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ARTICLE

Petrographic and Mineralisation Potentials of Precambrian Pegmatities and Associated Rock Units of Olode Area, Southwestern Nigeria

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ABSTRACT

The geology of the Olode area, south-western Nigeria was investigated petrographically and geochemically in order to elucidate the mineralisation potential of the rock units in the area. The area under study is generally change to underlained by granite gneiss, mica schist and pegmatites. Petrographical studies indicated prevalence of anhedral quartz (30 - 50%), plagioclase (14 - 20%), orthoclase (12 - 15%), muscovite (11 - 15%), tourmaline (6 - 10) and other minerals (8 - 11%) for the pegmatite. The high value of SiO_2 and Al_2O_3 is consistent with the petrographical study. High values and wide range in Ba (34 - 737 ppm) and Zr (3.8 - 132.6 ppm) strongly support a mixture of igneous and sedimentary. The bivariant plots of Rb vs K/Rb, Zn vs K/Rb and Th vs K/Rb indicated a partial series of fractionation, suggesting that the pegmatites are of rare element classes while granite gneiss and mica schist belong to the barren muscovite and rare element classes. This was supported by high ratios of K/Cs and K/Ba but low Th/U values indicating distinctively low rare metal mineralization. The plot of Na_2O/Al_2O_3 vs K_2O/Al_2O_3 revealed an igneous precursor for all the rock units. The negative Eu anomalies especially in the pegmatitic rock unit indicates fractionation and point toward a late metasomatic effect and their relatively weak negative Ce anomalies, also suggest their rare metal mineralization. The pegmatites, granite gneiss and mica schist of Olode area considered as barren as all the samples plotted below the Gordiyenkos and Beus' line of mineralization.

1. Introduction

The occurrence of pegmatite in many parts of the world are of high profitable significance, pegmatites are unique rocks which are differentiated by a notable size of individual crystals, instantaneous crystallization of diverse mineral stages (Figure 1). The south-western pegmatites of Nigeria are categorized into three, namely, (1) the least mineralised category at the southern part, (2) more mineralized category at the somewhat northern part of the area and (3) most mineralized category at the extreme of the anorogenic Mesozoic granites of central Nigeria [1].

Generally, pegmatites host numerous metallic and

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non-metallic minerals that are of immense economic profit. Therefore, the increase in global order for these raw materials especially the rare metals (Ta-Nb-Sn), has led to the increased interest in the search for economically feasible deposits in Nigeria [2-5] (Figure 1). Pegmatites of rare-element class are generally categorised into three groups: LCT (Li, Cs, Ta), NYF (Nb, Y, F) and a rare mixed LCT + NYF groups [6,7].

In Nigeria, Precambrian pegmatites occur generally in the western half of Nigeria trending NNE - SSW [8]. Nevertheless, current researches such as those of Garba [9], Okunlola [10], Okunlola and Oyedokun [5], Akintola, *et al.* [11] have revealed that they also occur on a minor scale in the southeast and northeastern parts. The pegmatite bodies and associated rocks of this study area, part of Ibadan sheet 261 S.E were studied with the view of revealing their petrographic and geochemical characteristics in order to understand their genesis and rare metal mineralisation potentials. This, it is anticipated will add on to the list of data of rare metal mineralised pegmatites and associate rocks in Nigeria. Okunlola [10] previously defined the metallogeny of the Nigerian rare metal bearing pegmatites outlining seven broad fields namely; Kabba-Isanlu, Ijero-Aramoko, Keffi-Nassarawa, Lema-Ndeji, Oke-Ogun, Ibadan-Osogbo and the Kushaka-Birnin Gwari fields (Figure 1).

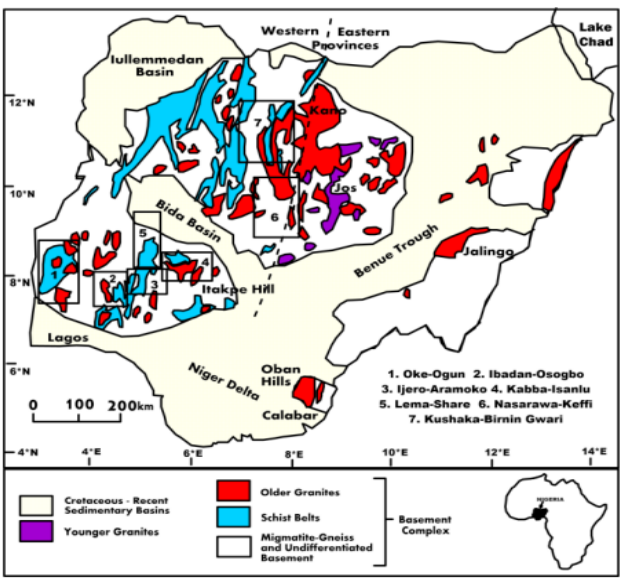

Figure 1. Geological map of Nigeria showing the different fields of pegmatite in Nigeria (modified after Okunlola [10])

2. Geological Setting

The area under investigation is within the basement complex of SW Nigeria, lying within the Pan-African belt which was formed from the impact of the passive continental margin of the West-African Craton and the active margin of the Tuareg shield during the Pan African tectonic event [12] (Figure 2).

Nigeria is underlained by Precambrian basement complex rocks that bears the relics of the Liberian (ca 2500 Ma), Eburnean (ca 2000 Ma) and Pan-African (ca 600 Ma) tectonic events; it is polycyclic and generally categorised into: migmatite gneiss complex, the schists belts and the older granite suite [13,14] (Figure 3). The Migmatite- Gneiss-Quartzite Complex: consisting of biotite and biotite hornblende gneisses, quartzites and quartz schist. Schist Belts, comprising paraschists and meta igneous rocks, which include schists, amphibolites, amphibole schists, talcose rocks, epidote rocks, marble and calc-silicate rocks. The basement rocks occupy about half of the Nigeria territory and are mainly N-S to NNE-SSW trending belts of low grade supracrustal (and minor volcanic) groups. Additional minor rocks used in delineating them are carbonates, calc-gneiss and banded iron formation (BIF) and Older granites [13,14].

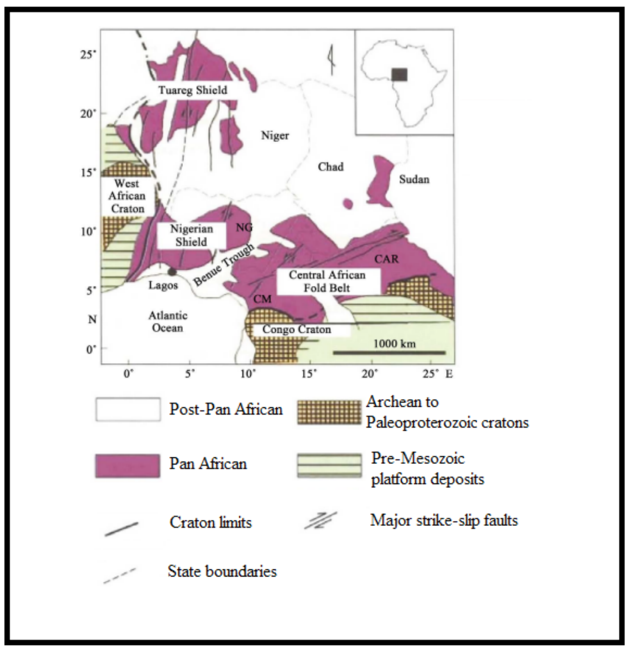

Figure 2. Sketch map of Africa showing Pan-African domains in West Central Africa. CAR: Central African Republic, CM: Cameroun, NG: Nigeria (Modified after Toteu[15])

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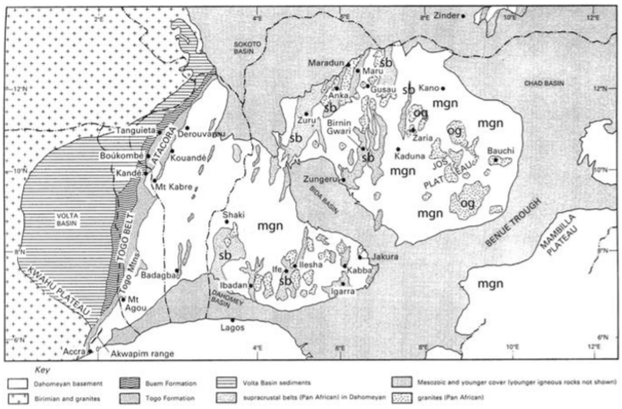

Figure 3. Map showing the basement geology of Nigeria: The Migmatite-Gneiss Complex (mgn), the Schist Belts (sb) and the Older Granites (og) (Modified after Wright[16])

3. Research Methods

The pegmatites and the associated rocks were cautiously observed during the course of mapping for their field and mineralogical distinctiveness with a view to discover those with high mineralisation potentials. Whole rock and mineral sampling was done throughout the mapping exercise. Thin-section slides were also prepared for petrographic studies. Carefully selected whole rock samples were crushed at the Thin-section laboratory of Department of Geology, University of Ibadan, Nigeria. The whole rock pegmatite samples as well as associated rock samples were analysed for major and trace elements at the Acme Analytical Laboratories Limited, Vancouver, British Columbia Canada using the Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) techniques. The procedure involves digestion of representative sample of whole rock pegmatite and associated rocks using nitric acid. About 0.5g of each sample was measured into the dry digested tube. 3-4 drops of distilled water was added to the wet sample. 5ml of HCl was added to wet the sample and the solution was stirred. 5ml of nitric/perchloric acid was added in the ratio 3:2 and stirred. The digesting tube was left overnight heating. The samples were leached out with 6ml HCl in a tube and made up to 20ml mark with distil water. To avoid caking, the content was shaken vigorously and the resulting solution is referred to as stock solution. The stock solution was used directly to determine the elements. This technique consist of sample introduction system, referred to as Nebulizer, the ICP torch, the high frequency generator, the transfer optics, the spectrometer, the interface and computer. A digested solution of the sample to be analyzed is introduced into the ICP torch as an aqueous aerosol, the light emitted by the atoms or ions in the ICP is converted to an electrical signal by a photomultiplier in the spectrometer. The intensity of this electrical signal is compared to a previously measured intensity of a known concentration of the element and the concentration value is then computed.

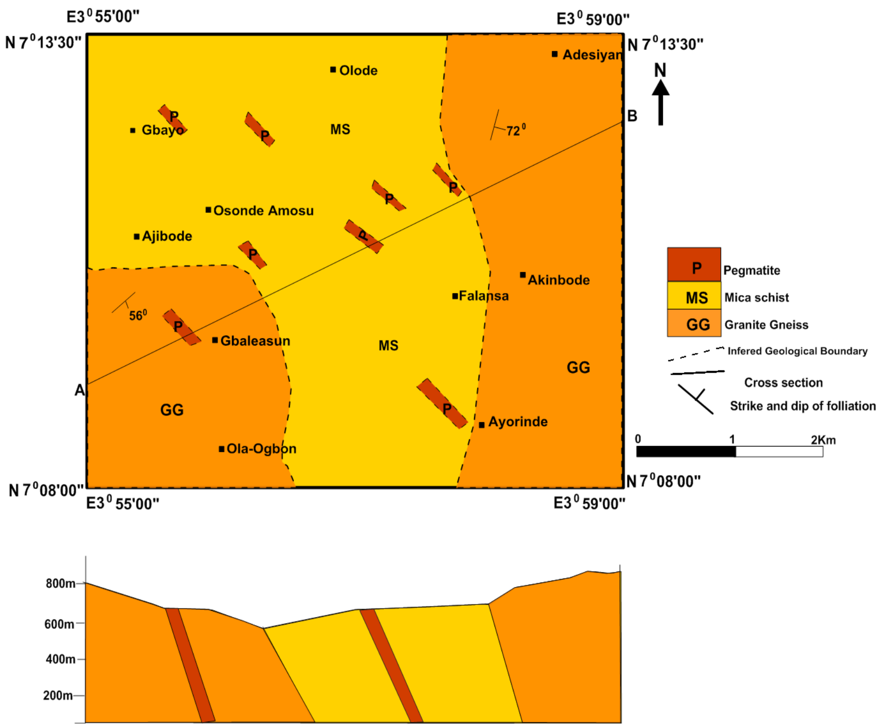

Figure 4. Geological map of the study area

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4. Results and Discussion

4.1 Field Description and Petrograpic Studies of the Rocks

The area under study is generally underlained by granite gneiss, mica schist and pegmatites at Olode, Gbayo, Moleke, and Falansa areas, and granite gneiss and quartzite around Gbaleasun, Olojuoro axis and Onipede areas (Figure 4). The pegmatite trends in NE-SW direction extending from Abeokuta to Wamba-Jemaa area in central Nigeria as reported by Jacobson and Webbs[8].

The rock types observed in this area are described below:

4.1.1 Granite Gneiss

This occurs in the northern part of Olojuoro, in close association with the quartzite. It also outcrops at the south-western portion of the study area, covering Amosu, Ajibodu and Gbaleosun (Figure 4). Characterised by a porphyritic texture with a general medium-fine grain and mineral lineation, defined by the alignment of feldspar, quartz and microcline minerals, especially on the outcrops along Olojuoro-Falansa area. Quartz veins intrude the rock body. From thin-section studies, minerals observed are quartz, microcline, and plagioclase feldspars (Figure 5: Table 1).

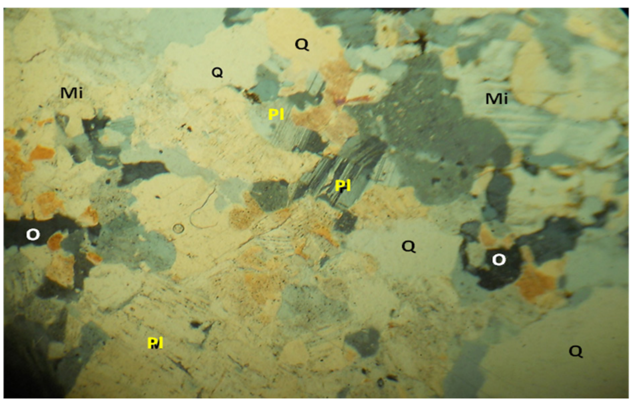


Figure 5. Photomicrograph of granite gneiss (03) in a transmitted light showing quartz(Q), microcline (Mi), plagioclase (P) and Opaque minerals (O). Mag. X40

4.1.2 Mica Schist

The schistose rocks are largely composed of biotite and feldspars, typically dark grey in colour. The schists frequently occur as layered relicts, lensoidal or pool of pods. They are exposed at uneven intervals within the enveloping pegmatitic zone in the Olode area as horizontally-dipping bodies inter-layered with the rare metal bearing pegmatite (Figure 4). From thin-section studies, minerals observed are quartz, biotite, microcline, and plagioclase feldspars. Muscovite occurs as elongated minerals and exhibits its characteristics Pleochroism (Figure 6) Quartz veins intrude the rock body.

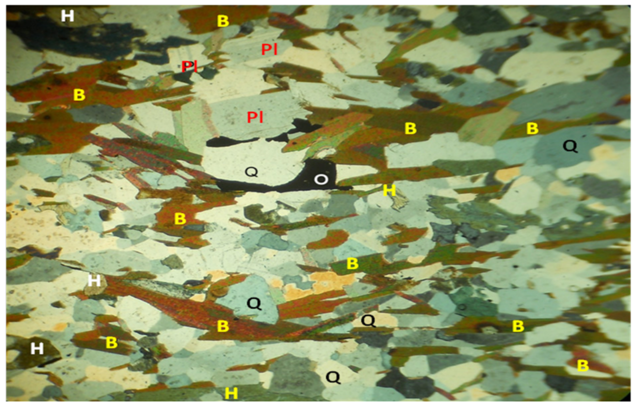


Figure 6. Photomicrograph of mica schist (05) in transmitted light showing Quartz (Q), Biotite (B) hornblende (H), plagioclase (P) and Opaque (O) minerals. Mag. X40

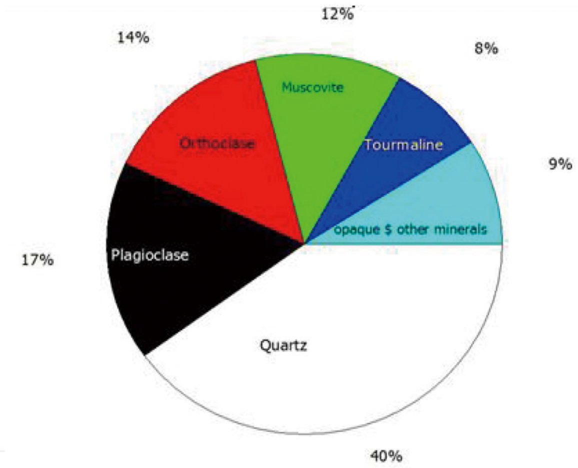
4.1.3 Pegmatite

Pegmatites in Olode area occur as intrusions in the granitic host rocks occurring as massive and tabular bodies (Figure 4). They are coarse grained (ranging from 1.7cm - 15cm) rock with a unique creamy white appearance. The main mineral assemblages are microcline, quarzt, biotite, and dull-dark specks of tourmaline (with striations on the sides) and grains of reddish-brown garnet were seen in hand specimen. The pegmatite shows zoning. Generally, four major zones can be recognised. The first (outermost) zone is composed of muscovite and feldspar with some biotite. The second zone is composed of quartz and feldspar (plagioclase) which in samples collected from Falansa show intergrowth. The third zone is composed of quartz seen to be the core of the pegmatite body and lastly, a fourth zone, which is composed of quartz, albite, tourmaline, muscovite and the gemstone beryl. muscovite composition. Dull-dark specks of tourmaline (with striations on the sides) and grains of reddish-brown garnet were seen in hand specimen.

Petrographic studies of the pegmatites indicated that they contain mainly quartz (30-50%), orthoclases (12-15%), K- feldspar (14-20%), muscovite (11-13%), tourmaline (6-10%) and opaque minerals (Figure 7, Table 1).

Table 1. Modal distribution of estimated mineral in pegmatites of Olode area

Minerals	% composition	
	Range	Average n=4
Quartz	30-50	40
Plagioclase	14-20	17
Orthoclase	12-15	14
Muscovite	11-13	12
Tourmaline	6-10	8
Others minerals (Opaque)	8-11	9



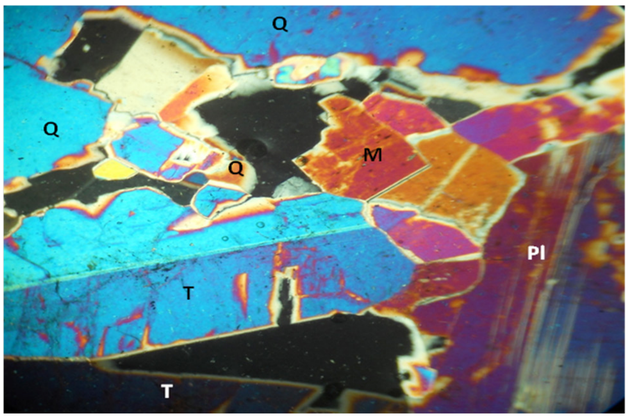


Figure 7. Photomicrograph of pegmatite (RR04) in transmitted light showing quartz (Q), plagioclase (P), muscovite (M), tourmaline (T) and opaque minerals. Mag. X40

4.2 Major, Trace and Rare Earth Element Geochemistry

The SiO_2 values for the rocks varied from 57.2% - 84.6%, with mica schist having the lowest and pegmatite with the highest. The mean percentage value is 68.89% (Table 2). The high percentage of SiO_2 in the rocks is probably due to the high concentration of aluminosilicates and silica minerals which include quartz, alkali and plagioclase feldspar (Table 2). The SiO_2 values for the whole rocks, especially, the pegmatites are higher compared to values of Ta-Nb mineralised pegmatites across Nigeria [10,17,18]. Al_2O_3 has the highest value of 19.26% in the granite gneiss and lowest value of 8.14% in the pegmatite. Although it ranges from 8.14% - 19.26%, this Al_2O_3 content is related to some alumina bearing minerals such as feldspars and micas. The sharp contrast in the values of the alumina content in the pegmatite simply confirms the complexity of the Olode pegmatites. The Fe_2O_3 concentration of the rock ranges from 0.36% - 9.2%, with mica schist having the highest due to the high concentration of ferromagnesian minerals like biotite and hornblende. Pegmatite has the lowest value. The mean values of Fe_2O_3 is15.11% (Table 2).

The MgO concentration of the rock ranges from 0.3% - 4.56%, with the average value of 1.42%, granite gneiss has the highest value while pegmatite has the lowest range value. The CaO concentration is lowest in pegmatite and highest in mica schist with the range of 0.06% - 6.46%, the mean value is 1.98% (Table 2).

Na_2O concentration ranged from 1.51% - 7.14% with mean value of 4.19%. Pegmatite has both the highest and lowest values. The high Na_2O value in the rock is due to high alkali feldspar concentrations. The abundance of K_2O can be traced to the muscovite content of the rocks. K_2O ranges from 0.91%- 6.54% with mean value of 3.38%. TiO_2 concentration ranged from 0.01% - 1.06%. The mica schist has the higher value and pegmatite have the least value. The average value of TiO_2 is 0.32% (Table 2).

P_2O_5 is observed to decrease as SiO_2 content of the various rocks decrease. P_2O_5 varied from 0.03% - 0.4%, while mica schist has the highest range and granite gneiss have the least. MnO values are also generally low. It ranges from 0.01% - 0.28% with the pegmatite having the highest value and lowest range is for granite gneiss. This is however expected because in magma differentiation, Fe^{2+} substitutes for Mn^{2+}. Cr_2O_3 concentration ranges from 0.00% - 0.03% with mean value of 0.02% (Table 2).

Trace and rare earth element data presented in Tables 3 and 5 showed that the rock units of Olode area

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Table 2. Major oxides concentration in rocks samples of Olode area

Sample Number →	RR01	RR02	RR03	RR04	RR05	RR06	RR07	RR08	RR09	RR10
Rock Types →	Pegmatite				Mica schist			Granite gneiss		
Unit →	%	%	%	%	%	%	%	%	%	%
Oxides ↓										
SiO_2	76.68	84.6	69.54	73.51	58.61	57.20	58.91	66.46	72.29	71.10
Al_2O_3	13.46	8.14	16.99	15.59	14.82	16.75	14.85	19.26	15.27	15.95
Fe_2O_3	0.55	0.36	0.65	0.49	9.18	9.20	8.48	0.64	0.77	1.01
Mgo	0.06	0.03	0.11	0.06	4.54	3.74	4.43	0.11	0.06	1.01
CaO	0.39	0.06	0.41	0.38	4.81	5.12	6.46	0.49	0.44	1.2
Na_2O	4.9	1.51	4.52	7.14	2.85	3.14	3.13	5.59	4.59	4.50
K_2O	2.78	4.21	6.54	0.91	2.12	1.86	1.14	4.88	5.36	4.03
TiO_2	0.01	0.01	0.01	0.02	1.06	0.87	0.88	0.05	0.09	0.16
P_2O_5	0.09	0.05	0.28	0.38	0.30	0.40	0.26	0.05	0.03	0.04
MnO	0.07	0.03	0.03	0.28	0.12	0.09	0.15	0.01	0.07	0.01
Cr_2O_3	0.003	<0.002	<0.002	<0.002	0.019	0.034	<0.002	<0.002	<0.002	<0.002

Table 3. Trace Elements Composition (ppm) of rock unit in Olode Area

Elements	Pegmatite				Granite gneiss			Mica schist		
	1	2	3	4	5	6	7	8	9	10
Ni	<20	<20	<20	<20	<20	<20	<20	61	69	46
Sc	<1	<1	<1	<1	2	3	1	31	27	24
Ba	34	79	95	34	308	594	737	437	412	209
Be	9	63	4	119	3	3	6	<1	<1	<1
Co	3.2	1.5	1.8	1.8	1.9	1.6	3.7	33.6	22.7	24.9
Cs	4	18.2	24.2	13.6	0.7	0.5	6.9	36.2	52.1	16.3
Ga	14.2	9.6	18.8	20.6	20.7	16	17.1	16.2	18.6	16.1
Nb	5.9	11	11.1	141.1	12.4	11.2	5.9	7.6	4.4	6.8
Rb	134.2	337.6	502.9	105.5	95.5	74.1	131.2	69	199.8	34.8
Sn	6	4	4	3	2	3	2	3	1	2
Sr	7.6	43.7	55.3	27.3	44.6	46.4	864.7	222.3	685.8	213.5
V	16	18	16	21	15	17	31	170	193	173
Zr	95.60	3.80	19.7	44.1	24.30	63.00	72.7	180	132.6	83.5
Y	4.7	0.4	0.7	1.2	28.9	38.1	1.7	24	26.1	20.5
Mo	0.1	<0.1	60.1	0.3	<0.1	<0.1	<0.1	0.1	<0.1	3.4
Cu	1.9	2.1	4.5	2.7	6.1	3	49.8	122.1	95.6	12.2
Zn	1	<1	1	18	32	38	42	72	63	35
Au	5.8	2	19.3	<0.5	1.5	2.7	1.1	1.7	2.6	4.7
Hf	4.7	0.2	1.7	3.6	0.8	3.4	2.4	4.1	3.9	2.1
Ta	1.4	4.6	7.1	162.4	1.1	1.3	1.6	0.8	0.6	2.3
Th	1.7	1.4	1.9	7	7.8	7.3	3.7	2.1	1	0.7
U	5.5	0.7	1.9	7	0.9	1.8	3.7	2.3	1	0.7
W	2.2	5	1.2	1.4	<0.5	<0.5	<0.5	0.8	<0.5	0.5
Na	36,351	11,202	33,532	53,909	21,143	23,294	23,220	41,470	34,051	33,384
K	23,078	34,949	54,292	7554	17,599	15,441	9464	40,511	44,496	33,455
Fe	3847	2518	4546	3427	64205	64345	59309	4476	5385	7064
Mn	542	232	232	2169	929	697	1162	77	542	77

are relatively low in rare metals; Ce (0.6 - 4.4 ppm; 7.3 - 26.7 ppm; 32 - 40.1 ppm), Nb (5.9-141.10 ppm; 5.9 - 12.4 ppm; 4.4 - 6.6 ppm), Sn (3 - 6 ppm; 2 - 3 ppm; 1 - 3 ppm), Rb (105.50 - 502.9 ppm; 74.1 - 131.20 ppm; 34.80 - 199.80 ppm) and Ta (1.40 - 162.40 ppm; 1.1 - 1.6 ppm; 0.80 - 2.30 ppm), for the pegmatite, granite gneiss and mica scist repectively. The Sn, Ta and Nb values are very low compared with those of the richer Nasarawa-Keffi, Kushaka Ta-Nb fields of Nigeria, granitic pegmatites of Komu area, pegmatite and associated lithologies of Igbeti area, Pegmatities of Awo Area, within Southwestern, Nigeria respectively [5,10,19].

The high values of incompatible elements notably Ba and Zr and the wide range of variations in the trace element content, especially those of Ba (34 - 737 ppm) with the mean of 293.9 ppm and Zr (3.8 - 132.6 ppm) with the mean of 64.62 ppm strongly support a mixture of igneous and sedimentary (Table 3). Ba has the utmost partition coefficients for alkali feldspar and biotite compared to other major components in granitic rocks since both are impoverished in Ca- bearing plagioclase [20].

The elemental ratios of Rb/Sr and K/Rb values (Table 4) are relatively high in contrast with the majority of the other rare metal pegmatites of Nigeria [21]. This value propose and signify an early phase of progressive fractionational crystallisation and likely mineralization [22]. The obtained high ratios of K/Cs and K/Ba but low Th/U values indicate a distinctively low rare metal mineralization [9] (Table 4).

The Rb values plotted against K/Rb ratios for the rep-

Table 4. Ratios of selected trace elements of different rock units from Olode area

Elements	Pegmatite				Granite gneiss			Mica schist		
	1	2	3	4	5	6	7	8	9	10
Th/U	0.31	2.00	1.00	1.00	8.67	4.06	1.00	0.90	1.00	1.00
Ta/W	0.64	0.92	5.92	116.00	2.20	2.60	3.20	2.63	1.20	4.60
Rb/Sr	17.66	7.73	9.09	3.86	2.14	1.60	0.15	0.31	0.03	0.16
Ba/Rb	0.25	0.23	0.19	0.32	3.23	8.02	5.62	6.52	2.06	6.01
Zr/Hf	20.34	19.00	11.59	12.25	30.38	18.53	30.29	43.90	49.49	39.76
Sr/Rb	0.06	0.13	0.11	0.26	0.47	0.63	6.59	3.22	3.43	6.14
Rb/Cs	33.55	18.55	20.78	7.76	136.43	148.20	19.01	1.91	3.83	2.13
Rb/Ce	30.50	562.67	386.85	95.91	5.22	2.78	17.97	1.72	6.24	1.29
K/Ba	678.76	442.39	571.49	222.18	57.14	25.99	12.84	92.70	108.00	160.07
K/Rb	171.97	103.52	107.96	71.60	184.28	208.38	73.13	587.12	222.70	961.35
K/Cs	5769.50	1920.27	2243.47	555.44	25141.43	30882.00	1371.60	1119.10	854.05	2052.45
K/Ce	5245	58248	41763.08	6295	2146.22	1544.10	2253.33	2665.20	3111.60	2742.21
K/Nb	3911.53	5923.58	4891.17	53.54	1419.27	1378.66	1604.07	5330.39	10112.73	5146.92
Ta/Nb	0.24	0.42	0.64	1.15	0.09	0.12	0.27	0.11	0.14	0.34
Ta/(Ta+Nb)	0.19	0.29	0.39	0.54	0.08	0.1	0.21	0.10	0.12	0.25
Na/K	1.58	0.32	0.62	7.14	1.20	1.50	2.45	1.02	0.77	1.00
Zr/Sn	15.93	0.95	4.93	14.70	12.15	21.00	36.35	60.00	132.6	41.75
Y/Nb	10.60	11.40	11.80	142.3	41.30	49.30	7.60	31.60	30.50	27.30
Mn/(Mn+Fe)	0.12	0.08	0.05	0.39	0.01	0.01	0.02	0.02	0.09	0.01
K_2O/Na_2O	0.57	2.79	1.45	0.13	0.74	0.59	0.36	0.87	1.17	0.90
K_2O/Al_2O_3	0.21	0.52	0.38	0.06	0.14	0.11	0.08	0.25	0.35	0.25
Na_2O/Al_2O_3	0.36	0.19	0.27	0.46	0.19	0.19	0.21	0.29	0.30	0.28
A/CNK	1.75	1.41	1.48	1.85	1.52	1.51	1.38	1.76	1.47	1.64

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resented Olode rock units (Table 4: Figure 8a) showed an observed wide dispersal of data with a general negative correlation flanked by the two fractionation marker. The pegmatites plot in the fields corresponding to non-mineralized muscovite and mineralized rare element classes while the granite gneiss and mica schist plot within the non-mineralised musovite class [23] (Figure 8a). The line that separates mineralized from non mineralized muscovite pegmatites and other rock units of Olode is at the K/Rb ratio of about 100 [24].

The binary plot of Zn values with K/Rb ratios revealed a wide scattered data with a negative correlation linking the two markers (Table 4; Figure 8b). The pegmatites plot in mineralized rare element classes with one sample of granite gneiss while the mica schist and the remaining granite gneiss plot in the field of non-mineralized musco-

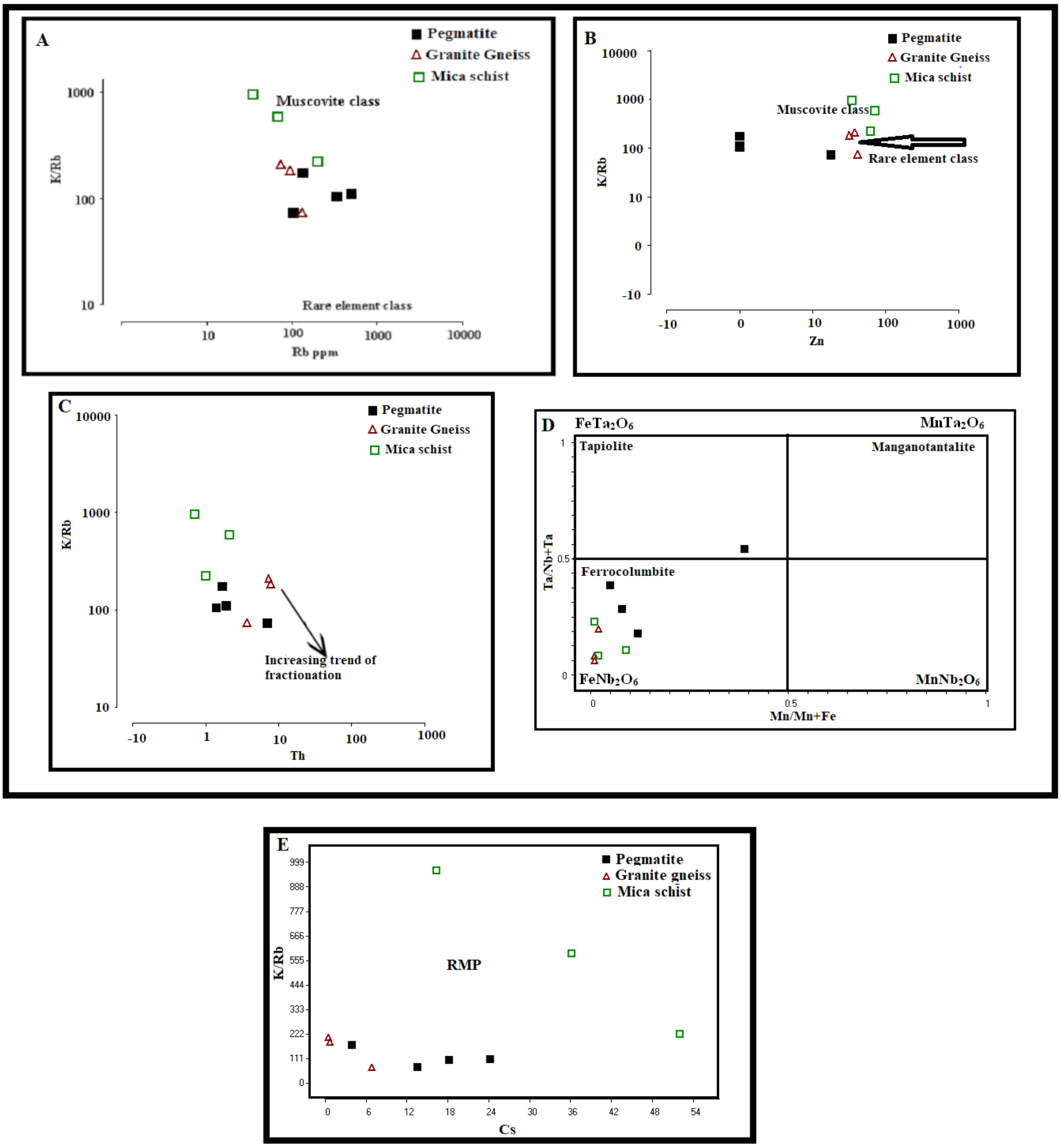

Figure 8. Plot of A: Rb vs K/Rb, B: Zn vs K/Rb, C: Th vs K/Rb, D: Tantalite-columbite quadrilateral diagram and E: K/Rb vs Cs for Olode pegmatite and its associated rock units (Field of muscovite and pegmatites rare element classes; after Cerny and Burt [23])

vite.

The plot of Th vs K/Rb ratios (Figure 8c) revealed an approximately consistent range of values for Th despite the values of K/Rb. It has been shown that there is a progressive depletion of Th during crystallization of the felsic magma [25,26]. The relatively fewer number of representative samples prevent definite conclusion to be made from this discrimination diagram.

Subsequent to the categorization criteria of pegmatites based on bulk chemistry signatures [25,26] and plot of Ta/(Ta+Nb) Vs Mn/(Mn+Fe) (Figure 8d), suggest that the Olode pegmatites are of the rare element class, complex pegmatite, probable of the LCT petrogenetic family (Li, Rb, Cs, Be, Ga, Sn, Ta) and plot mainly in the field of ferro-columbite group. This diagram expresses changes in chemical evolution of pegmatite during crystallization from magmatic melt. The pegmatites are of per aluminous bulk composition (A/CNK>1; Table 4) (where A: Al_2O_3, CNK: CaO+ Na_2O+K_2O). Cerny [27] opined that the LCT family has a mild to exceptionally per aluminous granitic precusor composition. From the plot of K/Rb vs Cs, the pegmatites and granite gneiss in the study area are rare metal bearing because all the pegmatites and granite gneiss samples plot within the field of rare metal pegmatite "RMP" (Figure 8e).

The low values of Ti, Ba and Zr (Table 4) with relatively high Rb, and Cs (but low Cs in the granite gneiss) composition signify high fractionation of the pegmatites, although the somewhat high Cs values of the Olode pegmatites show moderately high alkali metal fractionation (Cerny, 1989). The Olode pegmatite samples are relatively higher in Ta composition than in the granite gneiss and mica schist showing that the pegmatites in Olode area are tantalite rich (Table 4).

Overall petrochemical trends and variations point to the fact that the Olode granite evolved from a relatively poorly fractionated magma, possibly derived from a source rich in Zr, Sr, Rb and Ba, but comparatively depleted in Ta

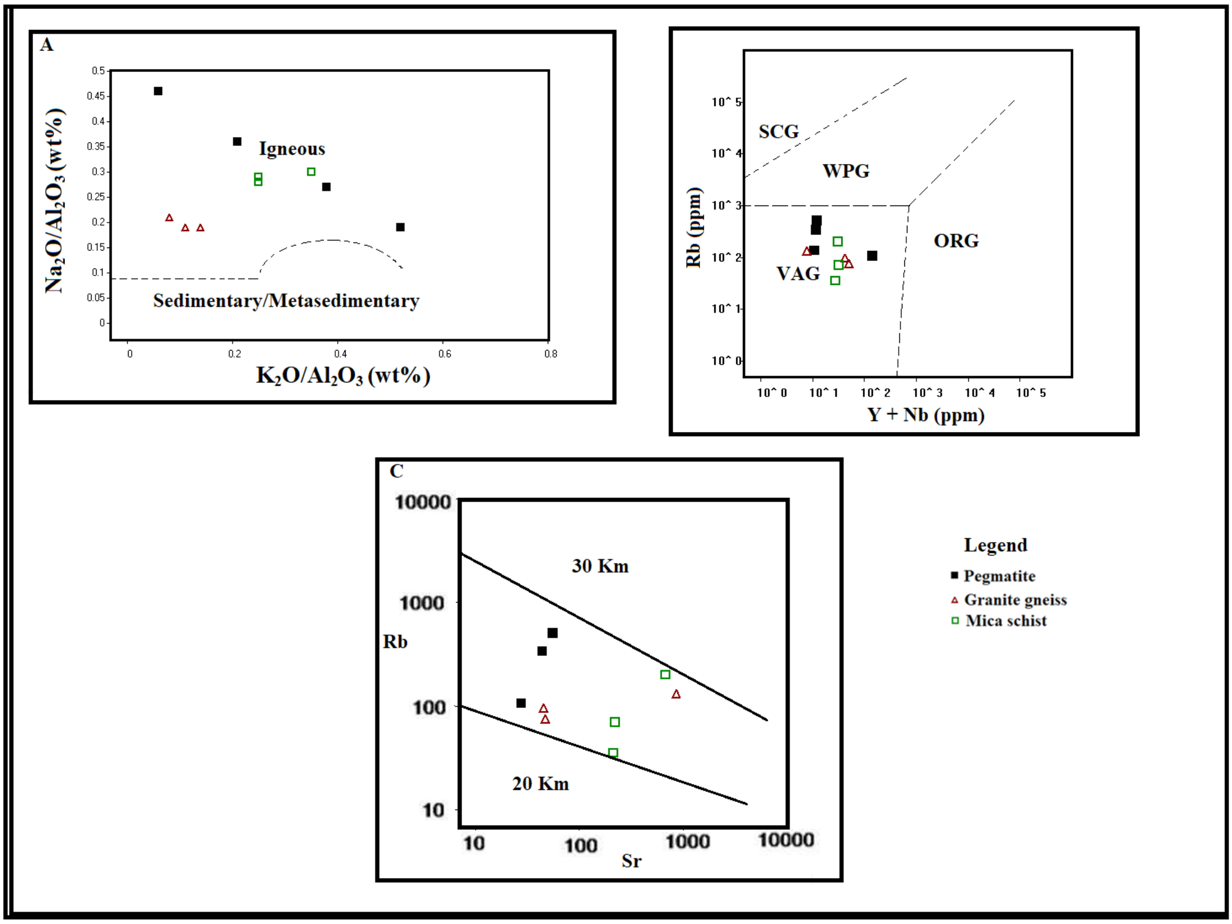

Figure 9. Plots of A: Na_2O/Al_2O_3 vs K_2O/Al_2O_3 showing variation diagram for the Field of Igneous and Meta sedimentary rocks (After Garrels and Mackenzie [29]); B: Rb vs (Y+Nb) discriminant diagram: Rb vs Sr for the pegmatites and associated rock units of Olode area

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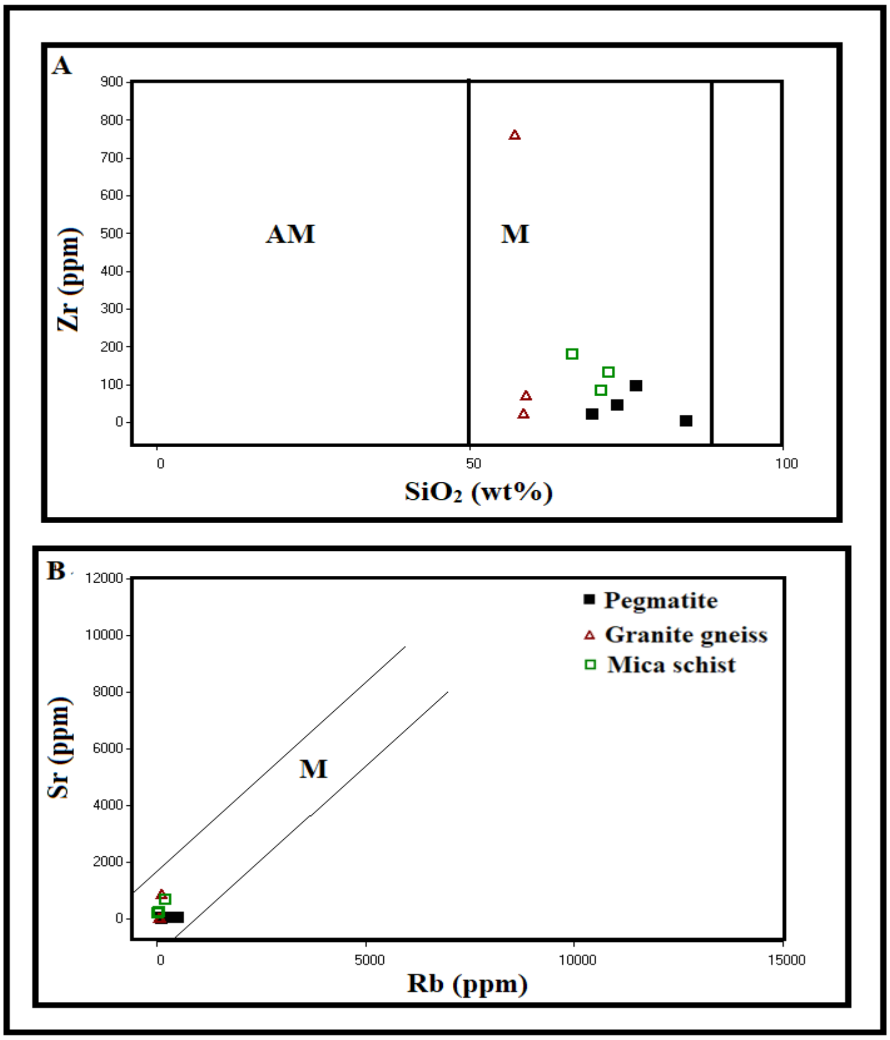

Figure 10. Plots of A: Zr vs SiO_2 and B: Sr against Rb for the pegmatites and associated rock units from Olode area

and Nb. Post-magmatic processes may have affected the body [28]. This is possibly evident in the enrichments in Ba and Sr.

The plot of Na_2O/Al_2O_3 vs K_2O/Al_2O_3 revealed an igneous precursor for the pegmatite which plot in the granite-igneous field of Garrells and Mackenzie [29] (Figure 9A), hence signifying and suggestive of a granitic-igneous precusor for the Olode rock units. All the sampled rock units plot in the field of volcanic arc granites (VAG) on the Rb vs Y+Nb diagram (Figure 9B) while Rb vs Sr bivariant plot of Condi [30], crustal thickness during emplacement of these pegmatite and the associated rock units reached about 30km (Figure 9C).

The plots of Zr vs SiO_2 (Figure 10a) and Sr vs Rb (Figure 10b) revealed a homogeneous setting with all the samples plotting in the magmatic “M” field, thus signifying Olode pegmatites and the associated rocks to be a basement with supracrustal protoliths of homogenous chemistry in nature.

In the rock units of Olode area; Rare earth elements (REE) composition as presented in Table 5 indicated a chondrite normalised plot (Figure 11) which shows a relatively high light rare earth elements (LREE; La, Ce, Pr) values and relatively lower heavy rare earth elements (HREE; Er, Lu, Yb) values in the granite gneiss and mica schist than the pegmatitic rock unit. There is a negative Europium (Eu) anomaly especially in the pegmatitic rock unit of Olode. This according to Taylor *et al.* [31] proposed fractionation and point toward a late metasomatic effect. The observed relatively weak negative Ce anomaly in Olode rock units, most especially in the pegmatitic rock unit (Figure 11) may also suggest their rare metal mineralization.

Taylor [32] proposed earlier that where there is an ob-

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Table 5. Rare Earth Elements Composition (ppm) of rock unit in Olode Area

Rock units→ Elements↓	Pegmatite				Granite gneiss			Mica schist		
	1	2	3	4	5	6	7	8	9	10
La	1	0.4	0.9	1.2	8.2	10	4.2	15.2	14.3	12.2
Ce	4.4	0.6	1.3	1.1	18.3	26.7	7.3	40.1	32	26.9
Pr	0.36	0.08	0.16	0.16	2.78	3.44	0.74	4.94	4.18	3.19
Nd	2.2	<0.3	1.1	0.9	10.6	12.2	3.5	21.9	17.6	14.3
Sm	0.59	0.15	0.12	0.21	3.32	4.35	0.52	4.67	4.11	2.84
Eu	0.1	0.11	0.15	0.16	0.1	0.98	0.38	1.47	1.27	1.36
Gd	0.52	<0.05	0.19	0.06	3.81	4.54	0.56	5.14	4.36	3.42
Tb	0.16	0.03	0.04	0.06	0.79	0.91	0.09	0.78	0.74	0.62
Dy	1.03	0.18	0.08	0.33	5.68	6.24	0.54	4.75	5.16	3.17
Ho	0.15	0.03	0.03	0.05	0.94	1.22	0.1	1.05	1	0.71
Er	0.23	0.04	0.07	0.25	2.51	4.12	0.22	2.45	3.18	1.95
Tm	0.1	0.02	0.02	0.03	0.36	0.6	0.04	0.42	0.42	0.37
Yb	0.99	0.1	0.12	0.35	2.37	4.25	0.3	2.57	3.15	2.29
Lu	0.16	<0.01	0.03	0.04	0.32	0.57	0.05	0.36	0.48	0.3
Pb	2.1	0.9	1.4	2	4.5	2.8	10.7	1.9	0.9	0.9
Li	2.2	0.4	0.5	7.5	0.1	0.1	0.2	0.4	3.2	0.4
Ti	0.01	0.01	0.01	0.01	0.01	0.01	0.2	0.3	1.2	0.2

served weak negative Cerium anomalies and a strong negative Eu anomaly as obtained mostly in pegmatite samples of Olode (Figure 11) it is an indication of significant fractionation and metasomatism. In addition, Piper [33] and Garba [9] considered that Negative Ce anomalies of rare metal pegmatites and rocks of igneous origin is an indication of oxidising state during mineralisation and interface between magmatic-melt fluids and host rocks over long distances at times.

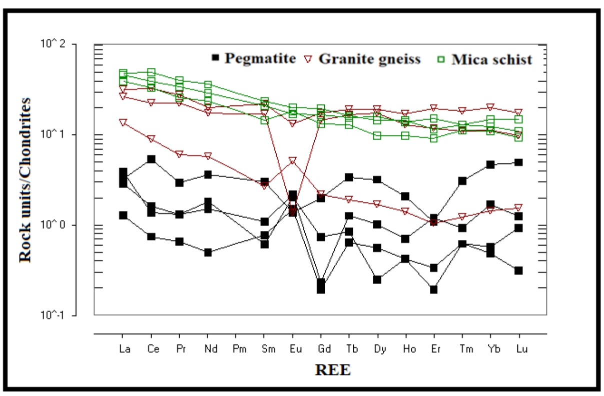

Figure 11. Chondrite normalized plots of Olode rock units

4.3 Mineralization Potential of the Olode Pegmatites and Its Associated Rock Units

Economic mineralization of the pegmatites, granite gneiss and mica schist were evaluated using variation plots Ta vs. Ga (Figure 12A), Ta vs. Cs + Rb (Figure 12B), Ta vs. K/Cs (Figure 14C) and Ta vs. Cs (Figure 12B). On the plots, samples below the Bleus (1996) and Gordiyenkos (1971) line of mineralization are regarded as barren while those plotted above are considered mineralized. From the plots, the pegmatites, granite gneiss and mica schist of Olode area considered as barren as all the samples plotted below the Gordiyenkos line of mineralization.

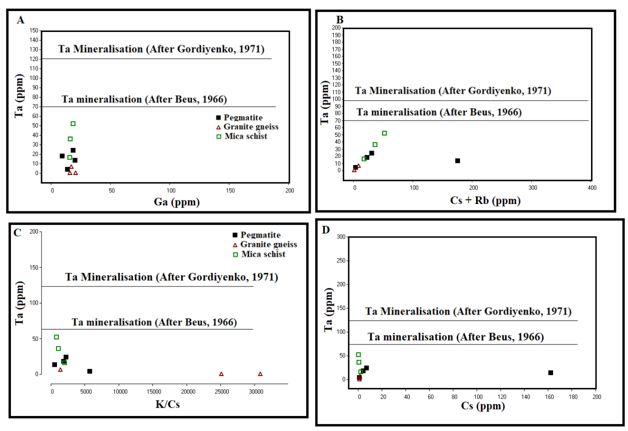

Figure 12. Plot of A) Ta vs Ga, B) Ta vs (Cs+Rb), C) Ta vs K/Cs and D) Ta vs Cs for the Olode rock units (After Gordinyenko, 1971 and Beus, 1966).

5. Conclusions

The Olode area under study which is majorly Underlained

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by granite gneiss and mica schist was intruded by low lying NNW-SSE trending pegmatites. Petrographic results indicated high quartz (30 - 50%), plagioclase (14 - 20%), orthoclase (12 - 15%), muscovite (11 - 15%), tourmaline (6 - 10) and other minerals (8 - 11%) for the pegmatite. The high percentage of SiO_2 and Al_2O_3 in all the rock units studied is consistent with the petrographic study. The high values and the wide range of variations in the trace element content, especially those of Ba (34 - 737 ppm) with the mean of 293.9 ppm and Zr (3.8 - 132.6 ppm) with the mean of 64.62 ppm strongly revealed a mixture of igneous and sedimentary. The bivariant plots of Rb vs K/Rb, Zn vs K/Rb and Th vs K/Rb indicated a partial series of fractionation, indicating that the pegmatites belong to the rare element classes while the granite and mica schist rock units belong to the barren muscovite and rare element classes. The elemental ratios of Rb/Sr and K/Rb values signify an early phase of progressive fractionational crystallisation and likely mineralization. This was supported by the high ratios of K/Cs and K/Ba but low Th/U values indicating a distinctively low rare metal mineralization. The plot of Na_2O/Al_2O_3 vs K_2O/Al_2O_3 revealed an igneous precursor for the pegmatite which plot in the granite-igneous field of Garrells and Mackenzie. The negative Europium (Eu) anomaly especially in the pegmatitic rock unit indicates fractionation and point towards a late metasomatic effect and the relatively weak negative Ce anomaly probably indicates their rare metal mineralization. The pegmatites, granite gneiss and mica schist of Olode area are thereby considered barren as all the samples plotted below the Gordiyenkos and Beus line of mineralization.

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