



Science Forum (Journal of Pure and Applied Sciences)

Journal Homepage: <https://atbu.edu.ng/science-forum/>

Geochemical Dispersion of Major and Trace elements in Termite Mound and Soil from Shanono Area, Northwestern Nigeria: Implication for Mineral Exploration

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ABSTRACT

Geochemical prospecting of economically extractible ore deposits in regions characterized by thick in-situ and transported cover are usually fraught with a lot of challenges owing to the fact that dispersion of indicator elements to the surface is often constricted. In this study, we used major and trace elements data of soil and termite mound samples from Shanono, northwestern Nigeria to determine the possible presence of deeply buried gold and related mineralization in the area. In this regard, Biological Absorption Coefficient (BAC) and Principal Component Analysis (PCA) were carried out on the major and trace elements compositions of the soil and termite mound samples. The results revealed high concentrations and BAC values of potential pathfinder elements for gold such as As, Ag, Zn, and Cu in the study samples, which has been interpreted to indicate the presence of deeply concealed gold mineralization in the area. In addition, the termite mound samples from the study are also enriched in Ni and Cr, indicating the possible presence of chromite and/or platinum group elements mineralization in the area. This study, therefore, highlight the efficacy of using termite mound and soil as an exploration tool to vector toward potentially buried gold and related mineralization in a regolith-dominated terrain.

ARTICLE INFO

Received 12 July 2024
Received in Revised Form 21 July 2024
Accepted 30 July 2024
Published 02 August 2024
Available online 02 August 2024

KEYWORDS

Regoliths,
Mineralization,
Prospecting,
Termite mound,
Nigeria

1 Introduction

Geochemical prospecting of economically extractible ore deposits in regions characterized by thick in-situ and transported cover are usually fraught with a lot of challenges owing to the fact that dispersion of indicator elements to the surface is often constricted (Stewart and Anand, 2014). Consequently, conventional surficial geochemical exploration techniques that utilize soil and stream sediments as sampling media have limited success, because geo-chemical dispersion patterns that may result from ore bodies are often hidden by chemical and mechanical processes independent to the mineralization (Stewart and Anand, 2014; Ilunga Ngoy et al, 2022). Thus, the use of integrated or novel exploration techniques are recommended in most of these regolith-dominated terrains (Stewart and Anand, 2014).

One of the notable feature of the tropical and subtropical regions of the world such as Africa, south America and Australia is the occurrence of large species of fungus-growing termites that occupy about 40–60% biomass of macro fauna in those regions (Jouquet et al., 2004, Stewart et al., 2012). These macro invertebrate species play important role in the development of soil profile and, thus, are regarded as soil engineers in the driest tropical ecosystems (Jouquet et al., 2004; Ilunga Ngoy et al, 2022). In order to protect themselves from predators and environmental hazards, termites build formidable biological structures (mounds) by reworking and transporting soils below ground to the earth surface (Stewart et al., 2012). During these mounds building activities, termites may descend to depths of up to 50 m to find water and moist materials and, in the process, can also bio-accumulate several minor and trace elements that can act as indicators/pathfinders for economical significant ore deposits, especially in regolith-dominated terrains (Stewart and Anand, 2014; Ilunga Ngoy et al, 2022). Termites are also considered as good indicators of geological structures including faults and fractures as well as in delineating the limits of underlying geological formations, particularly in a warm tropic climate region of world where high degree of chemical weathering typically produce thick surficial cover

that can conceal bedrock and their associated mineral deposits (Halley et al., 2015). Consequently, several studies have demonstrated that termite mound can be used as a powerful mineral prospecting tool in search of economically important deposits of gold (Stewart and Anand, 2014) and base metals (Ilunga Ngoy et al, 2022), and uranium deposits (Jouquet et al., 2004).

In this contribution, we present major, minor and trace elements geochemistry of termites' mound and soils from Shanono Gold Field, Northwestern Nigeria. Our primary objectives were to: (i) determine the geochemical dispersion mechanism of minor and trace elements in termite mound and soil and in the area, and (ii) evaluate the efficacy of utilizing termite mound and soil as prospecting tool to vector toward potentially buried gold and related mineralization in the area.

2.0 Geological Settings

The Shanono are is an orogenic gold mineralized area that lies within the Pan-African Basement Complex of northwestern Nigeria. The area form parts of a network of Pan-African orogenic belts that extends across the African continent and into the Brasiliano orogen of South America (Figure 1). These Pan-African orogenic belts are typically composed of Archaean and Proterozoic rocks that were reworked by Neoproterozoic to Cambrian orogenesis, together with a variable proportion of juvenile material (Goodenough et al., 2014, Girei et al, 2019). Their formation marked a Wilson Cycle involving the opening and closing of oceans and the convergence of several exotic terranes and island arcs during the Neoproterozoic to Cambrian amalgamation of Gondwana, between 750 and 500 Ma (Ajibade and Wright 1989). In West Africa, these Trans-Saharan Pan-African Belts separate the Archaean to Mesoproterozoic West African and Congo cratons.

In Nigeria, the Trans-Saharan Belt has been divided into western and eastern terranes separated by a major north-south lineament (Ferré et al., 1996). The Western terrane is composed largely of Archaean to Mesoproterotic

basement rocks comprising the migmatitic gneisses with minor amphibolites that display greenstone affinities; as well as a cover of synformal schist belts consisting of low-metamorphic grade, highly deformed, metasedimentary, and metavolcanic rocks with metamorphic grade ranging from greenschist to upper amphibolite facies (Ferré et al., 1996). In contrast, the Eastern Nigeria terrane is underlain by high-grade migmatitic gneisses that have Palaeoproterozoic protoliths but were migmatized during the Neoproterozoic, with metamorphic grade ranging from lower amphibolite to granulite-facies in places (Goodenough et al., 2014). The crystalline

basement rocks of both the western and eastern terranes have been intruded by suites of Pan-African syn- to post-collisional granitoids dubbed as Older Granites to distinguish them from the Mesozoic anorogenic alkaline granitoids otherwise known as “Younger Granites, which are confined to the eastern terrane (Ferré et al., 1996; Girei et al., 2019). However, the Older Granites are more voluminous in the eastern terrane than in the western terrane. Moreover, both western and the eastern terranes are cut by several NNE–SSW-trending ductile shear zones that are tens to hundreds of kilometers in length (Goodenough et al., 2014, Girei et al., 2019).

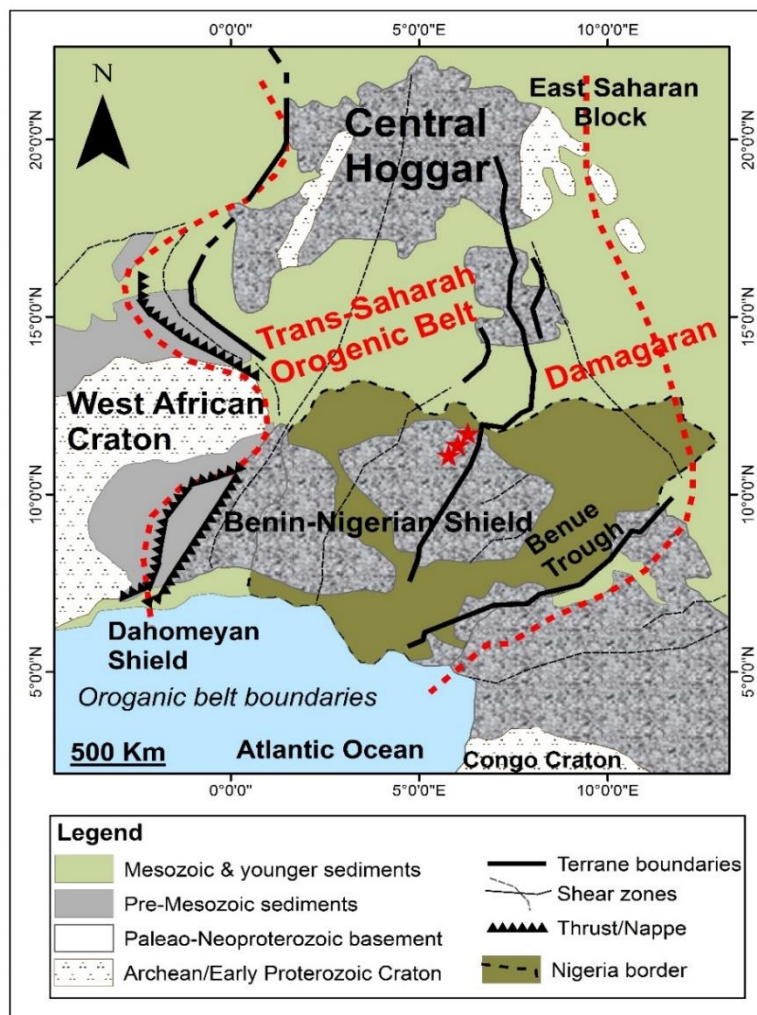


Figure 1: Geological map showing the location of the Nigerian Shield in relation to the Trans-Saharan Orogenic Belt (After Ferré et al., 1996)

2.0 Sampling and Analytical Techniques

Field work was carried out within the Shanono area and twenty (20) samples of termite mounds and soils were collected for geochemical analysis. The termite mound samples were collected from the top of the mound as well as near the contact of mounds with soil. In contrast, soil samples were collected at 300 mm and 500 mm depths with the B- horizons. Both termite mound and soils were crushed and sieve to obtained the <150 μm fractions for geochemical analysis. The sieved samples were later pulverized using gan agate ball mill prior to analysis prior to geochemical analysis.

Geochemical analysis was carried out using an energy dispersive X-ray fluorescence (XRF) spectrometer (Rigaku NEX DE EDXRF). The XRF analysis was carried out using pressed-powder disc. The analysis was performed under helium (He) atmosphere using a palladium (Pd) X-ray tube at a voltage of 60 kV and current 10 μA with 10 mm beam spot size, and silicon (Si) drift detector comprised of Peltier electronic circuit cooling system. Standard less calibration was employed using Fundamental Parameters (FP) methods software (Rigaku RPF-SQX) to allow for elemental quantification of completely unknown. The software can automatically estimate elemental concentration and provide appropriate corrections. Rigaku NEX DE EDXRF spectrometric analysis can be employed to measure a wide range of atomic elements, from sodium (11) through uranium (92), while providing elemental detection limits from low parts-per-million (ppm) to high weight percent (%wt). The analytical uncertainties were generally within 0.1-1% (RSD).

3. Results

3.1 Major and Trace Elements Composition

The representative samples of termite mound from Shanono are relatively enriched in TiO_2 , K_2O , CaO , MgO , Fe_2O_3 , but depleted in SiO_2 , Al_2O_3 , and P_2O_5 when compared with the representatively soil samples in the area (Table 1). Similarly, selected trace elements including Ni, Cr, Cu, Zn, Pb, Rb, Sr and Zr are relatively enriched in termite mound samples than soil samples. To enable better comparison between concentrations of major and trace elements in termite's mound and soil samples of the Shanono area, we employed the commonly used Biological Absorption Coefficient (BAC), a biogeochemical parameter that relate the ratio of elements concentration in termite mound (C_{tm}) to that of the nearby soil (C_{ss}) use as background (Reddy 2014).

The simplified equation can be expressed as $\text{BAC} = C_{\text{tm}}/C_{\text{ss}}$. Using the equation, a BAC value greater than one (1) is considered as positive and is interpreted to represent enrichment of an elements in termite mound relative to nearby soil, while BAC value less than one (1) is regarded as negative and indicate relative depletion of an elements in in termite mound relative to nearby soil (Reddy 2014). Table 2 show the calculated BAC values of termite mound and soil samples from Shanono area. It is noteworthy that chalcophile elements such as Cu, Ni, Zn and Pb, mostly yield BAC values greater than one (1) which indicate their enrichment in termite mound samples relative to soil samples. Moreover, feldspar compatible trace element including Rb, Ba and Sr generally yield BAC values greater than one (1), which indicate their enrichment in termite mound samples relative to soil samples (Table 2).

Table 1: Major and Trace elements composition of termite mound and soil samples from Shanono.

Sample No	Cr		Ni		Cu		Zn		As		Rb		Sr		Zr		Ag		Ba	
	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss
1	50.5	102	43.3	31	55.2	19	45.3	14	21.2	2.8	553.5	468	259	210	2425	1700	9.15	11.9	523.5	434
2	41.5	38.4	47.35	38.4	61.7	52	61.05	41	13.1	29.1	701	469	350.5	200	2475	1830	13.85	8.6	642.5	488
3	60.6	89.2	24.7	54.3	50.9	56	40.45	48	14.1	38.2	638	426	237.5	178	2395	1690	12.45	14.6	531.5	407
4	162.7	71	115.6	31.5	96.7	54	68.9	38	16	19.4	521	391	487	156	1915	1730	13.4	14.8	697	376
5	132.5	262	114.3	185	81.1	119	50.55	79	4.6	15.5	305.5	285	454	459	1825	1970	12.5	14.9	667.5	643
6	111.5	75.6	112.1	43	77.8	52	52.55	30	3.93	4.46	239.5	207	354	343	2005	1750	13.45	13.1	658	576.5
7	164.5	142	83.8	66	79.7	75	64.55	46	5.52	4.46	301	260	352.5	315	2015	1970	13.05	13.1	670.5	635
8	132	46.1	81.75	28.2	80	47	102	20	8.34	6.23	337	253	330.5	175	1940	1790	12.85	9.2	698	397

Note: Tms represent termite mound samples, while Tss represent soil samples

Table 2: Calculated Biological Absorption Coefficient (BAC) values of termite mound and soil samples from Shanono

sample No.	MgO		Al2O3		SiO2		P2O5		K2O		CaO		TiO2		MnO		Fe2O3	
	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss	Tms	Ss
1	0.01	0.00	14.35	15.40	69.80	70.20	1.78	1.82	3.66	3.32	0.97	0.45	1.71	1.24	0.06	0.03	6.51	6.77
2	0.07	0.00	14.55	15.20	67.55	69.90	1.86	1.76	4.55	3.50	1.42	0.56	1.60	1.46	0.09	0.03	7.18	6.53
3	0.07	0.00	12.55	13.90	72.45	71.90	1.71	1.82	4.70	3.21	0.85	0.47	1.47	1.53	0.07	0.05	5.08	6.08
4	0.38	0.00	12.20	13.10	68.15	73.70	1.79	1.81	3.73	3.51	1.77	0.45	1.65	1.34	0.13	0.04	9.00	5.00
5	0.51	0.28	11.70	15.70	69.65	63.90	1.75	1.67	2.64	1.93	1.42	1.32	1.82	2.27	0.11	0.13	9.52	11.70
6	0.47	0.17	9.35	7.81	73.75	79.20	1.72	1.86	2.47	2.73	1.84	1.17	1.64	1.61	0.19	0.07	7.54	4.38
7	0.34	0.27	10.40	11.20	71.70	73.40	1.76	1.74	2.59	2.73	1.31	1.10	1.81	1.75	0.09	0.08	8.88	6.70
8	0.35	0.09	9.66	8.55	73.50	80.50	1.71	1.77	2.86	3.04	1.73	0.62	1.56	1.28	0.14	0.04	7.44	3.13

Sample

No	V	Cr	Ni	Cu	Zn	Ga	As	Rb	Sr	Zr	Y	Nb	Ag	Ba	Pb
1	1.53	0.50	1.40	2.89	3.19	3.22	7.57	1.18	1.23	1.43	1.33	1.19	0.77	1.21	0.87
2	1.22	1.08	1.23	1.19	1.49	1.26	0.45	1.49	1.75	1.35	1.28	1.11	1.61	1.32	3.58
3	0.60	0.68	0.45	0.90	0.84	0.82	0.37	1.50	1.33	1.42	1.07	1.06	0.85	1.31	3.00
4	1.76	2.29	3.67	1.79	1.84	1.24	0.82	1.33	3.12	1.11	1.47	0.93	0.91	1.85	1.89
5	0.53	0.51	0.62	0.68	0.64	0.43	0.30	1.07	0.99	0.93	0.79	0.73	0.84	1.04	0.66
6	0.95	1.47	2.61	1.49	1.73	1.46	0.88	1.16	1.03	1.15	1.31	1.21	1.03	1.14	0.88
7	1.14	1.16	1.27	1.07	1.41	1.18	1.24	1.16	1.12	1.02	1.23	1.15	1.00	1.06	1.26
8	1.35	2.86	2.90	1.69	5.13	1.54	1.34	1.33	1.89	1.08	1.57	1.25	1.40	1.76	1.64

3.2 Principal Component Analysis

Principal Component Analysis (PCA), a multivariate statistical technique is employed to enable the reduction of data into few components (Sikakwe et al., 2020). The results of the PCA show that some major and trace elements such as MgO, CaO, Fe₂O₃, MnO, Ti₂O, Ni, Cr, Zn, Cu, V,

Ag, Nb, Sr and Y show similar behaviour, but are inversely correlated with silica (Figure 2). In contrast, other major and trace elements including Al₂O₃, P₂O₅, K₂O, Rb and Zr show similar behaviour and are linearly correlated to silica (Figure 2). This data can be used to constrain the nature of bedrock and related mineralization in the study area.

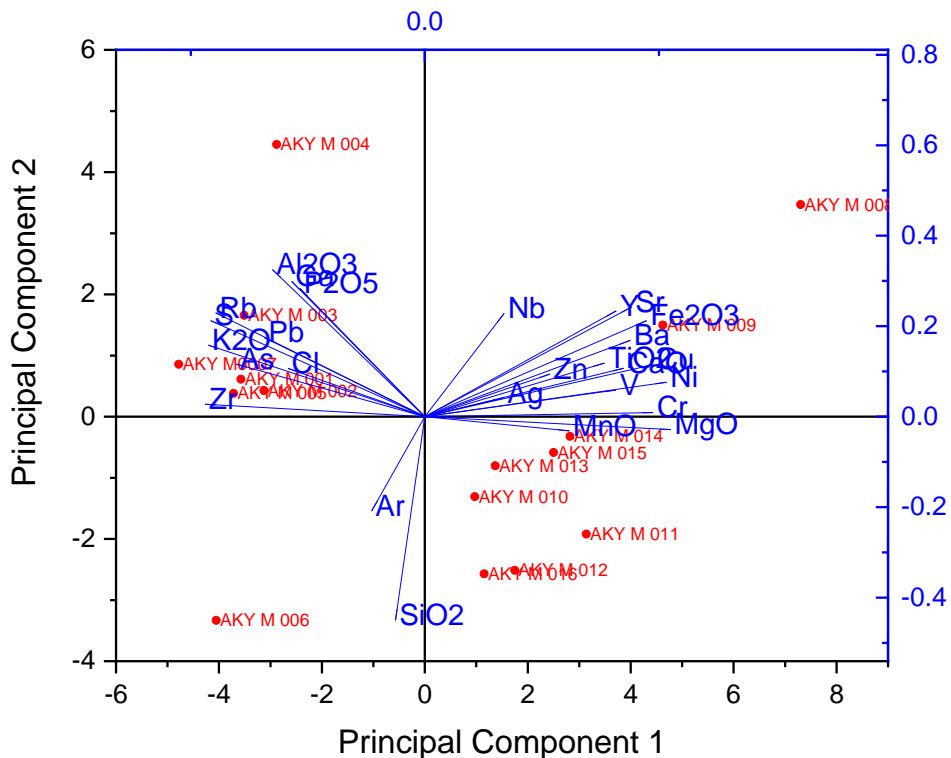


Figure 2: Bi-plot of PC1 and PC2

4.0 Discussion

4.1 Constrain on Bedrock Geology and Associated Mineralization

Major and trace elements typically show different behavior and dispersion pattern in regoliths such as residual soil and termite mound (Jouquet et al., 2004, Stewart et al., 2012). In particular, transition metals with ionic charge ranging from +3 to +4, Rare Earth Elements (REE) and aluminium are known to be relatively immobile during regolith-forming processes, such as weathering and alteration (Halley, 2020). However, Mg, Fe, and large ion lithophilic elements such as Rb, Sr and Ba are very soluble and highly mobile in surficial environment (Halley et al, 2015). Thus, a nuanced understanding of element behavior and dispersion patterns can provide useful clues on the nature of bedrock geology and the associated mineralization, especially in regolith-dominated terrains (Stewart et al., 2012).

The major and trace elements dispersion pattern in termite mound and soil from Shanono area allow constrain to be placed on the nature of bedrock and associated mineralization. In particular, the high concentration of feldspar compatible trace elements such as Rb, Ba and Sr couple with the high Zr in termite mound samples from Shanono area as indicated by their positive Biological Absorption Coefficient (BAC) can be interpreted to indicate that the area is probably underlain by feldspar-rich bedrocks such as granitic rocks. This is consistent with the report of geological mapping of the area (Elatikpo et al, 2022, Gewaza et al., 2021). Nonetheless, the relatively high concentration of MgO, Ni and Cr in termite mound samples from Shanono may indicate the presence of deeply buried mafic and ultramafic rocks as well as their associated mineralization such as podiform chromite and/or platinum group of elements (e.g Halley 2020).

4.2 Implications for Mineral Exploration

Previous studies reported the presence of economically important orogenic gold mineralization in Shanono area (Elatikpo et al, 2022, Gewaza et al., 2021). Moreover, it is well established that during their mounds building activities, termites may descend to depths of up to 50 m to find water and moist materials and, in the process, can also bio-accumulate several minor and trace elements that can act as indicators/pathfinders for economically significant ore deposits, especially in regolith-dominated terrains (Stewart and Anand, 2014; Ilunga Ngoy et al, 2022).

Thus, in this study, we used termite mound and soil samples as prospecting tool to vector toward potentially buried gold and related mineralization in the area. Considering that the X-ray fluorescence techniques utilized for this study has low detection limits for gold and its traditional pathfinder elements such as bismuth, tellurium and tungsten, we used chalcophile elements such as Cu, Zn and Pb together with As and Ag as possible pathfinder elements for gold and related mineralization. The use of chalcophile elements as a possible pathfinder for gold is justifiable, considering that a previous study has demonstrated the close association between gold and sulfides in most Nigerian gold deposits (Garba, 2000; 2003).

Importantly, the result of principal component analysis has indicated a good correlation between Ag, Zn, Cu and AS in termite mound samples from the study area (Figure 2). Thus, the high concentrations of Zn, Cu, As and Ag in some selected samples of termite mound and soil from Shanono can be interpreted to suggest the presence of some concealed gold mineralization in the area (Figure 3). In addition, samples of termite mound from Shanono also show high concentrations of Ni and Cr, which probably indicate the presence of chromite and/or platinum group of elements mineralization associated that may be associated with mafic and ultramafic rocks in the area.

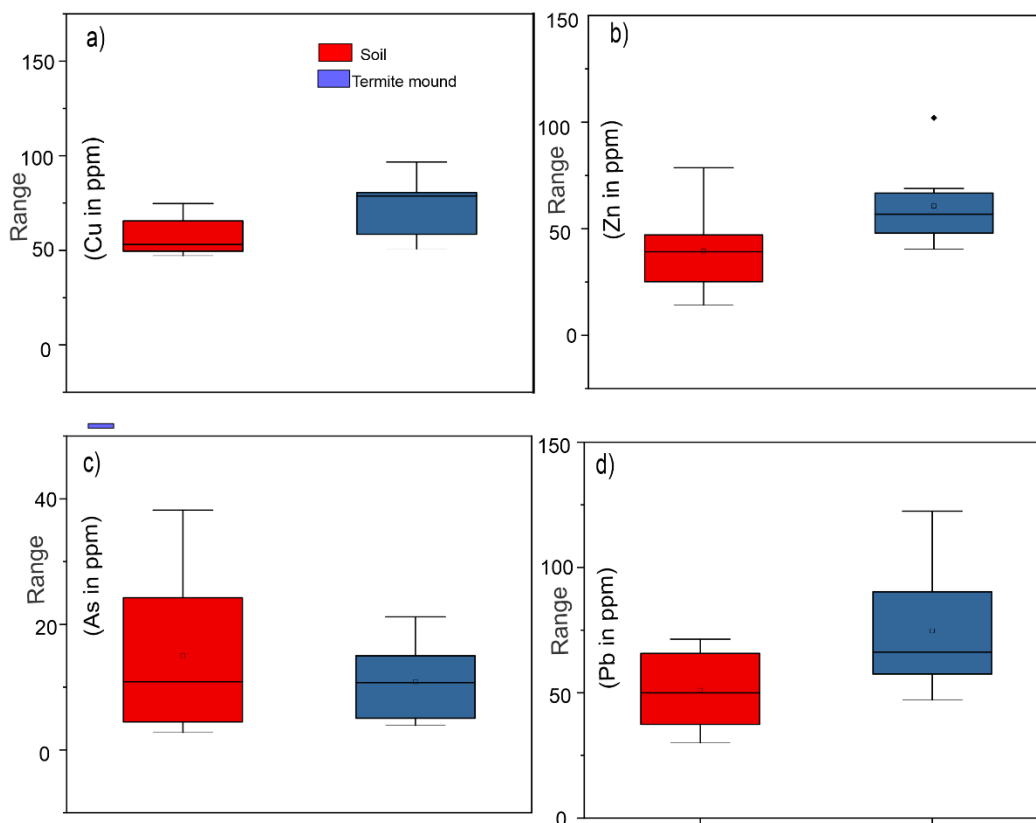


Figure 3: Boxplot of some selected trace elements in soil and termite mound samples from the study area.

5.0 Conclusions

Geochemical analysis of soil and termite mound samples from Shanono area have been carried out to determine the possible presence of deeply buried gold and related mineralization in the area. Consequently, Biological Absorption Coefficient (BAC) and Principal Component Analysis (PCA) were carried out on the major and trace elements compositions of the soil and termite mound samples. The results revealed high concentrations and BAC values of potential pathfinder elements for gold such as As, Ag, Zn, and Cu in the study samples, which has been interpreted to indicate the presence of deeply concealed gold mineralization in the area. In addition, termite mound samples from the study are also enriched in Ni and Cr, indicating the possible presence of chromite and/or platinum

group elements mineralization in the area. This study, therefore, highlight the efficacy of using termite mound and soil as an exploration tool to vector toward potentially buried gold and related mineralization in a regolith-dominated terrain.

Acknowledgement

This research was funded by the Tertiary Education Trust Fund (TETFUND) through the Institutionally Based Research (IBR) grant. We thank the anonymous reviewers for their constructive criticism, which helped us to improve our work.

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