SCIENCE FORUM (JOURNAL OF PURE AND APPLIED SCIENCES) 23 (2023) 29 –33

Science Forum (Journal of Pure and Applied Sciences)

journal homepage: https://atbu.edu.ng/science-forum/

Determination of pathfinder elements for gold in the Kano state's Schist belt, Nigeria: A statistical approach

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ABSTRACT

A statistical study to establish the pathfinder elements for Gold (Au) in the Kano state's Schist belt, Nigeria is presented in this article. The strenuous activity of artisanal miners to locate the mineral due to the complex regolith of the study area is a thing of concern. To achieve the aim, multivariate statistics of Principal Component Analysis (PCA) was applied to the geochemical data from eight rock samples obtained through Microwave Plasma Atomic Emission Spectroscopy. The PCA indicated three components in the data accounting for 84.03% of the total variability. The second component, which explains 28.065% of the total variance, has Calcium (Ca), Chromium (Cr), Manganese (Mn), and Silver (Ag) with some positive association with Gold (Au) and Iron (Fe). This component is attributable to the chemical sediments drift between the rock formations accompanied by other constituents of minerals present. It is expected that these elements (Ca, Cr, Mn, and Ag) can be used as pathfinders for gold in the study area.

ARTICLE INFO

Artcle history:
Received 06 May 2022
Received in revised form
21 December 2022
Accepted 21 December 2022
Published 06 July 2023
Available online 06 July 2023

KEYWORDS

Geochemical analysis
Kano Schist belt
Pathfinder elements
Principal component analysis

1. Introduction

Gold has found a high place in the human mind throughout world history. Its uses are found in the electronic industry, medicine, aerospace devices, jewelry, medals, coins, and so on (King, 2019). It is the most used mineral mined from the earth. Despite its many uses, it is very scarce and difficult to locate especially in complex regolith structures (Arhinand Nude 2009). Anand et al. (2001) as stated by Arhin et al. (2015) concluded that the identification of the relationship among trace elements with specific minerals and mineralogical control structures in the regolith may be a better tool to use to identify and rank gold anomalies.

The Schist belt part of Kano state [(bounded within latitudes 11.50° N to 12.50° N and longitudes 7.50° E to 8.50° E, it sits in between the Kazaure and Karau-Karau schist belt (Obaje, 2009)] is a promising area for many mineral resources including gold (Shehu et al., 2019; Shehu and Yelwa, 2022). The belt is characterized by Schist rocks, Gneiss-Migmatite-Granite complex rocks, and Younger granite complex rocks. It also has Quaternary, Tertiary, and Cretaceous sediments as well as alluvium (Figure 1). Interactions with the artisanal miners around the location revealed that gold is available; however, it always takes them many unsuccessful attempts before locating the mineral. The area considered in this study is one where ground magnetic

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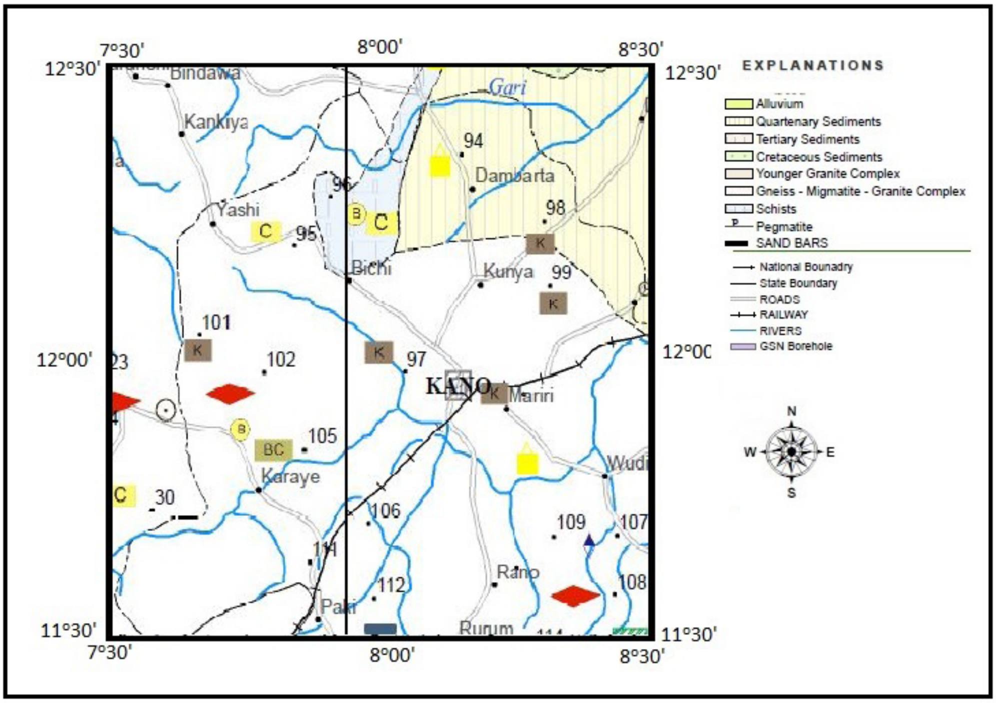

Figure 1. Geologic map of the study area (Nigerian Geological Survey Agency 2009).

and geochemical surveys were carried out by Shehu et al. (2021a) and Shehu and Yelwa, (2022) respectively. It is bounded by latitudes 12.4663° N to 12.4995° N and longitudes 7.9764° E to 7.9858° E.

Researchers have successfully used multivariate Statistical approaches, such as Principal Component Analysis (PCA), for establishing element associations (Arhin et al., 2015; Anand et al., 2018; Nude et al., 2012). The PCA involves the extraction of principal components from the primary dataset; each principal component is supposed to represent a process or set of processes that impact the variation of the values of the parameter (Nude et al., 2012). The PCA derives its application from the mathematics of covariant matrix and its eigen values and eigen vectors.

Consider a set of multivariate data; we obtain the covariant matrix of the data, and then we obtain the eigen values and the eigen vectors of the covariant matrix. The next step is to order the eigen vectors by eigen values, highest to lowest. This gives us the component in order of significance.

In this article, PCA was carried out on the geochemical dataset to determine the association between the elements with a view to determining the pathfinder elements for gold. The data were obtained from geochemical analysis (Shehu and Yelwa, 2022) done on rock samples in the study area using the Microwave Plasma Atomic Emission Spectrometry technique.

2. Materials and Methods

2.1. Materials

The following materials were used for this study:

i) Geochemical dataset obtained from Shehu and Yelwa (2022)

ii) IBM SPSS Statistics 20

2.2. Method

PCA was carried out on the geochemical dataset to determine the association between the elements in the study area using IBM SPSS Statistics 20.

The nature of geochemical data is such that they are spatially dependent, and at each sample location, many different processes must have influenced the element abundance. This makes the data inherently non-normal. On the other hand, the main theory fundamental to the application of PCA is for the data to follow a normal distribution. Hence, the need to normalize the data through a logarithmic transformation is demonstrated by Nude et al. (2012).

Therefore, the logarithm of each of the geochemical data was taken and the results were used for the PCA.

The Kaiser criterion, which recommends that only those components with accompanying eigenvalues greater than or equal to 1 should be kept

Table 1. Summary statistics of elemental analysis data.

Element	Minimum (ppm)	Maximum (ppm)	Mean (ppm)	SD (ppm)
Zn	8.55	56.33	25.49	18.40
Cu	2.08	84.37	25.21	35.33
Pb	0.00	1.25	0.16	0.44
K	19.78	792.90	237.79	281.27
Mn	17.60	701.52	160.20	237.29
Cr	2.25	24.31	6.35	7.52
Fe	11.44	532.92	157.10	177.82
Ca	9.10	97.18	27.83	29.53
Al	26.08	797.59	274.71	236.48
Si	18.71	621.32	324.76	195.40
Ag	0.00	0.09	0.03	0.03
Au	0.04	0.64	0.15	0.20

Table 2. Summary statistics of log-transformed data.

Element	Minimum (ppm)	Maximum (ppm)	Mean (ppm)	SD (ppm)
Zn	0.931966	1.750740	1.297338	0.334976
Cu	0.318063	1.926188	0.989684	0.643421
Pb	0.000000	0.096910	0.012114	0.034263
K	1.296226	2.899218	2.062109	0.590510
Mn	1.245513	2.846040	1.867725	0.548822
Cr	0.352183	1.385785	0.639111	0.354446
Fe	1.058426	2.726662	1.93989	0.533935
Ca	0.959041	1.987577	1.299955	0.345773
Al	1.416308	2.901780	2.287257	0.431531
Si	1.272074	2.793315	2.377053	0.473772
Ag	−2.00000	0.000000	−1.32330	0.612259
Au	−1.39794	−0.19382	−1.03910	0.408920

(Nude et al., 2012), was used to obtain the number of components to extract.

3. Results and Discussions

Table 1 shows the summary statistics of the geochemical data while Table 2 shows the log-transformed data. The large SD values recorded in Table 1 show the non-normal nature of the data. The data have, however, been normalized through logarithmic transformation. This is obvious in the low standard deviation values obtained in Table 2.

The scree plot in Figure 2 shows that only three components are associated with eigen values greater than or equal to 1. These components are those kept.

The indicated three components in the data accounted for 84.03% of the total variability. Table 3 shows the variance explained for each of the components extracted. The component matrix indicating the component model showing the loading of the various variables is presented in Table 4 (values below 0.2 are suppressed).

It is obvious in Tables 3 and 4 that the first component which accounts for 43.795% of the total variance is dominated by Al, Si, Fe, and K with some contribution of Mn, Cu, Ca, Cr, and Zn. In the same vein, the second component, which explains 28.065% of the total variance, has Ca, Cr, Mn, and Ag with some positive association with Au and Fe. The third component which explains 12.163% of the total variance has Zn and Ag with a small contribution from Si and Cr.

Component 1 can be associated with the geology of the study area. The area is dominated by a conglomerate of minerals rich in iron, chromium, silicon, and aluminum. This fact is indicated by Shehu et al. (2021b).

Components 2 and 3 can be attributed to the chemical sediments drift between the rock formations accompanied by other constituents of minerals present.

Although gold has a small contribution to component 2, it has a positive association with calcium, chromium, manganese, and silver. It is expected that these elements (Ca, Cr, Mn, and Ag) can be used as pathfinders for gold in the study area.

4. Conclusion

In this study, we found that calcium, chromium manganese, and silver can be used as pathfinders for gold. These results were obtained through PCA of geochemical data obtained from the study area.

Knowledge of the Pathfinder elements for gold help miners in their exploration activities in that it provides a reliable indicator of the sought for mineral.

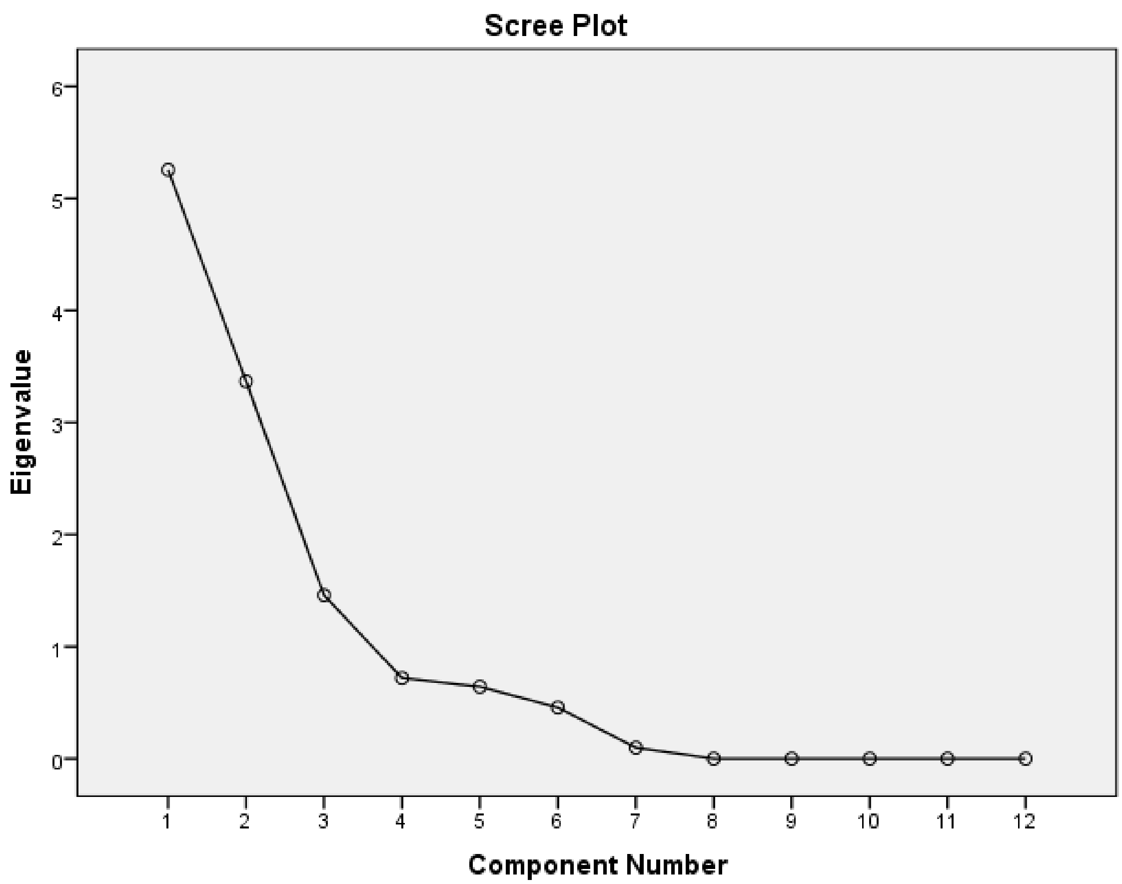

Figure 2. Scree plot of eigen value against component number.

Table 3. Total variance explained.

Component	Eigen Value	% of Variance	Cumulative % of variance	Extracted Eigen Value	% of Variance	Cumulative %
1	5.255	43.795	43.795	5.255	43.795	43.795
2	3.368	28.065	71.860	3.368	28.065	71.860
3	1.460	12.163	84.023	1.460	12.163	84.023
4	0.720	5.999	90.023			
5	0.642	5.348	95.370			
6	0.457	3.810	99.181			
7	0.098	0.819	100.000			
8	2.83×10^{-16}	2.36×10^{-15}	100.000			
9	9.48×10^{-17}	7.90×10^{-16}	100.000			
10	2.60×10^{-17}	2.17×10^{-16}	100.000			
11	-5.62×10^{-17}	-4.68×10^{-16}	100.000			
12	-1.32×10^{-17}	-1.10×10^{-15}	100.000			

Table 4. Component matrix.

Element	Component		
	1	2	3
Pb	−0.933	*	−0.236
Al	0.909	*	*
Au	−0.849	0.204	*
Si	0.840	−0.203	0.384
Fe	0.837	0.246	−0.320
K	0.715	*	−0.451
Ca	0.430	0.837	*
Cr	0.253	0.837	0.338
Mn	0.579	0.681	*
Zn	0.249	−0.676	0.618
Ag	*	0.657	0.609
Cu	0.521	−0.647	*

*Value below 0.2.

References

Anand RR, Hough RM, Salama W, Apandiar MF, Butt CRM, Gonzalez-Alvarez I, et al. Gold and pathfinder element in ferricrete gold deposits of the Yilgran Craton of Western Australia: a review with new concepts. Ore Geol Rev 2018; doi: https://doi.org/10.1016.joregeorev.2018.11.003

Anand RR, Wildman JE, Varga ZS, Phang C. Regolith evolution and geochemical dispersion in transported and residual regolith – bronzewing gold deposit. Geochem Explor Environ Anal 2001; 12:256–76.

Arhin E, Nude PM. Significance of regolith mapping and its implication for gold exploration in Northern Ghana: a case study at Tinga and Kunche. Geochem Explor Environ Anal 2009; 9:63–9; doi:10.1144/1467-7873/08-189

Arhin E, Boadi S, Hall MC. Identifying pathfinder elements from termite mound samples for gold exploration in regolith complex terrain of the Lawara belt, NW Ghana. Afr Earth Sci 2015; doi: http://dx.doi.org/10.1016/j.jafrearsci.2015.05.022

King HM. The many uses of gold. 2019. Available via www.geology.com/mineral/gold/uses-of-gold.shtml retrieved on17/08/2019

Nude PM, Asigri JM, Yidana SM, Arhin E, Foli G, Kutu JM. Identifying pathfinder elements for gold in multi-element soil geochemical data from the Wa-Lawra Belt, Northwest Ghana: a multivariate statistical approach. Int J Geosci 2012; 3:62–70; Doi: 10.4236/ijg.2012.31008

Obaje NG. Geology and mineral resources of Nigeria. Springer, Heidelberg, Germany, 2009.

Shehu SJ, Aku MO, Saleh M, Bunawa AA, Sharafa SB. A reconnaisannce study to delineate the potential mineral zones around the Schist Belt areas of Kano State, Nigeria using airborne magnetic data. J Geol Min Res 2019; 11(2):14–21; doi: 10.5897/GMR2018.0307.

Shehu SJ, Aku MO, Saleh M, Bunawa AA, Lawan M, Sani F. The use of euler deconvolution technique in the estimation of depth to magnetic source bodies around the schist belt parts of Kano State, Nigera. Jourdan J Phys 2021a; 14(1):19–23; Doi: https://doi.org/10.47011/14.1.2

Shehu SJ, Aku MO, Saleh M, Bunawa AA, Abdullahi YM, Mohammed A. 2D-inversion of ground magnetic data acquired around the Schist Belt areas of Kano State, Nigeria for estimation of causative body parameters. FUW Trends Sci Technol J 2021b; 6(3):842–8. Available via www.ftstjournal.com

Shehu SJ, Yelwa NA. Investigation of the solid mineral deposits in Kano state's Schist belt using geochemical analysis. FUDMA J Sci (FJS) 2022; 6(1):394–401; Doi: https://doi.org/10.33003/fjs-2022-0601-827