

GOLD IN PLANTS: A BIOGEOCHEMICAL APPROACH IN DETERMINING GOLD ANOMALIES UNDERCOVER- A CASE STUDY AT HOMASE/AKOKERRI, GHANA

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ABSTRACT

This study examines whether gold concentrations in tree bark can be used to identify geochemical anomalies beneath regolith at Homase/Akokerry, Ghana. Forty bark samples were collected from four plant species: Kokoma (10), Nyamedua (10), Sesamasa (10), and Ofram (10). The samples were analysed for gold and selected pathfinder elements using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Kokoma recorded the highest average gold concentration, whereas Nyamedua and Ofram had lower values. Gold concentrations above the 0.5 ppm threshold reported by Lintern (2007) occurred in several samples. The results also include measurements of copper and arsenic for comparison with gold. The variation observed among the plant species indicates that tree bark may provide useful geochemical information in regolith-covered areas, although the plant results require confirmation with geological and conventional geochemical data.

Keywords: Mineralisation; gold; regolith-dominated; biogeochemistry

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INTRODUCTION

Gold exploration becomes more difficult where mineralised material is concealed beneath soil, transported sediments or weathered rock. Methods such as panning and sluicing are useful where mineralised material is exposed, but they provide less direct information when the surface is covered. Plant tissue offers an alternative material for geochemical investigation because elements taken up from the surrounding soil and water can be measured in the vegetation.

Gold may occur as free metal, in association with sulfide minerals, or in other forms within the weathering environment. Plants obtain water and dissolved elements from their surroundings, and some of the absorbed material can be retained or redistributed within plant tissues. Measuring gold in vegetation therefore gives an indirect indication of the geochemical conditions around the plant. A measured concentration in plant tissue, however, does not by itself demonstrate the presence or economic importance of an underlying deposit.

Plant-based gold investigations have been carried out in several ways. Field studies can compare the elemental composition of vegetation growing over known mineralised ground with vegetation from areas regarded as background. Such comparisons can help identify sites that merit additional investigation. Experimental work has also considered the use of plants as biosensors, including genetically modified plants designed to respond to gold in soil or water. This approach is different from the use of naturally occurring vegetation adopted in the present study.

Lintern (2007) reported differences in plant gold concentrations between vegetation growing over known gold deposits and vegetation from areas without known deposits. Sheoran *et al.* (2013) also examined

the use of plants in gold detection and discussed genetically engineered plants capable of detecting gold in soil, with a reported detection limit of 0.1 ppm.

Biogeochemical exploration uses the chemical composition of biological material to obtain information about the surrounding geological environment. Plants can take up and retain metals in tissues such as roots, stems and leaves (Chang and Ismail, 2019). Gold concentrations in plant tissue can therefore be used as an indirect measure of geochemical conditions where direct sampling of the underlying material is difficult. The approach is relevant to regolith-covered areas, although interpretation is affected by differences among plant species, soil chemistry and environmental conditions that influence metal availability and uptake.

Regolith, including soil, sediment and weathered rock, can mask mineralised material below the surface. In these settings, biogeochemical exploration involves examining biological material for elemental patterns that may be related to mineralisation. Vegetation has been used as a medium for biogeochemical prospecting since the nineteenth century (Reid *et al.*, 2008). Where vegetation is sufficiently widespread, its distribution also provides a practical basis for sampling and assessing geochemical variation across an area.

Previous work shows that plant responses to gold can differ between species and environments. Lintern (2007) documented variation in gold uptake among plant species, although the work was not directed specifically at regolith-dominated terrain. Sheoran *et al.* (2013) considered genetically modified plants rather than naturally occurring field populations. In Ghana, Arhin *et al.* (2018) investigated plant-based gold anomalies but did not compare several plant species growing within the same setting.

The present study therefore compares several naturally occurring plant species under the regolith conditions at Homase/Akokkerri. The analysis considers gold together with arsenic and copper and examines differences in their concentrations among the sampled species. The purpose is to determine whether the plant-tissue results contain anomalous gold values that could be useful in directing subsequent exploration.

Geologic Setting

Homase/ Akokeri is located in southwestern Ghana, adjacent to the Obuasi gold mine. It is hosted within the Ashanti Gold Belt, at an altitude of more than 2.7 km from sea level. The area is part of the West African Craton, which consists primarily of ancient Precambrian rocks. This craton is composed of various metamorphic and igneous rocks that have undergone extensive geological processes

over billions of years. The belt is the key district of gold mineralisation in the Paleoproterozoic terrane of West Africa. The area is covered by lithologies of the same volcanic-sedimentary. Birimian Supergroup and the overlying clastic sedimentary Tarkwaian Group which were jointly folded and metamorphosed under greenschist facies conditions during the Eburnean tectonothermal event at about 2.1 Ga. Regional facilitation and subparallel shear zones hosting mesothermal gold mineralisation developed during deformation coeval with metamorphism.

The region includes greenstone belts, which are volcanic and sedimentary rocks that have been metamorphosed. These belts are typically associated with gold mineralisation and include various rock types such as basalts, andesite and sedimentary sequences.

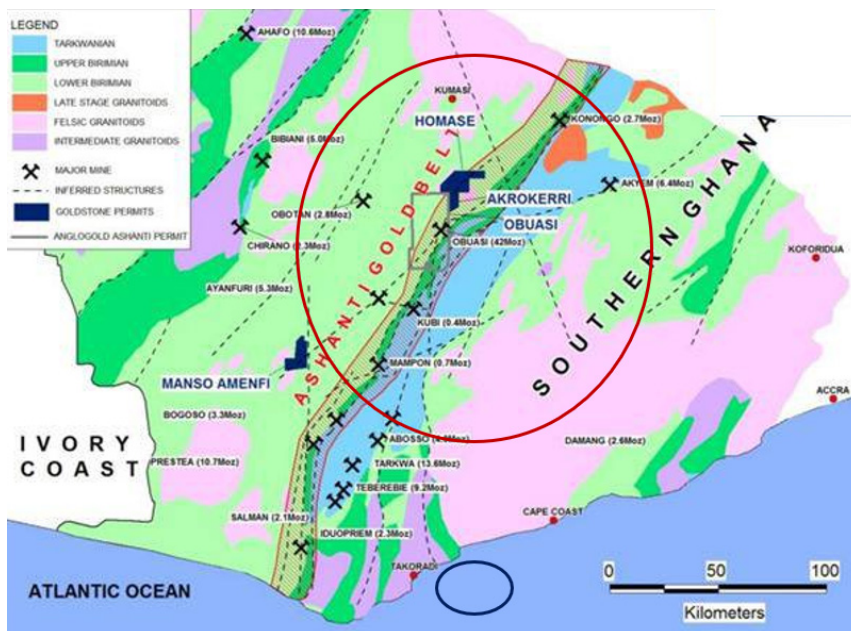


Figure 1: A Geological Map of the Study Area [in red circle] (Leaders *et al.*, 2018)

Lithology

The main lithologies reported in the area are schists, gneisses and granitic rocks. The metamorphic units occur with volcanic and sedimentary sequences. Granitoid intrusions are also present and may be related to hydrothermal systems associated with mineral deposition.

Mineralisation

Gold mineralisation in the Homase/Akokkerri area is associated with quartz veins, shear zones and stockwork structures within the metamorphic rocks. Pyrite and arsenopyrite occur among the sulfide minerals associated with the mineralisation. Gold is present both as disseminated mineralisation and within more concentrated vein systems.

Artisanal mining has been carried out in the area and provides evidence that gold mineralisation occurs at or near the surface. Because such workings may be concentrated around mineralised zones, their distribution is relevant when interpreting plant geochemical results. Additional soil and rock sampling would help establish whether anomalous plant concentrations correspond to mineralised material in the subsurface.

Mechanisms of Gold Uptake by Plants

Plants take up water and dissolved elements from the soil, and some of these elements are subsequently transferred or retained in different tissues. Roots, stems, leaves, twigs, flowers and bark can therefore contain elemental information derived from the surrounding environment. This makes vegetation suitable for sampling in biogeochemical investigations.

Element concentrations within plant tissues can reflect conditions in the soil and may assist in identifying areas of anomalous metal content (Chang and Ismail, 2019). Elements commonly considered in mineralised

environments include arsenic (As), chromium (Cr), zinc (Zn), manganese (Mn), silver (Ag) and lead (Pb). Gold is not an essential element for plant growth, but it may be taken up when it is available in the soil (Arhin *et al.*, 2018).

Vegetation growing on metal-rich soils may develop physiological mechanisms that restrict, tolerate or otherwise respond to elevated metal concentrations (Sheoran *et al.*, 2013). On this basis, plants used in metal studies are commonly described according to their pattern of metal uptake and accumulation. Sheoran *et al.*, (2013) group them into three categories:

- i. Indicators; plants which take up metals in proportion to its quantity in the soil and are used for exploration of mineralised soils.
- ii. Excluders; plants which do not take up metals to their shoots rather accumulate them in their roots.
- iii. Hyperaccumulators; plants which accumulate inordinate concentration of metals in their shoots.

For this study, attention is given to plants capable of accumulating metals in above-ground tissues. Gold is not readily soluble under all soil conditions, so its uptake depends on processes that increase its availability before transport into the plant (Reid *et al.*, 2008). The occurrence of gold in vegetation over regolith may reflect the movement of weathering-derived material through the soil–plant system. Such measurements can provide a surface geochemical expression, but they should not be assumed to represent undisturbed material at depth without supporting evidence (Arhin *et al.*, 2018).

Gold has been detected in different types of vegetation, including grasses, trees and crops. Its occurrence in plant tissue is generally linked to uptake from the surrounding soil followed by movement or retention within the plant. The amount accumulated can vary

with plant species and with the chemical and environmental conditions controlling gold availability.

Plant material containing metals has also been studied for metal recovery using processes such as chemical leaching, bioleaching and pyrometallurgical treatment. These applications are different from exploration, where the objective is to use plant chemistry as an indicator of the surrounding geochemical environment. Remote sensing is another exploration approach, but vegetation can cover or obscure surface expressions of buried mineralisation (Chakraborty *et al.*, (2020)). Biogeochemical sampling provides a direct way of examining the elemental composition of the vegetation itself. Its application is facilitated by the widespread distribution of plants and the relatively limited surface disturbance required for sampling (Chang and Ismail, 2019).

Metal uptake by plants can involve passive movement with water as well as biological transport processes (Baker *et al.*, 2018). Root exudates can also modify the chemistry of the surrounding soil and affect the availability of metals (Agarwal *et al.*, 2024). Gold accumulation has been reported in species such as Eucalyptus and some ferns (Kahangwa *et al.*, 2021).

Concentrations of gold and other elements in plant tissue can be measured using analytical methods such as inductively coupled plasma mass spectrometry (ICP-MS).

METHODS

The study used plant-bark sampling followed by laboratory preparation, chemical analysis and interpretation of the resulting geochemical data. The approach was intended to examine whether variation in the elemental composition of vegetation could provide evidence of anomalous gold concentrations beneath the regolith at Gold Stone Mining.

The Homase/Akokerri area was selected on the basis of its geological setting and previous gold-mining activity. Geological maps and available information on mineralisation were used to define the study area and to guide the sampling locations.

Published work on plant uptake of metals and the use of vegetation in mineral exploration was reviewed before field sampling. The review covered biogeochemical pathways, phytogeochemical exploration and previous studies of gold accumulation in plants. These studies provided the background for interpreting the concentrations measured in the selected species.

Sampling was carried out using a systematic grid across the study area. Locations were chosen with reference to the geological setting and known mineralisation zones, and control locations away from these zones were included for comparison. The selected plant species were locally occurring vegetation considered suitable for metal accumulation studies.

At each selected location, bark from the target trees was collected and the geographic coordinates were recorded using GPS. Forty bark samples were obtained in total, with ten samples each from Kokoma, Nyamedua, Sesamasa and Ofram. The outer bark was removed to reduce possible atmospheric contamination, following the procedure described by Arhin *et al.* (2018). The remaining bark was cut into smaller pieces for laboratory preparation.

The bark samples were washed to remove surface material and then dried at 60°C until a constant weight was obtained. The dried material was pulverised with a pestle and mortar and passed through a <2 mm mesh. It was subsequently sieved to obtain the <125 µm fraction used for chemical analysis.

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) Analysis

A 0.5 g portion of each powdered sample was digested using a mixture of concentrated

nitric acid (HNO₃), hydrochloric acid (HCl) and perchloric acid (HClO₄) in a 1:3:1 ratio. The digestion was carried out on a hot plate at 95 °C for approximately 2 h until near dryness. After cooling, the digest was diluted to 50 mL with 2% HNO₃ and filtered before analysis. Au, As, Cu and other trace elements were determined by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) at SGS Commercial Laboratory, Accra, using the GE_IMS23050 analytical package. The analysis provided concentrations in the ppm range. Quality control involved certified reference materials, procedural blanks and duplicate samples.

RESULTS

The forty tree-bark samples produced measurable concentrations of Au, As and Cu, with differences among the four plant species. The individual analytical results are presented in Table 1.

Table 1: Geochemical Mineral Expressions in Tree Bark Samples

Species	Au (ppm)	As (ppm)	Cu (ppm)
Nyamedua	0.1	0.19	6.12
Nyamedua	0.1	0.21	3.2
Nyamedua	0.1	0.14	4.19
Nyamedua	0.1	0.64	2.61
Nyamedua	0.1	0.53	5.45
Nyamedua	0.1	0.33	4.04
Nyamedua	0.1	0.4	4.43
Nyamedua	0.1	0.61	5.06
Nyamedua	0.1	0.45	5.49
Nyamedua	0.1	0.33	6.19
Sesamasa	4.1	0.5	3.97
Sesamasa	0.9	0.8	6.22
Sesamasa	9.4	0.22	8.78
Sesamasa	0.9	1.13	8.38

Sesamasa	1.3	0.41	5.44
Sesamasa	0.6	0.71	5.51
Sesamasa	0.4	0.72	7.22
Sesamasa	0.7	2.16	7.6
Sesamasa	0.3	0.78	7.89
Sesamasa	0.1	0.68	4.47
Kokoma	18.1	0.28	3.54
Kokoma	1	2.44	5.56
Kokoma	0.7	2.94	4.28
Kokoma	0.7	0.79	4.51
Kokoma	0.3	1.81	5.05
Kokoma	0.6	0.31	3.96
Kokoma	0.8	0.5	3.75
Kokoma	0.5	0.14	5.07
Kokoma	1.3	3.05	4.56
Kokoma	0.5	0.35	5.31
Ofram	0.1	0.21	7.19
Ofram	0.1	0.21	4.04
Ofram	0.3	2.18	6.82
Ofram	0.3	0.73	6.17
Ofram	0.1	0.95	6.87
Ofram	0.1	0.65	5.33
Ofram	0.1	0.45	6.18
Ofram	0.1	0.38	8.48
Ofram	0.6	0.5	9
Ofram	0.5	0.32	9.42

RELATIONSHIP BETWEEN GOLD (AU) CONCENTRATION AND ARSENIC (AS) CONCENTRATION

The Au and As data were evaluated using a scatter plot and linear regression.

The fitted line has a negative slope, but the very small R^2 value indicates that the linear relationship between Au and As is weak. Linear regression was used to obtain the fitted relationship.

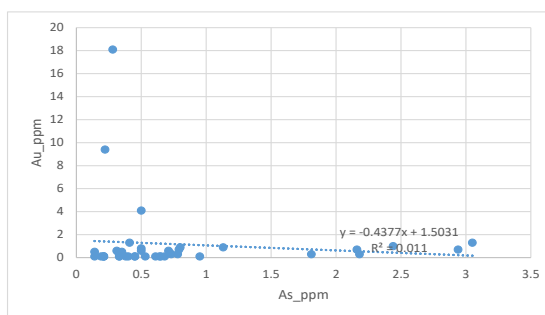


Figure 2: A Scatter Plot Showing the Relationship Between Gold Concentration and Arsenic Concentration in the Samples

The regression analysis produced the following equation:

$$\text{Au} = -0.4377\text{As} + 1.5031 \text{ ----- Eqn (1)}$$

$$R^2 = 0.011 \text{ ----- Eqn (2)}$$

$$R = 0.105 \text{ ----- Eqn (3)}$$

Where:

A slope of -0.4377 means that the fitted Au value decreases by 0.4377 ppm for each 1 ppm increase in As. Given the low R^2 , this coefficient should not be taken as evidence of a strong predictive relationship.

The intercept of 1.5031 is the fitted Au value when As is zero. Since the observed data show

little linear association, the intercept is best regarded as a parameter of the regression model rather than a direct estimate of Au concentration under field conditions.

Relationship Between Gold (Au) Concentration And Copper (Cu) Concentration

The Au and Cu concentrations were also examined with a scatter plot and linear regression. The fitted line has a negative slope, while the R^2 value of 0.0048 shows that the linear association is very weak.

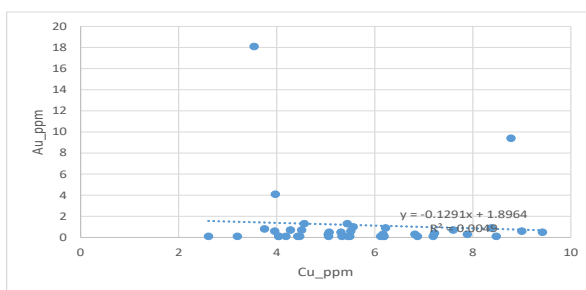


Figure 3: A Scatter Plot Showing the Relationship Between Gold Concentration and Copper Concentration in Samples.

The regression analysis yielded the equation: $R^2 = 0.0048 \text{ ----- Eqn (5)}$

$$\text{Au} = -0.1291\text{Cu} + 1.8964 \text{ ----- Eqn (4)} \quad R = 0.069 \text{ ----- Eqn (6)}$$

Where:

A slope of -0.1291 corresponds to a fitted decrease in Au concentration of 0.1291 ppm for each 1 ppm increase in Cu. The very small R^2 indicates that Cu accounts for little of the variation in Au in this dataset.

The intercept of 1.8964 represents the fitted Au concentration when Cu is zero. It is a parameter of the regression model and should not be interpreted separately from the observed data.

Table 2: Standard Deviation of Gold Concentrations:

Plant Species	Avg. Au (ppm)	Std. Dev. (σ)
Kokoma	2.45	± 0.89
Nyamedua	0.1	± 0.02
Sesamasa	1.87	± 0.76
Ofram	0.22	± 0.11

Sheoran *et al.*, (2013) reported typical plant Au concentrations of about 0.001–0.1 ppm, while Lintern, (2007) reported 0.5 ppm as a threshold above which plant Au may be considered anomalous. In the present dataset, several Kokoma and Sesamasa samples exceeded 0.5 ppm. Nyamedua remained at 0.1 ppm across the ten samples, while Ofra was generally low, with only a small number of higher measurements.

DISCUSSION

Gold concentrations in the bark samples ranged from 0.1 to 18.1 ppm and differed considerably among the four plant species. Kokoma had the highest mean concentration, influenced strongly by the 18.1 ppm measurement, while Nyamedua had the lowest. Sesamasa also contained elevated values, including 4.1 and 9.4 ppm. The results therefore show that Au accumulation was not

uniform across the sampled vegetation (Huang *et al.*, 2013; Sheoran *et al.*, 2010).

Most samples contained 0.1 ppm Au, whereas one Kokoma sample recorded 18.1 ppm. This observation is substantially higher than the other measurements and has a strong effect on the species mean. It may reflect a local geochemical condition, but the plant result alone cannot establish the presence of an orebody. The 4.1 and 9.4 ppm values in Sesamasa provide additional locations for follow-up sampling. Variation in metal accumulation between plant species has also been reported by Reith *et al.*, (2007).

The study area has limited artisanal mining according to the observations made during the study. This reduces, but does not remove, the possibility that surface disturbance affected the measured concentrations. Sampling across both mined and relatively undisturbed locations would provide a better basis for distinguishing natural geochemical dispersion from possible anthropogenic inputs.

Kokoma showed the widest range of Au concentrations, largely because of the 18.1 ppm measurement. Differences in root structure, soil composition and plant physiology may contribute to variation in metal uptake (Sumiahadi and Acar, 2018). Nyamedua and Ofra generally contained lower Au concentrations, whereas Sesamasa included several elevated measurements. The results therefore indicate that plant species should be considered when interpreting vegetation-based geochemical data.

The Au–Cu regression has a negative slope of -0.1291, but its R^2 value of 0.0048 indicates that the relationship is very weak. The data do not provide strong evidence that Cu concentration explains variation in Au concentration in the sampled bark. Copper may still be considered during exploration because of its use as a pathfinder element,

but its value in this study requires testing with additional samples and independent geochemical information.

Kadel-Harder *et al.*, (2021) discussed arsenic as a pathfinder element for gold mineralisation. In the present dataset, the Au–As regression also has a negative slope, with $R^2 = 0.011$ and $R = 0.105$. The low R^2 indicates that the fitted relationship is weak. Thus, although As is relevant to gold exploration, the present measurements do not demonstrate a strong Au–As association at Homase/Akokerri.

CONCLUSION

This study assessed gold concentrations in bark from four plant species at Homase/Akokerri using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The results show differences in Au concentration among the species and individual sampling locations. Several observations were above the 0.5 ppm threshold reported for anomalous plant Au, while the Au–As and Au–Cu regressions were weak.

i. Gold Uptake: Kokoma and Sesamasa contained several samples with Au concentrations above 0.5 ppm.

ii. Comparison to Standards: Several samples exceeded the 0.5 ppm threshold reported by Lintern (2007).

iii. Artisanal Mining Impact: The study area had limited artisanal mining activity, but this does not rule out possible surface contamination or disturbance.

iv. Commercial Viability: Plant geochemistry can assist with anomaly screening, but it should be used together with conventional exploration methods before conclusions are drawn about a deposit.

v. Future studies should use larger datasets and integrate plant geochemistry with other geological and geophysical information, including remote sensing where appropriate.

The results show that plant-bark chemistry can identify samples with elevated Au concentrations in the study area. The strongest values were confined to a small number of samples, so their spatial distribution and relationship to subsurface mineralisation require further investigation. Plant data are therefore best treated as supplementary evidence and interpreted alongside geological, soil and rock geochemical information.

Table 3: How Biogeochemical Prospecting compares to Traditonal Exploration Methods

Method	Gold Detection Range (ppm)	Advantages	Limitations
Soil Sampling	0.5–50 ppm	High accuracy, widely used	Requires excavation, costly
Rock Geochemistry	1–100 ppm	Direct ore detection	Limited to exposed rocks
Biogeochemical Sampling	0.1–18.1 ppm	Non-invasive, cost-effective	Requires validation with other methods

Biogeochemical sampling may assist with anomaly screening in vegetated, regolith-covered areas. Any anomalous plant results should be followed by geological, geochemical and geophysical investigations before

conclusions are made about the continuity or economic significance of a deposit.

RECOMMENDATION

Further work should examine the factors that control Au uptake among the plant species studied. Measurements of soil pH, moisture, organic matter and the chemical form of Au could help explain differences in plant concentrations.

Larger surveys that include both mineralised and background locations would also provide a stronger basis for assessing the spatial distribution of anomalies. Plant geochemistry can then be compared with soil and rock geochemistry, remote sensing and geophysical data.

Laboratory studies of plant–soil interactions could also help separate biological uptake effects from changes caused by local soil chemistry. Establishing species-specific background concentrations would improve the interpretation of anomalous Au values in subsequent surveys.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this study or the manuscript.

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