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Geochemistry and Petrogenesis of Schists: A Case Study of Sheets 203 (Lafiagi) SW and 224 (Osi) NW, Southwestern Nigeria

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ABSTRACT

Large distributions of meta-sedimentary rocks of the Precambrian period are visible and have been deposited in association with Schist rocks in Sheets 203 (Lafiagi) SW and 224 (Osi) NW in southwestern Nigeria. Below these formations are Migmatitic and granitic gneisses which have been intruded by granitoids of Late to Post Pan African age. From petrographic and geochemical studies, the meta-sedimentary rocks are identified as pelitic schists which are derived from immature feldspathic volcanic rocks of arkose to greywacke range. The high concentration of Ba about Rb content shows that the source material for the schists contained an abundance of K-feldspar while the moderate Cr concentrations and high Ni levels are clear indicators of abundance in mafic minerals. The CIA values that were established revealed that very little alteration of the initial rock took place. The area under investigation has similar petrological, structural, and geochemical characteristics with the Ilesha Schist Belt to the south from which it extends to the north.

Keywords: Geochemical composition; Petrogenesis; Meta-sedimentary rocks; Precambrian; Para-schists; Granitic gneisses; Migmatitic gneisses; Island Arc tholeiites; Sheets 203 (Lafiagi) SW and 224 (Osi) NW; Southwestern Nigeria.

1. Introduction

The Nigerian basement complex is the largest collection of the Trans-Saharan mobile belt located between the cratons of West Africa and Congo. The basement is made up of various petrolithologic groups, including the migmatite-gneisses quartzite complex, the schist belt, the Pan African Older granites, and the Undeformed dykes [1],[2]. The western part of the basement contains many noticeable schist belts, which are Proterozoic rocks with a north-southerly trend.

In the region of Southwestern Nigeria (where this study originates), the primary rock types consist of migmatite, gneisses, amphibolites, granites, and pegmatites. Additional significant rock formations include the schists, consisting of biotite schist, quartzite schist, talc-tremolite schist, and muscovite schist. The crystalline rocks penetrated these schistose rocks [3]. The schist belts mentioned are Iseyin-Oyan, Maru, Anka, Zuru, Kazaure, Kushaka, Igarra, Wonaka, Karaukarau, Zungeru-Birnin Gwari, and Ilesha [4]. There have been few detailed geological investigations conducted on different units of the Precambrian Basement Complex in the Iseyin-Oyan Schist Belt when compared to other schist belts in Nigeria. These rocks, along with various lithological units in the schist belts across Nigeria (except for the Iseyin-Oyan schist belt), host scattered occurrences of sulfide mineral grains and base metal deposits [5].

This research aims to investigate the Schists of Sheets 203 (Lafiagi) SW and 224 (Osi) NW, located in southwestern Nigeria, through a thorough geochemical analysis to better understand their origins and petrogenetic characteristics.

1.1. Study Objectives

The objectives of the study include the following:

(1) To analyze the petrographic characteristics of meta-sedimentary rocks in Sheets 203 (Lafiagi) SW and 224 (Osi) NW, Southwestern Nigeria.

(2) To determine the geochemical composition of the schists and their associated rocks, including the presence of major and trace elements such as Ba, Rb, Cr, and Ni.

(3) To investigate the petrogenesis of the para-schists, focusing on their derivation from moderately weathered feldspathic igneous rocks, such as arkosic to greywacke compositions.

(4) To evaluate the degree of weathering of the original rock formations through the calculation of Chemical Index of Alteration (CIA) values.

(5) To compare the structural and petrological features of the studied area with the Ilesha Schist Belt, establishing its geological continuity.

2. Geology of the Study Area

The research area is within the Basement Complex in the southwest region of Nigeria (Figure 1). It spans from Longitudes 5˚ 00'- 5˚ 15' and Latitudes 8˚ 15'- 8˚ 37', encompassing roughly 1100km^2 in the northeast of Ilorin and southeast of Jebba. The main rocks found in the region are meta-sediments such as quartzite, schist, and marble. These rock formations are supported by granodioritic-tonalitic and granitic gneisses that have been partially melted and share the same age fabrics. Late- to Post-Pan African granitoid invaded and intersected the textures of the gneisses and the meta-sediments. This situation has also been documented in other areas of the schist belt in southwestern Nigeria [6]. The region features rough terrain with heights varying between approximately 200 and 500m. Situated in a tropical humid climate area, the region experiences temperatures ranging from 21 °C to 34 °C. The main seasons are the Rainy Season (April to October) and the Dry Season (November to March). The mean annual rainfall typically reaches 1,250 mm annually. This paper focuses on the Shists, which trend in the NNE-SSW direction and are closely associated with the quartz mica schist. They are limited to the western and central regions of the area.

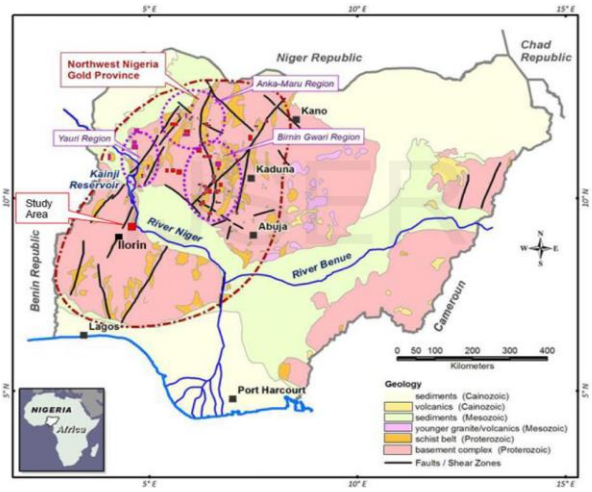

Figure 1. Geological map of Nigeria showing the study area

2.1. Geological Rocks of the Study Area

(a) Gneisses

The granodioritic-tonalitic gneisses and the granitic gneisses, which show varying degrees of migmatization, are prominently visible in the eastern portion of the research site. Migmatization becomes more pronounced in the eastern direction, where clear layers of dark, aged basic paleosome are interspersed with lighter, newer felsic neosome. The gneisses typically trend in a WNW to NE direction. Schist xenoliths can be found in the gneisses. The main minerals consist of quartz + plagioclase (An 28-An 40) + microcline + biotite + muscovite ± hornblende. Accessory minerals consist of opaque ± apatite ± allanite ± sphene ± zircon.

(b) Meta-sediments

The meta-sediments consist of rocks that have the same age and metamorphic characteristics as the gneisses underneath them. They blend seamlessly and are frequently mixed. The most prevalent meta-sediments are foliated and massive quartzite varieties. They are in the central, southwestern, and northwestern regions. Quartzite is adjacent to mica schist, amphibolite, gneisses, marble, granite, and pegmatite. Over 90% of the mineral composition is made up of quartz, with small amounts of feldspar, muscovite, altered biotite, and sometimes garnet and opaque minerals. Quartz-mica-schists as well as pelitic and semi-pelitic quartz-mica-sillimanite-schists can be found in the western part of the region. Signs of folding, garnet alteration, and rough contact metamorphic zones are plentiful. The light-colored quartz-mica-schist appears phylitic in high-strain regions. The collection consists of quartz, muscovite, biotite, plagioclase with or without garnet, microcline, and opaque materials. Patches of pelitic to semi-pelitic schists with varying compositions are sporadically visible, primarily found in the western and northern regions. The mineral components consist of biotite + quartz + muscovite + sillimanite + plagioclase + microcline + garnet ± kyanite ± opaque minerals. Garnet is commonly found and frequently exhibits internal textures, indicating tectono-thermal deformations within a regional context. Sillimanite and kyanite are often found in regions where contact metamorphism occurs.

(c) Amphibolite

There are two kinds of amphibolites, massive and foliated, found in the northern, eastern, and western regions as thin, flat rocks mixed with meta-sediments, except in the east near Owa-Kajola, where they are mixed with migmatitic gneiss and marble. They are also found as xenolithic and boudinaged inclusions within the migmatitic gneisses. The amphibolites in the northcentral and eastern regions of the study area, particularly near Budo-Idowu and Owa-Kajola, display foliation, while those in the western area are unfoliated. The amphibolites were characterized by a mineral assemblage of Hornblende + plagioclase + quartz + actinolite-tremolite + biotite ± garnet ± calcite ± sphene. Chalcopyrite is found as a significant secondary mineral in the amphibolites near Owa-Kajola.

(d) Granitoid

Granodiorite of different shades, ranging from mesocratic to melanocratic, can be found predominantly in the northwest corner of the region, with scattered deposits in other areas. The rocks have a medium to coarse grain size and consist of a mixture of quartz, plagioclase, biotite, hornblende, and microcline. Accessories that are associated include opaque, sphene, and alanite. Porphyritic and mesoporphyritic granites, as well as fine to medium-grained granites, are prevalent and make up the primary granitoids in the region. Granites containing a mineral assemblage of Quartz + microcline + plagioclase + biotite + hornblende + muscovite + opaque minerals + alanite + sphene ± zircon.

3. Materials and Methods

The research process included geological field mapping, sampling, and geochemical analysis. The geological mapping of the study area was carried out on a scale of 1:25,000. Large, and fresh rock samples were randomly collected for analysis. To prepare for thin-section analysis, rock samples were collected following the methods outlined by Paschier and Trouv in 2005. A total of nine pelitic to semi-pelitic schist samples were analyzed using atomic absorption spectrometry (AAS) and inductively coupled plasma (mass spectrometry and optical emission spectrometry) to determine their major, trace, and rare earth element compositions. The samples were initially crushed using a hammer at the Laboratory/Workshop of the Department of Geology and Mineral Sciences, Geoearth Project Limited. They were then further milled to a size of ≤40µ using a carbide-coated milling machine. The atomic absorption spectrometry (AAS) analyses were performed at the Nigerian Geological Survey Agency's Laboratory in Kaduna, while the inductively coupled plasma (ICP-MS/OES) analyses were carried out at Activation Laboratories Ltd (ACTABS) in Canada.

4. Results and Discussion

4.1. Geochemical Results

The findings from the samples that were analyzed are displayed in Tables 1 and 2. The schists exhibit silica contents ranging from moderate to high (53.5-77.8%). The alumina levels range from moderate (8.3%) to extremely high (23.8%) [7]. The dominance of Ba over Rb in the meta-sediments indicates that they originated from a protolith rich in K-feldspar. This claim is also backed up by High Ba, Rb, Sr, and Cr levels are elevated, pointing to a considerable presence of mafic components in the initial sediments. The calculated CIA values for the samples show a low to moderate degree of weathering of the sources [8],[9].

Table 1. Trace elements of the study area

Trace Element	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9
Ba	688	481	503	499	45.87	998	102	66.7	45
Cr	135	224	198	219	32.2	26.99	127	171	8
Mo	1.01	1.86	1	0.18	1	0.71	1.5	0.52	0.81
Ni	8	12.2	72	69	8	18.3	69.3	155	7.2
Rb	146	136.2	175.9	7.69	6.22	7.88	155.8	4.6	5.29
Sr	80	123	119	98.3	159	201	96	10.55	0.29
Y	8.22	16.33	28.1	7.33	5.69	28.1	24.1	21.2	19.88
Zr	81	9	174	18.2	39	7.2	1.22	8.2	34

*__SD 1-9__ denote Schist samples from the study area.

Table 2. Geochemical composition data of schist samples

Major Oxides	SCH1	SCH2	SCH3	SCH4	SCH5	SCH6	SCH7	SCH8	SCH9
SiO_2	53.5	77.8	68	58.3	55.8	60.8	72.9	67.5	62.8
TiO_2	0.17	0.29	0.38	0.8	1.22	0.07	0.12	0.29	0.38
Al_2O_3	8.3	10.29	23.8	15.9	18.5	22.9	12.8	13.9	15.8
Fe_2O_3	1.5	2	0.57	7.02	9.88	0.54	0.73	2.1	3.88
MnO	0.02	0.05	0.19	0.17	0.15	0.21	0.04	0.09	0.08
MgO	7.22	1.66	1.8	3.45	2.55	3.2	1.2	3.17	1.55
CaO	11.22	2.59	3.1	2.54	3.22	1	1.96	2.55	2.8
Na_2O	1.02	2.41	2.2	1.84	1.33	1.58	0.91	0.78	2.65
K_2O	3.22	1.59	1.8	3.02	1.51	1.93	2.2	2.39	3.21
P_2O_5	0.09	0.05	-	0.17	0.19	-	0.15	0.22	0.16
LOI	12.99	1.3	1.1	1.66	1.32	0.98	2.66	3.01	2.22
Na_2O+K_2O	1.49	1.40	1.53	1.35	1.79	8.51	1.07	9.98	2.07
Na_2O/Al_2O_3	0.16	0.13	0.06	0.07	0.01	0.01	0.02	0.12	0.12
K_2O/Al_2O_3	0.02	0.01	0.01	0.01	0.09	0.36	0.07	0.60	0.01

***SCH 1-9** denote Schist samples from the study area.

Table 3. (ICV)% and (CIA)% of the Schists in the study area

Sample	CIA%	ICV%
SCH1	46.0	3.18
SCH2	77.6	0.53
SCH3	83.5	0.38
SCH4	70.3	1.23
SCH5	80.3	0.51
SCH6	71.9	1.27
SCH7	72.6	0.49
SCH8	65.4	0.88

NB: Index of Compositional Variability-ICV; Chemical Index of Alteration-CIA.

4.2. Discussion

The intertwined and gradually changing connections between the schists and quartzite, as well as among different types of schists, suggest that sediment was deposited in an environment with inconsistent flow conditions. This means that periods of high flow were followed by periods of low flow, resulting in the deposition of heavier sediments followed by lighter ones. The vertical presence of meta-sediments interwoven with each other illustrates this occurrence, whereas the gradual connections highlight this phenomenon horizontally. It is believed that the schists originated from sedimentary rocks (para-schists) rather than those formed from igneous protoliths [10]. The examination of rock samples has revealed a notable quantity of graphite in the connected marble formations at Owa-Kajola and Oreke, providing strong evidence for a sedimentary source.

The discriminant plot of K_2O/Al_2O_3 vs Na_2O/Al_2O_3 (Figure 2) supports this field evidence, showing that the schist samples fall within sedimentary and meta-sedimentary fields. It was also determined that the metamorphosed sediments were originally from rocks with arkosic to sub-arkosic compositions, as shown in the graph of Na_2O vs K_2O (Figure 3). The predominance of Ba compared to Rb in the meta-sediments is also indicative of protoliths rich in K-feldspar, particularly in granitic rocks. The elevated levels of Ba, Rb, and Sr in most of the rocks are like the compositions identified by [11] for the metasediments. Likewise, the arrangement of the rocks on the SiO_2/CaO graph (Figure 4) indicates they are primarily from the Greywacke category, confirming the previously mentioned conclusion about their sedimentary origin.

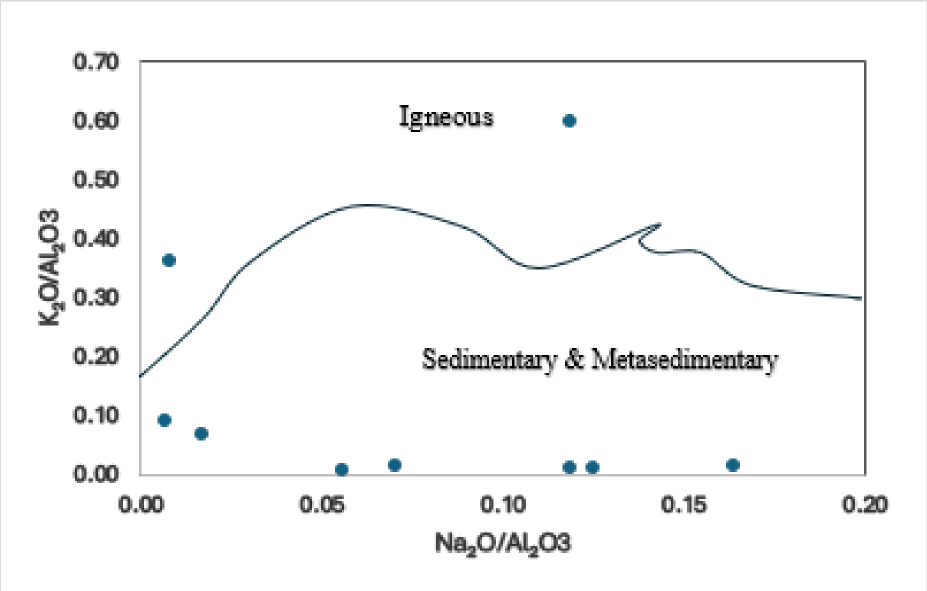

Figure 2. K_2O/Al_2O_3 against K_2O/Al_2O_3 plot for the schists in the study area

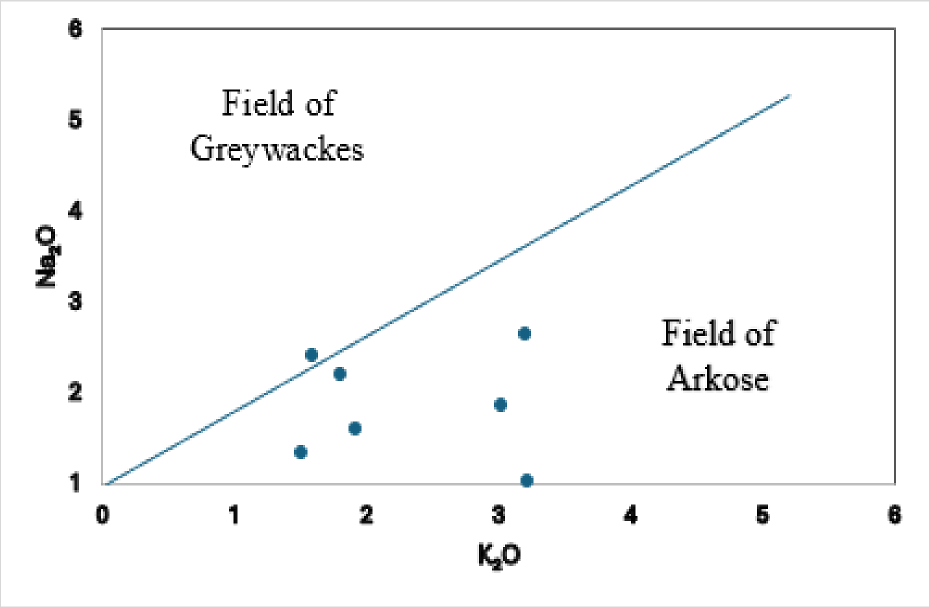

Figure 3. Na_2O against K_2O plot for the schists in the study area. One sample plot is in the field of greywacke while the rest are in the arkose or arkose/wacke interface. This suggests that the arkosic protolith has a little greywacke characteristic

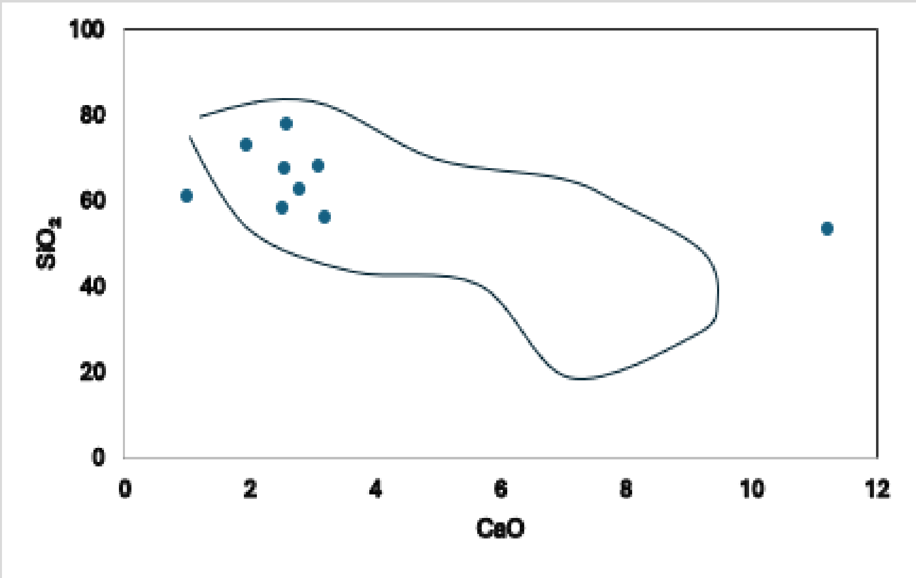

Figure 4. SiO_2 against CaO plot for the schists in the study area. The schists share a little similarity with the Franciscan Greywacke, which shows an affinity for the Wacke class of sedimentary protolith as indicated above

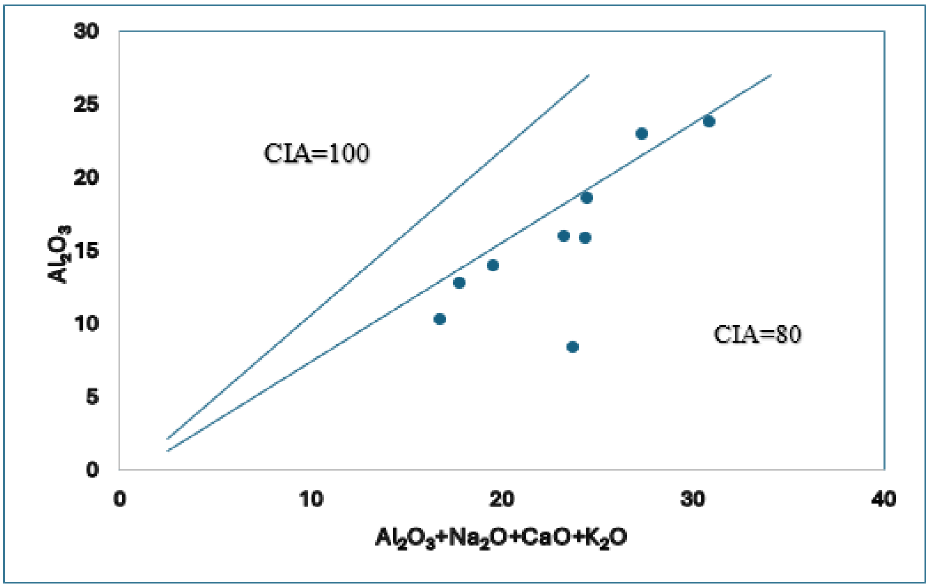

Figure 5. Al_2O_3 against Al_2O_3+Na_2O+CaO+K_2O plot for schists in the study area). About 90% of the samples plot in the Low CIA inference field (CIA=80)

The initial sediments likely included high quantities of feldspar, clay minerals, carbonates, and organic material. Increased levels of Cr and, from time to time, Ni found in the rocks suggest the existence of certain quantities of mafic components within the sediments. The Cr and Ni would have been included in or made-up part of the organic material that was deposited alongside carbonates in the formation of the marble. The arkosic grey wacke or feldspathic grey wacke protolith is common in psamitic to semi-pelitic schists [11]. The increased Zr in the geochemical results of certain schist samples is probably due to the presence of detrital zircon from the feldspathic sediments. This indicates that zircon was a secondary mineral in the original granite rock, which supplied the sediments. The Chemical Index of Alteration and the Index of Compositional Variability (Table 3) were used to calculate the degree of source rock weathering and sediment maturity of the protolith. It can be inferred from the CIA that the original rock of the study region has undergone minimal weathering (Figure 5). All the rock samples plot in the inference field of sedimentary/ metasedimentary rocks.

5. Conclusions

The schistose rocks in some areas of Sheets 203 (Lafiagi) SW and 224 (Osi) NW are likely para-schists made up of arkosic to greywacke materials, believed to have come from slightly to moderately weathered feldspathic igneous origins. The initial sediment brought downstream was somewhat matured but eventually sorted into distinct layers due to changes in the flow patterns.

The following should be taken into consideration for the study area for prospects:

(i) To enhance the understanding of regional tectonics and geological history, the study's findings could provide new insights into the tectonic evolution of Southwestern Nigeria, particularly in relation to the Pan-African orogeny and its impact on the area's geologic structures.

(ii) For potential mineral exploration, the identification of mafic components and trace elements such as Cr and Ni may indicate potential areas for future exploration of valuable mineral resources, including chromium and nickel deposits.

(iii) In contributing to regional geological mapping, the findings could contribute to updating geological maps, improving the understanding of rock formations in Southwestern Nigeria, and aiding further academic and industrial research.

(iv) For geochronological studies, the study's results may open up opportunities for more detailed geochronological analysis to accurately date the granitoid and amphibolitic rocks, providing a clearer timeline for the area's geological events.

(v) For comparative studies in West African geology, the petrogenetic and geochemical data from this study could be compared with other Schist belts in West Africa, helping to refine regional correlations and interpretations of ancient geological processes.

Declarations

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Competing Interests Statement

The authors declare no competing financial, professional, or personal interests.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

All the authors took part in literature review, analysis, and manuscript writing equally.

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