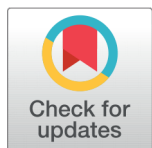


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Mineralogy and Geochemistry of Hydrothermally altered Talcose rocks from Ila Orangun-Oyan areas, part of Southwestern Nigeria

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Abstract

Background/Objectives: Talcose rocks within Precambrian Basement Complex serve as relics of Archean greenstones. Alterations associated with polycyclic-orogenies that affected this complex is studied to understand mineralogical and geochemical alterations. **Methods:** Five fresh samples of talcose rocks were collected during field mapping. These samples were cut into thin sections to reveal modal mineralogy, altered minerals and degree of alteration of such minerals. Mineral phase identification of the talcose rocks was conducted using X-ray Broker D8 ADVANCE diffractometer while whole rock analysis was carried out using Inductively Coupled Plasma Mass Spectrometry. **Findings:** Lithological relationship revealed from field evidence showed that the talc bodies occurred in close association with micaceous schist. The mineral assemblage of talc, tremolite, actinolite, chlorite and calcite suggest low grade greenschist metamorphic facies from possible hydrothermal alteration. Geochemical results revealed the following range of concentrations; SiO₂ 42.19-59.03%; Al₂O₃ 1.1 - 11.8%; Fe₂O₃ 7.64-9.56%; MgO 24.47-26.639%; Ni 594-1207ppm; Co 43.2-113.9ppm; Sn 6-41ppm; V 32-75ppm and Zr 1.3-58.7ppm, and these are typical of talcose rocks. Petrogenetic studies suggest a komatiitic origin with a peridotitic komatiite precursor for the talc-chlorite-tremolite schist. Enrichment in LREE, depletion in HREE and a negative Eu anomaly suggest alteration of the parent magma for the talcose rock and plagioclase fractionation. The trends observed for the LILE, HFSE and REE suggest possible contamination or mixing of crustal and mantle materials during the formation of the protolith.

Ni and Co concentrations are higher than average crustal values with implication for ultrabasic to basic magma composition for the komatiitic progenitor and also suggestive of possible mineralisation. **Conclusion:** Mineralogical examination has revealed a talc-chlorite-tremolite composition for the talcose rocks with peridotitic komatiite precursory while geochemical composition supported ultrabasic magmatism similar to those with the Ilesha schist belt.

Keywords: Ila Orangun-Oyan; Talcose rocks; Hydrothermal alteration; Peridotitic Komatiite; Ilesha schist belt

1 Introduction

Talc bearing rocks have been reported within the schist belts; which are mostly restricted to the western part of Nigeria although smaller occurrences of schist belts have been reported in the eastern portion of the country.⁽¹⁾ Talcose rocks are metamorphic rocks formed from the alteration of mafic and ultramafic rocks⁽²⁾ as well as from the metamorphism of siliceous dolomitic carbonate rocks. Talcose rocks have been reported to be in close association with mafic, ultramafic and metasedimentary rock especially within the Ilesha schist that has been widely studied.^(3,4) A knowledge of their geology can aid in a better understanding of the associated rocks and the geologic evolution of the areas in which they outcrop. Talc is an industrial mineral whose suitability for industrial and other applications depends on its mineralogy and physico-chemical properties. Talcose rocks are the major source of talc, therefore a study of the occurrence of talc-bearing rocks and the geochemistry of the talc they contain is germane.

Talc occurrences have been reported within most parts of the Ilesha schist belt,^(3,4) and studies have been conducted on their petrology, petrogenesis, mineralogy as well as their industrial applicability and economic potential by several authors from areas like Baba Ode,⁽⁵⁾ Erin Omu,⁽⁶⁾ Wonu-Apomu,^(7,8) Kumaru,⁽⁹⁾ Oke-Ila⁽¹⁰⁾, Ile-Ife, Ikirun and Esa Oke,⁽¹¹⁾ Itagunmodi-Igun⁽¹²⁾ and parts of the Ilesha schist belt.⁽¹³⁾ However, there is a dearth of research data on talcose bodies within the Ila Orangun-Oyan area of the Ilesha schist belt.

Ifewara fault zone which hosts the Ilesha schist belt divides the schist belt into eastern and western halves with contrasting lithologies^(14,15) ([Figure 1](#)). Evidences of shearing may be linked with hydrothermal and metasomatic alterations that possibly affected previously emplaced rocks. This study therefore intends to determine the origin, mineralogy and geochemistry of Talcose bodies within Ila Orangun-Oyan area and the extent to which the shearing and hydrothermal processes affected the talc bodies in the area. It also aims to establish if the talc bodies in the Ila Orangun-Oyan area are a continuation of the deposits in other parts

of the schist belt located south of the area studied.

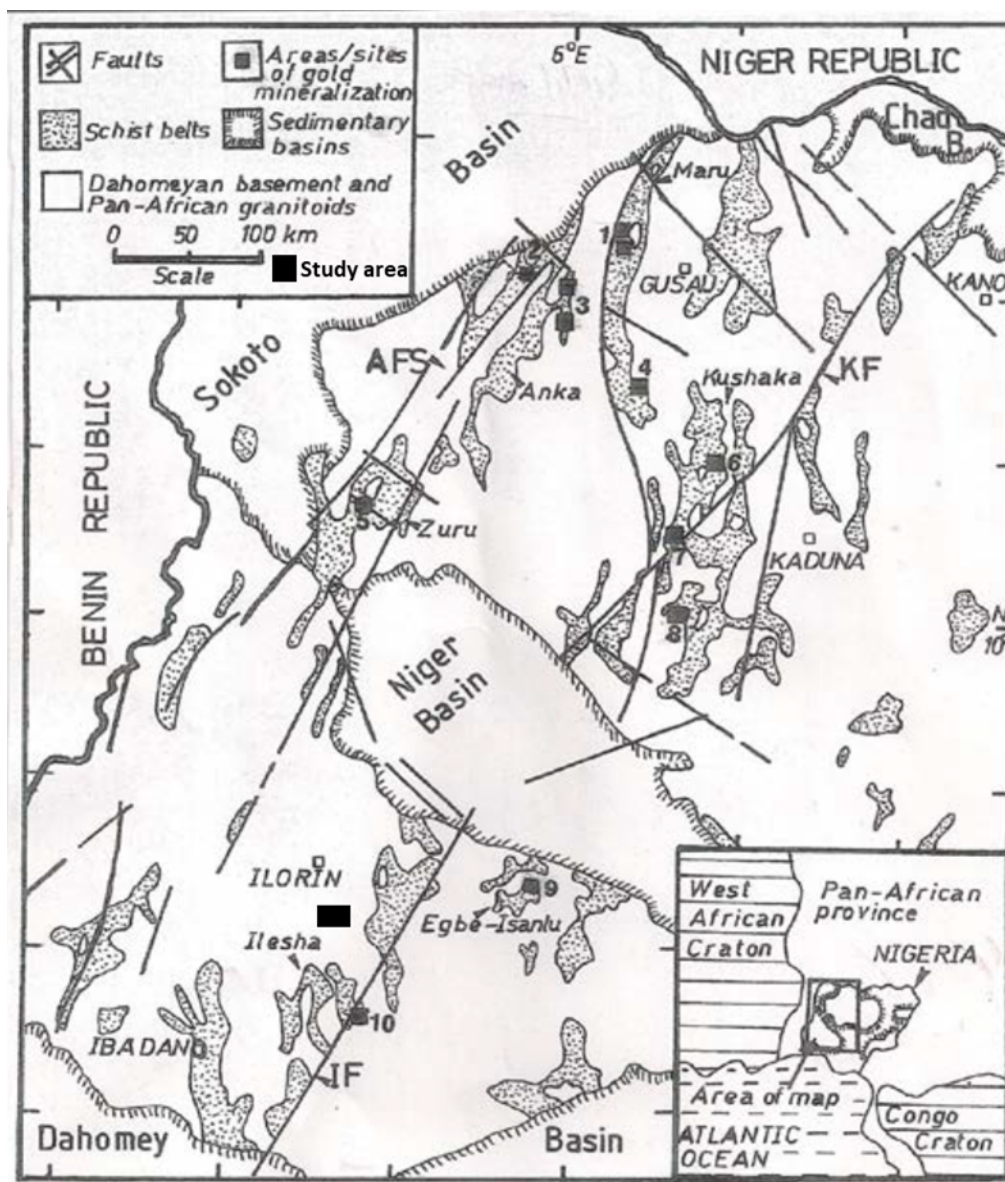


Fig 1. Geological Map of the Western half of Nigeria showing the Schist belts and the major lineaments.⁽¹⁵⁾ The Schist belts are: 1. Zungeru-Birnin Gwari, 2. Kushaka, 3. Malumfashi, 4. Kazaure, 5. Wonaka, 6. Maru, 7. Anka, 8. Zuru, 9. Iseyin-Oyan River, 10. Ife-Ilesha, AFS = Anka-Yauri-Iseyin fault system, KF = Kalangai fault, IF=Ifewara fault

2 Location and Geology of the study area

The study area lies within the geographical space defined by Longitudes $04^{\circ} 49' 00''$ E and $04^{\circ} 57' 00''$ E, and Latitudes $08^{\circ} 00' 00''$ N and $08^{\circ} 04' 00''$ N. Major settlements in the study area includes Ila-Orangun and Oyan towns. The study area is located within the Ilesha schist belt found within the basement complex of Nigeria which forms part of the N-S trending orogenic belt and has been reported to consist of three broad lithologic units namely; a) The migmatite-gneiss complex alongside with quartzite b) schist belts

which are upper proterozoic supracrustal rocks and c) Older granites otherwise called the Pan-African granitoids. (2,16,17) The Ilesha schist belt consist largely of schistose rocks and have been widely studied by several researchers. (18) Talcose rocks however, occur as enclaves within the major lithologies and are thought to be results of polycyclic episodes of deformation and metamorphism. Geological mapping of the study area revealed mica schist (muscovite and biotite schist), talc schist, gneiss, (biotite granite gneiss, granite gneiss and biotite hornblende gneiss), quartzite, porphyritic granite and pegmatites as the main rock units in the area (Figure 2).

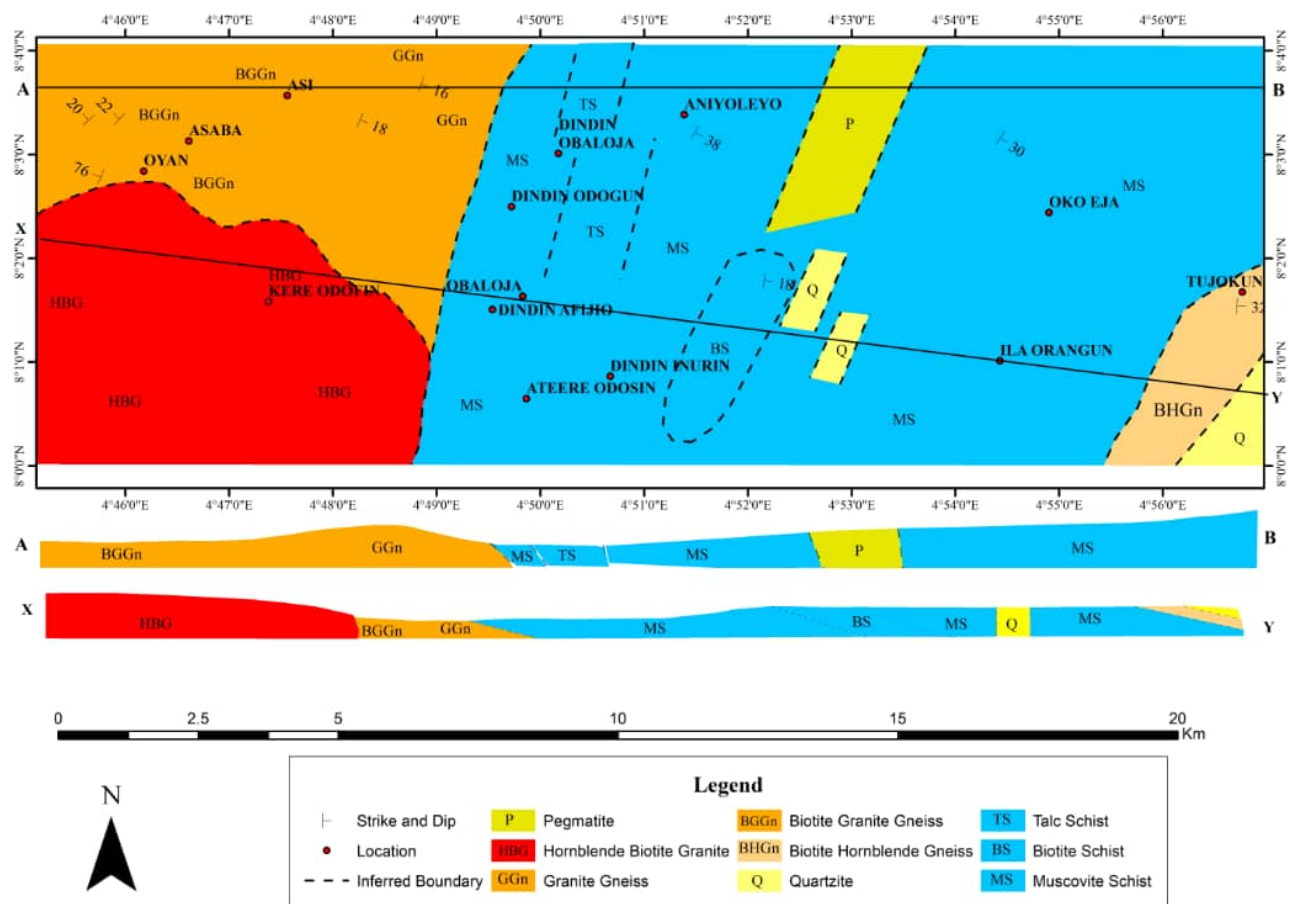


Fig 2. Geological map of the study area

3 Material and Methods

Detailed geological mapping of the study area was carried out using the topographic map of Ilorin SE Sheet 223 on a scale of 1: 50,000 as the base map. Prior to field mapping exercise, the topographic map of the study area was systematically gridded into a total of 48 grids. The appropriate locations of different lithologic units encountered in the course of mapping were recorded on the base map with the aid of the Global Positioning System (GPS). Representative portions of each lithologic unit were sampled and labeled accordingly in the sample bags. The rock types, geological information as well as measurements taken on the outcrops were appropriately recorded. Thirty-two (32) least altered rock samples were retrieved during

the field mapping of the study area and five (5) of these were talcose rocks.

Sixty-four (64) thin section slides were prepared from all the representative samples (all rock units) and studied for their mineralogical assemblages under the petrographic microscope at the Department of Geology, University of Ibadan, Nigeria and Universite de Lome, Togo.

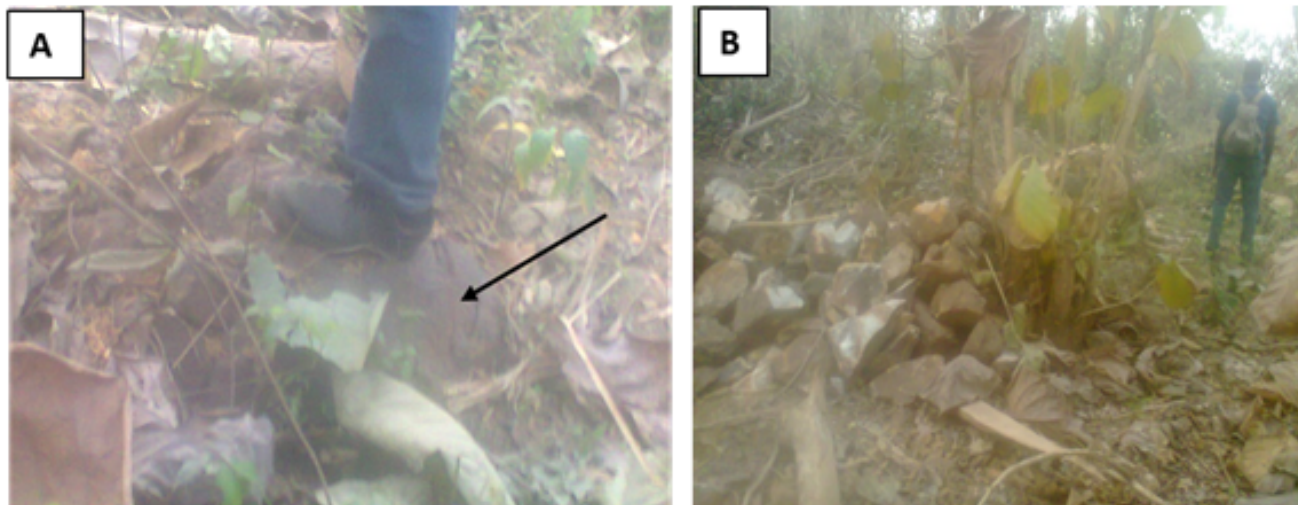
Representative samples were also pulverised and sent to Bureau Veritas Mineral Services, Vancouver, Canada for whole rock analysis using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) as well as to France for mineral phase identification (XRD) using a Broker D8 ADVANCE diffractometer (CuK α radiation) operating at conditions of 40kV, 40mA and step size of 0.025/s over the 2°-65°2 θ angular range. Subsequent to the whole rock analysis, 15g of each of the pulverised samples were digested using lithium borate fusion technique. For the mineral phase identification, each mineral was identified by their characteristic peak positions^(19,20) and compared with International Centre for Diffraction Data (ICDD) files using X'Pert Highscore software. The relative proportions of the minerals were determined using the peak area ratios of each mineral characteristics peak.

Data obtained from the analyses were evaluated using descriptive statistics and geochemical variation plots.

4 Results and Discussion

4.1 Lithological relationship and petrographic studies

The Talc-chlorite-schist are restricted to the northern part of the area and outcropped within the more widespread mica schist ([Figure 3 A](#)). Surface exposures are weathered and revealed a whitish colouration with a soapy feel. Fresh samples were obtained from the quarry pits within the area ([Figure 3B](#)). Fresh samples appeared greenish and less soapy ([Figure 3C-D](#)). They occurred as small lensoid bodies, and are generally low-lying and poorly exposed.



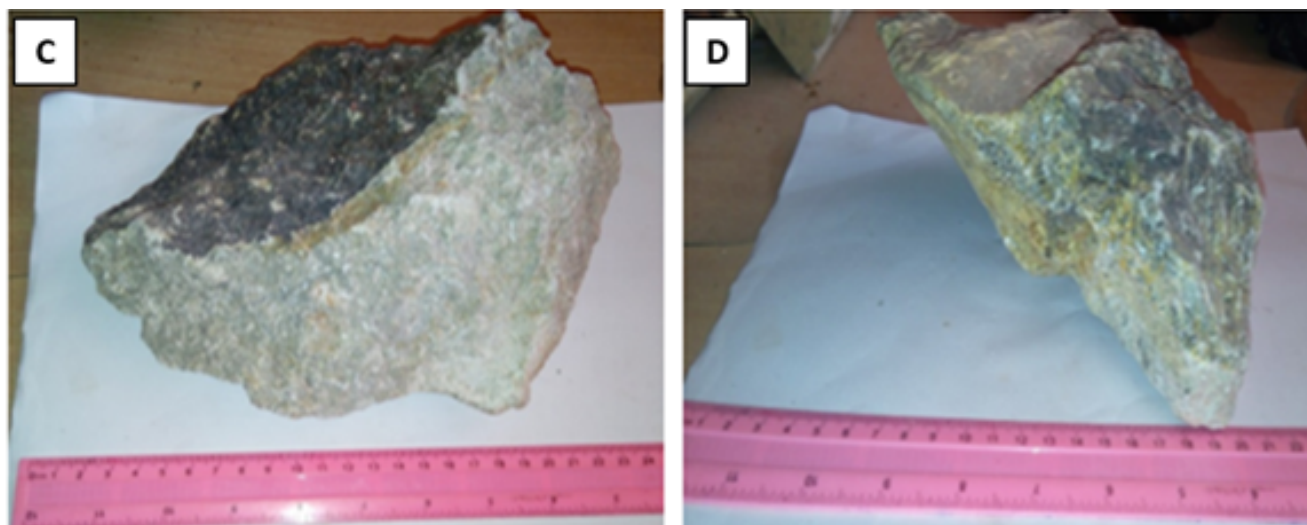


Fig 3. (A) Field occurrence of talcose rocks; (B) Talc-Chlorite-Tremolite Schist recovered and piled up for transportation; (C and D) Hand specimens of Talc-chlorite-tremolite schist

In thin section, fibrous tremolite, actinolite, chlorite and talc were observed ([Figure 4](#)). Talc crystals ranged from colourless (in plane polarized light) to off white or grey colour under cross polar. Chlorite crystals displayed greenish to bluish-green colour. The tremolite crystals appeared as fibrous crystals. The chlorite is responsible for the greenish colour of the talc schist while the brownish colouration which is due to iron oxidation observed for the chlorite is indicative of weathering effect. Talc and chlorite are the dominant minerals, followed by tremolite and trace amount of long needle-like fibers of anthophyllite and actinolite ([Table 1](#)). The mineralogical composition from thin sections describe talc schist bodies as talc-chlorite-tremolite schist.

Table 1. Modal analysis of the Talc-chlorite-tremolite schist in the study area

Minerals	R33a	R33b	R34
Talc	45	40	50
Tremolite	20	22	30
Chlorite	25	30	16
Anthophyllite	2		2
Actinolite	1		
Others	1	2	
Opaque	6	6	2
Total	100	100	100

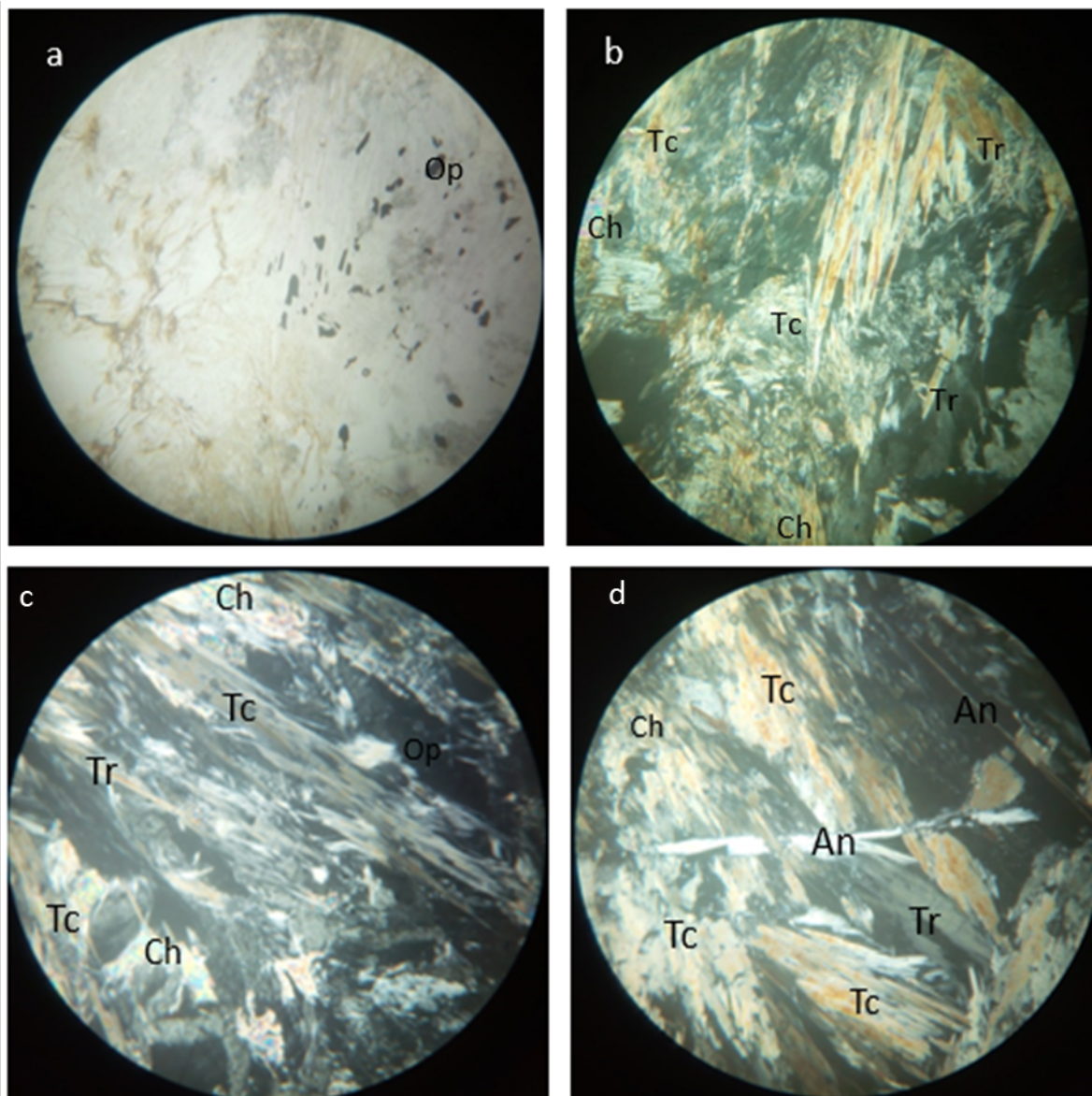


Fig 4. Photomicrograph of Talc-chlorite-tremolite schist showing fibrous and prismatic crystals under polarized light (a) and cross polarized light plane (b, c and d) showing weak foliation (Mag.40x). (Tc-Talc, Tr-Tremolite, Ch-Chlorite, An-Anthophyllite and Op-Opaque)

4.2 Mineralogy of the talc schist

The XRD result of the mineralogical analysis revealed talc, chlorite, tremolite and calcite ([Figure 5](#)) as the mineral constituents. Noticeable peaks of talc and chlorite were observed in the X-ray diffractogram of the samples while no primary silicate minerals were preserved in the mineralogical assemblage.

The mineralogical analysis showed that the compositional ranges of the minerals were talc 9-15%; chlorite 21-67%; tremolite 15-47% and calcite 7-23% ([Table 2](#)). Samples showed varied proportions in percentages of chlorite (Ch), tremolite (Tm), Calcite (Ca) content ([Table 2](#)). Some samples showed relatively elevated proportions of Ch over the others while some also revealed higher Tm and

Ca compositions. The mineralogy suggests possible presence of chlorite varieties such as penninite, clinocllore, sheridanite, corundophilite or klemenite which are monoclinic with positive optic sign (Figure 5). Chlorite minerals from thin section appeared pleochroic with colours ranging from green to brown. Chromium-bearing monoclinic chlorite accounts for the greenish colour of the talc schist with less than 6% Cr₂O₃. The brownish colouration as observed in thin section showed pleochroic effect with increasing Fe content and suggestive of penninite (Manganese chlorite). The presence of talc, chlorite and tremolite indicate low grade greenschist metamorphic facies. The presence of calcite suggests late stage hydrothermal or secondary mineralization. (21)

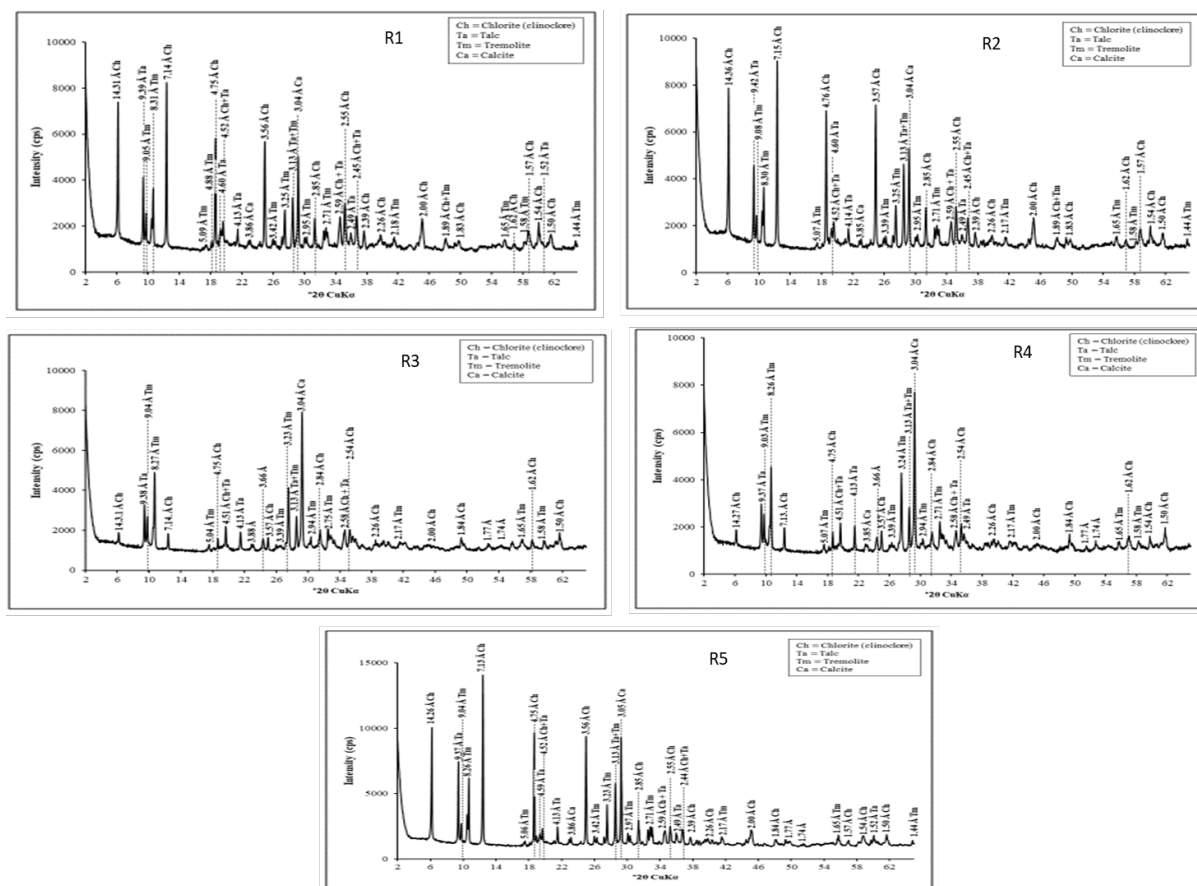


Fig 5. X-Ray Diffractograms for the Talcose rocks (Diffractograms of talcose rocks in the study area depicts predominant chlorite, talc, tremolite and calcite)

Table 2. Summary of the mineralogical composition (in %) of the Talc-chlorite-tremolite schist from the study area

	Mineral proportions (%)			
	Talc	Tremolite	Chlorite	Calcite
R1	9	17	67	7
R2	14	15	62	9
R3	9	47	21	23
R4	15	34	30	21
R5	13	15	63	9

4.3 Geochemistry of the talc schist

The results of the geochemical analysis for the talc-chlorite-tremolite schist is presented in Table 3. The major oxide composition (wt. %) include: SiO_2 , 42.19-59.03; Al_2O_3 , 1.1 - 11.8; Fe_2O_3 , 7.64-9.56; MgO , 24.47-26.64; CaO , 0.18-1.51%; Na_2O , 0.03-0.04; K_2O , 0.01-0.02 and TiO_2 , 0.06-1.46. The MnO and Cr_2O_3 ranged from 0.08-0.15 and 0.05-0.77, respectively while P_2O_5 concentration was below the detection limit. Average SiO_2 (52.59 wt. %) conformed with published talc schist data from the southwestern part of Nigeria suggesting influence of regional metamorphism during Late Archean to Early Proterozoic times.^(8,12) The average MgO concentration (25.34 wt. %) is typical of talcose rocks.⁽²²⁾ The relative enrichment of SiO_2 (with average value, 52.59%) and depleted values of Na_2O , CaO and K_2O have been attributed to chemical weathering and relative chemical mobility of Na, Ca and K during hydrothermal alteration respectively.^(8,12) The Cr_2O_3 values (av. 0.42) were present but in lower concentration supporting the less than 6% Cr_2O_3 for chromium chlorite with positive optic sign suggesting clinocllore, penninite, sheridanite etc. Average MnO value (0.12) supports manganese chlorite. Hence, the chlorite of the study may consist of clinocllore and possible penninite.

The major oxide compositions for the talcose rocks in the study area displayed similar compositions with rocks of komatiitic origin and peridotitic protolith as reported from previous works.^(23,24) The correlations observed in the bivariate plots between major oxides vs MgO (Figure 6) especially SiO_2 vs MgO depicted possible derivative from fractional crystallisation of an ultrabasic magma.⁽¹³⁾ Samples that have high chlorite and lower Ca proportions (Figure 5, Table 2) were observed to show lower SiO_2 concentrations (Table 3). Density of chlorite decreases with Si and increases with Fe. Some samples showed lower SiO_2 and lower FeO and $\text{FeO}/\text{FeO}+\text{MgO}$ concentration values and therefore support clinocllore chlorite while samples with higher SiO_2 and higher FeO and $\text{FeO}/\text{FeO}+\text{MgO}$ support penninite chlorite (Table 3). A relationship with Ca could be established. Samples believed to consist of chlorite clinocllore showed lower Ca proportions (Table 2) from the diffractograms (Figure 5) while samples believed to consist of probable penninite chlorite showed higher Ca proportions. The presence and abundance of calcite in the mineralogical assemblage did not reflect similar pattern of enrichment in the CaO concentrations. This may be due to the relative enrichment of Ca bearing amphiboles. Actinolite tends to break down into chlorite and calcite in the presence of H_2O and or CO_2 .²¹ With higher degrees of breakdown Al is released. With increasing grade of metamorphism chlorite reduces in proportion to yield Al-rich amphibole and plagioclase.⁽²¹⁾ Table 3 showed higher concentrations of Al_2O_3 in some samples compared with others. Samples with $\text{Al}_2\text{O}_3/\text{TiO}_2$ less than 20 corresponds to Al depleted komatiite progenitor ($\text{Al}_2\text{O}_3/\text{TiO}_2 < 20$ and flat HREE) while samples with values greater than or equals to 20 implies possible Al undepleted komatiite progenitor ($\text{Al}_2\text{O}_3/\text{TiO}_2 \sim 20$ and flat HREE).^(25,26)

Table 3 presents the trace element concentration (ppm) of the rocks. These include: Ba, 3-22 (mean- 9.2); Nb, 0.2-11.7 (mean- 3.74); Sn, 6-41 (mean- 21.8); V, 32-75 (mean- 47.2); Zr, 1.3-58.7 (mean- 23.24); Cu, 8.2-34 (mean- 15.16) and Zn, 7-17 (mean- 11.2). Rb, Hf and Sc values fall within the range of values for ultramafic rocks with komatiite origin.⁽²⁴⁾ Most of the elements had concentrations below the average crustal values proposed by Taylor⁽²⁷⁾ except for Ni and Co whose mean values of 1008 and 75.46 ppm respectively were higher than the average crustal values of 75 ppm and 25 ppm respectively (Table 3) typical of ultramafic rocks. Ni and Co are good indicators of magma from mantle peridotite source⁽²⁸⁾ and high concentration of these elements suggest the alteration (hydrothermal/metamorphism) of ultramafic rock (parent rock) containing ferro-magnesian mineral like olivine/pyroxene that characterise rocks of peridotitic or dunitic compositions.⁽²⁹⁾ These parent magmatic bodies under hydrothermal conditions can yield talcose rocks where olivine alter into pyroxenes or serpentines.⁽²⁹⁾ The moderate to high

concentration of compatible elements; V and Co confirms their immobile nature during low grade metamorphism, hydrothermal alterations and weathering activities.^(8,28,30) The low concentrations of High Field Strength Elements (HFSE); Zr and Sr implied that the parent magma is depleted in these incompatible elements.⁽³¹⁾ The ratios Nb/Th and Th/Yb ranges from 0.7-2.4 and 0.8-28.6 respectively and these values greater than 1 are indicative of crustal contamination of mantle derived magma.⁽²⁹⁾

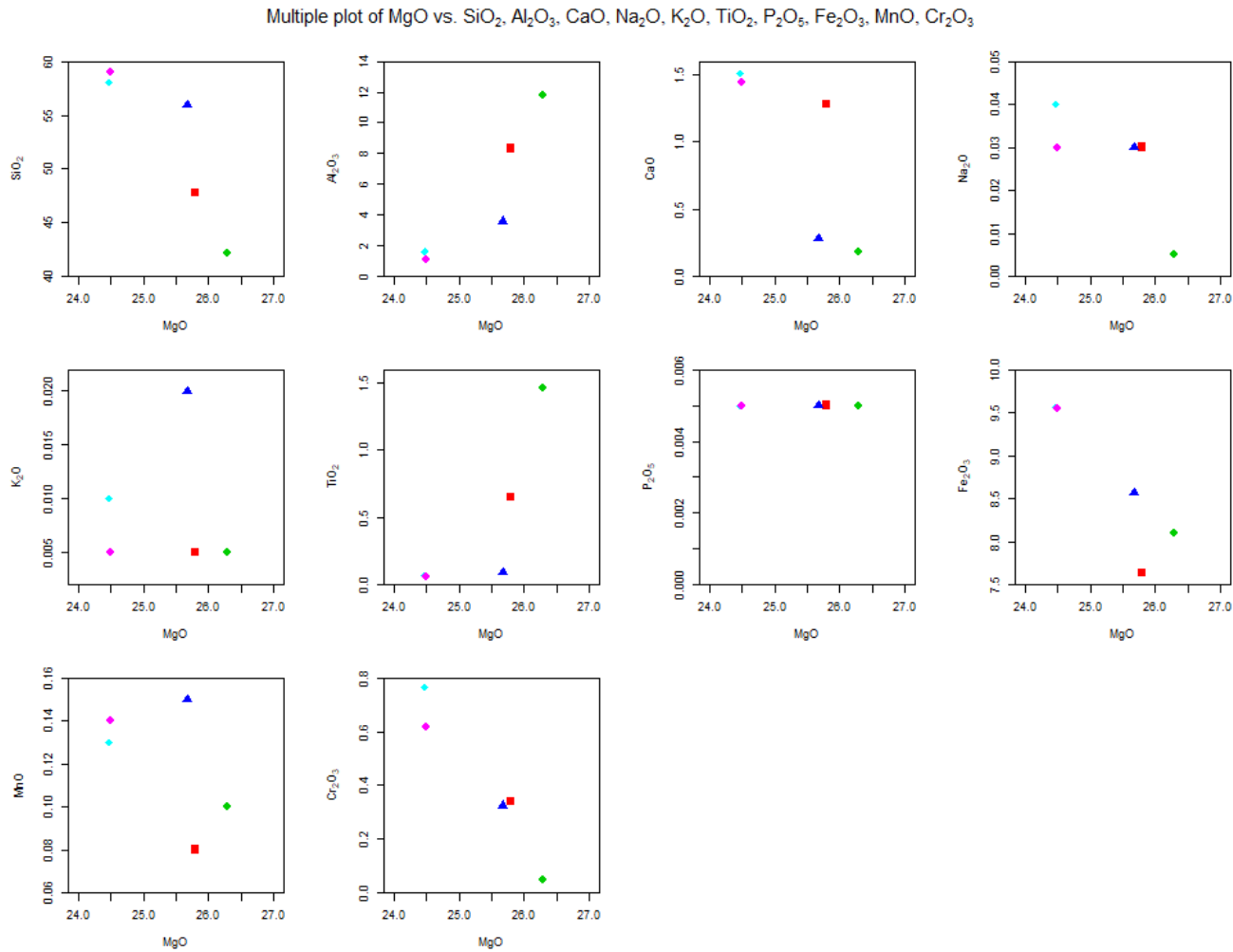


Fig 6. Bivariate plots of major oxides against MgO for the Talc-Chlorite-Tremolite schist

Table 3. Major oxides (wt. %) and trace elements (ppm) compositions of the Talc-chlorite-tremolite schist from the study area

Samples	R01	R02	R03	R04	R05	Mean	ACV
Major oxide (wt.%)							
SiO ₂	47.73	42.19	55.9	58.08	59.03	52.59	
Al ₂ O ₃	8.32	11.8	3.59	1.62	1.1	5.29	
Fe ₂ O ₃	7.64	8.1	8.57	9.56	9.55	8.68	
MgO	25.8	26.29	25.67	24.47	24.49	25.34	
CaO	1.28	0.18	0.28	1.51	1.44	0.94	
Na ₂ O	0.03	0.005	0.03	0.04	0.03	0.03	

Continued on next page

Table 3 continued

K ₂ O	0.005	0.005	0.02	0.01	0.005	0.02	
TiO ₂	0.65	1.46	0.09	0.07	0.06	0.47	
P ₂ O ₅	0.005	0.005	0.005	0.005	0.005	0.005	
MnO	0.08	0.1	0.15	0.13	0.14	0.12	
Cr ₂ O ₃	0.34	0.049	0.325	0.766	0.619	0.42	
LOI	7.5	9.2	4.9	3.2	3	5.56	
Fe ₂ O ₃	7.64	8.1	8.57	9.56	9.55	8.684	
FeO	6.87	7.28	7.71	8.6	8.59	7.81	
FeO+MgO	32.67	33.57	33.38	33.07	33.08	33.154	
FeO/(FeO+MgO)	0.21	0.22	0.23	0.26	0.26	0.236	
FeO+TiO ₂	7.52	8.74	7.8	8.67	8.65	8.276	
Al ₂ O ₃ /TiO ₂	12.8	8.1	39.9	23.1	18.3	20.44	
Trace elements (ppm)							
Ba	10	22	5	6	3	9.2	425
Ni	1165	1207	594	972	1102	1008	75
Sc	8	8	4	12	10	8.4	22
Co	76	113.9	43.2	72.1	72.1	75.46	25
Cs	0.2	0.2	0.05	0.05	0.05	0.2	3
Hf	1.1	1.6	0.3	0.05	0.05	1	3
Nb	5.1	11.7	1.2	0.5	0.2	3.74	20
Rb	1.2	1.6	1	0.6	0.05	1.1	90
Sn	11	6	41	33	18	21.8	2
Sr	4.2	1.6	1.6	5.9	4.8	3.62	375
Ta	0.5	1.1	0.3	0.2	0.05	0.53	2
Th	5.1	8.3	0.5	0.4	0.3	2.92	9.6
U	0.2	0.2	0.3	0.05	0.05	0.23	2.7
V	57	75	32	36	36	47.2	135
Zr	41.9	58.7	9.8	4.5	1.3	23.24	165
Cu	11.3	13.1	34	8.2	9.2	15.16	55
Pb	0.7	0.3	0.2	0.3	0.1	0.32	12.5
Zn	14	17	7	9	9	11.2	70

The normalization of the trace elements with the primitive mantle values⁽³²⁾ generated a spider plot (Figure 7 A) with variations in the enrichment and depletion pattern of the Large Ion Lithophile Elements (LILE) and High Field Strength Elements (HFSE). Enrichment in Th, U and Ta and slight depletion in Rb, Sr and Ba were observed within the talcose rock. Cs, La, Pr, Nd and Sm were found to be enriched while Zr, Ce, P, Nb, Ti, Pb and Eu (slightly depleted) were observed to be depleted in the spider plot. Dy, Y, Yb and Lu showed an almost flat pattern. These variations could have resulted from leaching of some of the mobile and immobile elements (Compatible and Incompatible elements) during alteration (metamorphism and weathering processes) of the parent rocks.^(28,33) The spidergram also revealed derivation of parent magma from a depleted mantle⁽³⁴⁾ with evidence of metasomatism as seen from the enrichment of La, Pr, Sm and Cs⁽³¹⁾ as well as contamination of the mantle materials with crustal materials. The concentration of some trace elements in the talcose rocks also compared well with talcose rocks from other places. Co and Ni have similar range with talcose rocks from Esie⁽²⁴⁾ and Itagunmodi-Igun⁽¹²⁾ areas. The high concentration of Ni and Co could serve as a pointer to mineralisation during exploration for base metals.

4.4 Rare earth element geochemistry for Talc-chlorite-tremolite Schist

The rare earth element concentrations for the talc-chlorite-tremolite schist in the study area are presented in Table 4. Average concentrations (ppm) of La, Ce, Sm, Eu, Yb and Lu were 17.98, 27.32, 2.29, 0.38, 0.40 and 0.05, respectively. (La/Yb)_N, (La/Sm)_N and Eu/Eu* ratios were 6.26-79.74, 1.99-6.54 and 0.38-0.76, respectively. This is indicative of LREE/HREE enrichment and the negative Eu anomaly implies minimal

plagioclase fractionation in the talc-chlorite-tremolite schist. The origin of the talcose rocks in the study has been attributed to the alteration of the ultramafic rock, Komatiite therefore the fractionation of the LREE compared with the HREE may be due crustal contamination of the parent magma.⁽²⁸⁾

Table 4. Rare earth elements (ppm) compositions of the Talc-chlorite-tremolite schist from the study area

Samples	R01	R02	R03	R04	R05	Mean
La	30.4	34.3	15.9	2.6	6.7	17.98
Ce	43.4	84	3.5	2.8	2.9	27.32
Pr	6.49	6.68	3.61	0.82	1.99	3.92
Nd	24.1	23.4	13.4	3.5	7	14.28
Sm	4.04	3.3	1.95	0.82	1.33	2.29
Eu	0.67	0.33	0.42	0.19	0.3	0.38
Gd	3.03	2.1	1.79	0.78	1.1	1.76
Tb	0.34	0.19	0.23	0.12	0.16	0.21
Dy	1.45	0.72	1.15	0.63	0.81	0.95
Ho	0.26	0.1	0.25	0.1	0.13	0.17
Er	0.62	0.3	0.69	0.31	0.42	0.47
Tm	0.09	0.05	0.08	0.05	0.06	0.07
Yb	0.51	0.29	0.54	0.28	0.38	0.4
Lu	0.06	0.03	0.08	0.04	0.06	0.05
Y	7.4	3.3	10.1	2.9	4.3	5.6
(Eu/Yb) _N	3.74	3.24	2.21	1.93	2.24	2.67
(La/Yb) _N	40.19	79.74	19.85	6.26	11.89	31.59
(La/Sm) _N	4.73	6.54	5.13	1.99	3.17	4.31
Eu/Eu*	0.59	0.38	0.69	0.73	0.76	0.63
ΣLREE	109.1	152.01	38.78	10.73	20.22	66.17
ΣHREE	6.36	3.78	4.81	2.31	3.12	4.08
ΣREE	122.86	159.09	53.69	15.94	27.64	75.84

The rare earth elements (REE) values were normalized with REE-primitive mantle.⁽³²⁾ The plot (Figure 7B) showed LREE patterns with high La and Pr peaks, V-shaped negative Ce anomaly, slight depletion in HREE with slight negative Eu anomaly. The plot generally revealed enrichment of LREE with the negative anomaly for Ce and a near flat HREE. Negative Ce anomaly reflects a redox reaction involving change in Ce³⁺ to Ce⁴⁺ associated with possible hydrothermal/metasomatic alterations.⁽³⁵⁾ Probable crustal contamination evidenced in LREE enrichment could be responsible for the Eu²⁺ anomaly. Crustal rocks rich feldspars (plagioclase) may contaminate the meta-ultrabasic rock (komatiite) during metasomatism, shearing and uplift which led to the formation of the talcose bodies of the study and may account for the negative Eu anomaly in the REE plot (Figure 7B). The REE patterns shown by the rocks indicated crustal contamination and plagioclase fractionation with more LREE fractionation compared to the HREE.^(28,31) Variations in the more mobile incompatible Large Ion Lithophile Elements (LILE) observed in Figure 7A and near flat signature of the relatively immobile High Field Strength Elements (HFS) support evidences for metasomatism/hydrothermal alterations during the prevalent Pan African orogeny.^(36,37) Therefore, the trends observed for the LILE, HFSE and REE suggest possible contamination or mixing of crustal and mantle materials during the formation of parent rock.⁽³⁸⁾

The patterns shown by some samples reflect a minor deviation from the rest due to their chemistry; low silica, high alumina, low Fe₂O₃ and TiO₂ as seen in Table 5. Also, the relative abundance of nickel and cobalt in these samples is suggestive of the composition of their origin and possibly, the degree of weathering of the samples. Samples with slight enrichment in Ce indicate the association of crustal contamination in the magma during the evolution of the rocks. Comparison of the REEs in the study area with talcose rocks from other area revealed that the LREE in the Ila Orangun-oyan area is higher

than those from the Esie⁽²⁴⁾ and Ife-Ilesha⁽⁴⁾ area while the HREE in the study area is lower than those from the Ife-Ilesha area⁽⁴⁾ Table 5. These are some of the compositional differences in the geochemical characteristics of talcose rocks within the Ilesha schist belt.

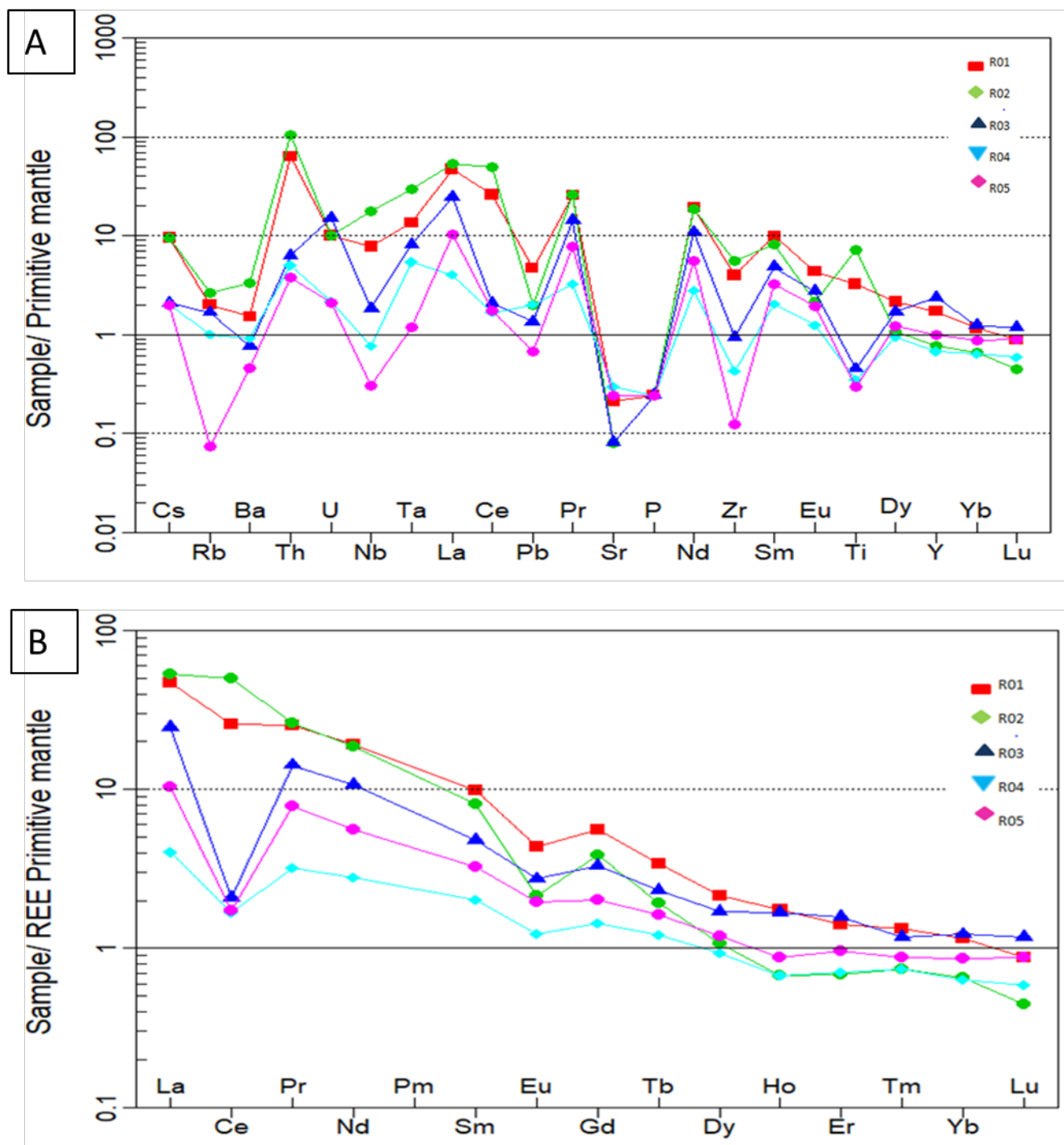


Fig 7. (A) Spider plots of trace elements normalized after the Primitive mantle⁽³²⁾ for the talc-chlorite-tremolite schist; (B) Spider plot normalised by REE Chondrite⁽³²⁾ for the talc-chlorite-tremolite schists.

Table 5. Comparison of the talc-chlorite-tremolite schists of the study area with talcose rocks from other parts of Nigeria and world

	Study area ⁽¹⁾		Itagunmodi-Igun ⁽¹²⁾	Esie ⁽²⁴⁾	Oke-Ila ⁽¹⁰⁾	Ife-Ilesha ⁽⁴⁾	PISB ⁽¹³⁾	Isanlu ⁽³⁷⁾	Munro ⁽²²⁾
	Range	Mean							
SiO ₂	42.19-59.03	52.59	57.53	56.21	52.30	48.23	50.45	52.15	43.9
Al ₂ O ₃	1.1-11.8	5.29	2.60	1.66	3.14	5.18	2.34	2.90	7.25
Fe ₂ O ₃	7.64-9.56	8.68	7.73	6.90	5.22	10.58	6.78	6.19	10.18
MnO	0.08-0.15	0.12	0.11	0.10	0.18	0.15	0.1	0.12	0.21
MgO	24.47-26.29	25.34	24.84	29.71	26.98	28.19	29.29	31.52	23.45
CaO	0.18-1.51	0.94	0.64	0.16	7.40	3.79	1.2	2.71	6.96
Na ₂ O	0.03-0.04	0.03	0.04	0.16	0.05	0.29	0.02	0.06	0.33
K ₂ O	0.01-0.02	0.02	0.03	0.03	0.03	0.05	0.02	0.04	0.07
P ₂ O ₅	<0.01	-	0.02	0.02	0.02	0.16	0.01	0.06	-
Co	43.20-113.9	75.46	76	70	66	-	85.3	61.6	-
Ni	594-1207	1008	1246	1370	774	-	532.98	1809	-
Zn	7-17	11.20	16	112	78	-	11.2	106	-
La	2.6-34.3	17.9	-	2.13	-	3.0	-	-	-
Ce	2.8-84	27.32	-	24.31	-	7.9	-	-	-
Nd	3.5-24.1	14.28	-	2.25	-	1.8	-	-	-
Sm	0.82-4.40	2.29	-	0.48	-	0.7	-	-	-
Eu	0.19-0.67	0.38	-	0.10	-	0.5	-	-	-
Yb	0.28-0.54	0.4	-	0.23	-	0.7	-	-	-
Lu	0.03-0.08	0.05	-	<0.04	-	0.3	-	-	-

PISB= Parts of Ilesha schist belt

4.5 Petrogenesis

The origin of the talc-chlorite-tremolite-schist (TCTS) were determined using the plot of Al₂O₃ against FeO/FeO+MgO⁽³⁹⁾ and the talcose rocks were found to be komatiitic in origin (Figure 8 A). The samples also plotted within the peridotitic komatiite field on the Al₂O₃ – FeO+TiO₂ – MgO⁽⁴⁰⁾ with four of the samples within the peridotitic komatiite and one sample within the basaltic komatiite (Figure 8B). This lone exception can be attributed to its high alumina, low silica, low potassium and high magnesium content and not necessarily a change in the nature of its origin. These deductions therefore suggest that komatiite-an ultramafic mantle-derived volcanic rock, is believed to be the protolith of the talc-chlorite-tremolite schist.

The komatiitic protolith of the studied talc schist has similar chemistry with the meta-ultramafic rocks from Ife-Ilesha schist belt Nigeria⁽⁴⁾, ultramafic rocks from Munro township, Canada⁽²²⁾, ultramafic schist from Isanlu area, Egbe-Isanlu schist belt,⁽³⁷⁾ talcose bodies from Oke-Ila,⁽¹⁰⁾ and talcose rocks from Itagunmodi-Igun area.⁽¹⁰⁾ Comparison of the chemistry of the talcose rocks in the study area with other areas within and outside Nigeria is displayed in Table 5.

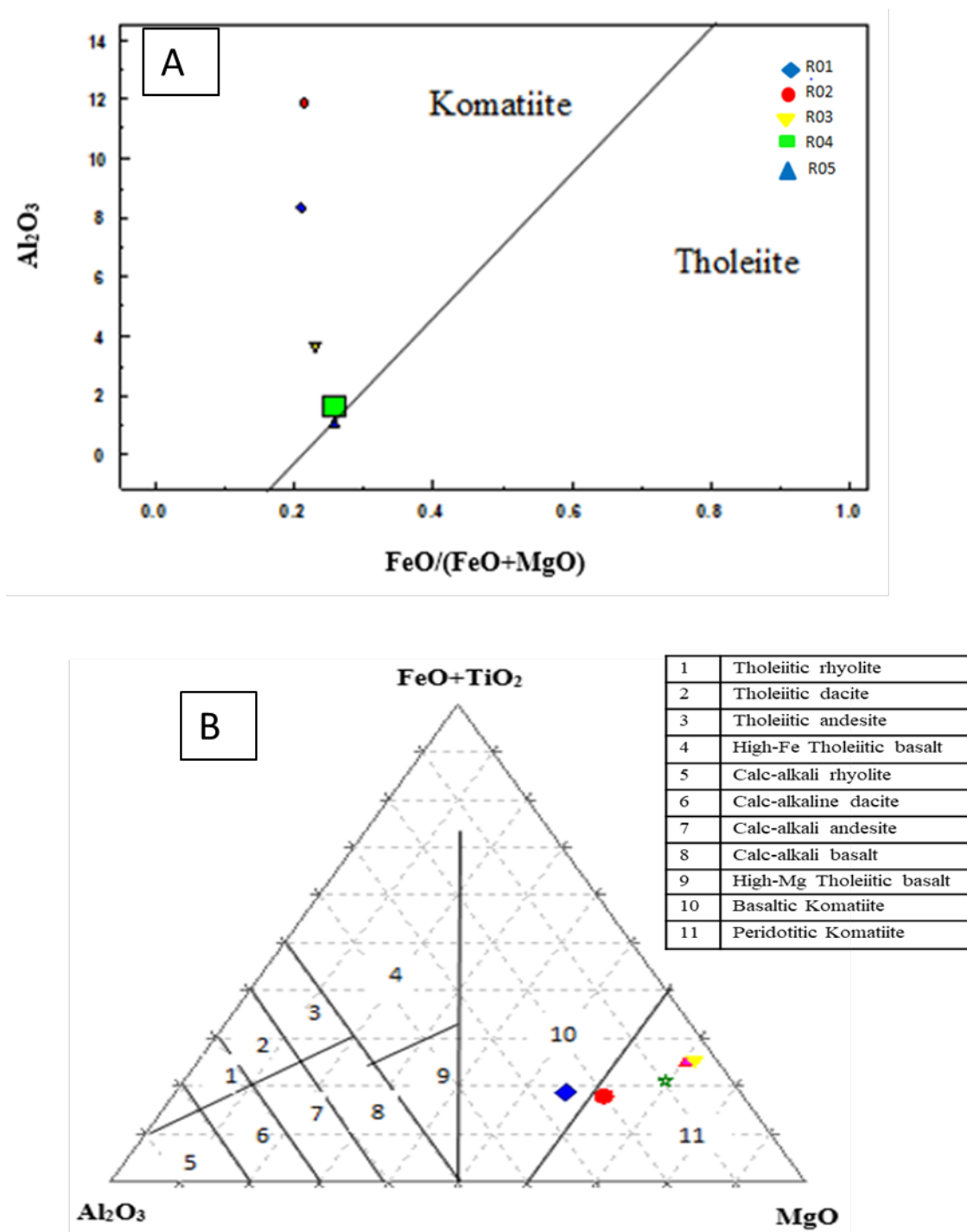


Fig 8. (A) Plot of Al_2O_3 against $\text{FeO}/(\text{FeO}+\text{MgO})$ ⁽³⁹⁾ for Talc-Chlorite-Tremolite schist of the study area; (B) Ternary classification of volcanic rocks to determine the source of the talc-chlorite-tremolite schist where Al_2O_3 - $\text{FeO}+\text{TiO}_2$ - MgO ⁽⁴⁰⁾ are plotted.

5 Conclusion

The talc schist from the Ila Orangun-Oyan area is of the talc-chlorite-tremolite schist variety, and consists of talc and chlorite as the major minerals. Significant amounts of Ni and Co were detected which confirm the ultramafic magma composition of the parent rock as well as a pointer to possible mineralisation. The talcose rocks are of komatiitic origin with peridotitic komatiite protolith, suggesting origination due to metamorphism of an ultramafic mantle-derived volcanic rock. REE geochemistry revealed enrichment in LREE, depletion in HREE and a negative Eu anomaly suggestive of minimal plagioclase fractionation. LILE and HFSE concentrations showed evidences of alteration of parent rocks during metamorphism /hydrothermal alteration and also indicate possible crustal contamination of the mantle materials during the formation of the protolith.

The talcose rocks of the study area compared well in origin and geochemical characteristic with those from other areas within and outside the Ilesha schist belt; thereby suggestive of genetic relationship or continuity between the occurrences. This study has therefore provided additional information on the occurrence, origin and geochemical nature of talcose bodies within the Ilesha schist belt of Nigeria.

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