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GOLD IN TREES AND HIDDEN ANOMALIES IN DIVERSE REGOLITH TERRAIN: A CASE STUDY AT PELANGIO MAMFO CONCESSION, GHANA

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Abstract
Deep-rooted trees absorb minerals including gold from the weathered materials and translocate the resources to different structures of their body. This occurs as part of general elements translocation process and those considered toxic to trees move to the extremities and other preferential areas away from the tree biological functioning zones. After investigation of several plant species, Sapele (Enthandrophragma cylindricum) tree bark was used as supplementary medium to soils in areas under cover; sixteen samples were collected from roots, barks, twigs and leaves. Fire assay was used and analysis of the results divulged differences in gold signatures in samples. The highest gold expression of 1045 ppb was found in bark samples with a minimum of 9 ppb occurring in twig samples. Gold averages from Sapele (i.e., from the leaves, twigs, roots and bark sampled) were 116.44 ppb, 89.53 ppb, 209.25 ppb, and 352.31 ppb, respectively. The high gold in leaves over twigs may be an attribute of aeolian gold contamination coalescing with the absorbed gold. Roots being close to source of mineralization had lower gold than bark samples and this is accredited to gold toxicity and its subsequent movement away from the xylem to the bark. The best part of a tree considered appropriate as a supplementary medium to soil samples is bark samples.

Keywords*: Gold, Regolith terrain, Pelangio Mamfo, Sapele, Geochemical*

Introduction
Data on gold discovery and resource inventories for metals indicate that the discovery rates in the mineral industry are declining and discovery costs are rising steeply (Schodde, 2015). This looming crisis is linked to several factors. These factors include lack of finance to push the exploration programmes and exploration moving to more complex regolith terrains. The complex regolith creates geochemical data interpretation challenges. This phenomenon results in false anomaly follow-ups, consequently accounting for the closure of many exploration expeditions. The regolith is made up of consolidated and unconsolidated weathered materials. According to Arhin and Zango, (2015) the regolith can host or mask gold geochemical anomalies and can as well influence the geochemical anomaly at a place due to physical and chemical processes that control metal transports in the secondary environment. The unevenly distributions of the regolith mapping units exacerbate the surface geochemical expressions in measured gold in samples. This accounts for the coexistence of residual and transported gold anomalies in a diverse regolith terrain without embarking on regolith studies. The regolith study is a specialized field and requires the attention of an expert to map and interpret.

In sustaining the mineral industry, there is a need to search for new mineral resources in the regolith complex terrains. Arhin and Affam, (2009) have demonstrated the use of termite mound as a supplementary sample medium for gold exploration. Termites build termitaria from weathered materials burrowed deep from subsurface, generally obtained beneath the transported regolith. Evidence for <125 μm size fractions of the termite mound materials were identified by Arhin and Nude (2010) as an appropriate sample medium for gold exploration. The use of termitarium as a sample medium was good but had a shortfall of not being common in some geographical areas. This necessitated the use of trees with deep taproots that penetrate beyond the regolith and translocate gold in solution from the *in situ* weathered bedrock. Mclnnes *et al*. (1996) used outer bark of *Astronidium palauense* tree in Papua New Guinea to reliably indicate gold (Au) concentrations in the substrate. The root system reached at least 4 m depth, allowing greater penetration than surface soil samples. Arhin *et al*. (2018) after investigation of several plant species such as *Triplochiton scleroxylon* (Wawa), *Petersianthus africanus* (Asia), *Alstonia boonei* (Nyamedua), and *Enthandrophragma cylindricum* (Sapele) found the root system of Sapele to reach at least 5 m depth, allowing greater penetration than surface soil samples. Sampling parts of this tree was recognized to be tested at Pelangio concession at Manfo where geochemical targets tend to be buried by depositional and ferruginous regolith regimes.

Gold absorbed is transported by the roots system to the various parts of the tree. Many authors, (Girling and Peterson, 1980; Shah and Belozerova, 2009; and Ostroumove *et al.*, 2014) who recognized the toxicity of gold to plants further noticed the movement of gold to extremities or in preferential zones within the tissues in order to reduce deleterious biochemical reactions to plants. Indeed, gold concentration levels will be different when comparing the concentrations at the various plant parts. Establishing the part of the plant to yield good and reliable gold concentration that detects the hidden anomaly is the focus of this paper. It is therefore the objective of this paper to define more precisely the clear spatial anomaly patterns with good contrast to background for the parts of plants sampled.

Furthermore, when plants absorb and translocate gold, it could be absorbed in non-ionic form unlike the other elements which usually absorb in their ionic forms in soil solution (Lintern *et al.*, 2013; Silberbush & Ben-Asher 2001). However, there is no general agreement among investigators as to the forms of gold that are absorbed by plants. Many posit that it is absorbed in the form of nanoparticles. In any case, gold nanoparticles of 10 mμ size theoretically can enter into the vascular system of a plant (Anderson *et al.*, 1999; Shacklette *et al*., 1970). If gold is absorbed by plants it would be conducted along the soil solution into the xylem vessels. The intriguing question here is when gold is absorbed by plants, where does it end up?

In general, heavy metals have been reported to be transported to the soil from various sources where they are absorbed by plants (Yan *et al*., 2012) and the concentrations of these metals in the plant tissues have been traced to various factors such as wind direction (Jaradat & Momani, 1999) and water action (Ghrefat & Yusuf, 2006). If the plants are unable to use all the elements entering together with the basic nutrients, they normally free themselves from the excess by discarding them into protective and structural tissues, or finally, transporting them into organs and tissues (Shacklette *et al*., 1970). Thus, the solubilization of native gold by hydrogen cyanide and the absorption of cyanide compounds of gold by various plant species are likely to occur in natural environments (Shacklette *et al*., 1970). *Eucalyptus* in particular was reported to contain gold originated from mineral deposits and support the use of vegetation biogeochemical sampling in mineral exploration. Absorption and hydraulic lift could possibly be mechanisms by which trees take and translocate gold in this study.

Methodology

Location and Physiographic Setting

The research was carried out at Pokukrom-Subriso gold prospecting licence area in Manfo traditional area edged red in Figs. 1 and 2, respectively.

Fig.1: Location of study area shaded red

Source: Arhin *et al.* (2018)

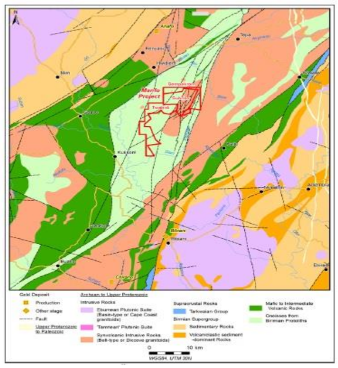

Fig.2: Regional geology of the study area

Source: Arhin *et al.* (2018)

The landscape consists of undulating terrains with low hills and isolated hills separated by relatively wide and narrow valleys. The hills height ranges between 190m and 280m above sea level (Dickson & Benneh, 1995). The climate of the area is tropical with distinct wet and dry seasons. Annual rainfall ranges from 700 to 2,100 mm. Vegetation is rainforest-type and the dominant species are *Enthandrophragma cylindricum* (Sapele) and *Aningeria spp* (Asanfena) with tree-densities of about 12 trees and 9 trees per hectare, respectively.

Regolith

The area is characterized by deep weathering with simple and complex weathering histories. These forms of weathering histories tend to render the regolith landform units uneven. The spatial anomalies from soil geochemistry in the relict regolith relate to the underlying gold mineralization. Anand *et al.* (2006) reported that the surface processes that move the regolith mapping units around and subsequently cement the units during lateritization processes do influence the associated gold geochemistry. Avoidance of defining 'False' anomaly as 'True' anomaly may be realized on the assurance of collecting surface samples beneath the complex regolith or on the guarantee that surface samples collected are residual in character.

Geology

The study area is situated at the eastern edge of the Paleoproterozoic Sefwi-Bibiani Birimian Belt. Underlying the area is primarily the metavolcanic, metasedimentary, volcanoclastic and basin granitoids (Hirde *et al*., 1996, Fig. 2). The metavolcanic rocks contain basalt and dolerite, with lesser gabbro, tonalite and diorite (Kesse 1985). Intruding the volcanic rocks is belt granitoids. They are small discordant to semi-discordant, late or post-tectonic soda-rich hornblende-biotite granites or granodiorites that grade into quartz diorite and hornblende diorite (Hirde *et al*., 1996). The basin granitoids intrude the metasedimentary rocks that are made up of phyllite, schist and some wackes. The intrusive bodies consist of large concordant and syntectonic batholitic granitoids commonly banded and foliated. They are two-mica potassic granitoids, containing both biotite and muscovite, with the biotite dominating (Leube *et al.,* 1990). The rocks in this area were deformed around 2.1 Ga during the Eburnean orogeny (Abouchami *et al.*, 1990; Milési *et al.*, 1991; Taylor *et al.*, 1992). This orogeny had been reported to have association with shear-zone mineralisation (Griffis *et al*., 2002; Kesse 1985). These deformational events therefore place the study area into orogenic gold province of global significance.

Sampling Procedure

Criteria for sampling

The known mineralized areas based on geological prospectivity information gathered from the exploration work by Pelangio Gold Ltd. supported with the evidence of weak, high and subtle soil geochemical gold expressions in these areas necessitated the sampling of trees. The tree locations and characteristics of gold spatial anomalous patterns as well as the depths at which the root system penetrates the weathered materials were used as part of the criteria in selecting the tree species for the study. Complementing this criterion was the lessons learnt from the exploratory biogeochemical survey conducted in this same area by Arhin *et al*. (2018) that revealed differences in concentration levels of gold between the tree species. This led to the selection of Sapele (*Enthandrophragma cylindricum*) as the appropriate tree species because of the high concentration of gold results obtained from them relative to the other tree species. Additionally, the widespread occurrence of Sapele (*Enthandrophragma cylindricum*) coupled with its relatively high density, an easy to recognize and identify made Sapele (*Enthandrophragma cylindricum*) a tree of choice to sample. Also, the evaluation of interview results obtained from the people of Pokukrom, Nfante and Subriso further found *Enthandrophragma cylindricum* to satisfy all the criteria parameters better than the other tree species.

Study design

As part of the study design, four trees were selected for sampling at known mineralized terrains. Four different sub samples were collected from each tree and these included samples from root, bark, twig and leaf. For the bark samples, sampling was conducted by scraping a thin layer of the tree trunk, after which the real sample was scraped around the girth of the tree at breast height (i.e., 1.5 m from the ground surface) using a locally made cutlass. Other samples were also collected from the roots, leaves and twigs of the same trees. Each component part was thoroughly mixed and sub-sampled. All the collected samples were placed in already labelled large plastic sample bags. Samples weight of between 500g for the root and bark and 1000g for leaf and twig were collected. Parameters such as tree's location, the tree's circumference (girth) at 1.5m level from ground surface, estimated height, and radial extent were recorded. The challenges in establishing age of trees necessitated the sampling of Sapele with average circumference (trunk girth) of 4m to 5m. Additionally, trees that had excellent quantity of foliage and showed very good colour and turgidity of leaves including stems/trunks were subjected to the sampling. The study also made sure that the sampled trees had no degrees of infection or insect attacks on any parts of the plant.

Treatment of samples collected

All the samples were oven dry; pounded to reduce the surface area and then sieved to <125 µm size fraction. 50g portions of the sieved samples were weighed and placed in labelled Kraft sample bags for gold analysis at Australian Laboratory Services (ALS) Geochemical Laboratory in Kumasi using modified Fire Assay (FA) analyses. The standard Fire Assay technique used 30g weight samples with detection limit (DL) of 10 ppb for the gold analysis. However, in this research, to operate at a lower detection limit of 5 ppb, the sample weight was increased to 50g. In addition, certified reference materials (CRM) namely; LEA-16, OXA89 and CREAS222 were inserted in the batch of samples and sent to the commercial laboratory ALS-Chemex – Ghana to serve as controls.

Data Analysis

The data was analysed with descriptive statistics using means and standard deviations. Multivariate statistics were also used to show the relationship between gold and some other elements whilst component matrix of the Factor Analysis was also employed.

Results and Discussion

The sampled Sapele trees' height ranged from 36 to 38m whilst their girth ranged between 4.1 and 4.5m. The radial extent of the trees was between 5.0 and 5.8m (Table 1). The trees characteristics determined such as girth, height and radial extent did not show any significant differences ($p>0.05$) amongst those parameters in the sampled trees.

Table 1: Trees parameters at a known mineralized terrain in Pelangio Manfo Project area, Ghana

Tree label	Girth (m)	Height (m)	Radial extent (m)
AS001	4.3	37	5.2
JW001	4.1	36	5.0
NY001	4.5	38	5.8
OP001	4.4	37	5.6

N.B: AS, JW, NY and OP represent Subriso, Siawkrom, Nfante and Pokukrom communities, respectively where the trees were sampled. Thus, assigned field identification.

The analysis of the certified reference materials (CRM); LEA-16, OXA89 and CREAS222 inserted in the batch of samples sent to the commercial laboratory, ALS-Chemex – Ghana, for the purpose of assessing the analytical quality of the data is presented in Table 2. The analytical values of the three CRM samples produced numerical values close to the 'true values' of the actual CRM certified values for gold in LEA-16, OXA89 and CREAS222 certified reference materials (Table 2). The standard deviations for the CRM's appear low and range from 0.06 to 0.68 from the expected mean and therefore the quality of the analytical data received from the laboratory was deemed acceptable.

Table 2: Certified reference materials results for quality assurance analysis

Standard	Actual CRM	Measured CRM
LEA-16	0.536	0.5240
OXA89	0.095	0.0855
CREAS222	1.300	1.2200

The challenge of using the conventional geochemical exploration method is worsened due to the lack of incorporating the surface landscape modifications in soil geochemical data interpretations. The processes that affect the landscape modifications do also influence the gold geochemistry. The consequences are the patchily distributions of enhanced and subdued gold expression (Anand & Paine 2002; Arhin *et al.*, 2015), contributing in parts to concealed gold anomalies from detection (Butt, 2000), using surface samples like soils. Gold generally known as a relatively immobile element, associates well with some elements. Birimian system of Ghana hosts many of Ghana's gold of which many of the discovered gold deposits have an association with chalcophile minerals (Dzigbodi-Adjimah, 1993; Kesse, 1985) containing arsenic (As), copper (Cu), zinc (Zn) and lead (Pb). The multi elements analysed alongside gold (Au) in the tree parts samples were processed using multivariate statistics to show some relationship between Au and some other elements. The component matrix (Table 3) of the Factor Analysis (FA) of the Au-group or component 2 showed Au correlating moderately well with As and weak correlations with Cu and Fe. Lead (Pb) exhibited negative correlation in the Au-group.

Table 3: Component matrix of gold and some other minerals

	Component							
Elements	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Au scaled	-0.041	0.729	-0.073	0.521	-0.024	-0.091	0.262	0.218
Ag	0.426	-0.479	0.591	0.093	0.393	-0.066	-0.060	0.203
As	0.362	0.396	0.422	-0.193	0.270	0.551	-0.117	-0.131
B	0.165	-0.732	-0.031	0.146	0.440	-0.085	-0.039	0.367
Ba	-0.349	0.655	-0.227	-0.047	0.157	0.453	0.232	0.328
Be	-0.036	0.301	0.589	0.605	-0.099	-0.099	0.204	-0.134
Bi	0.912	0.267	-0.108	0.010	-0.059	-0.219	-0.047	-0.068
Cd	0.800	-0.232	0.005	-0.141	-0.296	0.108	0.362	0.201
Hf	0.823	0.301	-0.178	-0.163	0.068	0.380	-0.075	-0.106
Hg	0.853	-0.009	-0.327	0.087	-0.205	0.086	0.039	-0.123
In	0.730	0.327	0.276	0.235	-0.194	-0.206	0.247	-0.216
Mo	0.792	-0.138	0.315	0.121	-0.109	0.134	-0.219	0.338
Nb	0.725	0.455	-0.106	0.086	0.137	0.408	-0.096	0.202
Ni	0.713	-0.374	-0.146	0.271	0.425	0.013	0.178	-0.166
Pb	0.255	-0.089	0.475	-0.323	-0.637	0.119	0.011	-0.061
Pt	-0.032	0.794	-0.357	0.048	0.248	0.017	0.295	0.080
Rb	-0.006	-0.608	0.400	0.166	0.388	0.201	0.388	-0.285
Sb	0.013	0.690	0.178	-0.279	0.241	-0.360	0.350	0.268
Sc	0.935	0.256	-0.126	-0.016	-0.018	-0.100	-0.082	-0.116
Te	-0.469	0.072	-0.238	0.219	0.158	0.523	-0.195	-0.079
Th	-0.045	0.315	0.726	0.530	-0.217	0.132	0.064	-0.017
TI	0.777	-0.155	-0.123	0.226	0.448	0.042	0.175	-0.140
Zn	0.750	-0.164	-0.083	-0.133	-0.438	0.099	0.383	0.080
Zr	0.005	0.355	0.194	-0.712	0.424	-0.224	0.153	-0.195

Extraction Method: Principal Component Analysis.

a. 8 components extracted.

From Table 3, it appears As can be used as a pathfinder element for Au in using tree samples in Au exploration in this area. However, the significance of complimenting pathfinder elements to support the general use of gold only in anomaly delineation in complex regolith environment is demonstrated by the gold results of the four trees sampled in the known mineralized area in Pelangio concession. The total variance explained (Table 4) indicates 12.6% of the amounts of variance in the original variables accounted for by each component are from the Au-group.

Table 4: Total Variance Explained

Initial Eigenvalues			Extraction Sums of Squared Loadings		
Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
20.715	48.174	48.174	20.715	48.174	48.174
5.402	12.562	60.736	5.402	12.562	60.736
4.594	10.684	71.420	4.594	10.684	71.420
3.094	7.194	78.614	3.094	7.194	78.614
2.452	5.703	84.317	2.452	5.703	84.317
1.836	4.271	88.588	1.836	4.271	88.588
1.482	3.447	92.035	1.482	3.447	92.035
1.338	3.111	95.146	1.338	3.111	95.146
0.808	1.880	97.026			
0.646	1.503	98.529			
0.342	0.795	99.324			
0.291	0.676	100.000			

Different gold results were obtained for the same tree species sampled. The minimum gold values were found in OP001 with gold signature of 9 ppb in twig samples (Fig. 3). Hitherto this value would have been considered as below detection limit (DL) using the standard FA analytical method with DL of 10 ppb. Example subsample NY001 assayed 383 ppb whilst its matching twig sample assayed 98 ppb. Notwithstanding the locations of the parts of tree sampled and their closeness to the bedrock gold mineralization source, there are areas where leaf samples had higher Au value than its immediate twig sample. The variation in gold expressions between the two media needs further investigation. As has been in the earlier speculation that vegetation samples may have association with aeolian contamination. This cannot be ascertained in this study as it is not all the leaf samples that showed high gold concentration results compared with the immediate twig samples. The precaution of scraping the trunk before the bark sampling was not applied to the other parts of the tree. This thus makes it very challenging to refute the speculative conclusion of aeolian contamination in the leaf samples. However, this observation confirms Lintern *et al*.'s (2013) point that active biogeochemical adsorption of Au exists and provides insight into its behaviour in natural samples. The increasing gold signatures from the root to the bark samples in NY001 suggest the absorption capacity of root system to take up gold from the weathered materials to the other parts of the tree.

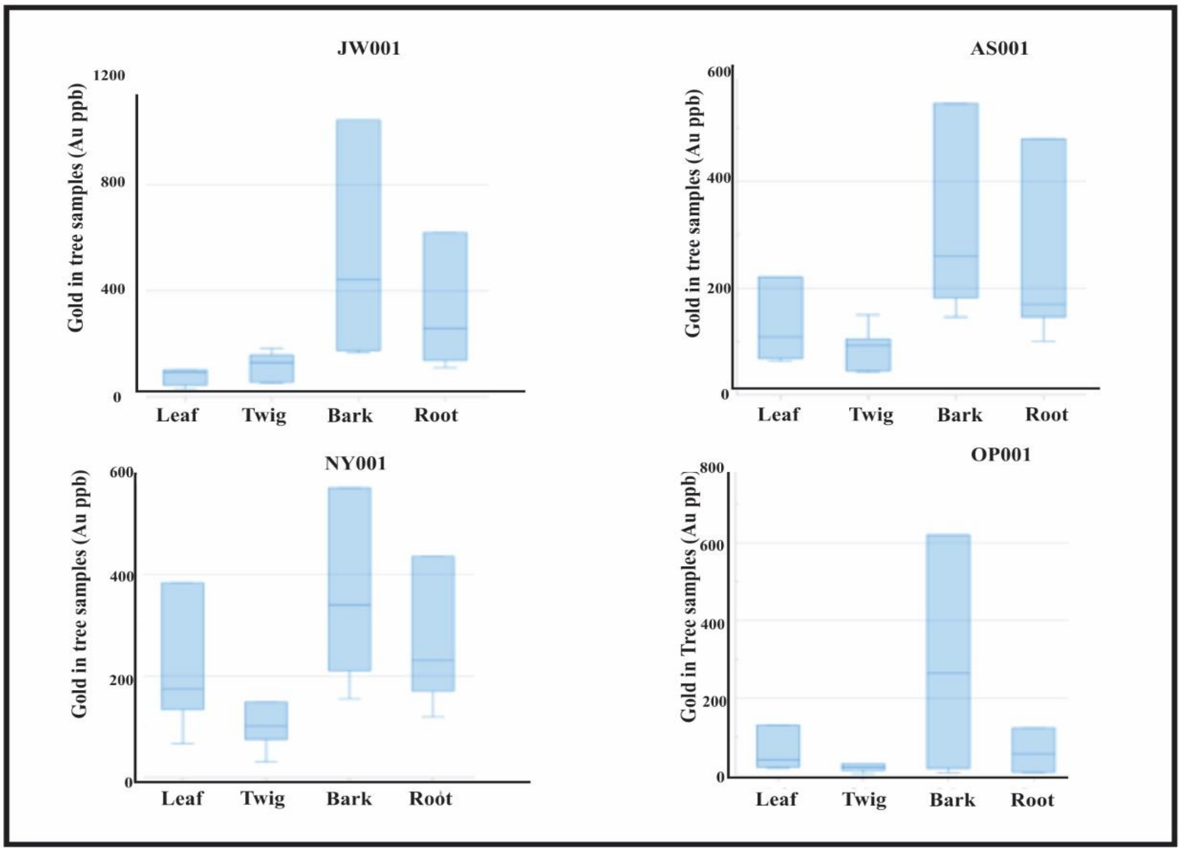

Fig. 3 Gold in parts of samples in the same tree at a known mineralized terrain in Pelangio Manfo Project area, Ghana

The maximum gold value of 1045 ppb was obtained from bark sample collected from JW001 (Fig. 4). The concentration levels between tree samples can be observed among trees located on the gold mineralization. Gold anomalous areas can be located and defined. For instance, in JW001 (Fig. 4), the highest gold signature was found in bark samples followed by root samples. Then, as a dissolved mineral, the gold gets transported throughout the tree but the non-essentiality of gold for the biological function of the tree results in their movement to the extremities or to any preferential zones of the tree through biotic process (Gardea-Torresday *et al*., 2002). Consenting to the understanding that gold ions are toxic to trees in its biological functions (Lintern *et al*., 2013) and trees growing directly over a gold deposit have higher-than-normal concentrations of the element in their roots, barks, leaves and twigs than the surrounding trees outside the mineralized area (Arhin *et al*., 2018; Lintern *et al*., 2013) motivated the sampling of four parts from four different trees located in a mineralized zone in this study. The results showed the relevance of using tree parts as a supplementary medium to soil geochemical surveys for gold exploration.

The average of averages of gold in the sampled parts of the tree in order of significance towards anomaly definition are bark> root> leaf> twigs with resultant gold averages of 352.31 ppb >209.25 ppb >116.44 ppb > 89.53 ppb, respectively. The fact that the living tissues of plants do not use gold in its food preparation may explain the high gold expressions in the bark of trees. Gold absorbed from the underlying bedrock mineralization are translocated to different parts of the tree. This biotic process will occur within cells in order to reduce deleterious biochemical reactions. The significant gold signatures in bark may be attributed to re-concentration of the gold ion during expulsion by the living tissues.

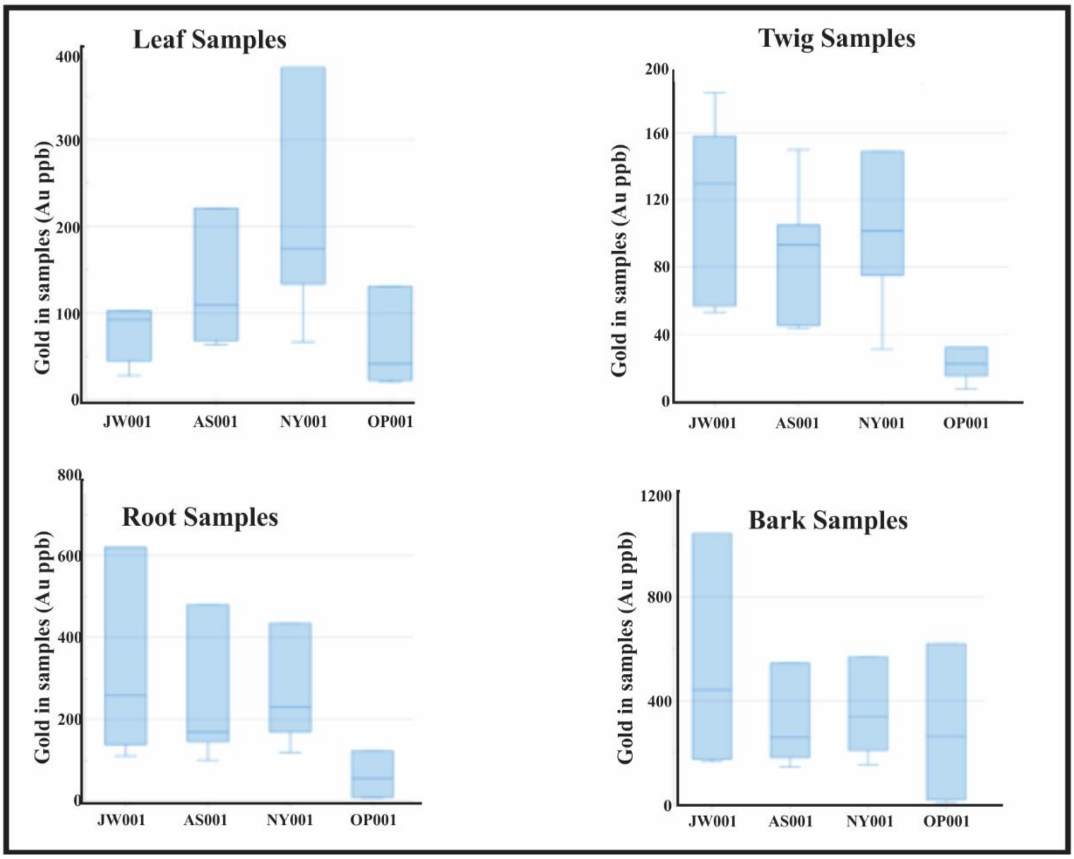

Fig. 4 Gold expressions in tree parts from four trees samples at a known mineralized area in Pelangio Manfo Project area, Ghana.

The results obtained in this research confirmed the link between abiotic and biotic geochemical processes at the earth surface asserted by Lintern *et al*. (2013) and demonstrates strongly the significant but sporadically distributed mass of Au ion within the tree samples.

The results obtained for the four Sapele trees sampled appeared the gold concentration in JW001 increased through re-concentration process during the biotic process as the unwanted gold was relocated to the bark. Normally, gold concentrations decrease away from the source materials so it will be out of place if gold concentrations in twigs are lower than concentration levels in leaf samples. Nevertheless, there are results in this study where twig samples are lower than the gold concentrations in the leaf. Causes of this anomaly require further studies to proof or disapprove the gold adsorption on leaf adding more impetus to the theory of aeolian contamination in biogeochemistry. Though the samples were collected from the same tree species but gold concentrations in AS001 (Fig. 3) seem different while the highest concentrations were found in bark samples followed by root samples. However, there is a departure from the normal pattern where the concentration trend should decrease to the leaves. Relatively high gold signature was recorded for leaf samples over the twig samples. Unless proving otherwise, the increase in gold signatures in leaf samples may not be the result of the translocation of the absorbed gold from roots through the shoot system of the tree, rather this could be the outcome of adsorption of gold through aeolian contamination. The behaviour of gold concentrations in samples collected from NY001 (Fig. 3) is similar to that of AS001 (Fig. 3). The relatively high gold concentrations in leaf samples over its corresponding twig samples may be the interplay of gold concentrations from both absorbed and adsorbed gold. Gold expressions in samples collected from OP001 (Fig. 3) further indicated the bark samples to have high concentrated gold relative to other preferential zones sampled from the trees suspected to host some of the translocated gold. The comparison of gold in the sampled tree parts in the four trees subjected to this study (Fig. 4) showed most of the gold is concentrated in the bark samples with the leaf and twig samples registering low gold concentrations. JW001 appeared to have highest gold concentrations in the bark than the root and twig samples with least concentration in leaf samples. The contrast between the anomalous gold concentrations and the background appear to be consistent with the bark samples. The high gold assays consistently were measured in the bark samples. The average of the averages of sample results from the four trees showed bark samples to be the best medium to be used for gold geochemical survey as an average of 116.44 ppb for leaf, 89.53 ppb for twig, 209.25 ppb for root and 352.39 for bark samples (Fig. 4). The high average for the leaf could be a result from aeolian contamination but this needs further investigation as the area of the investigation is in the rainforest region with thick vegetation that may suppress aeolian contamination. The possible contamination from bugs and insects that run up and down the tree trunk from the soil can transport mineral particles from the soil but the initial scrapping of thin veneer of the trunk before the bark sampling eliminated any form of mineral contamination.

Conclusion

Tree roots are able to absorb minerals including gold from earth. The absorbed minerals translocated from the roots to other parts of the tree have varied gold concentrations. Maximum gold concentration of 1045 ppb was found in bark samples of tree with JW001 whilst the least gold signature found in twig sample of OP001 with concentration of 9 ppb. The highest gold average in all the samples analysed was 352.39 ppb and this was obtained in bark samples. The average gold values increase from twig< leaf< root< bark. The high gold signatures in bark samples was explained to be the contribution of biotic process that expels absorbed gold considered as toxic to the biological functioning of the tree. This process re-concentrates gold in the bark samples thus enriching it over gold in roots. The relatively high concentration of gold in leaves over its corresponding twig samples were presumed to be added or adsorbed gold through aeolian contamination. In conclusion, the root systems of trees especially the deep-tap roots penetrate deep into the residual weathered materials absorb minerals including gold and thus translocate them to various parts of the tree. The relative abundances of gold vary from one part to the other with highest concentrations occurring at the bark of the tree. Pitching the gold averages among the parts sampled for gold anomaly definition, the authors find the bark of trees as an appropriate sample medium in support of soil samples in Greenfield exploration for mineral exploration.

References

Abouchami, W., Boher, M., Michard, A.,& Albarede, F. (1990). A major 2.1 Ga event of mafic magmatism in West Africa: an early stage of crustal accretion. *Journal of Geophysical Research*,95 (11), 17605-17629.

Anand, R. R. & Paine, M. (2002). Regolith geology of the Yilgarn Craton and its implications to exploration: One paper thematic issue of the Australian. *Journal of Earth Sciences*, 49, 3-164.

Anand, R. R., Wildman, J. E., Varga, Z. S.,& Phang, C. (2006). Regolith evolution and geochemical dispersion in transported and residual regolith–Bronzewing gold deposit: Geochemistry: *Exploration, Environment, Analysis*, 1 (12), 256–276.

Anderson, W. N. C., Brooks, R. R.,& Stewart, B. R. (1999). Gold uptake by plants. *Gold Bulletin*,32 (2), 48- 58.

Arhin, E.& Affam, M. (2009). Fluoride in groundwater and its implication in West Gonja district of Ghana,*Ghana Mining Journal*, 11,47-52.

Arhin, E.& Nude, P.M. (2010). Use of termitaria in surficial geochemical surveys: Evidence for >125-μm size fractions as the appropriate media for gold exploration in Northern Ghana.*Geochemistry, Exploration, Environment, Analysis*, 10,401-406.

Arhin, E., Torkonoo, S., Zango, M. S.,& Kazapoe, R. (2018). Gold in Plant: a biogeochemical approach in detecting gold anomalies undercover- a case study at Pelangio Gold Project at Mamfo Area of Brong Ahafo, Ghana.*Ghana Mining Journal*, 18 (1),39 - 48.

Arhin, E.& Zango, S.M. (2015). Unravelling regolith material types using Mg/Al and K/Al plot to support field regolith identification in the savannah regions of NW Ghana, West Africa.*Journal of African Earth Sciences,*112, 597-607.

Butt, C. R. M., Lintern, M. J.,& Anand, R. R. (2000) Evolution of regolith and landscapes in deeply weathered terrain–implications for geochemical exploration. *Ore Geology Reviews*, 16, 167–183.

Dickson, K. B.& Benneh, G. A. (1995). *A New Geography of Ghana*. 3rd Revised Edition. Longman, UK.

Dzigbodi-Adjimah, K. (1993). Gold and geochemical patterns of the Birimian gold deposits, Ghana, West Africa. *Journal of Geochemical Exploration*, 47 (1-3), 305-320. https://doi.org/10.1016/0375-6742 (93)90073-U.

Gardea-Torresdey, J. L., Parsons, J. G., Gomez, E., Peralta-Videa, J., Troiani, H. E., Santiago, P.,& Yacaman, M. J. (2002). Formation and growth of Au nanoparticles inside live alfalfa plants. *Nano letters*, 2(4),397-401.

Ghrefat, H. & Yusuf, N. (2006). Assessing Mn. Fe. Zn. and Cd pollution in bottom sediments of Wadi Al-Arab Dam. Jordan. *Chemosphere,*65, 2114-2121.

Girling, C. A. & Peterson, P. J. (1980). Gold in plants. *Gold Bulletin*,13, 151- 157.

Griffis, J., Barning, K., Agezo, F. L.,& Akosa, F. (2002). *Gold deposits of Ghana, prepared on behalf of Ghana Mineral Commission*. Accra, Ghana.

Hirdes, W., Davis, D. W., Ludtke, G.,& Konan, G. (1996). Two generations of Birimian (Paleo Proterozoic) volcanic belts in north-eastern Cote d'Ivoire (West Africa): consequences for the 'Birimian controversy.*Precambrian Research*, 80 (3/4),173–191.

Jaradat, Q. M. & Momani, K. A. (1999). Contamination of roadside soil, plants, and air with heavy metals in Jordan, a comparative study. *Turkish Journal of Chemistry*, 23, 209-220.

Kesse, G. O. (1985).*The mineral and rock resources of Ghana*. A. A. Balkema Press, Rotterdam, Netherlands.

Leube, A., Hirdes, W., Mauer, R.,& Kesse, G. O. (1990). The early Proterozoic Birimian Super group of Ghana and some aspects of its associated gold.*Precambrian Research*, 46,139-165.

Lintern, M., Anand, R., Ryan, C.,& Paterson, D. (2013). Natural gold particles in Eucalyptus leaves and their relevance to exploration for buried gold deposits. *Nature Communications*,4, doi: 10.1038/ncomms3614.

Mclnnes, B. I. A., Dunn, C. E., Cameron, E. M.,&Kameko, L. (1996). Biochemical exploration for gold in tropical rain forest regions of Papua New Guinea. *Journal of Geochemical Exploration*, 57**,** 227-243.

Milési, J.P., Ledru, P., Ankrah, P., Johan, V., Marcoux, E.,& Vinchon, C. H. (1991). Themetallogenic relationship between Birimian and Tarkwaian gold deposits in Ghana. *Mineral Deposita*,26 (3), 228-238.

Ostroumove, A. S., Poklonov, A. V., Kotelevtsev, V. S.,&Orlov, N. S. (2014). Toxicity of gold nanoparticles for plants in experimental aquatic system. *Moscow University Biological Science Bulletin*, 69 (3), 108 – 122.

Schodde, R. (2015). Canada's discovery performance. MinEx. 2015. www.minexconsulting.com/Publiction.html.

Shacklette, T. H., Lakin, W. H., Hubert, E. A.,& Curtin, C. G. (1970). *Absorption of Gold by Plants.* Washington, US

Shah, V. & Belazerova, I. (2009). Influence of metal nanoparticles on soil microbial community and germination of lettuce seeds. *Water, Air and Soil Pollution,* 197, 143-148.

Silberbush, M. & Ben-Asher, J. (2001). Simulation study of nutrient uptake by plants from soilless cultures as affected by salinity build up and transpiration. *Journal of Plant and soil*,233 (1), 59-69.

Taylor, P.N., Moorbath, S., Leube, A.,& Hirdes, W. (1992). Early Proterozoic crustalevolution in the Birimian of Ghana: constraints from geochronology and isotope geochemistry. *Precambrian Research,* 56, 97-111.

Yan, X., Zhang, F., Zeng, C., Zhang, M., Devkota, L. P.,& Yao, T. (2012). Relationship between heavy metal concentrations in soils and grasses of roadside farmland in Nepal. *International Journal of Research in Public Health*, 9,3209-3226.