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The Geology and Geochemistry of Kakafu Pegmatites: An Investigation for Lithium Ore Bearing Minerals (Lepidolite-Spodumene), Pategi North Central Nigeria

Tanko, I.Y. [1], Magaji, I. A.[2]., Dauda B.I.[3] and Segun A.B.[4]
[1,2&4]Department of Geology and Mining, Nasarawa State University, Keffi, Nigeria
[3] Ministry of Solid Minerals Abuja, Nigeria

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Abstract: *The preliminary investigation of the Kakafu pegmatites was conducted, with the aim of carrying out detail geological mapping and geochemical analysis to reveal common field and geochemical features that will lead to understanding the nature of the Kakafu pegmatites, for the purposes of identifying its lithium minerals potential. Geological mapping reveals three lithological units in the area, which includes; muscovite schist, biotite granite and pegmatite veins. Mineral composition observed in the field and as hand specimen are quartz, plagioclase and orthoclase feldspars, muscovite, biotite and tourmaline. Also the two lithium minerals recognized by the investigation; lepidolite and spodumene (kunzite) grades vertically with depth and along the veins in areas where the veins swells. The main lineament features (fractures, joints and folds) observed trends in the NE-SW, NW-SE, N-S and E-W directions, these directions correspond with orientations of the pegmatites in the study area. Geochemical plots of K vs Rb; K/Rb vs Rb; Li_2O vs SiO_2 and Ca O vs SiO_2 show linkages amongst the pegmatites of the study area. Also the plots of* ***A****/CNK vs SiO_2 and TiO_2 vs SiO_2 show all the pegmatites samples fall in the fields of S-type and igneous protolith respectively. These linkages amongst the Kakafu pegmatites suggest they are genetically related to one another, and have same origin (igneous protolith). In terms of mineral potential assessment, the plots of* ***A****/CNK vs SiO_2; Li_2O vs SiO_2 and REE show that the Kakafu pegmaites are strongly peraluminous and hence potential for lithium ore mineralization. Furthermore, the concentrations of Li_2O of Kakafu pegmatites ranges between (0.82-2.27wt%) and averagely all are above 1wt%. This suggests the Kakafu pegmatites to be moderately potential for lithium ore mineralization.*

Keywords: geology, geochemistry, pegmatite, lithium ore, mineralization

INTRODUCTION

Lithium is considered to be a strategic metal for the rest of the 21st century due to the following factors; on one hand, the worldwide Li demand increases every day, mainly for technological and industrial applications such as Li-ion batteries for mobile phones or electric vehicles, air treatment and lubricants (Kesler *et al*., 2012). On the other hand, both brine and rock (pegmatites) sources are not in abundance worldwide (Kesler *et al*., 2012). Even though Li is readily available in the earth's crust especially in pegmatites, not all pegmatites are considered economic sources either because of low percentage Li content or because of the great difficulty to extract it, mainly due to lack of detailed investigation of the Li-bearing deposits. Pegmatite is the main source of Li-bearing mineral in Nigeria. Lithium in pegmatites is most commonly found in the minerals spodumene, amblygonite, petalite, lepidolite etc. Today in Nigeria most Li bearing pegmatite mines lack maximum recovery and productivity largely due to lack of understanding of the characteristics of the pegmatites, such as mode of occurrence, mineralogy, textural and structural features, composition and partly due to the kind of unorganized exploration, exploitation and processing activities by artisanal miners.

The Kakafu pegmatite is a new found Li-ore bearing pegmatite deposits located at Kakafu, Pategi Local Government Area of Kwara state presently facing the challenges of lack of organized and systematic exploration and exploitation activities due to lack of adequate understanding of the characteristics of the pegmatites. The site is about five (5) Cadastre units located on topographical sheet No. 204 (Pategi) and lies between the following coordinates: 5^{o} 28′ 50.0″ and 5^{o} 38′ 20.0″ and 8^{o} 31′ 50.0″ and 8^{o} 40′ 30.0″.

The aim of the project is to conduct systematic geological and geochemical investigation to understand the nature of the Kakafu pegmatites, for the purposes of identifying its lithium minerals potential and other associated ore minerals.

Physiographic Settings

This involves the topography, climate, drainage pattern and vegetation. The topography of the area is characterized by elongated ridges and valleys. The area is watershed with minor stream all over the place and most of the streams are seasonal. The drainage patterns observed are dendritic and trellis. Humid tropical climate is prevalent in the area, marked by the alternating wet and dry seasons. The area is forested with medium to tall trees which retains rain water and allows for deep weathering of the sub-surface rocks. This favours the formation of rich fertile soil for agricultural activities in the area. The temperature is moderately high during the day and also varies from season to season (Meteorological Centre Ministry of Environment, Ilorin (2022). Two periods of high temperatures are recorded annually. The first period occurs in March-April and the second period in August - October. The average daily temperature varies between about 20 ºC (for a very cold day) and about 35 ºC (for a very hot day).

REGIONAL/GEOLOGICAL SETTING

Overview of the Basement Complex of Nigeria

The basement complex is one of the three major litho-petrological components that make up the geology of Nigeria. The Nigerian basement complex forms a part of the Pan-African mobile belt and lies between the West African and Congo Cratons and south of the Tuareg Shield. It is intruded by the Mesozoic calc-alkaline ring complexes (Younger Granites) of the Jos Plateau and is unconformably overlain by Cretaceous and younger sediments. The Nigerian basement was affected by the 600 Ma Pan-African Orogeny and it occupies the reactivated region which resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin (Burke and Dewey, 1972; Dada, 2006). The basement rocks are believed to be the results of at least four major orogenic cycles of deformation, metamorphism and remobilization corresponding to the Liberian (2,700 Ma), the Eburnean (2,000 Ma), the Kibaran (1,100 Ma), and the Pan-African cycles (600 Ma).The Nigerian Basement complex rocks are subdivided into:

1. The Migmatite-Gneiss Complexes;
2. The meta-volcano sedimentary (Schist Belt);
3. The Older Granites; And
4. The felsic and basic dykes

For the purpose of this work the Older granites and felsic and basic dykes are further discussed in detail , this where the pegmatites of the area belongs.

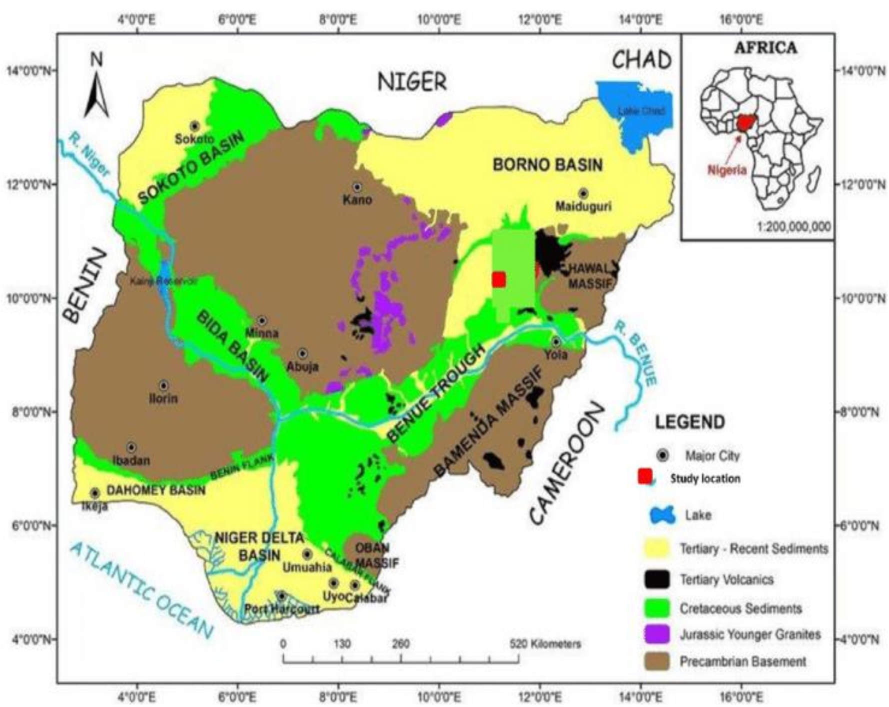

Fig.2: Map of the Basement Complex of Nigeria

The Older Granites and felsic and basic dykes

They are widespread throughout the Basement Complex and occur as large circular masses within the schists and the older Migmatite-gneiss complexes. The older granites vary extensively in composition. The older granites are the most obvious manifestation of the Pan-African Orogeny and constitute above 40 – 50% of the Basement Complex outcrop. They vary in composition from tonalite through granodiorites to granite and syenite. Granodioritic composition is the most common. Texturally, they vary from strongly foliated gneiss varieties to undeformed rocks. Rahaman (1988) describe the following petrographic types: Migmatitic granite gneiss, pegmatite, aplite and vein quartz, undeformed pegmatites, two mica granites and quartz vein. Jones and Hockey (1964) suggested that the foliation in granite is as a result of post-emplacement during the Orogeny. Geochemically, they plot in the field of arc and/or collisional granites on tectonic discriminant diagrams. Available geochronological data showed that most bodies were emplaced between 700 – 500 Ma. Pegmatites associated with the older granites show an appreciable degree of mineralization. There is diversity in their distribution in northern and central part of Nigeria. They also occur in Jos in association with the younger granites of tin province.

METHODOLOGY

Field Mapping

The field investigation was carried out in two stages, first was a reconnaissance survey, where mode of occurrence of host rocks and pegmatite veins and their relationships were identified. Topographical features such as drainages (streams and rivers), relief, undulating nature of the area and other field features were noted for further studies. While the second stage is field mapping undertaken on a scale of 1:25,000. The geological field mapping was carried out using some tools such as topographic map, geologic hammer, compass-clinometer and global positioning system (GPS).

The map was gridded and features of interest were identified and plotted on both the field and base map at the appropriate locations. Outcrops were identified and their lithology, structure, mineralogy, texture, structures and homogeneity were identified, measured and recorded. Field data measurements of orientations, strikes and dips were taken with compass-clinometer and recorded, co-ordinates of every sampling point were also taken. Rock samples collected during the geological field mapping were subjected to laboratory work which involved sample preparation, thin section for petrographic studies and chemical analyses for major and trace elements in the rocks were carried out at the Nasarawa State University, Geology and Mining Department Petrographic laboratory and Geochemical laboratory of Geology Department, Gombe State University, Gombe and Zirconex Mining Ltd. Kado, Abuja Geochemical laboratory.

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RESULT AND DISCUSSION

Geology of the Study Area

Kakafu area lies within the North Central Basement Complex of Nigeria characterized by different rock types consisting of gneisses, schists, granites, dolerites and pegmatites. On the basis of field relationships, the gneisses are found underlying the schists in the area, and both the gneisses and the schists were intruded by the granitoids (granites, dolerites and pegmatites). The veins and dykes of pegmatites and dolerites respectively are seen mostly oriented in the NE-SW and N-S whilst in other places crosscutting one another. The main structural features generally observed in the area are folds, fractures, joints and other penetrative tectonic foliations. The fractures and joints trend mainly in the NE-SW, N-S, NW-SE directions. These directions correspond with the trend of the pegmatites in the area.

Table 4.1: Sets of fractures and joints trends in the area

Fracture	No.	Joints	No.
057 /45^0	6	156/75^0	5
065/50^0	5	064/35^0	6
035/30^0	6	178/65^0	5
045/80^0	4	024/72^0	7
115/50^0	3	178/52^0	4
055/800^0	5	085/30^0	5
165/75^0	6	043/55^0	5

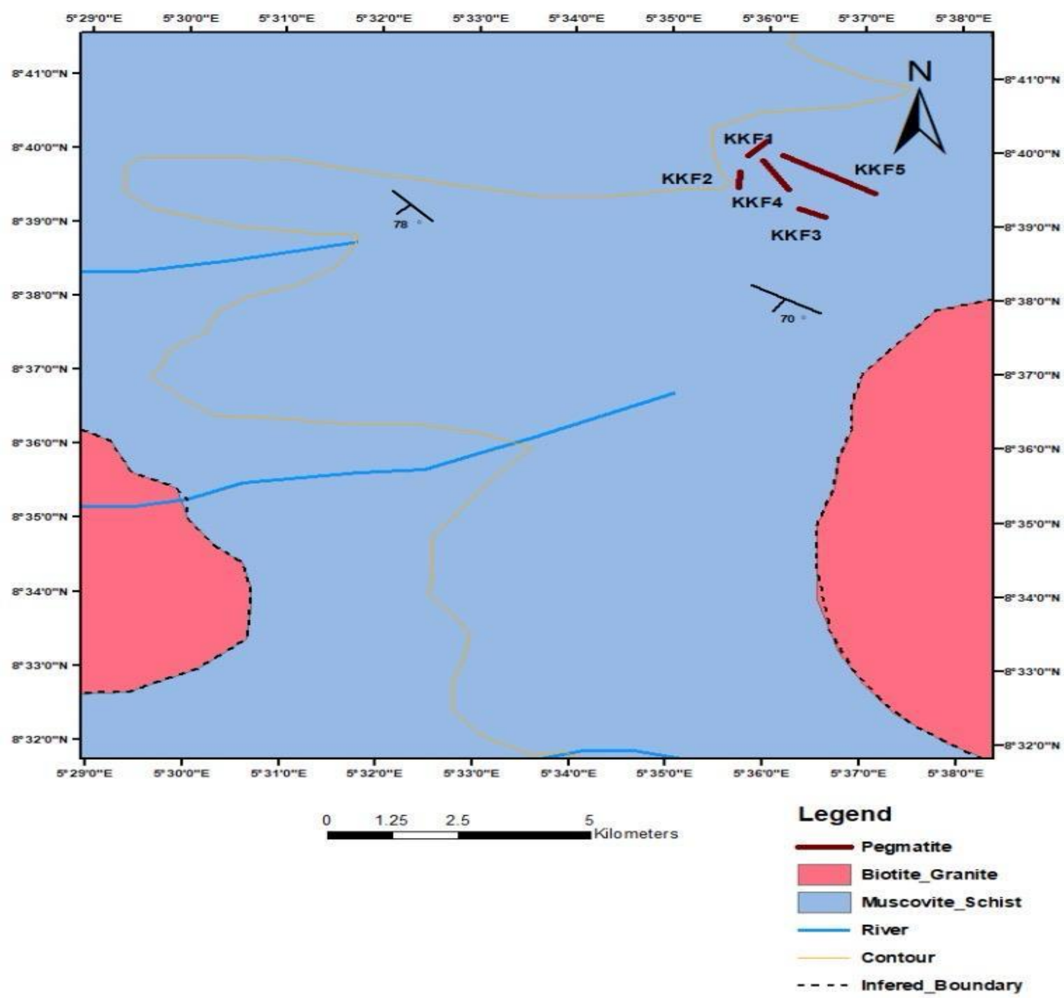

Figure 4.1 Geological Map of the study area

The schists

Schists in the study area occured as low lying outcrop exposed along the road cut and stream channel as well. It covers about 60% of the study area, the schist is known for its schistosity structure and some of them are having traces of quardzofeldspathic bands. The schist is the host (parent rock) for pegmatites. The minerals that make up the schist outcrops in-situ in the field are; dark patches of opaque minerals, hornblende, biotite, muscovite, quartz. The outcrops are massive in size and trending in the NE-SW direction while most of the pegmatites were trending in the NW-SE direction. The dimension of most of the outcrops ranges from 30-200m in length and 6-12m in height and width of 8-16m where exposed. The structures found on most of the schist are; fractures, joints, quartzofeldspathic veins and quartzites, schistosity. The linear structures (joints, fractures foliation) on some of the schist outcrops are trending in the N-S, NE-SW, NW-SE and E-W directions.

(a) (b)

Plate 4.1: (a) Outcrop of Schist (host rock) (b) Sample of schist containing crystals of lepidolite obtained near contact between pegmatite (KK5) and schist (host rock).

The granites

The granitic rock in the area is medium- to coarse-grained granite in texture which occurs in a number of places around the pegmatite veins. The major occurrence of the granite is towards the central part of the mapped area west of the major pegmatite vein. Another outcrop of highly fractured granitic rock is found at the north eastern part of the study area. All the occurrences of the medium- to coarse-grained granite in the area are commonly low-lying hills with large boulders scattered over it. The granite is pinkish-grey to grey in colour, grain size varies between medium and coarse grained (plate 4.2). The rocks are highly fractured and jointed with trends majorly aligned the trends of the pegmatites majorly in NE-SW and N-S. There are also xenoliths of older country rocks (schists) found within the granitic rock**.**

(a) (b)

Plate 4.2: (a) Outcrop of granite with host schist (b) Sample of fractures and joints

The Pegmatites

The pegmatites in the study area occur in swarm pattern spread north-eastward of the granitic rocks into the schists with main veins trending between 145-165 SE and most of the minor off shoots trend parallel to the main veins but at other places crosscutting obliquely in the NE-SW or E-W. Five pegmatites veins were identified in the study area where active artisanal miming activities was taking place, they include Kakafu vein 1 (KKF1), Kakafu vein 2 (KKF2), Kakafu vein 4 (KKF4), Kakafu vein 5 (KKF5) and Kakafu vein 7 (KKF7). Pegmatite veins constitute about 20% of the rocks of the study area. The major vein in the area Kakafu vein 5 (KKF5) stretched for about 2km and 2-6m thick exhibiting thin and swell shapes along the stretch of the vein. While other veins are 300-500m, 50-200m long and 3-4 and 1-2m thick. The pegmatites are hosted by both schist and gneisses mostly exhibiting sharp contacts at some places where exposed while highly obliterated at other places. Generally the pegmatites contained; quartz, plagioclase feldspars, microcline, muscovite, sericite, biotite as observed on the field. Detailed field features and description of pegmatite veins are presented in table 4.2.

Kakafu Pegmatite vein 1 (KKF1)

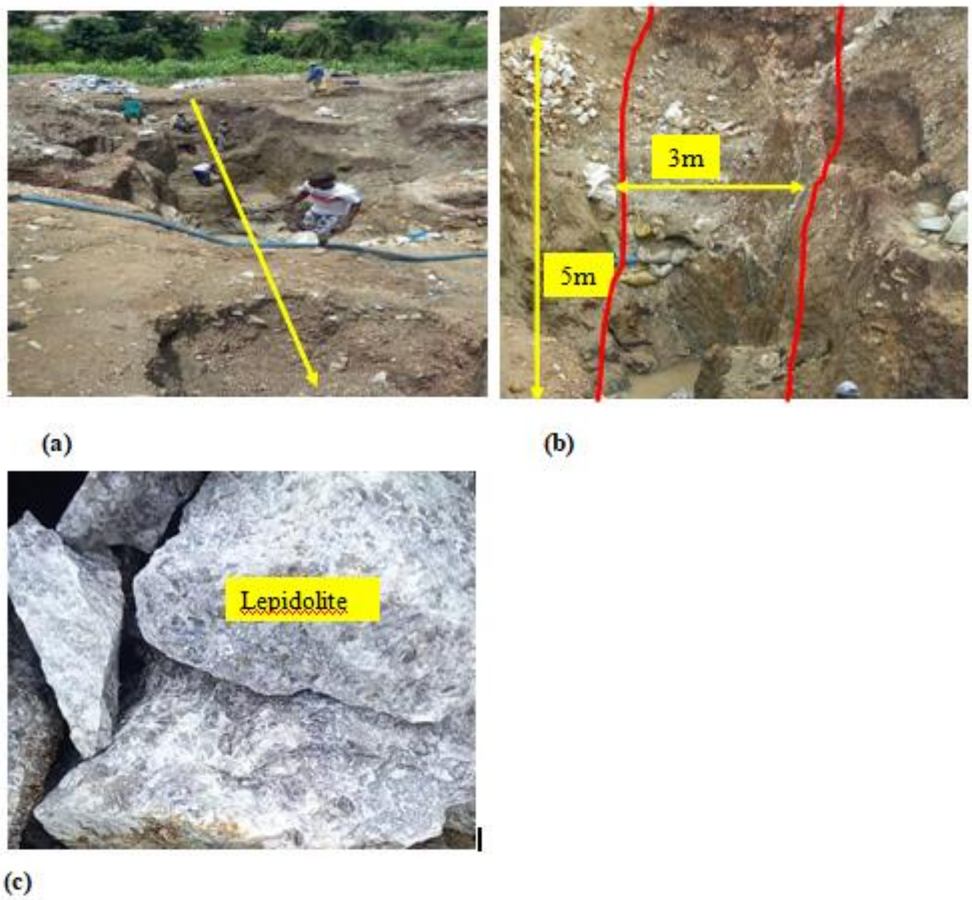

Plate 4.3: Kakafu vein 1(KKF1) (a) Aerial view of the vein (b) Depth, thickness, outline of the mineralized pegmatite vein and contact with the host schist (c) Samples of lepidolite collected at 5m depth from KKF1.

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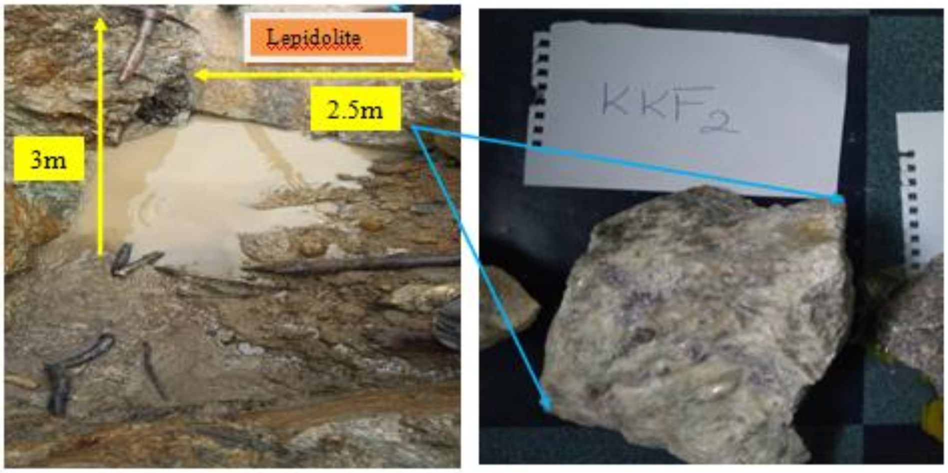
Kakafu Pegmtite vein 2 (KKF2)



(a) (b)

Plate 4.4: Kakafu pegmatite vein 2 (KKF2) (a) Depth, thickness and outline of the vein KKF2 (b) Lepidolite interlocked with feldspars and quartz sample of KKF2 collected at 2m depth.

Kakafu Pegmatite vein 4 (KKF4)

(a) (b)

(c)

Plate 4.5: Kakafu pegmatite vein 4 (KKF4) (a), surface view of the KKF 4 (b) Samples of low grade two colours tourmaline (pink-green) collected at 3m depth and (c) Lepidolite samples collected at 5-6 m depth.

Kakafu Pegmtite vein5 (KKF5)

(c) (d)

Plate 4.6: Kakafu pegmatite vein 5 (KKF 5) (a) surface view of the KKF 5, (b) sharp contact between the KK 5 and host schist (c) a pit along the vein dug to a depth of about 6-7m (d) sample of spodumene with intergrowth of pinkish kunzite, purplish lepidolite and feldspars

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Kakafu Pegmtite vein7 (KKF7)

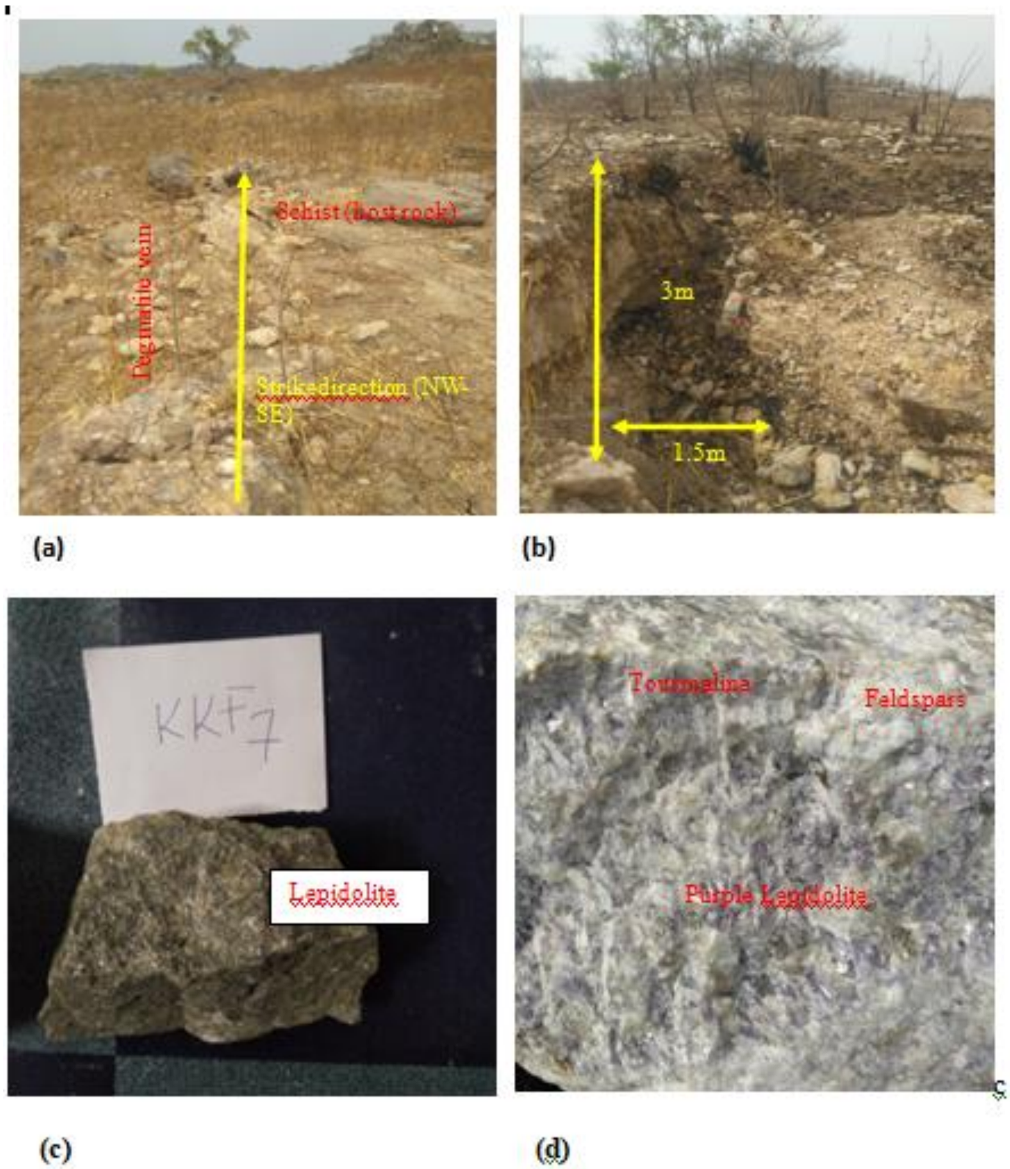

Plate 4.7:Photograph of Kakafu pegmatite vein 7 (KKF7) (a) Surface view of the vein (b) Pit dug along the vein at depth of about 3m. (c) and (d) Samples of purple coloured lepidolite with greenish coloured tourmaline and feldspars collected at 3-4 m depth.

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Table 4.2: General Field Features and Specimen Description of the pegmatites

S/N	Field Features								General specimen description and major mineral composition
	Name	Location	Orientation		Size		Contact with Host Rock	Host Rock	
			Strike	Dip	Length	Thicknes s			
1	**Kakafu Pegmatite KKF1**	. 8º 39' 49.31"N. and 5º 35' 48.52"E	021ºNE	70ºNW	400m	2-5m wide	Sharp	Schist and Granite	Coarse to medium very coarse grained texture observable biotite + muscovite + quartz + opaque minerals
2	**Kakafu Pegmatite KKF2**	8º 39' 48.8"N. and 5º 35' 48.23"E	081ºNE	80ºSE	650m	2m wide	Sharp with slight alteration	Schist	very coarse grained texture observable mineral + muscovite + quartz + opaque+ Clavelandite + zircon
3	**Kakafu Pegmatite KKF4**	8º39' 04.0"N. and 5º 36' 34.0"E	157ºSE	78ºSW	300m	2.5m wide	Sharp	Schist	Coarse to very coarse grained texture consists biotite + plagioclase + quartz + opaque
4	**Kakafu Pegmatite KKF5**	8º39' 31.0"N. and 5º 36' 51.0"E.	155ºSE	70ºSW	2km	2-6m wide	Sharp	Schist	Coarse to very coarse grained texture consist plagioclase + muscovite + quartz + sericite
5	**Kakafu Pegmatite KKF7**	8º39' 49.3"N. and 5º 35' 48.0"E.	176ºSE	80ºSE	450m	2.5m wide	Sharp and altered	Schist	Very Coarse to coarse grained texture observable minerals includes; biotite + microline + Plagioclase + quartz + Clavelandite + tourmaline + opaque minerals (dark patches)

Geochemistry

This section presents the results and interpretation of the geochemical analysis of pegmatite samples collected from the study area.

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Major Oxides (Wt %)	KKF1A	KKF1B	KKF1C	KKF2A	KKF2B	KKF2C	KKF4A	KKF4B	KKF4C	KKF5A	KKF5B	KKF5C	KKF7A	KKF7B	KKF7C
SiO_2	67.48	67.5	67.52	66.62	66.6	66.58	73.28	73.3	73.31	71.48	71.5	71.52	53.33	53.3	53.1
TiO_2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.575	0.555	0.535
Al_2O_3	17.08	17.1	17.12	16.82	16.8	16.78	15.42	15.4	15.38	16.28	16.3	16.32	11.18	11.2	11.22
Fe_2O_3	0.593	0.573	0.553	0.153	0.133	0.113	0.285	0.265	0.305	0.313	0.333	0.353	4.15	4.17	4.19
MnO	0.211	0.191	0.171	0.0612	0.0412	0.0212	0.131	0.111	0.091	0.206	0.186	0.166	0.141	0.121	0.101
MgO	0.11	0.13	0.15	ND	ND	ND	0.0727	0.0927	0.1127	-0.0414	-0.0614	-0.0514	7.39	7.41	7.4
CaO	0.714	0.734	0.754	1.71	1.69	1.67	ND	ND	ND	0.183	0.203	0.223	15.6	15.8	16
Na_2O	6.45	6.48	6.43	7	7.56	7.45	ND	ND	ND	4.96	4.98	4.95	3.05	3.07	3.09
K_2O	4.39	4.41	4.42	3.91	3.89	3.87	6.25	6.27	6.29	3.95	3.97	3.99	3.17	3.19	3.2
P_2O_5	1.08	1.06	1.04	2.5	2.52	2.54	1.69	1.67	1.65	1.2	1.22	1.24	0.596	0.616	0.636
LiO_2	1.44	1.46	1.42	1.59	1.61	1.6	0.82	0.88	0.85	2.01	2.27	2.17	1.22	1.29	1.24
Ratios															
Na_2O+K_2O	10.84	10.89	10.85	10.91	11.45	11.32	ND	ND	ND	8.91	8.95	8.94	6.22	6.26	6.29
A/CNK(ASI)	1.48	1.47	1.48	1.33	1.28	1.29	ND	ND	ND	1.79	1.78	1.78	0.51	0.51	0.5

Table 4.3 Major Oxides concentration of the pegmatites of the study area

Table 4.4 Trace Element Concentration of the Pegmatites of the Study Area

S	KKF1A	KKF1B	KKF1C	KKF2A	KKF2B	KKF2C	KKF4A	KKF4B	KKF4C	KKF5A	KKF5B	KKF5C	KKF7A	KKF7B	KKF7C
Sc	363.0	366.0	350.0	357.0	358.0	345.0	297.0	296.0	290.0	360.0	356.0	354.0	399.0	400.0	394.0
V	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	850.0	957.0	899.0
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	199.0	235.0	230.0
Ni	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	57.3.0	56.5.0	54.5.0

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Rb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	25.9.0	26.9.0	24.5.0
Sr	15300.0	16400.0	16500.0	6070.0	6090.0	6080.0	2667.0	25600.0	25500.0	10300.0	10600.0	10500.0	1012.0.0	1120.0	1089.0
Y	65.8	67.9	66.7	59.0	57.0	55.0	234.0	233.0	236.0	46.4.0	47.9	46.8	190.0	193.0	195.0
Zr	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	20.1	19.8	19.6
Sn	84.1	83.8	84.6	35.2	36.5	36.9	12.7	12.3.0	12.8	16.1	15.8	15.6	119.0	121.0	120.2
Cs	59.9	60.4	60.1	30.3	30.9	31.1	92.3	91.9	92.1	76.9	77.4	77.6	ND	ND	ND
Ba	710.0	724.0	727.0	465.0	472.0	469.0	1740.0	1720.0	1719.0	349.0	352.0	355.0	525.0	530.0	533
Ta	36.6	36.3	37.1	61.9	62.1	62.7	449.0	447.0	450.0	106.0	104.0	107.0	1160.0	1140.0	1170.0
Li	83.1	82.7	82.5	239.0	241.0	242.0	280.0	279.0	280.0	60.1	59.3	56.9	-22.3	-22.2	-22.2
K	14400.0	14600.0	14200.0	15900.0	16100.0	16000.0	8200.0	8800.0	8500.0	20100.0	22700.0	21700.0	12200.0	12900.0	12400.0
Ratios															
K/Rb vs Rb	2.38	2.23	2.22	5.35	5.3	5.28	19.46	2.03	2.05	3.18	3.11	3.15	26.01	23.65	24.4

Table 4.5: Correlation coefficient of the concentrations of trace element of the pegmattes

	S	Sc	V	Cr	Ni	Rb	Sr	Y	Zr	Sn	Cs	Ba	Ta	Li
S	1													
Sc	0.6767832	1												
V	0.6745441	0.9992392	1											
Cr	0.6779494	0.9979665	0.9953293	1										
Ni	0.6782153	0.9986832	0.9959844	0.9995742	1									
Rb	-0.6393364	-0.5853318	-0.5842334	-0.5861937	-0.5857705	1								
Sr	-0.3142096	0.4677613	0.4673969	0.4677057	0.467424	0.0490387	1							
Y	0.6776295	0.9981181	0.995916	0.9999122	0.9992611	-0.5863086	0.4679254	1						
Zr	0.7751605	0.7910559	0.7898754	0.7914503	0.7911418	-0.4137747	0.1449067	0.791625	1					
Sn	-0.8198451	-0.7858756	-0.7844958	-0.7868128	-0.7863126	0.7090431	-0.0104566	-0.7869766	-0.785427723	1				
I	-0.8670734	-0.2496088	-0.2491705	-0.2499065	-0.2497476	0.4827674	0.7349316	-0.2499585	-0.491659235	0.6052667				
Cs	-0.8265816	-0.2304855	-0.2299662	-0.2309179	-0.2307647	0.525854	0.7404241	-0.2309359	-0.342270926	0.5620678	1			
Ba	0.3826025	0.934385	0.9329047	0.9358232	0.934858	-0.4378732	0.7396714	0.936153	0.610243967	-0.578683	0.0996213	1		
Ta	-0.8447431	-0.6569678	-0.655808	-0.6577628	-0.6573423	0.3981425	0.1522283	-0.6578986	-0.708790816	0.4971864	0.6279471	-0.4441576	1	
Li	0.3997213	-0.239744	-0.2389741	-0.2416847	-0.2406924	-0.1803493	-0.8515262	-0.2418442	-0.200422472	0.0113274	-0.8051064	-0.4736993	-0.3752427	1
K	-0.9539887	-0.5561508	-0.5549681	-0.5571079	-0.5567348	0.6767737	0.4651899	-0.5571715	-0.606589944	0.8035881	0.9315061	-0.2454018	0.73842	-0.5606503

4.2.1 Classification of the pegmatites

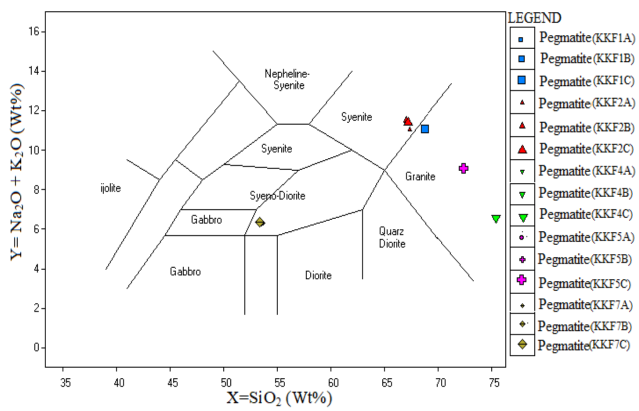


Figure 4.1 : Plots of Na2O+K2O vs SiO2 of the pegmatites

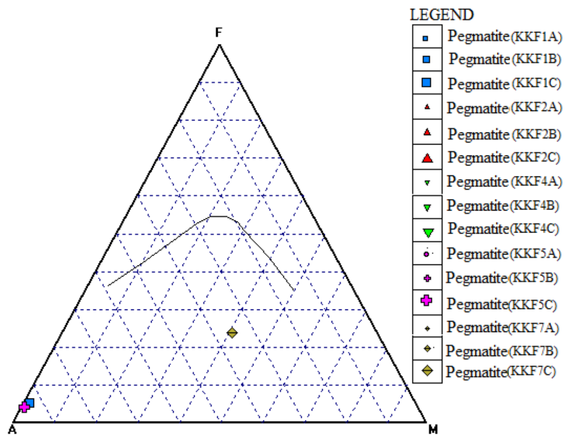


Figure 4.2: Plots of AFM of the pegmatites

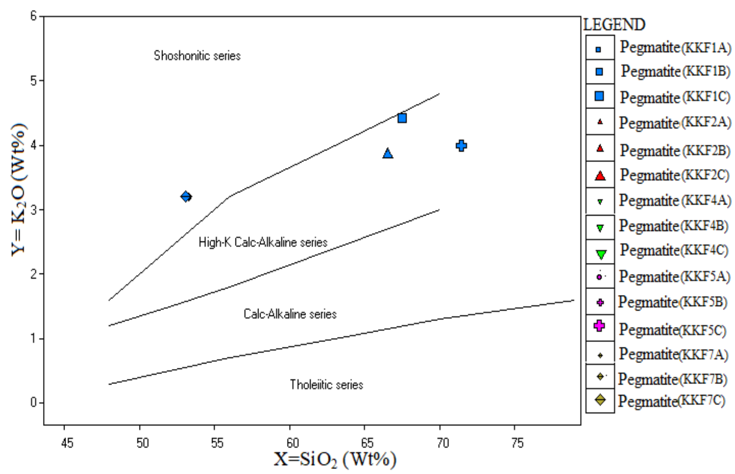


Figure 4.3: Plots of K2O vs SiO2 of the pegmatites

DISCUSSION

Field Features analysis

The Kakafu pegmatites occur as swarms in close proximity to the granites in the area (figure 4.1). This field relationship suggests them having link with the proximal granitic host rocks, as it is commonly found in most of the pegmatites fields of North central Nigeria (Webb and Jacobson, 1946; Adekeye and Akintola , 2007; Tanko, *et al* 2013, Tanko, 2014; Tanko et al 2015; Tanko and Dzigbodi-Adjimah, 2021; Tanko and Chime 2021). Also field features such as fracture trend, size and shapes of the pegmatites, orientation and types of contacts and host rocks recognized in the study area summarized in (table 4.2), indicates Kakafu pegmatites to be potential for rare metal as well as lithium ore minerals (Tanko, 2014; Tanko *et al.*, 2015; Tanko and Chime 2021;Tanko and Dzigbodi-Adjimah, 2021a and 2021b;).

Preliminary investigation with respect to lithium ore in this study is mainly restricted to the pegmatite veins in the area. Although not all the pegmatite veins in the area are highly mineralized with respect to lithium ore bearing minerals (lepidolite, spodumene and amblygonite etc.), but where highly mineralized the grades of the lithium mineral varies (Plates 4.3- 4.7).

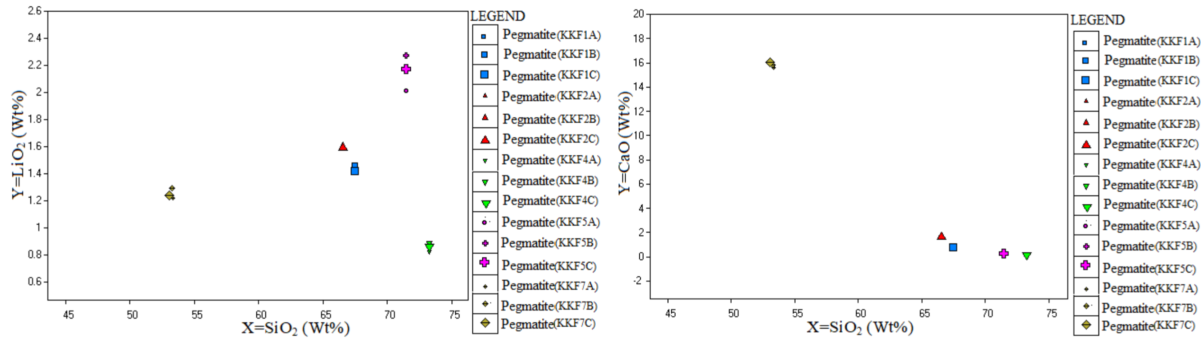
It is observed that some pegmatite veins show vertical variation and complexity of lithium ore minerals with depth (lepidolite to kunzite). On the surface and at shallow depth of about 3-2m (plates 4.3, 4.4 and 4.5) pinkish lepidolite is encountered which gradually change to purplish, whilst at depths of about 3-7m spodumene (kunzite) begins to appear (plate 4.6). Similarly, associated minerals such as feldspars (plagioclase and orthoclase), quartz, tourmaline and mica are found interstitially with lepidolite, spodumene (kunzite) and tourmaline (plate 4.5).

Along the stretch (trend) of the veins it was also seen that concentration of minerals varies, highest within swells and low where it pinches out. The colour of the minerals especially the lepidolite changes with increase in depth from pink to pale purple to deep purple (plates 4.5 and 4.7), whilst kunzite show white to pale pink colours, and becomes more compacted and hardened with depth (plate 4.6). The pegmatites of Kakafu area generally lacks schorl (black tourmaline) chacterizing their contacts with the host rocks, unlike some nonmineralized pegmatites of Keffi area (Tanko, *et al* 2013, Tanko and Chime, 2021; Tanko and Dzigbodi-Adjimh, 2021a and 2021b). This indicates Kakafu pegmatites being highly evolved and fractionated.

Furthermore, schist samples collected near contacts with pegmatites contained some crystals of lepidolite, this observation corroborates with geochemical analysis of those samples (Table 4.2). But further away from the contacts lepidolite crystals diminish; suggesting the presence of lepidolite in the host schist to be attributed to contact alteration referred to as lepidolization (plates 4.1 and 4.7). This may be an indication of lithium ore minerlaization of the Kakafu pegmites.

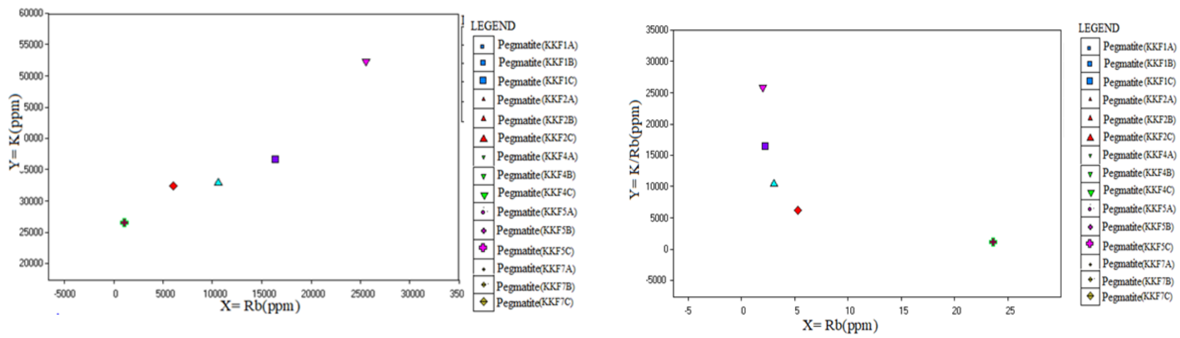
Geochemical features Analysis

Statistical analyses of major, trace and Rare Earth Elements(REE) showing relationships, sourc/origin and mineral potentials of the pegmatites of Kakafu in figures 4.4(a) & (b), 4.5 (a) & (b) and 4.6(a) & (b).



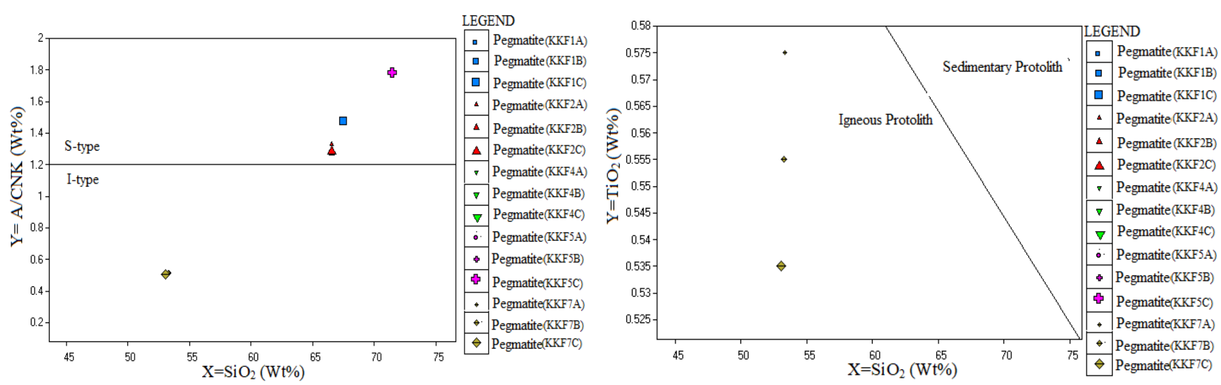
(a) **(b)**

Figures 4.4: (a) and (b): Plots of Li_2O vs SiO_2 and CaO vs SiO_2 showing the links amongst the pegmatites



(b) **(d)**

Figure 4.5: (a) and (b) Plots of K vs Rb and K/Rb vs Rb showing the link amongst the pegmatites



(a) **(b)**

Figure 4.5: (a) and (b); Plots of A/CNK Vs SiO_2 and TiO2 Vs SiO2 showing source /origin of the pegmatites

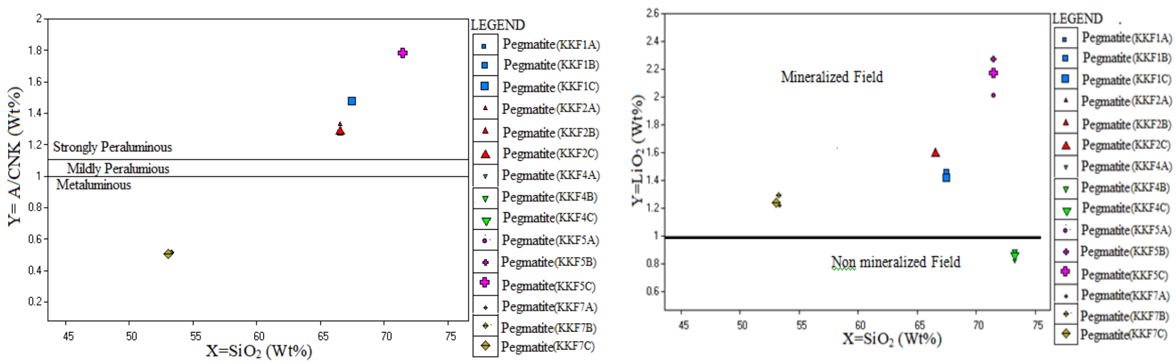


Figure 4.6 Plot of Li_2O Vs SiO_2 showing Lithium Mineralization boundary of pegmatites of north central Nigeira

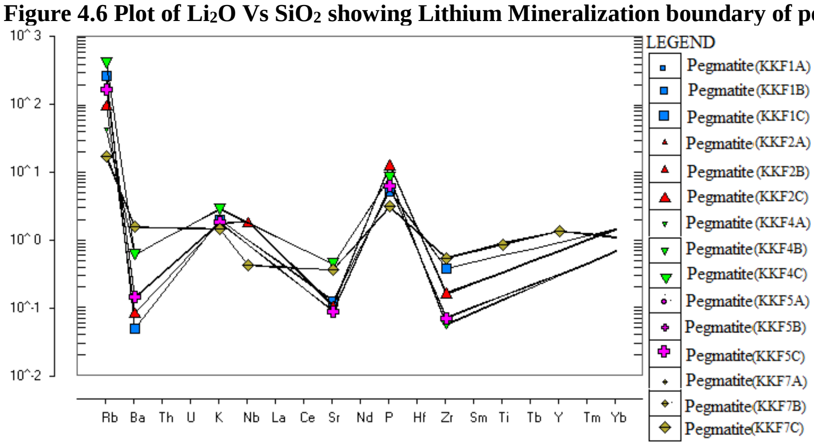


Figure 4.7: REE Plots of the Kakafu pegmatite

5.2.1 Pegmatite relationship, Origin and Mineralization Potential

To show that the Kakafu pegmatites are genetically related to one another, and have same origin, the plots of K vs Rb and K/Rb vs Rb and Li_2O vs SiO_2 and CaO vs SiO_2 are used. In the study area the plots of K vs Rb and K/Rb vs Rb, (figures 4.4(a) and 4.4(b) and Li_2O vs SiO_2 and Ca O vs SiO_2, (figures 4.5(a) and (b) show linkages amongst the pegmatites. This continuity in concentration shown in the plots above, (i.e. KKF4C to KKF7C and KKF4C to KKF7C is an indication of genetic relationship and same source /origin of the pegmatites of the study area. The plots of **A**/CNK Vs SiO_2 (figure 4.5(a), TiO2 Vs SiO2 (figure 4.5(b) show that all the pegmatites samples fall in the fields of S-type and igneous protolith respectively. These further show the Kakafu pegmatites to be of igneous origin.

In terms of mineral potential assessment, the plots of **A**/CNK Vs SiO_2 (figure 4.6(a)), Li_2O vs SiO2 (figure 4.6(a)) and REE (figure 4.7) indicate that the Kakafu pegmaites are strongly peraluminous and mineralized with respect to lithium ore. The extreme fractionation of Li_2O and lithophile elements is a common geochemical feature for mineralization of granitic pegmatites (Cerny, 1982a, 1982b; Cerny, 1991; London, 2005). Also most studies in the north central pegmatite fields of Nigeria considered concentration of oxides of Li_2O above 1wt% and high fractionation of lithophile elements (Rb, Cs) as common indicators of mineralized pegmatites (Wamba Pegmates (Kuester, 1990), Nasarawa pegmatites (Adekeye and Akintola, 2007) and Keffi pegmatites (Tanko, 2014; Tanko and Dzigbodi-Adjimah, 2021a and 2021b). In the study area concentration of Li_2O of Kakafu pegmatites ranges between (0.82-2.27wt%) and averagely all are above 1wt%. This suggests the Kakafu pegmatites to be relatively mineralized in lithium ore. Summarily, on the bases of both field and geochemical features observed in the study, the Kakafu pegmatites can be considered moderately mineralized with respect to lithium ore

CONCLUSION

The preliminary investigations of pegmatites in the study area have been successfully carried out and the following conclusions made:

1) Three main rock types recognized in the area are the muscovite schist, biotite granite and pegmatites.
2) Two different lithium minerals; lepidolite and spodumene (kunzite) were identified in the area
3) The mineral ore being sought for (lithium ore) is in abundance and grade and variety increases vertically with depth and along the veins in areas where the veins swells.
4) The continuity in concentration shown in the plots above, (i.e. KKF4C to KKF7C and KKF4C to KKF7C is an indication of genetic relationship and same source /origin (igneous protolith) of the pegmatites of the study area.
5) . Furthermore, the concentration of Li_2O of Kakafu pegmatites range between (0.82-2.27 wt %) and averagely all are above 1wt%. This suggests the Kakafu pegmatites to be moderately potential for lithium ore mineralization.

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