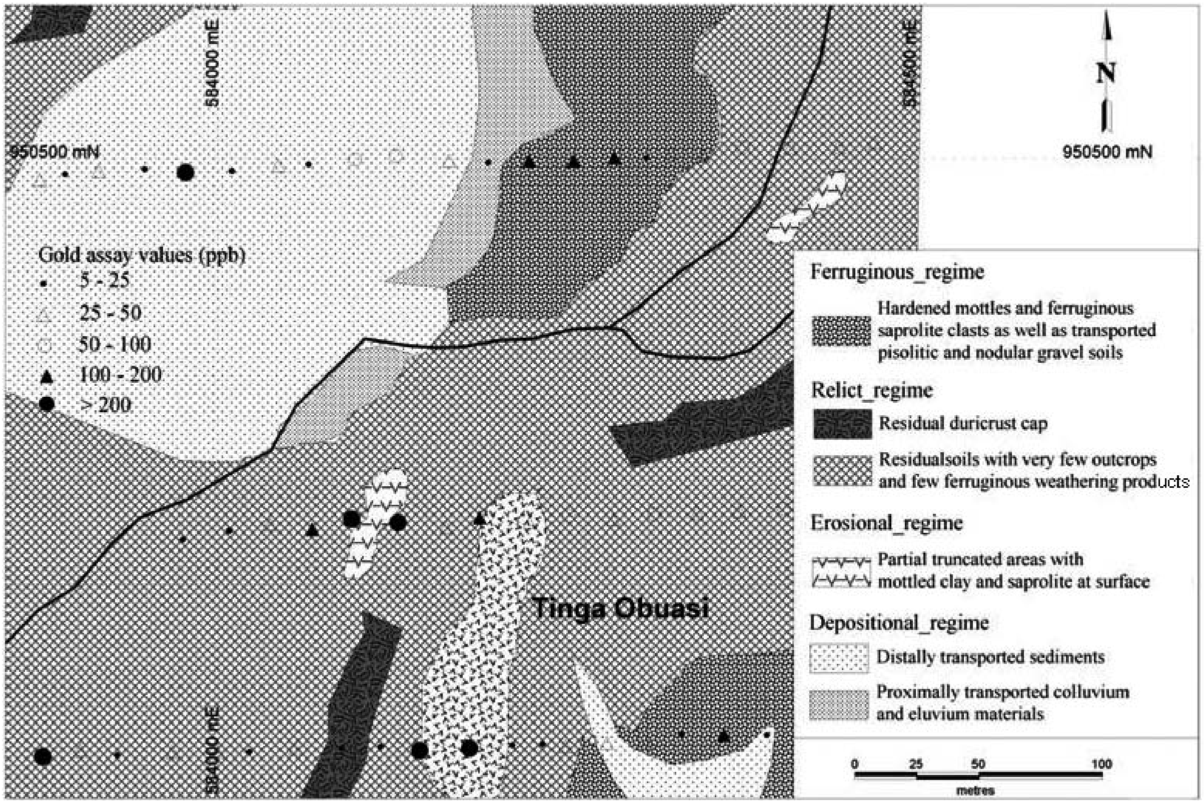

Fig. 3: Typical regolith map in northern Ghana (Arhin and Nude, 2009)

In addition to the residual regolith are transported regoliths. These are found generally at low pediments and low lying areas generally around drainage catchments areas. Ferricretes or transported laterites are widespread at the high and low pediments and sometimes in stream basins. They are characterized by rounded and sub-rounded lithic and quartz pebbles/fragments. Sometimes matured or old laterites are found embedded in an immature or younger laterite, with different weathering histories demonstrating that the ferricrete was not formed in-place. In addition to the above, certain areas have been overlain by indurated saprolite and usually appear silicified. Truncated areas exposing the saprolite are generally uncommon.

The landscape of the research area is gently undulating, at the moderate elevated areas or low pediment areas. The upland areas are generally marked by scree that decreases in fragment size down-slope. Thin layers of colluvium, which is interspersed with alluvial plains, cover the low-lying areas. The vegetation cover is generally sparse and consists of savanna woodlands with grass undergrowth. However, apart from Arhin and Nude's pilot work on the significance of regolith in gold exploration at Kunche where Azumah Resources (a local exploration company) is currently working, no detailed regolith work has been done (Fig. 3). The need to unravel potential gold mineralization under cover in this belt and similar areas in the sub region is vital, stemming from the fact that similar geological environment in the southern part of Ghana has seen several discoveries.

Regolith distribution and characteristics: Large areas of the world, especially the largely tropical to sub-tropical zone between latitudes 40º north and south, are characterized by a thick regolith cover (Butt and Zeegers, 1992). Much of this regolith is residual and consists of intensely weathered bedrock, but there are overlying component of transported materials, itself weathered to varying degrees. The savanna region of Ghana falls within this zone and the area generally lack thick residual regolith; although transported materials, including fluvial deposits and sheetwash deposits and laterite caps are widespread. Nonetheless, isolated occurrences of strongly weathered regolith are recorded from this region, either exposed or buried beneath the younger sediments, indicating that it was once more widespread. Much of the residual regolith has broadly lateritic characteristics, with a thick, clay-rich saprolite, generally with an overlying iron and/or aluminium-enriched horizon, although the latter may be only patchily developed or have been removed by later erosion. In places, the earlier regolith has been almost fully preserved; elsewhere, it has been partially or wholly eroded, or buried by sediments that may then be weathered. The outcomes are landscapes that consist of

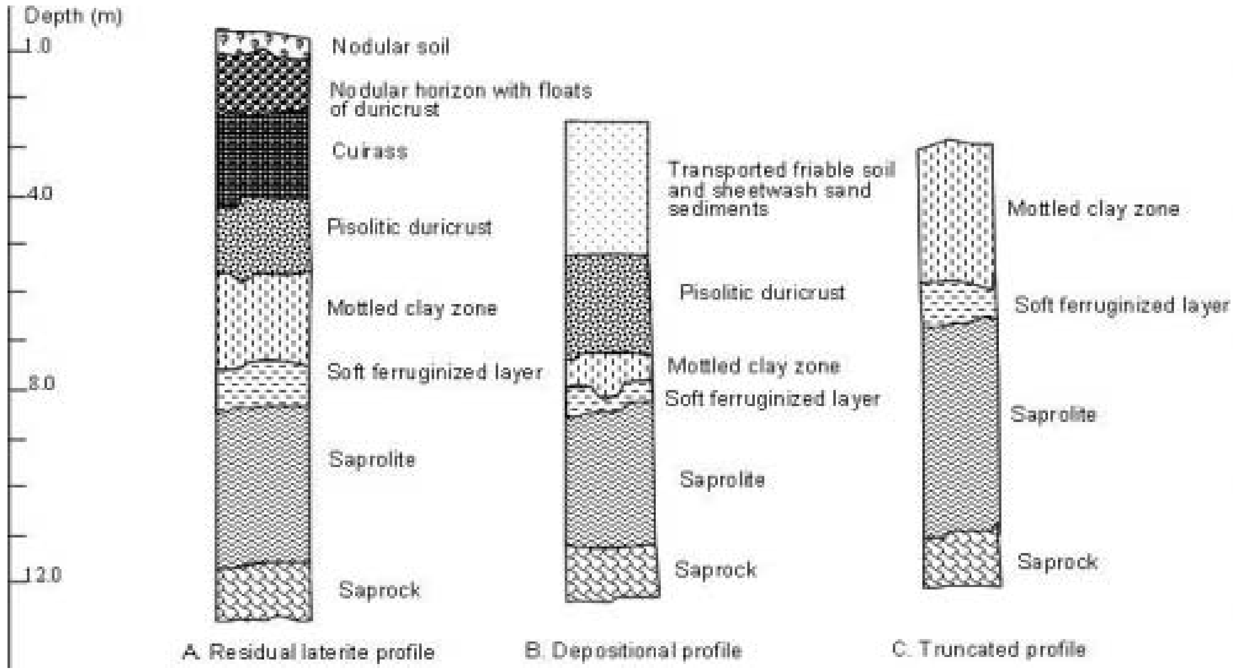

Fig. 4: Typical regolith stratigraphy in study area (Arhin and Nude, 2009)

a mosaic of different regolith-landform associations that are usually assumed not residual throughout (Fig. 4). The geochemical signatures obtained from this environment commonly appear mixed because of the differences in the regolith distributions and characteristic, so rendering a lot of false anomalies and complicated anomalous definitions.

SOME EXPLORATION CHALLENGES FROM LAND FORM MODIFICATIONS

Challenges from land modification: The complex regolith environment typically in Lawra Gold Belt of Northern Ghana, which has not been considered in the gold geochemical exploration surveys in the area presents both challenges and opportunities for mineral exploration (Arhin and Nude, 2009; Bolster, 1999; Butt and Zeegers, 1992). For instance, the profound differences in morphology, petrophysics and compositional characteristics of the derived residual regolith from the underlying rocks due to landscape modifications affect geological, geochemical and geophysical exploration procedures. In addition to the presence of transported overburden basin sediments worsens these problems, especially for geochemical procedures based on surface or near-surface sampling. Similarly, the formation of lateritic regolith that are formed under changed climatic settings modifies the landscape further and the effects of erosion during and after these events result in significant regolith-landform control on sample media. Incidentally knowledge of the distribution and properties of regolith components is not researched into and has not been factored into the numerous exploration surveys in this area (Fig. 5a to d) (Arhin and Nude, 2009; Griffis *et al*., 2002).

Dispersion patterns: Regolith features that are not factored into the geochemical exploration in the area in fact are essential for successful exploration in regolith-dominated terrains, whether for deposits concealed by the regolith (Fig. 5c to d) or for those hosted by it. Regolith-landform mapping is an essential first step, followed by characterization of the regolith materials themselves (Anand and Paine, 2002).

Conversely it appears the exploration companies that worked in the area did not use regolith-landform maps that aid to interpret the geochemical data in terms of models that describe the geochemical pathways followed by ore-related elements as they disperse during weathering. Therefore, not only do they fail to indicate the most appropriate sample media but also to assist in data interpretation (Bolster, 1999). Butt and Zeegers (1992) accordingly have reported of the increasingly emphasis on regolith landform mapping, using a combination of remote sensing procedures, followed by field checking to interpret surfacial geochemical data. This regolith landform mapping prior to the execution of the geochemical survey aid in sample selections and selection of thresholds. The integration of these maps and its superimposition on the geochemical maps can reveal inventories of surface materials, interpret some weathering styles and geomorphologic processes, but it will require field inspection to provide definitive exploration guides.

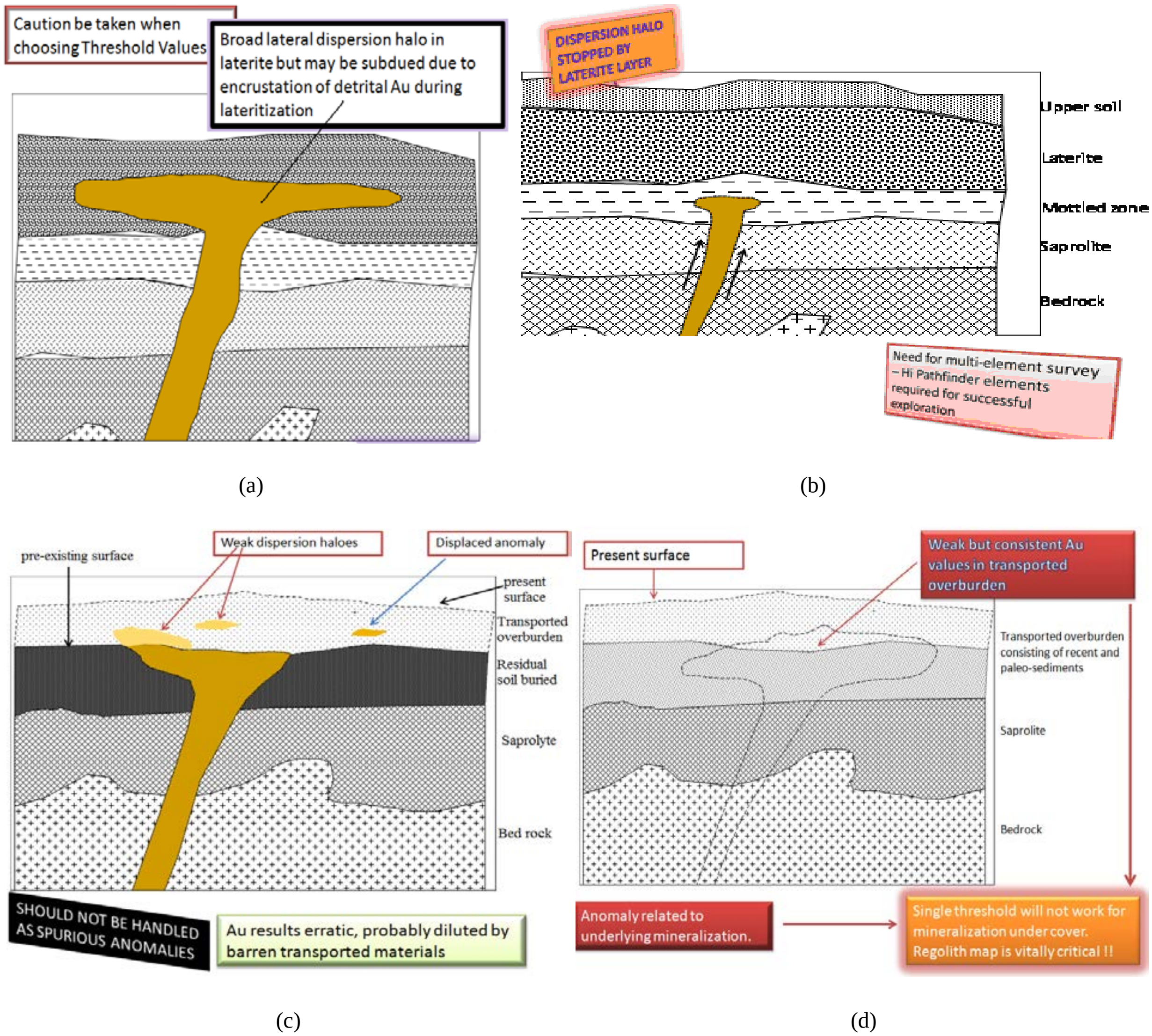

Fig. 5: Some exploration issues from landform modifications and variable

Appropriate pathfinder element for gold deposits: Freyssinet (1994) has indicated that lateritic weathering of lode deposits result in little dispersion of gold except in the upper horizons. In addition it has been found that lateral, detrital and chemical dispersion occurs in residual laterites commonly with leaching and depletion in the top 1 to 3 m and enrichment below. This provides a very broad, multi-element, near-surface exploration target. But the appropriate pathfinder elements for gold in this area are still not known. In southwest Ghana, Oberthuer *et al.* (1996) have shown that one of the four major types of gold mineralization in Ashanti belt is associated with auriferous arsenopyrite and pyrite. Contrastingly, Allibone *et al*. (2004) have also indicated the gold deposit at Chirano, in southwest Ghana too is hosted by albite and carbonate-altered tonalite. The alteration assemblages at Chirano contrast with the graphite-carbonate pyrite-arsenopyrite-pyrrhotite assemblages that generally dominate the lode gold deposits in Southwest Ghana, which are hosted by graphitic shear zones and Birimian sedimentary rocks (Allibone *et al*., 2004). But, Yao and Robb (2000) have also founded that the mineral assemblage in granitoid-hosted gold deposits at Obuasi was mainly composed of pyrite and arsenopyrite, with minor chalcopyrite, spharilite and rutile. Considering the differences in mineral assemblages for dissimilar gold deposits have revealed that analysis for appropriate pathfinder elements (e.g., As, Sb, W, Cu, Bi) are necessary for all environments as this can assist in the definition and prioritization of anomalies for further exploration. The use of gold only for gold exploration in the savanna regions may not be appropriate because of the strong leaching and depletion of gold often in the top 3 m of the regolith profile (Fig. 5). Also as reported by Griffis *et al*. (2002) most of the lithological rock samples analyzed for gold by many of the exploration companies that explored in the area from 1960 to 2002 returned insignificant geochemical gold assay values ranging from 0.1 gAu/t to about 2 gAu/t.

In addition, the concentrations and contrasts were low and wide in the surfacial soil samples. Anomalous gold targets were generally small. Usually this occurred when the analyses were done for gold only without considering the pathfinder elements. However, in mineral exploration, near-surface soil geochemical samples are collected to provide information on the underlying bedrock geochemistry. This practice has been successful for a long time and has led to countless discoveries particularly where the soils are residual and the bedrock is weathered and close to the surface. However, the tenor of a near-surface geochemical response to mineralization is affected by more than just the size of the mineral anomaly. Some very large mineral deposits do not necessarily have large surface geochemical expression (Gellatly *et al*., 1995; Cowley, 2001). The size and strength of a near-surface geochemical anomaly is a product of bedrock geochemistry that may or may not include impacts from regolith and geomorphology (Bolster, 2007). The lack of discovering prospective gold deposit in this area since the reported gold occurrence since 1935 (Kesse, 1985; Griffis *et al*., 2002) requires the need to incorporate regolith studies of the exploration environments. The usefulness of regolith studies would be shown when a regolith map is created. Furthermore, the erratic and subdued surface gold expression could be explained by regolith-landform map, coupled with accurate regolith profile logs. Knowledge of weathering history and its impact on element dispersion for effective exploration could be helpful.

Current practices: The lack of exploration for gold in the savanna regions of Ghana is demonstrated by the exploration companies' inability to integrate new exploration techniques. Generally it is expected that with the current high gold price of over $ 1000/Oz many companies would have been in the green field exploration. On the contrary, many exploration companies in Ghana have closed down their regional exploration wings (green field exploration) because of the lack of discovering potential gold targets. These regional exploration groups that worked in northern Ghana often define surficial anomalous targets but the follow up surveys commonly render negative results. The unreliable surficial geochemical results could be attributed to the regolith complexities, lack of understanding of the regolith environments, the elements dispersion as well as the remobilization of the metals in the regolith profiles (Arhin and Nude, 2009). Generally, robust surficial geochemical anomalies are detected in southwest Ghana where the regolith is not complex. Regrettably, these types of anomalies are not common in northern Ghana. Most parts of the area are characterized by subdued and isolated high gold values that do not appear prospective for follow up.

Besides, the exploring companies do not understand the nature and genesis of the regolith and thus assume potential mineralization would be associated with strong anomalies. The resultant effect is the difficulty in delineating the blind or hidden deposits in the area. The difficulty of discovering new gold deposits since the gold occurrence was first reported has made many exploration companies downgrade the possibility of potential gold mineralization under cover. It seems the lack of substantially improving the geochemical methods of exploring for gold deposits under cover and also understanding the regolith environment is the cause of unsuccessful exploration expedition in the area. For instance the incorporation of regolith factors into the geochemical exploration protocols and use of geophysics by Azumah Resources Limited led to the upgrade of 240 koz gold discovered by Ashanti Exploration to over 500 koz. It is from this perspective that a research to understand the regolith environment, its processes and the element dispersion mechanisms in selected areas within the Lawra Birimian belt is to be undertaken.

METHODS AND RESULTS

Regolith mapping: Radiometric and/or land-sat data would be interpreted to determine the land surfaces of the study area. The different surfaces could be classed using the FRED classification system. This classification system would categorize the land surfaces into ferruginous, relict, erosion and depositional regimes. Thus, instead of using (Anand and Paine, 2002) RED classification; FRED classification that separates the ferruginous regime from relict regime would be used. The Terrain or Landscape Classification map developed from the remote sensed data ought to be used as a base map. The regolith map for the area would then be established through field studies as well as extrapolation from the remote sensed data. The field studies could aim at collecting ground truth information about various regoliths and landform attributes from field sites and from general field observations. This would help to determine the regolith topo-sequence characteristics for each mapping units and the classifications defined and extrapolated from the remote sensed data. The final extrapolation of the regolith map boundaries would be done from radiometric/landsat images and be authenticated from the information obtained from regolith profiles established from natural exposures and dug pits.

Regolith characterization and geochemistry: The field studies of the regolith profiles and the element concentrations and distributions in the different regolith regimes could be done by excavating pits from land surface to the bedrock. For instance in Lawra Belt, spatial distribution of pits can be; 2 pits at ferruginous regime; 5 at relict regime; 2 at erosional regime and 5 at depositional regime. Approximately, a total of 280 samples could be collected from the surface regolith materials and the 14 dug pits. Allocations of the samples could be 50 from ferruginous, 100 from relict, 30 from erosional and another 100 from depositional regimes. The pit profiles would be logged first. This would be done by identifying the different layers in the profiles after which the materials in a layer would be sieved to examine the shapes of the litho-relicts and quartz fragments. The origin of the regolith materials, either be residual or transported would be determined from the pits and natural exposures logs. Distribution and characterization of principal regolith mapping units would then be conducted by determining:

- Petrographic-morphological features
- Mineralogical and major element composition of the surface materials and their relationship if any, to underlying regolith units and bedrock

Major element and trace element data would be collected at this phase from no known mineralization areas to provide useful background information. Two types of regolith maps could be established. First, factual map based on the mappable units on the ground truth survey. The second map would be interpretive map based on genetic groupings or classification of materials with respect to the mappable units. The classification units would be ferruginous, relict, erosional and depositional regimes. The two maps would be superimposed on a remote sensed data. Then, the information obtained from established regolith stratigraphy would be used to modify the regolith map. The tentative regolith maps developed from the Terrain or Landscape Classification and the Genetic or Factual map would then be upgraded to final regolith map. This final map would adequately describe the terrain with respect to the geomorphology and regolith so that the user can visualize the terrain and know what materials are at or close to surface. The genetic map would form the basis for Geochemical Sampling Strategy Map.

Geochemical sampling: An orientation survey could be conducted to determine detailed dispersion studies around mineralization in each of the principal mapping regime to determine dispersion characteristics and geochemical signatures in different surface and subsurface units. In addition multi-element analysis that yields numerous elements would be conducted as some of the elements may have a local importance. Generally the most important pathfinder elements for gold in geochemical environment recommendable are As, Sb, W, Bi, Mo (Butt and Zeegers, 1992). Approximately about 54 samples would be sampled along the topo-sequence vertically. The sample intervals would be dictated by the horizon thicknesses. However, the field sample weight of homogenized sieved samples would not exceed 2 kg. Four samples will be collected from each of the five pits that will be dug at the relict regime. This would make available 20 samples for geochemical analysis. The upper soil and the laterite samples would be sieved to -125 µm using the appropriate mesh size at the laboratory after the 2 mm field seiving. Eight samples would be taken at ferruginous regime; 6 samples at erosional regime and 20 samples at the depositional regime and these would be analyzed for gold Fire assay with Atomic Absorption Spectrometry (AAS) finish. The associated pathfinder elements such as Ag, Cu, Pb, Zn, Mo, Ni, Co, Cd, Bi, As, Sb, Fe, Mn, Te etc., could be detected using ICP-MS.

Metal transfer and pathfinder elements for gold exploration: Multi-element survey to understand the metals transfer in the regolith profiles and the identification of the pathfinder elements for gold in the area could also be conducted. This could be done by following up geochemical gold results obtained from the pits and the surfacial regolith materials that showed significant gold values $\geq$100 ppb to establish appropriate pathfinder elements for gold, instead of using gold only, which is not a detectable geochemical anomalies under cover. Additional 300 or more surfacial regolith samples would be collected from the four regolith regimes. Also 10 pits distributed over the various regolith regimes of which 40 vertical samples could be sampled and analyzed for multi elements and Au. These pits could be sited over known gold mineralization and defined gold areas from the geochemical survey.

Integration model: The surface geochemical gold results obtained from the survey would be used to develop a thematic geochemical map that would show the relative concentrations and distribution of gold in the surficial regolith materials from all regimes. This map would be draped on the final regolith map and thus be used to fully interpret the geochemical data for the different regolith regimes. Also graphs of gold and other elements would be plotted to identify pathfinder elements for gold exploration in the working area. The combination of the Spatial and Non-spatial analysis as well as the integration of regolith-landforms map and geochemical plot would aid to develop a model for effective exploration in the study/working area.

DISCUSSION

To achieve greater success in exploration in complex environment of northern Ghana is to substantially improve geochemical methods of exploring for gold deposits under cover or obscured by weathering. The realization of the exploration success would be envisaged through the following:

- Development of regolith-landform framework by conducting regolith-landform mapping and characterizing regolith profiles

- Investigation of the effect of regolith properties on metal migration
- Investigation of geochemical dispersion patterns and processes by a series of case studies
- Establishment of a conceptual model of geochemical dispersion pattern of gold and accompanying elements (Cu, As, Hg, Pb, Cd, Sb, Bi, Mo and W) based on case studies
- Development of appropriate methods of regolith mapping for exploration geochemistry, that takes into account weathering and geomorphic histories in the region to control exploration geochemistry and geophysics

CONCLUSION

The study concludes that:

- Lack of understanding the regolith complexities in northern Ghana has affected proper interpretation and planning of geochemical exploration. Hence it has affected new discoveries of gold under cover.
- Appropriate regolith mapping of terrains could assist in the delineations of minerals including gold and reduce gaps in geochemical coverage.
- Despite improvement in the sensitivity and reliability of gold analytical methods, some of the elements behave very differently to gold in primary and/or supergene environments requiring change of technique.
- Appropriate pathfinder elements for gold in that complex regolith environment may be necessary to provide indications of the possible source of hidden mineralization.

RECOMMENDATIONS

It is recommended that:

- A regolith map which could be used to plan and interpret near-surface geochemical data should be developed for Northern Ghana.
- Knowledge of the metal transfer within complex regolith environment could be investigated to determine the most appropriate pathfinder elements to assist exploration model.

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