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RESEARCH PAPER

Geology and Geochemistry of Lithium-Bearing Pegmatite in Gbugbu, Lafiagi Part of Sheet 203SW, Nigeria

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ABSTRACT

Pegmatites are associated with the late-stage crystallization of granitic magma, where the hydrothermal residual melts become enriched in incompatible elements, including lithium. The concentration of lithium mineralization in pegmatites is primarily is attributed to the magmatic fractional crystallisation, where lithium, being an incompatible element is concentrated in the residual melt during the final stages of magma crystallisation. the Nigeria Basement Complex, most importantly the granitiods that are characterized by their large crystal grain sizes which always associate with economically concentrations of lithium-bearing minerals such as spodumene, petalite, and lepidolite. This is study will unravel the geology, lithium mineralisation status and classify the lithium bearing pegmatite in Gbugbu using geochemical analysis data. The studied area is located south of Lafiagi town and north-eastern part of the Lafiagi Sheet 203SW, Nigeria bounded by Latitude 40 50’00’’N to 50 54’00N and Longitude 80 29’E to 80 33’E. The area is comprised of amphibole schists, biotite granite, granite-gneiss and pegmatite. The lithium bearing pegmatite are weathered at the surface in some locations. Ten pegmatites (10) and ten (10) host rock samples obtained in the field were analysed using XRF and ASS techniques respectively for major, trace and rare earth elements. The elements enrichment status of the studied pegmatite revealed the area is very high enriched in lithium and moderately enriched in Thorium, Niobium, Tantalum Cesium, suggesting the pegmatite is of Lithium-Cesium-Tantalum (LCT) family pegmatites enriched in the lithophile elements (Th, Nb and Ta), these lithophile elements are concentrate in silicate rich minerals.

Keywords: Lithium-Cesium-Tantalum, Elemnts enrichment, Lithophile elements, Granitic magma

INTRODUCTION

Pegmatites are the primary hosts for lithium mineralization in the Nigeria Basement Complex, most importantly the granitiod that are characterized by their large crystal grain sizes which always associate with economically concentrations of lithium-bearing minerals such as spodumene, petalite, and lepidolite (Cerný and Ercit, 2005). The formation of pegmatites is associated to the late-stage crystallization of granitic magmas, where the hydrothermal residual melts (after the crystallisation of major rock forming minerals) become enriched in incompatible elements, including lithium (Cashman, 1990; London, 1984). The concentration of lithium mineralization in pegmatites is primarily is attributed to the magmatic fractional crystallisation, where lithium, being an incompatible element (Simmons, *et al*, 2023) is concentrated in the residual melt during the final stages of magma crystallisation. Tectonic settings also play a major role in the concentration of lithium-rich pegmatites being associated with orogenic belts.

Nigeria's rare-metal pegmatites displayed various range of mineralization potential (Akintola,*et al.*, 2008), classified into three primary ore mineral associations:

(a) Lithium-dominant: characterized by the presence of spodumene, lepidolite, amblygonite, and petalite, indicating a strong lithium

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(b) Tin-Tantalum-Niobium: marked by the occurrence of cassiterite, tantalite, and columbite, highlighting the significance of these metals.

(c) Beryllium-Phosphate-Fluorine: featuring beryl, aquamarine, emerald, and other precious gem minerals, showcasing the pegmatites' potential for hosting high-value minerals.

The occurrence of lithium pegmatites in Nigeria Basement Complex are controlled by tectonic structures (Figure 1), indicating that their formation is influenced by the Nigeria geological framework of which the pegmatites, lithium-bearing minerals occur in distinctive style.

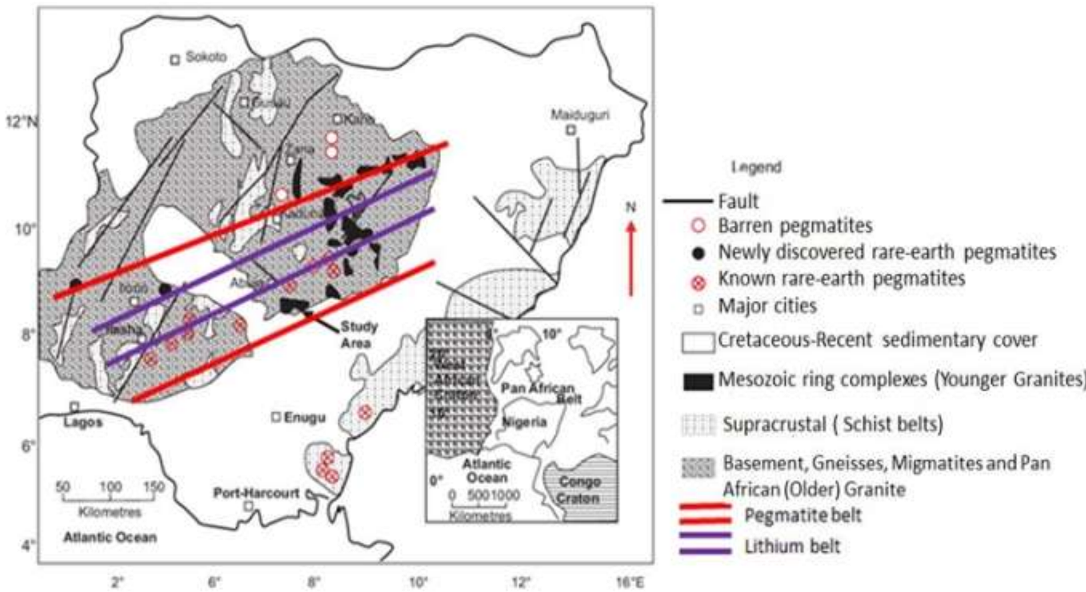

Figure 1. The Lithium belt within the pegmatite province of Nigeria (Akinola, 2014)

Lithium bearing pegmatites in Gbugbu was reported by Nigerian Geological Survey Agency in 2022/2023 during a regional geological mapping and this has prompted this research work.

It is therefore appropriate to carry out geological mapping and geochemical study to establish the mode of occurrence, degree of enrichment, and economic viability of the reported lithium bearing pegmatites in Gbugbu.

The Pategi-Share pegmatite district is located in the Pategi LGA on the eastern part of Kwara state that borders Kogi State to the east. The geology of the area is characterized by Cretaceous sediments of the Bida Basin to the north while the southern portion is underlain by the crystalline basement complex, composed of Precambrian migmatite-gneisses with isolated pockets of pelitic schists, amphibolites and granites lying within a deeply eroded terrain (Fig.13). The main areas with lithium mineralization are at Share and Kakafu.

Studied area the located south of Lafiagi town and north-eastern part of the Lafiagi Sheet 203SW, Nigeria Bounded by Latitude 4^0 50’00’’N to 5^0 54’00N and Longitude 8^0 29’E to 8^0 33’E Accessibility is through Oke-Ode - Lafiagi and Tsaragi Lafiagi road.

The aim of this study is to characterised the lithology, elemental composition, classify and unreal the lithium mineralisation status of lithium bearing pegmatites in Gbubgu area.

METHODODOLOGY

A topographic base map on a scale of 1:12,000 for the geological field mapping was extracted from the topographic map of Lafiagi Sheet 203SW.The study area was systematically mapped by traversing along available roads, footpath and stream channels. Outcrops visited were observed and described based on their surface mode of occurrence, colour, texture (grain sizes) and mineralogy composition in hand specimen. Strikes and dips of the (incline beds) outcrops and structures that were observed were been measured on foliated outcrops using compass clinometer and their joints orientation values were recorded in field notebook, coordinate of each studied outcrop were taken using Global Positioning System (GPS) alongside their elevations above sea level. Fresh representative samples of the rock samples were obtained from each outcrops using sledge hammer and labeled using permanent maker pen.

Ten pegmatites (10) and ten (10) host rock samples obtained in the field were selected for chemical analyses using XRF and ASS techniques respectively for major, trace and rare earth elements. The analysis was carried out at the Geological Survey Agency Kaduna.

RESULTS AND DISCUSSION

The study area is comprised of amphibole schists, biotite granite, granite-gneiss and pegmatite. The amphibole schist exposure account for about 27%, granite 50%, granite-gneiss 20% and pegmatite 3% (Figure 2). The schist strike in the NNE-SSW direction with average dip of 56^{o}E

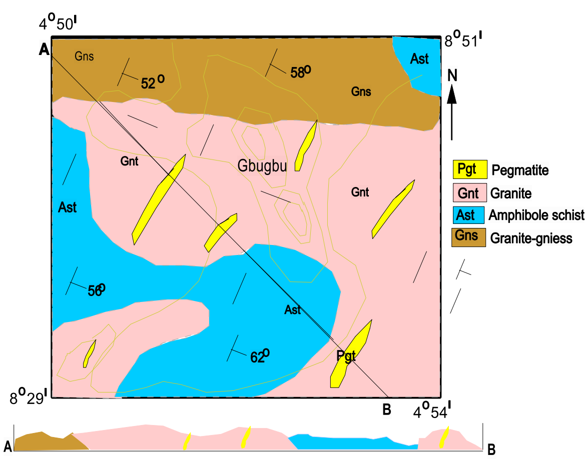

Figure 2. Geology map of the study area

Amphibole schists

Amphibole schists in the study area occurred as low lying outcrop exposed along the road cut and stream channel as well and weathered in most locations. It covers about 27% of the study area.

The minerals that make up the schist outcrops in hand specimen are; amphibole/hornblende, biotite, muscovite, quartz and plagioclase feldspar.

Biotite granite

The granite rock in the area is medium- to coarse-grained granite in texture (Plate I). These rocks are fractured and jointed with trends majorly aligned the trends of the pegmatites in NE-SW direction. The minerals observed in hand specimen are; biotite, muscovite, quartz and plagioclase feldspar.

Granite-gneiss

The migmatite-gneiss is of medium to coarsed grained with micro-fold in some locations, usually grey in colour (Plate II). Migmatite-gneiss showing strong banding of light minerals (neoosome) and dark minerals (paleosome) (Plate II). minerals observed in handspecimen includes; biotite, quartz, muscovite, and orthoclase feldspar.

Plate I: Biotite Granite

Plate II: migmatite-gneiss

Pegmatite

The lithium bearing pegmatite are well exposed in abandoned mining pits and stretched in NE – SW direction (Plate III). The lithium bearing pegmatite are weathered at the surface in some locations (Plate IV). In hand specimen the pegmatite is white and contain quartz, mica, and feldspar.

Plate III) Abandoned mining pit

Plate V: Weathered pegmatite

The principle joint direction of the out crops is NNE – SSW direction (Figure 3)which coincide with the Ifewara - Zungeru fracture system of the Nigeria Basement Complex.The average dip direction mesured in the is 580 W (Figure 2).The lithium – pegmatite out crops trend in the NE – SW direction parallel to foliation plane of granite -- gneiss (Figure 4).

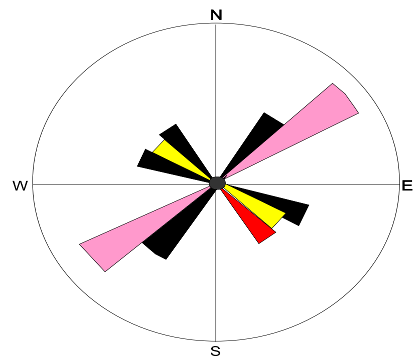

Figure 3: Direction of the joints

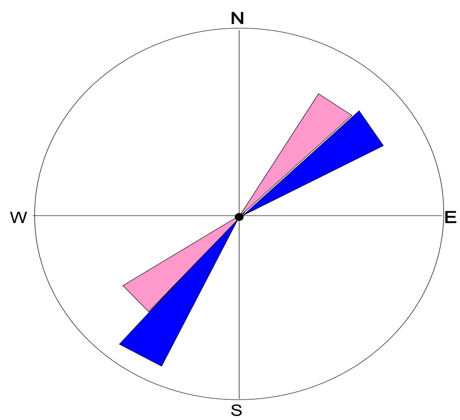

Figure 4: Strike of the lithium-pegmatite

The geochemistry results for major, minor and trace elements which are commonly used for the interpretation of petrogenesis of igneous are presented in Table 1, 2, 3, 4a and 4b respectively.

Table 1: Percentage major oxide distribution for Granite

Sample	SiO_2	Al_3SiO_2	Fe_2O_3	CaO	MgO	TiO_2	MnO	K_2O	Na_2O	P_2O_5	A/CNK	A/NK
shpg 1	76.2	9.93	4.07	0.84	1.65	0.48	0.91	1.75	1.83	0.29	1.41	1.17
shpg 2	76.5	9.76	4.08	0.86	1.67	0.47	0.87	1.75	1.84	0.28	1.43	1.31
shpg 3	75.8	9.61	4.97	0.85	1.92	0.46	0.86	1.72	1.75	0.26	1.37	1.11
shpg 4	75.3	9.96	4.96	0.82	1.93	0.47	0.86	1.75	1.71	0.27	1.23	1.26
shpg 5	77.2	9.98	4.87	0.84	1.54	0.46	0.86	1.65	1.75	0.28	1.38	1.31

Table 2: Percentage major oxide distribution for Amphibole Schist

Sample ID	SiO_2	Al_3SiO_2	Fe_2O_3	CaO	MgO	TiO_2	MnO	K_2O	Na_2O	P_2O_5	Total
shpg 6	60.2	9.98	4.87	0.84	1.54	0.56	0.86	1.65	1.75	0.28	99.43
shpg 7	66.6	9.98	4.98	0.84	1.91	0.53	0.84	1.75	1.85	0.28	99.5
shpg 8	65.5	9.76	4.08	0.86	1.67	0.54	0.87	1.75	1.84	0.28	98.08

Table 3: Percentage major oxide distribution Migmatite-gneiss

Sample	SiO_2	Al_3SiO_2	Fe_2O_3	CaO	MgO	TiO_2	MnO	K_2O	Na_2O	P_2O_5	Total
shpg 6	60.2	9.98	4.87	0.84	1.54	0.56	0.86	1.65	1.75	0.28	99.4
shpg 7	66.6	9.98	4.98	0.84	1.91	0.53	0.84	1.75	1.85	0.28	99.5
shpg 8	65.5	9.76	4.08	0.86	1.67	0.54	0.87	1.75	1.84	0.28	98.1

Table 4: Percentage major oxide distribution in pegmatite

Sample ID	SiO_2	Fe_2O_3	Al_2O_3	K_2O	MnO	TiO_2	MgO	CaO	Na_2O	P_2O_5	H_2O	Total
shpg 01	73.5	0.59	14.1	3.39	0.21	ND	0.11	0.71	4.45	1.08	2.17	100.65
shpg 02	72.5	0.57	13.1	4.41	0.19	ND	0.13	0.73	5.48	1.06	2.11	100.8
shpg 03	74.8	0.55	14.1	3.42	0.17	ND	0.15	0.75	5.43	1.04	1.68	102.55
shpg 04	73.6	0.53	11.8	3.91	0.06	ND	ND	1.71	5.24	2.5	2.25	102.2
shpg 05	74.9	0.55	11.8	3.89	0.04	ND	ND	1.69	4.56	1.52	1.55	100.7
shpg 06	74.6	0.51	12.8	3.82	0.02	ND	ND	1.67	4.23	2.54	0.28	100.55
shpg 07	74.3	0.58	12.4	3.25	0.13	ND	0.07	ND	4.21	1.69	1.35	99.06
shpg 08	73.3	0.56	13.4	3.27	0.11	ND	0.09	ND	4.92	1.67	2.16	99.66
shpg 09	74.8	0.53	14.4	3.29	0.09	ND	0.11	ND	4.02	1.65	0.25	100.14
shpg 10	73.5	0.49	12.3	3.95	0.2	ND	0.39	0.18	4.96	1.2	0.64	98.15

Total alkalies versus SiO_2 (TAS) plot for Granite and Pegmatite in the study area revealed their compositions trend plotted within the granite field and are classified as granites and granite-pegmatites respectively with $SiO_2 > 71$ (Figure 5)

Table 4b. Trace element concentration in pegmatites sample (ppm)

Sample ID	Ba	Be	Cs	Nb	Rb	Sn	Ta	Th	V	Li
shpg 1	0.011	7.02	6.92	47.29	101.49	2.00	5.30	26.52	8.00	621.00
shpg 2	0.012	3.01	6.85	47.17	102.50	2.02	4.90	26.50	8.01	633.00
shpg 3	0.014	3.00	7.97	47.30	100.54	2.00	4.33	26.53	8.01	602.00
shpg 4	0.015	3.00	6.92	47.30	102.50	2.02	5.30	26.52	8.02	611.00
shpg 5	0.006	3.00	7.04	47.31	101.51	2.02	4.31	25.97	8.02	611.00
shpg 6	0.004	3.00	7.09	47.30	102.51	2.04	5.32	25.97	8.02	421.00
shpg 7	0.006	3.00	7.91	57.31	102.53	2.00	4.31	26.50	8.03	422.00
shpg 8	0.005	3.00	7.09	57.32	102.52	2.01	4.30	26.53	8.00	433.00
shpg 9	0.004	3.00	7.07	57.30	101.51	2.00	4.33	26.57	8.01	611.00

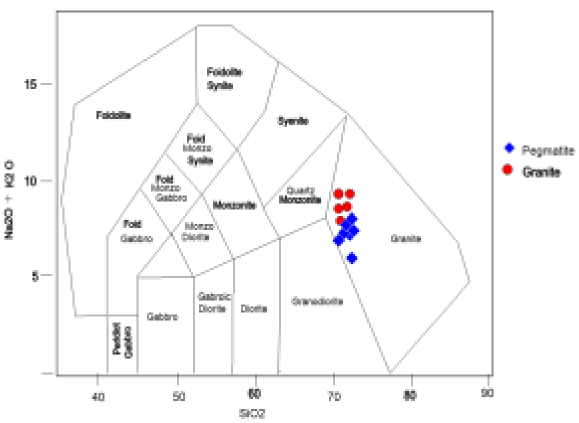

Figure 5. Total alkalies versus SiO_2 (TAS) plot for Granite and Pegmatite in the study area (Cox *et al*. 1979)

The plots of A/NK Vs A/CNK revealed the granite and pegmatite samples fall in the fields of S-type and peraluminous respectively, which shows that Gbugbu granite and pegmatite to be of sediments rich in aluminum protolith of convergent plate boundary (Figure 6).

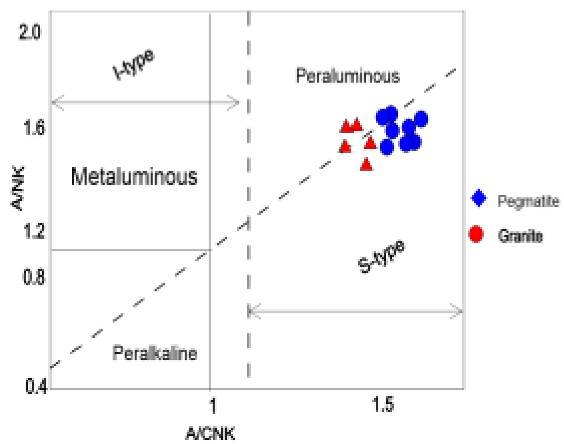

Figure 6. A/NK versus A/CNK for Granite and Pegmatite in the study area (Maniar and Piccoli, 1989)

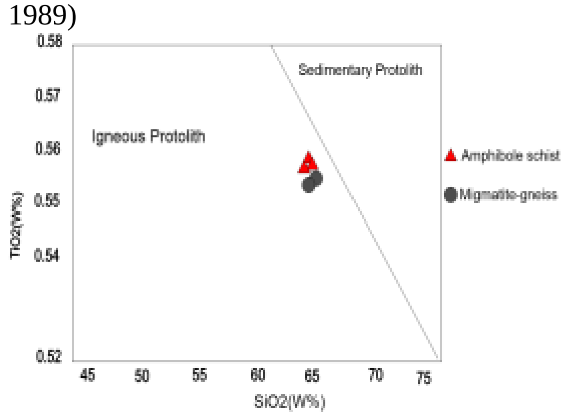

Figure 7. TiO2 Vs SiO_2 plot showing source /origin of Amphibole schist and Migmatite-gneiss in the study area (Garrels and Mackenzie 1971)

Plot of TiO_2 and SiO_2 reveal the amphibole schist and migmatite-gneiss are product of metamorphism of igneous protoliths (Figure 7)
Plot of Li and SiO_2 reveal the weathered pegmatites are non-mineralised while those obtained at abandoned mining pits are mineralized. (Figure 8), this indicate lithium mineralization potential with depth.

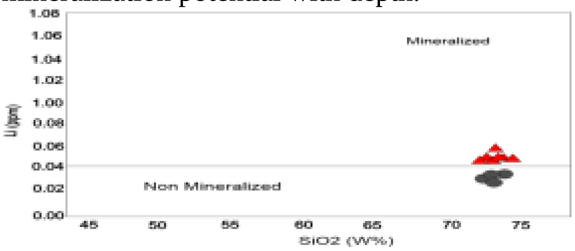

Figure 8. Li_2O Vs SiO_2 plot showing Lithium Mineralisation of pegmatites in study area

(Cerny, 1989)

Harker bi-variant plots are used to show oxides and trace elements variations in a rock and interpret genetic relationships of igneous rocks series

The Harker plots of SiO_2 (%) versus Li (ppm), Ta (ppm), Al_2O_3 (%) and Na_2O_3 of the chemical compositions of study pegmatites (Figure 9), shows the elements clustered around a point that indicate;

i). similar magmatic source

ii). similar protolith and environment of deposition

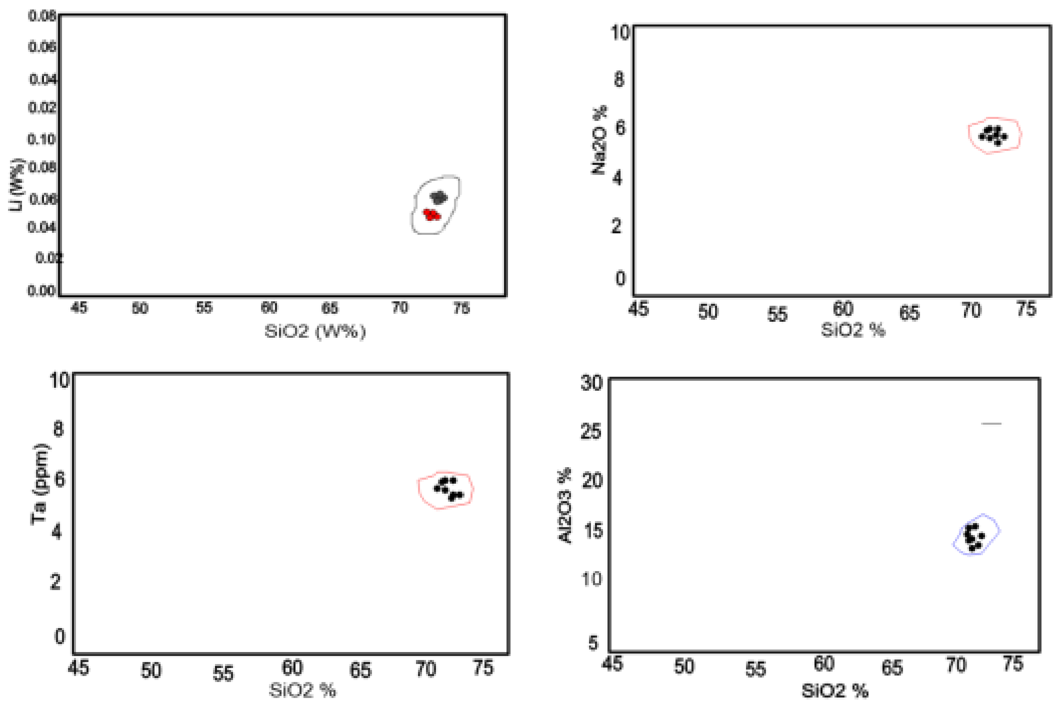

Figure 9. Mojor oxide versus trace elements bi-varite harker plots of pegmatites in the study area (Peccerillo and Taylor, 1976)

Lithium Enrichment Status

Five categories of enrichment factors were used for evaluating the economic potential of pegmatites in the study area as proposed by Sutherland, 2000 as follows:
i). EF < 2 is deficiency to minimal enrichment
ii). EF 2-5 is moderate enrichment
iii) EF 5-20 is significant enrichment
iv) EF 20-40 is very high enrichment
v). EF > 40 is extremely high enrichment

Table 5: Elemental Enrichment Status in the Study Area (ppm) (Sutherland, 2000).

Elements	Average Analysed Value	Background Concentration (ppm)	Computed Enrichment Factors (%)	Enrichment Status
Li (Lithium)	500.8	20	25.04	Very high enrichment
Cs (Cesium)	6.92	3.0	2.30	Moderate enrichment
Nb (Niobium)	50.29	20	2.51	Moderate enrichment
Rb (Rubidium)	101.912	90	1.13	Deficiency to minimal enrichment
Th (Thorium)	26.418	10	2.64	Moderate enrichment
Sn (Tin)	2.011	2	1.01	Deficiency to minimal enriched
Ba (Barium)	0.008	425	1.91	Deficiency to minimal enriched
Be (Beryllium)	3.403	2.8	1.22	Deficiency to minimal enriched
V (Vanadium)	8.013	135	0.59	Deficiency to minimal enriched
Ta (Tantalum)	4.673	2.0	2.33	Moderate enrichment

The elements enrichment status of the study pegmatite revealed the area is very high enriched in lithium and moderately enriched in Thorium, Niobium, Tantalum Cesium(Table 5), suggesting the pegmatite in the study area is of Lithium-Cesium-Tantalum (LCT) family of pegmatites enriched in the lithophile elements (Th, Nb and Ta), these lithophile elements are concentrate in silicate rich minerals.

CONCLUSION

i. The study area is composed of three lithologies of Pegmatite, Granite, Amphibole schist and Granite-gniess.
ii. The lithium bearing pegmatite are well exposed and stretched in NE – SW direction which coincide with the Nigeria Lithium belt trend.
iii. Total alkalies versus SiO_2 (TAS) suggest the study pegmatite is of granite-pegmatites
iv. The plots of A/NK Vs A/CNK revealed the granites and pegmatites are of S-type and peraluminous respectively suggesting the rocks to be of sediments rich in aluminum protolith of convergent plate boundary.
v. The Harker plots of SiO_2 (%) versus Li (ppm), Ta (ppm), Al_2O_3 (%) and Na_2O_3 suggested the pegmatites are of similar magmatic source and similar protolith and environment of deposition.
vi. The enrichment chemical status also suggested the pegmatites in the study area to be highly enriched in lithium, moderately enriched in Cesium and Tantalum and therefor belong to the Lithium-Cesium-Tantalum (LCT) family.

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