The Petrology, Geochemical Assessment of Lithium Pegmatite Rocks and Its' Industrial Applications from Kariya Province, Ganjuwa L.G.A., Bauchi State, North Eastern, Nigeria

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Abstract
The Petrology, Geochemical Assessment of Lithium Pegmatite Rocks and Its' Industrial Applications from Kariya Province presents a comprehensive analysis of the geochemical characteristics of lithium and associated elements in Kariya Province. A total of 35 geochemical samples were processed to evaluate lithium geochemical background and identify potential sources of lithium mineralization. The study reveals significant variations in lithium concentrations among the different areas, except for minimum anomalies values observed within some locations. The findings of this study point toward areas with high potential for lithium pegmatite and related granitic rocks deposits. The insights provided in this study offer valuable information for exploring and developing the significant lithium mineral resource in Kariya area. The identified potential sources of lithium mineralization areas that can serve as crucial guidelines for future exploration efforts in the region are; Wushi, Filin Shagari, Jangu Sabuwa, Gadar Maiwa, Rakajuwa, Ringim and Kafin Madaki towns.

1.0 INTRODUCTION

Nowadays, lithium (Li) has become an important element in many industries (e.g. energy storage), especially in the energy industry. Li can be found in many minerals, such as spodumene, lepidolite, amblygonite, petalite in granitic rocks and pegmatites (Averill and Olson, 1978, Gao et al., 2020, Zhang et al, 2020, Groves et al., 2022). These Li-bearing rocks evolved from highly fractionated granites (Cerny, 1991a,1991b, Muller et al., 2022, Shen et al., 2022) that migrated from parental granite to rare-metal-rich pegmatites including lithium bearing pegmatites. Lepidolite pegmatite are well defined Li sources.

Therefore, this research aim at to provide the petrology, mineralogy and geochemistry of lithium pegmatite and related granitic rocks in the study area, to understand the petrogenesis, tectonic setting and Li potentials from Kariya area.

2.0 The Geologic Settings

Lithium is associated with many minerals in various igneous rocks such as granite, and pegmatites, spodumene and petalite being the most common minerals.

The bulk compositions of pegmatites are poorly understood because of their highly heterogeneous occurrence. Pegmatites associated with felsic intrusions are texturally complex igneous rocks showing a very coarse texture, with large interlocking crystals. Pegmatites are formed when mineral-rich magma intrudes from magma chambers into the crust. The source granitic magma must be rich in lithium and also undergo extreme fractional crystallisation to form pegmatite deposits (London, 2018; Sykes and Schodde, 2019). There is no universally accepted model for the formation of pegmatites. A basic requirement of pegmatite formation is the initial composition of the pegmatite-forming melt and constraints on the pressure and temperature conditions. During magmatic differentiation, owing to the small value of the coefficient of distribution, the migration routes of Mg and Li are decoupled. Lithium accumulates in the latest differentiates of granitic complexes at their final stage of consolidation and thus gets concentrated in significant amounts in pegmatites. The final exotic mineral assemblages contain an abundance of lithium ion in spodumene, petalite, and lepidolite in addition to several others (London, 2018). There are two types of pegmatite deposits: (i) LCT pegmatites, and (ii) other pegmatites associated with magmatic and metasomatic rocks. LCT pegmatites show strong enrichment in Li, Cs, and Ta with the most abundant minerals such as spodumene, petalite, and lepidolite, in subduction and continental collision tectonic settings. Most LCT pegmatites are hosted in metamorphosed supracrustal rocks in the upper green schist to lower amphibolite facies and are mainly associated with Precambrian rocks. For example, the Greenbush pegmatite deposit in Australia was developed in 1983 and accounted for nearly 40% of the output of hard rock lithium in 2021 was formed about 2.5 billion years ago. This deposit is hosted by a giant (2,500 m long and 60-250 m width) pegmatite dyke intruding into amphibolite. It is a complex of tin, tantalum, lithium, and kaolin-bearing pegmatites, with extensive weathered and alluvial material at the surface (Sykes and Schodde, 2019). This deposit has the highest lithium grade (up to 5 wt.% Li_2O). Here spodumene containing lithium ore is mined from the fresh unweathered zones in the open pits. Recently, due to intense exploration for LCT pegmatites to supplement lithium production from the giant Greenbushes LCT pegmatite deposit, several new pegmatite-hosted spodumene deposits were discovered in the Yilgarn and Pilbara Cratons, and most of them anomalously enriched in Li with an extensive pegmatite geometry most suitable for open pit mining (Barber *et al*., 2022).
Lithium occur in three (3) major categories:

1. **Pegmatites** typically as the minerals **spodumene** and **lepidolite**.
2. Volcanic clays as hectorite, montimorillonite and bentonite (sedimentary rocks).
3. Brine and geothermal deposits which includes solar evaporates, playa lakes, and extracted subsurface brines from petroleum and geothermal production.

Spodumene: The name is from Greek meaning 'burnt to ashes', a reference to its most common colour: grey, although other striking colours occurred. Originally spodumene and the related minerals of granite pegmatites (eucryptite, lepidolite and petallite) were the main source of lithium but this position became eclipsed by lithium from brines, which is much cheaper to extract. However, spodumene still has considerable importance as a source of lithium. Pure spodumene ideally contains 8 percent (8%) Li_2O.

Spodumene is a type of pyroxene, whose basic structure consists of chains of SiO_4 tetrahedral. Each tetrahedron shares an oxygen ion with its neighbour building up these chains, which are then held together by interstitial Li^+ and Al_3^+ ions. This structure gives an orthorhombic or monoclinic crystal symmetry and two perfect cleavages at almost right angles to each other, which is a disadvantage when the mineral is used as a gemstone as it is easily broken along these cleavages. Spodumene is normally monoclinic (α-spodumene), but inverts to a tetragonal form.

2.1 Lithium Ore Deposit and Mineralization in Nigeria

Many African countries (most notably Zimbabwe, Namibia, Ghana, Democratic Republic of Congo, Mali, and others) have lithium ore deposit mostly found in low concentration in igneous rock nevertheless if appropriately exploited could be potential source for lithium concentration.
Nigerian lithium ore are found in the both in the Northern and Southern parts of the country such as Kogi, Nasarawa, Kwara, Oyo, Plateau, Bauchi, Gombe, and Adamawa. The most common lithium ore in Nigeria are spodumene, petalite, amblygonite, kunzite, and lepidolite. These lithium ore are exported as mined without any value addition to it, which reduces the revenue generated by the country from Mining and mineral industry table 3 below.
The pegmatites belt and the orientation of the units within it, appear to be related to rotational stresses created by the Benue Trough. From a more global perspective, this trend is probably the northern extension of the Brazilian pegmatite belt, which runs from Rio Grande del Sul to Rio Grande del Norte. The pegmatite field of Nigerian lithium deposit is part of late Pan African, rare (specialty) metals granitic pegmatites. The primary mineralization of tantalum, niobium, tin, beryllium, and lithium is hosted in quartz-feldspar-muscovite pegmatites.

Table 1: Lithium Ore Deposits in Nigeria

Deposits	State	Associated Minerals
Panda	Nasarawa	Pegmatite
Wamba	Nasarawa	Quartzite
Kabba	Kogi	Quartzite
Kushaka, Birnin Gwari	Niger	Pegmatite/Petalite
Isanlu Egbe	Kogi	Pegmatite
Ilesha	Osun	Pegmatite
Ijero Aramoko	Ekiti	Pegmatite
Arikya Tsauni	Nasarawa	Pegmatite and Quartzite
Kafin Maiyarki	Nasarawa	Granite
Itakpe Area	Kogi	Quartzite and Pegmatite
Oke Ogun	Oyo	Quartzite
Ago Iwoye	Ogun	Pegmatite
Hong	Adamawa	Lepidolite/Kunzite
Zuru	Zamfara	Petalite
Kafanchan	Kaduna	Spodumene/Kunzite
Lere	Kaduna	Petalite
Jos- South	Plateau	Quartzite/Lapidolite
Ganjuwa	Bauchi	Lithium Oxide/ Lithia
Gidan Boda, Baruten	Kwara	Spodumene

Keffi	Nasarawa	Lepidolite

Source: MMSD, 2022; Azomite Laboratory Report.

3.0 Materials and Methods

Various materials were used during the research work such as: Topo Map of the study area was used to demarcate the area of interest and all possible features were noted on it. Relevant field materials were used in collecting the samples and measurement were taken for structure observed during the field work.

3.1 Field Method

Traversing method was used at the beginning of the field work to identify the area of study and compare with the information acquired from Topo-map as reconnaissance. Thirty-five (35) different samples at different locations were collected from the field for laboratory studies and hand specimen descriptions.

3.2 Laboratory Studies Method

The laboratory work was done in two phases (i.e. Petrographic (thin section) analysis method using rock cutting and polishing machine and geochemical (whole rock) analysis method using X-Ray fluorescence machine and Atomic Absorption Spectrometry (AAS)).

4.1 Results and Discussions

The combined field occurrence, petrography and geochemistry data indicated that the granitic rocks and Li-bearing pegmatites in Kariya area have a close relationship as reflected by the highly fractional crystallization trend in some of the plots. This probably indicates that the Li-bearing pegmatites are part of the late stages of the highly fractionated granitic magma in the study area.
In this study, lepidolite pegmatite, one of Sn-Ta sources in Jangu, is defined as Li-bearing pegmatites in Wushi and considered as unzone lepidolite pegmatite in the area.
For the Li grade, the Li content of the Li-bearing pegmatites was 0.43%Li (1.204-0.134) as high grade and (0.010-0.001) as low grade. Spodumene pegmatite deposits have high grade Li in the study area (RG:1.204) Table 4.

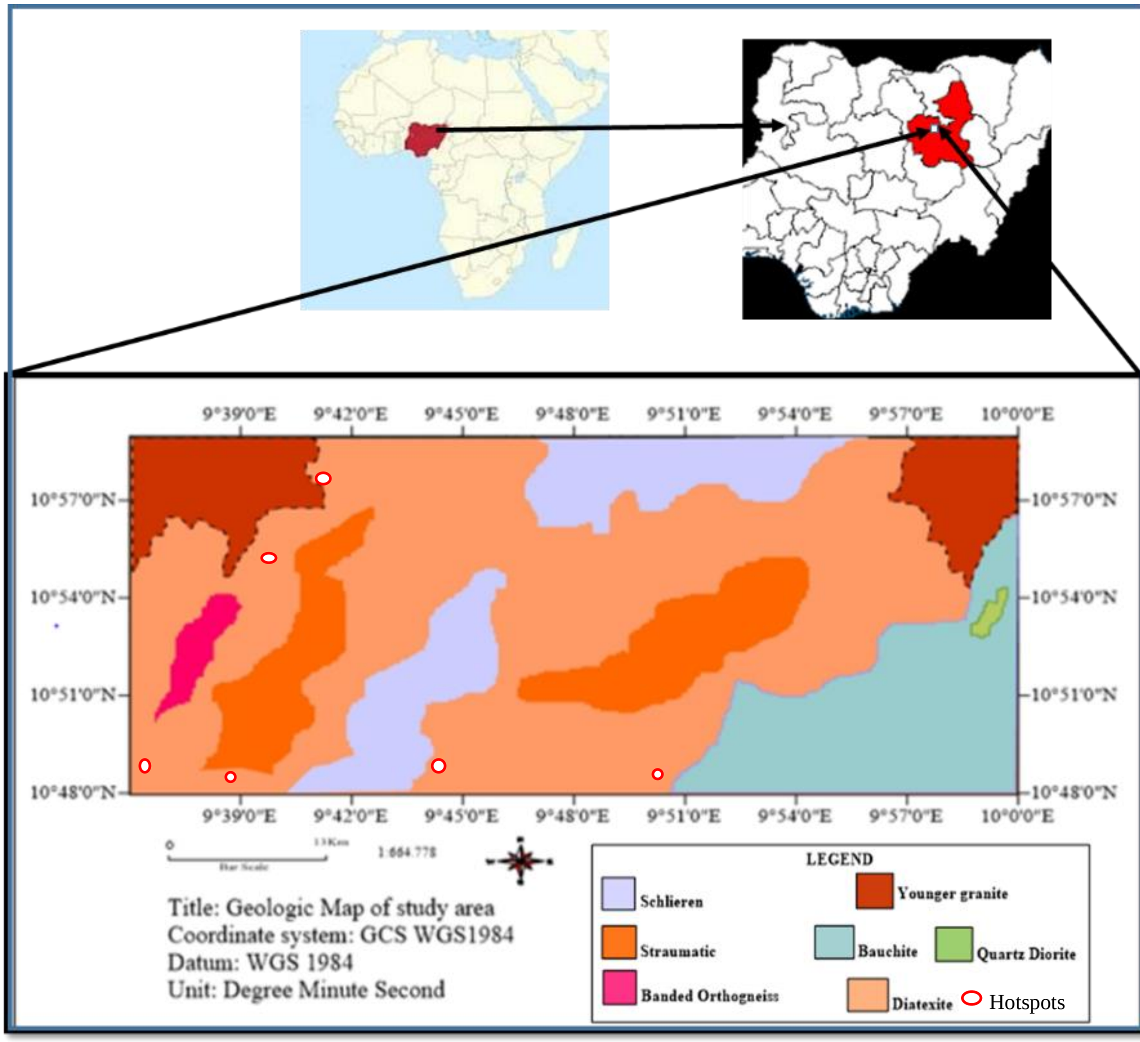


Figure 1: Geology and hotspots of the study area

Table 2: Major Oxides (wt %)

Oxides Composition	%	SiO2	CaO	MgO	SO3	K2O	Na2O	TiO2	MnO	P2O5	Fe2O3	Al2O3	H2O+	TOTAL
LSHm	31.16	1.23	30.39	Nd	0.07	Nd	1.87	0.05	0.93	9.75	17.26	7	99.71	
L 3	73.18	0.017	0.0678	Nd	4.425	2.019	0.449	0.048	0.35	4.213	11.911	1.4	98.08	
L JR	59.3	1.2	5.99	0.09	8.1	0.86	0.03	Nd	Nd	7.4	13.5	1.76	98.23	
L 5Ap	80.4	Nd	Nd	Nd	7.45	1.02	0.013	0.007	0.35	0.26	10.45	1	100.95	
LMii	76.51	1.17	0.13	Nd	6.6	0.61	0.098	0.016	0.4	1.49	12.37	1	100.39	
KP	69	0.47	0.002	ND	20.93	1.06	0.5	0.14	ND	1.36	1.28	5.01	99.75	
GPa	90.5	ND	ND	0.04	6.51	0.76	0.03	0.08	ND	0.1	0.7	0.45	99.17	
GPb	95.9	0.45	0.001	0.04	0.54	0.03	0.07	0.67	ND	0.37	0.34	0.86	99.27	
L 11b	62.89	3.46	0.49	Nd	5.54	2.64	0.41	0.07	0.61	5.04	15.41	3.1	99.66	
L 7	64.2	3.73	0.24	Nd	5.42	0.54	0.35	0.05	0.56	4.92	18.12	1.99	98.12	
LF1	55.37	4.56	1.34	Nd	6.41	0.59	0.77	0.11	1.15	9.46	16.81	3.5	100.07	
LB3	69.65	Nd	Nd	Nd	7.58	2.11	0.2	0.021	0.4	4.24	14.05	1.3	99.58	
LD 3	73.72	1.01	0.06	Nd	7.25	1.2	0.12	0.025	0.39	2.09	13.47	1.75	101.09	
G1	57.7	0.6	1.25	Nd	6.8	2	0.43	0.06	0.03	13.7	12.8	3.4	98.77	
KM1	66.54	0.45	0.03	Nd	12	1.21	0.2	Nd	0.1	5	13.02	2	100.55	
LEiii	52.85	6.09	1.54	Nd	4.09	3.64	0.98	0.071	1.55	7.68	17.69	3.54	99.72	
L 2d	73.775	1.478	0.145	Nd	2.088	1.655	0.108	0.019	0.379	0.873	15.124	1.56	97.22	
KM ii	67.187	1.637	0.277	Nd	5.469	1.2	0.573	0.078	0.408	8.207	13.993	2	101.04	
L 4*	70.01	1.77	0.21	Nd	6.42	2.46	0.11	0.051	0.41	2.87	14.3	1.3	99.91	
LEii	72.56	1.12	0.12	Nd	Nd	Nd	0.041	0.036	0.4	0.99	15.69	1.68	92.64	
LBii	46.1	8.39	5.44	0.088	2.45	0.21	1.28	0.11	0.94	13.93	15.63	5.2	99.77	
L 1	63.35	4.95	2.28	Nd	4.95	0.48	0.61	0.047	0.61	5.32	16.32	1.87	100.79	
LE iv	71.43	1.02	0.4	1.02	6.01	3.01	0.081	0.056	0.42	1.77	14.29	1.75	101.26	
KMiii	71.02	2	0.44	Nd	7.61	1	0.19	0.032	0.41	2.17	14.71	1.2	100.24	
LK3Cg	70.9	1.41	0.5	Nd	5.87	2.76	0.13	0.024	0.37	3.1	13.2	1.98	100.24	
BQ	73.68	0.034	0.3	Nd	8.52	0.76	0.2	0.006	0.36	0.4	14.83	1.5	100.59	
L 6	69.22	0.98	0.26	Nd	7.06	0.65	0.12	0.05	0.47	2.39	17.95	1.32	100.47	

LK 5	67.78	1.49	0.184	Nd	5.912	3.121	0.252	0.037	0.444	4.45	13.177	2.8	99.64	
LK 3A	73	0.15	0.02	Nd	5.67	1.56	0.3	Nd	Nd	2.12	13.8	1.56	98.18	
LMW2	78.11	0.32	0.06	Nd	8.12	3	0.7	Nd	Nd	1.83	17.3	1	110.44	
LMWII	50.33	3.09	8.65	0.1	1.03	0.9	1.43	0.05	ND	18.3	13.4	1.76	99.04	
LMW03		61.34	0.08	0.01	ND	18.4	1	0.86	0.08	0.05	1	14.12	2.87	99.81
LB3y		69.65	Nd	Nd	Nd	7.58	2.11	0.2	0.021	0.4	4.24	14.05	1.3	99.55
LK4B		59.49	1.08	0.08	Nd	5.93	4.95	0.16	0.15	0.44	6.6	18.5	2.3	99.68
LK 2		69.79	Nd	Nd	Nd	6.81	1.25	0.091	0.006	0.36	1.28	19.77	1.8	101.16
LBB		72.63	1.143	Nd	Nd	7.202	1.3	0.165	0.031	0.358	3.42	13.424	1.44	100.76
GY		52.9	8.4	0.94	0.06	2.06	0.4	2.02	0.32	ND	15.1	10.43	6.24	98.87

Table 3. Trace Elements (ppm)

Elements (ppm)			V	Cr	Cu	Sr	Zr	Ba	Zn	Ce	Pb	Bi	Ga	As	Y	Ir	Ni
	Rb	Mo	Co	Cd	Ru	Eu	Re	Nb	Ag	Ta	W	Hf	Yb	In	Se	U	Th
	Sb	Ge	Sn	Au	Hg												
LSH	268.8	135	3	41.6	296.4	20	54.9	<0.001	<0.001	3.2	21.2	<0.001	77.3	1.1	<0.001	1.4	<0.001
	<0.001	<0.001	<0.001	387.2	0.1	42.9	<0.001	5.5	0.67	8.8	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01
	106	Nd	ND														
L 3	48.5	224.4	47.6	107.3	177.8	183.3	108	20	33.3	10	23.8	0.2	23.7	<0.001	42.9	302.9	0.01
	0.034	<0.001	0.98	205.9	<0.001	32.9	673.6	12	2.45	11.78	12	<0.001	<0.001	0.042	7.2	<0.001	<0.001
	65.5	Nd	ND														
LJR	722	212.3	435	6230	1640	690	58	58.03	84	0.451	26	15.05	2.9	2.06	0.74	39	<0.001
	5	<0.001	8.6	38	<0.001	17	1.5	41	3.83	14	5	8.5	<0.001	<0.001	0.22	3.6	65.5
	43.3	0.43	ND														
L 5A	12.9	88.9	10.4	230.4	8.2	92.7	<0.001	<0.001	65.7	<0.001	12.8	<0.001	7.2	0.4	20.2	172	<0.001
	<0.001	<0.001	<0.001	10.6	<0.001	<0.001	<0.001	<0.001	<0.001	7	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	38.7	ND	ND														

L Mii	24	48	3	120.2	232.1	448.4	19.2	192.7	23.4	<0.001	18	<0.001	13.3	1.6	<0.001	<0.001	<0.001
	<0.001	<0.001	<0.001	71.2	2.3	6.1	70	2.07	0.81	33.5	<0.001	<0.001	<0.001	<0.001	10.9	7	20
	70.2	ND	ND														
KP	Nd	Nd	64	510	1.48	210	Nd	4	430	35	37	10	Nd	10	Nd	61.7	0
	0	0	0.9	Nd	Nd	100	6.45	24.88	1.05	0.02	Nd	Nd	Nd	Nd	Nd	Nd	Nd
	Nd	0.782	Nd														
GPa	ND	ND	21	130	ND	400	ND	30	170	ND	7.4	8.3	5	1.7	ND	77.7	0
	0	0	3	Nd	Nd	49	Nd	16	0.72	ND	Nd	Nd	Nd	Nd	Nd	ND	Nd
	Nd	1.002	ND														
GPb	20	14	240	ND	ND	12	70	31	100	13	14	6	20	2.3	ND	ND	0
	0	0	3.5	Nd	Nd	17	1.03	Nd	Nd	12	Nd	Nd	Nd	Nd	Nd	0.84	Nd
	Nd	0.43	6														
L 11	21.7	222.7	17.5	386	325.6	837.2	70	<0.001	29.8	<0.001	28.6	0.1	32,30	<0.001	47.8	142	<0.001
	<0.001	<0.001	<0.001	289.6	0.2	19.8	763.7	2.5	1.65	21	11.6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	72.9																
L 7	38	56.1	10.3	546.5	501.6	1350	102.3	<0.001	31.7	<0.001	37.6	0.4	27.4	0.4	14	175.3	<0.001
	<0.001	<0.001	<0.001	244.3	<0.0011		<0.001	788.4	2.9	0.6	13.5	20	<0.001	<0.001	<0.001	<0.001	<0.001
	<0.001	82.3															
LF1	10.6	61.6	18.1	692	696.5	1550	164.6	5	31.1	<0.001	34.3	0.9	51.3	<0.001	7.9	165	<0.001
	<0.001	<0.001	<0.001	557	<0.001	39.7	90.5	4	13	22.1	24.8	<0.001	0.2	<0.001	<0.001	1	<0.001
	92.8																
LB3	70	74.9	5	154.2	525.5	910	33.3	<0.001	17.4	<0.001	26.1	0.4	163.5	1.8	<0.001	39	<0.001
	<0.001	<0.001	<0.001	228.5	2.9	17	759.1	2.08	0.882	11	13.8	<0.001	<0.001	<0.001	8.5	3.24	68
	75.7																
LD 3	4.6	68.4	5.5	154.2	311.3	12	46.2	49	33.6	<0.001	26	<0.001	15	1.8	17.3	196.3	<0.001
	<0.001	<0.001	<0.001	114.7	1.8	4.7	<0.001	<0.001	0.01	8.5	1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	73.6																

G 1	620	320	365	490	2700	6450	192.5	39.25	40	0.44	6.5	6.5	20	1	<0.001	82	<0.001
	0.335	<0.001	8	33	0.044	24	1.35	64	3.05	14.5	0.55	5	0.35	0.01	0.28	0.33	85.6
	37	16.98308148		1.130084553													
KM 1	680	342	316	2020	1550	1820	565	56	847	0.673	12.5	17.5	3.5	6	<0.001	20	80
	0.2	1.011	<0.001	2	34.5	15.05	0.12	62	1.8	23.5	6.7	0.05	0.01	<0.001	2.25	14.5	56
	20.5	15.50641449		0													
LEiii	12	74.2	32.2	748.6	608.6	<0.001	114.1	<0.001	22.1	<0.001	29.3	15	41.2	0.3	8.4	96.4	<0.001
	<0.001	<0.001	<0.001	429.9	<0.001	26.6	<0.001	12	1.33	21	22.8	<0.001	<0.001	<0.001	<0.001	0.22	0.074
	146.5																
L 2	21	91.1	15.4	262.6	55.7	32	29.3	<0.001	65.4	5	5.09	3	4.3	2.02	17	36	0.009
	<0.001	0.005	1.23	41.3	<0.001	<0.001	<0.001	<0.001	0.003	13	1.3	2.23	0.28	<0.001	<0.001	<0.001	<0.001
	45.9																
KM ii	0.887	2.43	1.23	412.1	116.4	3.55	155.3	<0.001	38.9	3.98	27.7	1.4	14.1	1.2	<0.001	166.2	0.008
	0.998	<0.001	0.98	355.3	0.004	12.4	<0.001	15.5	2.23	6.67	22.6	<0.001	<0.001	0.025	59.7	0.55	<0.001
	149																
L 4	10	82.2	10.8	213.2	349.1	506.9	58.1	43.4	29.9	0.085	27.9	0.07	21.2	1.4	10.3	186.4	0.03
	<0.001	0.005	0.065	158.2	2	23.6	746.1	5.88	2.8	21	5.1	<0.001	<0.001	<0.001	6.5	0.65	0.05
	74.5																
LEii	1.23	43.1	2	33.1	93.5	21	15.2	<0.001	51.5	<0.001	37.3	<0.001	10	1.4	8.4	195	<0.001
	<0.001	<0.001	<0.001	44.5	<0.011	<0.001	<0.002	<0.001	<0.001	3.65	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	50.9																
LBii	278.3	90.5	65.2	838.6	160.7	545	169	<0.001	6.6	<0.001	27.4	2.1	30.8	<0.001	52.2	69.1	<.001
	<0.001	<0.001	<0.001	650.2	<0.001	15.9	931	3	0.43	8.5	<000.1	<0.001	<0.001	<0.001	<0.001	0.04	<0.001
	91																
L 1	126.7	139.6	37.9	660	292.9	90	82.7	<0.001	31.4	<0.001	31.6	2.2	23.9	<0.001	47.9	288.3	<0.001
	<0.001	<0.001	1.2	246.2	0.3	15	1.32	4	1	2	9.6	<0.001	<0.001	<0.001	32.4	<0.001	<0.001
	126.2																

LE iv	10.09	73.3	1.34	37.9	160	92.5	65.4	<0.001	85.5	<0.001	53.4	<0.001	108.1	0.7	12.9	463.7	0.2
	1.094	<0.001	2.06	74	3.2	22.1	<0.001	3.43	1	20	11	<0.001	<0.001	<0.001	44.3	0.66	<0.001
	115.8																
KMiii	20.5	410.6	5.5	441,90	143.2	13	51.9	543.1	34.6	<0.001	29.1	1.1	13.4	1.3	57.4	140.2	<0.001
	<0.001	<0.001	<0.001	133.9	1.9	5.6	<0.001	<0.001	0.03	6.7	3.4	<0.001	<0.001	<0.001	6.7	<0.001	<0.001
	55.2																
LK3C	32.9	128.9	15.7	46	306.5	125.9	81.6	24	33.6	<0.001	40.7	0.06	100.4	<0.001	26.7	307.5	<0.001
	<0.001	<0.001	<0.001	78.6	2.1	88	691.4	25	2.24	5	16.5	<0.001	<0.001	<0.001	22.3	0.031	<0.001
	76																
BQ	51	171.8	4	113	448.1	68	16.7	570	16.5	<0.001	24.4	<0.001	22.3	0.8	49	227.4	<0.001
	<0.001	<0.001	<0.001	47.8	2.5	15.6	<0.001	3.5	2	32	2.6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	40.3																
L 6	23	135.6	9	253.7	47.7	70	93.1	304.7	76.9	<0.001	37.3	<0.001	19.3	1	19.5	392.6	<0.001
	<0.01	<0.001	<0.001	128.5	<0.001	25.5	<0.001	3.2	0.54	18	10.8	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	139.5																
LK 5	1.7	139.6	25	89.5	410.3	256.5	154.4	<0.001	33.4	0.045	30.3	<0.001	61.4	0.4	39.6	181.5	0.001
	0.345	<0.001	8.7	162.8	<0.001	43.9	677.8	23.9	4	14	15	<0.001	0.25	0.21	14.1	0.3	<0.001
	70.8																
LK 3A	535	316	160.5	150	736	900.5	22	57	72.65	1.6	12.5	21.5	27	24	<0.001	29	<0.001
	1	0.004	5	53	0.076	10.8	0.7	38.5	7.8	6.68	2.02	3.55	0.1	0.1	0.24	0.55	36.41
	56.55																
LMW2	201.8	118.5	482	1830	5710	690	120	33	75.5	0.144	34	22.5	10.3	5	0.056	21.6	15.5
	<0.001	0.09	0.032	0.65	14	20.2	0.65	70.5	12.5	38.45	2.14	0.72	0.2	0.201	0.41	8.51	14
	51.1																
LMWII		401	145	134.5	1310	1220	3150	87	52	26.8	0.109	39.5	7.5	15.5	10	<0.001	29
	32.01	0.001	0.034	0.015	0.22	12.5	17	0.4	42.15	0.891	33	4.04	2.1	<0.001	<0.001	2	7.13
	20.5	21.5															

LMW03		613	325	293	270	720	100	60	45.5	18	0.219	17.8	7	39.2	3.13	0.005	9.84
	14.55	0.01	<0.001	<0.001	0.82	11	14.3	0.67	63	13.3	16	1.56	3	0.28	<0.001	0.22	12
	14.5	9.3															
LB3	70	74.9	5	154.2	525.5	910	33.3	<0.001	17.4	<0.001	26.1	0.4	163.5	1.8	<0.001	39	<0.001
	<0.001	<0.001	<0.001	228.5	2.9	17	759.1	2.08	0.882	11	13.8	<0.001	<0.001	<0.001	8.5	3.24	68
	75.7																
LK4B	7.85	297.3	0.78	113.9	1390	3.78	254.5	602.9	15.4	<0.001	43.8	3.6	69.8	<0.001	62	143.7	<0.001
	<0.001	<0.001	<.001	504.1	<0.001	<0.001	<.001	<0.001	<0.001	37.3	19.5	<0.001	<.001	<0.001	<0.001	<0.001	<0.001
	116.5																
LK 2	51	31.8	0.43	31.8	0.56	113.7	37	28.8	13.8	0.081	31.2	11.2	25.8	1.1	9.6	219.3	<0.001
	0.034	0.005	0.12	28.9	2.7	4.3	<0.001	0.8	0.55	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.22	<0.001
	53.3																
LBB	2	304.6	3.8	53.9	2.88	4	205.8	391.3	27.6	0.66	35.9	<0.001	88.3	<0.001	74.5	209.5	<0.001
	0.004	0.002	<0.001	171.7	<0.001	47.6	<0.001	7.76	1.66	0.44	12.2	<0.001	0.1	<0.001	28.3	0,55	<0.001
	134.9																
GY	73	196	63	2400	1100	300	25	Nd	22	Nd	Nd	Nd	Nd	Nd	18.2	76	0
	0	0	Nd	nd	Nd	Nd	Nd	Nd	Nd	12	Nd	Nd	Nd	Nd	Nd	0.84	Nd
	Nd																

Table 4: Results of AAS Analysis for Lithium Ore concentration (mg/l)

Sample ID		Conc. Mg/L	AA	SD	RSD%
1.	GM	0.003	0	0.001	108.6
2.	JR	0.134	0.018	0.001	3.288
3.	JR2	0.135	0.019	0	1.107
4.	JG	0.009	0.001	0.001	49.68
5.	RG	1.204	0.192	0.001	2.127
6.	RK	0.721	0.031	0.001	1.010
7.	KM	0.402	0.017	0	3.173
8.	WS	0.013	0.015	0.001	26.86
9.	KR	0.010	0.004	0	41.58
10.	BB	0.005	0.012	0.001	2.501
11.	NT	0.032	0	0.001	33.81
12.	SK	0.001	0.019	0.001	21.34
13.	DB	0.013	0.120	0	43.65
14.	ML	0.005	0.041	0	15.99
15.	SG	0.035	0.017	0.001	3.190

4.2 Petrographic Studies

Optical studies revealed that the migmatite rock units from the study area are medium to fine grained with the exception of pegmatite which is coarse grained. The main mineral assemblage include quartz, K-feldspar, plagioclase, biotite, orthopyroxene, serpentinites, cordierite, sillimanite, garnet and opaque.

Petrographic investigation indicates that biotite, orthopyroxene, cordierite and opaque minerals constitute the mafic aggregates while quartz and feldspar dominate the felsic assemblage. Quartz contents ranges from 42 to 57%, feldspar (20-26%), cordierite (3-6%), biotite (9-18%), muscovite (2-4%) while opaque varies between 3 and 8% of the rocks mass Table 2. Sample L6 is a granite that is medium to coarse grained displaying stringers of garnet mineral in hand specimen, under optical studies mineral quartz, biotite, orthopyroxene and metamorphic muscovite were seen and evidence of grain scale fluid migration was seen as some minerals were aligned along a uni-direction and are stretched signifying shear stress acted upon the rock, plate Vc red arrow indicating direction of the movement

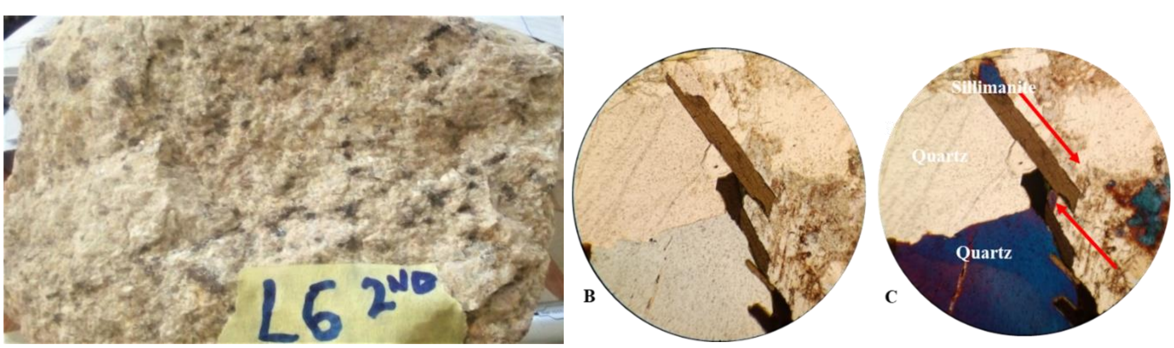


Plate I: Hand Sample L6 (Granite) and photomicrograph B. (PPL) and C (XPL)

Plate II, below is a hand specimen and photomicrograph of a pegmatite rocks from the research area where quartz in gray, muscovite in blue-green to yellow, microcline with cross hatched twinning were seen and noted.

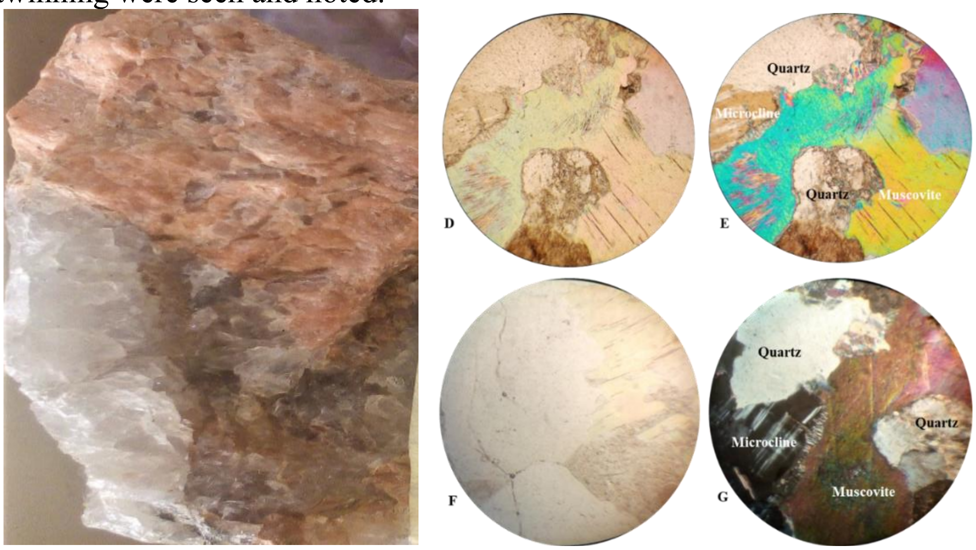
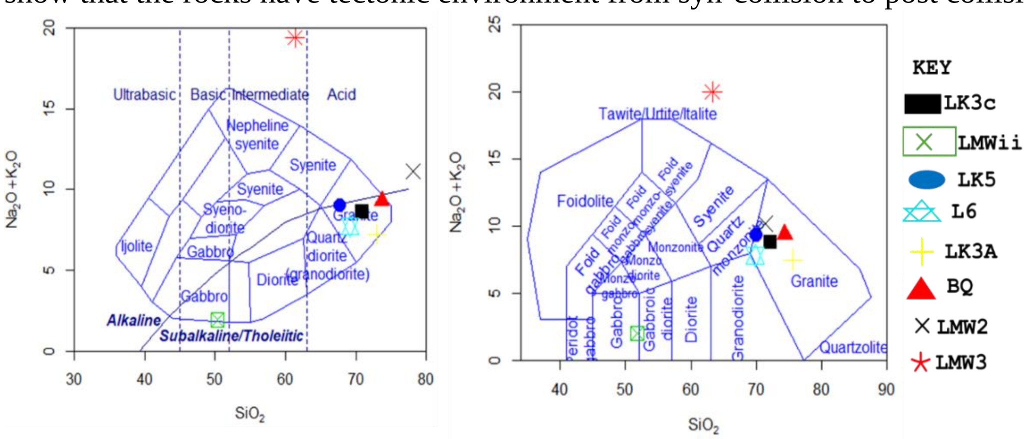


Plate II: Hand Sample and Photomicrograph of L5A (Pegmatite) D and F (ppl), E and G (xpl) (x100), Showing distinct view of Quartz, muscovite and microcline feldspar.

4.3 Rock Classifications

According to Middlemost (1994) and Le Bas *et al.*, (1986), Total Alkali Silica (TAS) plots, the rocks in the study area fall under granite domain from the plots below figure 2a and figure 2b show that the rocks have tectonic environment from syn-collision to post collision.



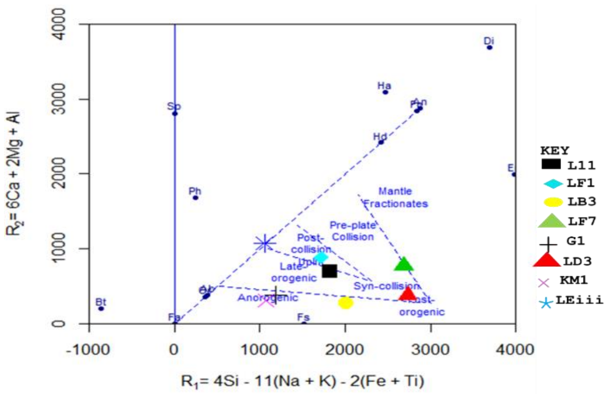


Figure 2a TAS Plot after Middlemost 1984 and Cox et al., 1979 and Figure 2b: Batchelor and Bowden 1985

Conclusions

The Li-bearing pegmatites and related granitic rocks in the study area have elucidate geological processes for petrogenesis, tectonic implications and Li-mineralization together with the Li-potentials as follow:

1. The Li-bearing pegmatites are characterized by lepidolite pegmatite and relate to the granitic rocks including porphyritic biotite-muscovite granite, biotite granite and muscovite-tourmaline granite.
2. The geochemical characteristics of both the Li-bearing pegmatites and related granitic rocks indicate peraluminous S-type granite affinity.
3. The enrichment of LILEs (e.g. Rb, K) and the depletion of Ba, Nb and Ti together with the slightly high LREE contents indicate that the studied rocks were emplaced from a Collisional Setting.
4. The Li-bearing pegmatites that evolved from highly fractionated S-type granitic rocks are related to the closure of West African Craton and Congo Craton during Pan African Orogeny.
5. The Li-bearing pegmatites, being among the Sn-Ta pegmatite deposits in Kariya area evolved from granitic rocks.
6. The Li-bearing pegmatites contained an average Li grade of 0.43%Li (1.204-0.001%) which is in line with several well-known Li-bearing pegmatite in the world.

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FIGURE 1