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RESEARCH ARTICLE

COMPOSITIONAL TRENDS AND RARE - METAL (Ta-Nb) MINERALIZATION POTENTIAL OF PRECAMBRIAN PEGMATITES IN KOMU AREA, SOUTH WESTERN NIGERIA

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ABSTRACT

Petrographic and geochemical evaluation of pegmatite bodies occurring as discontinuous dykes have been studied in Komu area of southwestern Nigeria, with a view to determine the compositional characteristics that may be related to Ta-Nb mineralization potentials. They are found intruding semi discordantly, the older assemblages of granite gneiss, amphibolites and semi pelitic schist. These Precambrian pegmatites bodies are usually coarse grained in texture. Thin section study reveals that they contain mainly quartz, muscovite mica, plagioclase (albite), microcline as the main minerals while tourmaline and beryl occur in subordinate amounts. Opaque minerals, mainly ilmenite, magnetite and tantalite are of accessory constituents. A total of thirty samples comprising whole rock pegmatites and mineral extract of muscovite mica were analyzed for major, trace and rare earth elements using Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) geochemical method which show the pegmatite samples to be generally highly siliceous with Sio_2 values ranging from (46.14-76.71%) with an average of 62.47% in the whole rock samples, and it also ranges from (45.28-57.50%) with an average of 48.34% in the muscovite extract samples. while Al_2 O_3 content could be as high as 30.72% in the muscovite extract samples and 21.06% in the whole rock samples depicting the complexity of the pegmatite rock. However, Fe_2O_3, TiO_2, and P_2O_5 contents are generally low (less than 5%). The samples are fairly enriched in Rb, Ba, Sr, Zr and the rare metals Ta, Li, and Nb. Albitization is indicated by Na/K ratio which are greater than (1.0) in most of the samples and Ti-Sn-Nb-Ta discriminate plot. Variation plots of K/Rb versus Rb, Ta versus Rb, Ta versus Nb, Ta versus K/Cs, Ta versus Cs+Rb and Ta versus Cs discriminant plot indicate the potentials of rare metal mineralization. On most of these diagrams, the samples plot close to those of Tanco deposits which are known to contain appreciable levels of Ta-mineralizaton, it also compares favourably with the pegmatite samples of Noumas, Central claims, Silver leaf and Odd west deposits which are known to contain fairly low level of Ta mineralization endowments.

INTRODUCTION

The Komu study area which lies between longitude 3° 00'E to 3° 05'E and latitude 8° 15'N to 8° 25'N was studied as a result of recent increase in global demand for rare-metal pegmatites due to their ability to host many metallic, non-metallic or industrial minerals and gem mineralization, especially, those that are of immense economic importance. (Garba, 2003., Okunlola and Ogedengbe, 2003., Akintola, 2004., Okunlola, 2005., Okunlola and Akintola, 2007., Okunlola and Akintola, 2008). Rare metal pegmatite occurrences in Komu area of southwestern Nigeria (Fig.1) are among the numerous bodies emplaced towards the end of the Pan African magmatism within the region from the Jos plateau Central Nigeria to Abeokuta area, southwestern Nigeria. (Jacobson and Webb, 1946; Kuster, 1990; Wright, 1970; Matheis and Caen Vachette, 1983; Okunlola and King, 2003).

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Ta-Nb pegmatite occurrences were also recently outlined into seven broad fields by Okunlola, (2005) to include Kabba - Isanlu, ljero - Aramoko, Keffi- Nasarrawa, Lema -Ndeji, Oke Ogun, Ibadan -Osogbo and Kushaka - B/Gwari. The present study area is within the Oke-Ogun field. In this study, attempts are made to evaluate the compositional trends in pegmatites of Komu area with respect to Ta-Nb mineralization. This entailed systematic geological mapping of the study area and examination of thin sections of whole rock pegmatite sample.
Geochemical analysis of the whole rock and muscovite samples extracted from the pegmatite samples for both major and trace element concentration was done using ICP-AES instrumentation method at Actlabs Ontario, Canada. It involves addition of 5ml of Perchloric acid (HClO4), Trioxonitrate (V) $HN0_3$ and 15ml Hydrofluoric acid (Hf) to 0.5gm of sample. The solution was stirred properly and allowed to evaporate to dryness after it was

warmed at a low temperature for some hours. 4ml hydrochloric acid (HCl) was then added to the cooled solution

Table 1: Average modal composition (%) of minerals in Komu pegmatites

Minerals	P3 (%)	P4 (%)
Microcline (M)	65	60
Quartz (Q)	25	10
Plagioclase (PL)	-	20
Tourmaline (T)	-	-
Biotite (B)	5	-
Muscovite (MU)	-	5
Garnet (G)	-	-
Accessories (A)	5	5

P3-P4 Represent Photomicrographs of Pegmatites from Komu study area

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. They are mainly N-S to NNE-SSW trending belts of low grade supracrustal (and minor volcanic) assemblages. Other secondary rocks used in delineating them are carbonates, calc gneiss and banded iron formation (BIF) and Older granites, which include granite, granodiorite, diorite charnockite, pegmatites and aplites.

FIELD DESCRIPTION AND PETROGRAPHY

The Komu study area is underlain by granite gneiss, amphibolites, pelitic schist and pegmatite, which occur as low lying intrusions into the older rocks (Fig.2).

Table 2: Major element oxide composition of Komu Pegmatites (Wt %)

Oxides	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	64.36	69.4	76.71	67.46	70.51	64.48	53.18	60.15	67.09	71.4	46.41	60.17	57.84	64.81
Al_2O_3	19.27	16.14	11.92	17.56	18.9	17.46	29.49	20.68	18.37	16.97	29.75	22.78	23.56	18.66
Fe_2O_3	0.62	0.79	1.53	2.06	2.64	0.63	2.82	7.96	4.76	3.66	10.12	5.66	0.47	4.05
MnO	0.023	0.578	0.428	1.355	0.53	0.749	1.413	2.31	1.14	0.39	0.28	0.13	0.27	2.02
MgO	0.02	0.06	0.05	0.02	<0.01	0.1	0.04	0.67	0.14	0.15	3.19	1.16	0.11	0.42
CaO	0.04	0.08	0.1	0.51	0.43	0.25	0.3	0.64	0.29	0.5	0.22	0.41	0.12	0.75
Na_2O	3.1	1	2.23	8.93	0.16	3.47	4.83	4.87	5.74	5.26	1.5	6.68	1.78	7.61
K_2O	11.28	6.71	3.54	0.18	0.11	4.11	0.16	0.3	0.22	0.18	4.33	1.41	7.95	0.62
TiO_2	0.016	0.028	0.018	0.015	1.096	0.031	0.031	0.117	0.066	0.063	0.82	0.23	0.02	0.14
P_2O_5	0.09	0.03	0.05	0.09	0.02	0.15	0.04	0.06	0.12	0.11	0.03	0.09	0.05	0.48
LOI	0.78	2.63	1.85	0.09	0.52	2.64	2.19	0.67	0.52	0.58	3.1	0.9	4.1	0.3
Total	99.59	97.46	98.44	98.27	94.96	94.05	94.51	98.43	98.45	99.27	99.52	99.62	96.27	99.87

Oxides	16	17	18	19	20	21	22	23	24	25	26	27	28	29
SiO_2	59.41	46.32	64.23	74.79	55.84	46.95	45.43	57.5	45.28	46.14	45.66	48.99	46.74	46.2
Al_2O_3	23.02	29.56	21.32	15.08	24.93	29.41	33.97	23.12	34.25	32.77	33.55	27.99	32.59	34.16
Fe_2O_3	6.16	10.26	2.26	2.54	3.28	5.83	3.77	0.28	3.58	3.55	3.68	5.67	3.36	3.37
MnO	0.13	0.28	0.04	0.06	0.22	0.16	0.1	0.26	0.09	0.09	0.09	0.16	0.11	0.17
MgO	1.26	3.16	0.45	0.25	0.7	1.4	0.11	0.06	0.23	0.28	0.1	1.33	0.24	0.09
CaO	0.39	0.22	0.29	0.22	0.12	0.02	0.01	0.04	<0.01	<0.01	<0.01	0.03	0.03	0.01
Na_2O	6.39	1.49	9.92	5.43	3.66	0.38	0.77	0.94	0.68	0.63	0.74	0.36	1.45	0.69
K_2O	1.32	4.36	0.55	0.64	5.82	9.68	10.16	9.27	10.34	10.17	10.71	9.26	9.33	10.36
TiO_2	0.24	0.83	0.1	0.09	0.14	1.23	0.36	0.03	0.1	0.14	0.35	1.26	0.36	0.17
P_2O_5	0.08	0.03	0.06	0.05	0.04	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LOI	1.1	2.9	0.6	0.05	0.04	4.6	5.2	4.9	5.4	6.1	5.5	4.6	5.7	4.7
Total	99.56	99.5	99.84	99.67	97.59	99.71	99.89	96.45	99.91	99.92	99.9	99.69	99.9	99.9

The numbers **1, 2, 3,…30** represent sample numbers. 1-20: Whole rock Pegmatite samples from Komu 21-30: Muscovite extracts from Komu Pegmatites.

and warmed to dissolve the salts. The solution was cooled; and then diluted to 50ml with distilled water. The solution is then introduced into the ICP torch as aqueous - aerosol. The emitted light by the ions in the ICP was converted to an electrical signal by a photo multiplier in the spectrometer, the intensity of the electrical signal produced by emitted light from the ions were compared to a standard (a previously measured intensity of a known concentration of the elements) and the concentration then computed.

REGIONAL GEOLOGICAL SETTING

Nigeria is underlain by Precambrian basement complex rocks, younger granites of Jurassic age and Cretaceous to Recent sediments. The basement rocks occupy about half of the land mass of the country, and is a part of the Pan-African mobile belt lying between the West African and Congo cratons (Elueze,2000). There are however contrasting documentation of the evolution of the basement rocks. However loosely, the basement is grouped into three major groups lithostratigraphically viz: the Migmatite-Gneiss-Quartzite-Complex: comprising biotite and biotite hornblende gneisses,

The *granite gneisses* are predominant in the study area and are mainly composed of biotite, quartz and hornblende. While the *amphibolites* occur as scattered lensoid bodies, they are mostly dark greenish rocks comprising hornblende, quartz and plagioclase. The *pelitic schistose* rocks are mainly composed of biotite and feldspars. Most of the outcrops which are weathered are restricted to the northern portion of the study area and because of their susceptibility to weathering; the areas underlain by these rocks in the fields are generally flat lying sometimes poorly exposed. Prominent exposures are sometimes limited to river streams and channels in this study area. The *pegmatites* trend mainly in the NNW-SSE direction. They occur as coarse grained rocks and is widely distributed occurring as veins intruding the amphibolites and gneisses. Some of the veins extend up to 500m in length and 50m width. The contact between the pegmatite intrusions and the host rock is usually gradational. Microscopic studies of the pegmatites reveal a mineral assemblage of mainly microcline, quartz, plagioclase, tourmaline, biotite and muscovite with accessory opaque minerals mainly ilmenorutiles, tantalocolumbite and garnet (Table 1).

Quartz: which has a low positive relief is well distributed and next in abundance to microcline; it occurs as anhedal grains.

Plagioclase: displays characteristic Carlsbad or albite twinning.

Biotite: occurs as dark brown platy minerals.

Table 3: Trace and Rare earth element data of Komu Pegmatites (ppm)

Elements	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ta	11.1	236	47.2	118	500	220	500	53.6	145	46	115.5	254.2	471.9	101.2	24.6
Cs	107	1000	1000	24.3	17.3	1000	47.9	14.4	15.8	15.1	216.8	16.2	4245	35.9	29.6
Rb	1000	1000	1000	46	34	1000	118	46	24	36	1527	80.6	10000	166.9	107.8
Sn	1	101	55	4	125	87	150	13	11	11	43	25	23	10	61
Nb	16	117	59	440	1000	147	641	397	385	142	417.4	1120	123.7	154.8	69
Sr	18	24	12	3	34	27	7	16	3	6	15.8	13.7	9.4	31.1	3
Y	2	2	2	94	91	2	2	177	50	4	17.4	28.3	0.8	88.2	48.8
Ba	17	13	10	10	206	213	5	23	15	14	177	18	26	16	11
Hf	0.3	2.1	1.2	12.4	164	1.6	6.9	15.2	21.7	5.4	18.6	9.5	2.5	39	1.4
Th	0.6	7.7	9.7	15.6	436	6	2	38.4	24.4	6.1	55.6	107.4	2.9	5.3	9.2
W	9	5	3	1	166	9	5	3	3	1	5	6.9	5.9	1.2	0.5
Be	5	15	26	7	8	15	9	4	5	5	240	948	22	10	7
Zr	7	12	50	149	265	29	25	167	186	53	458.4	101.7	9.8	374.2	14.6
Ga	28	71	49	29	6	77	163	62	56	61	117	79.1	130	39.5	117.5
Zn	30	30	40	30	240	30	100	330	290	390	927	760	1166	24	29
U	2.6	57	9.2	63.3	1000	22.8	40.3	35.5	42.3	25.4	5.1	34.1	15.2	9.3	3
Ti	26.7	34.9	27.2	0.5	0.6	16.3	0.7	0.3	0.1	0.1	0.4	0.1	22	0.2	0.3
Cu	30	20	50	50	20	50	90	30	60	40	1.3	2.3	0.7	12.9	3.4
Li	215.3	214.9	215	45.5	209.6	214.7	109.7	103.1	106.7	100.4	98.3	68.1	210.3	86.2	46.5
Elements	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Co	1	1	1	1	1	2	1	2	1	1	20.1	6.1	0.4	3.1	1.2
V	5	5	5	5	5	5	5	5	5	5	240	37	8	11	8
Ni	20	20	20	20	20	20	20	20	20	20	4.5	3.5	1.5	3.4	3.5
Sc	1	9	6	12	56	1	4	25	6	1	21	21	1	8	35
Pb	34	9	5	16	4450	7	50	12	12	5	3.5	8.5	2.6	11.6	4.5
Mo	2	2	2	2	3	2	2	2	2	2	0.9	1.3	0.2	1.2	1.3
La	0.7	0.8	0.7	4	4.2	1.6	0.7	7.9	2.9	1.1	73.4	14.8	1	3.6	1
Ce	1.6	1.9	1.6	10.2	7	2.8	1.3	21.5	8.3	2.7	154.4	39.8	2.9	13.1	2.7
Pr	0.17	0.27	0.21	1.44	1	0.31	0.16	3.24	1.27	0.37	18.31	5.55	0.34	2.13	0.34
Nd	0.7	2.4	1.7	9.8	7.5	1.1	0.6	22.1	10.5	3.1	68.7	20.5	1.4	10.7	1.3
Sm	0.2	1.4	0.8	4.3	3.7	0.3	0.2	10	5.5	1.9	23.74	17.34	0.59	8.02	1.4
Eu	0.05	0.05	0.05	0.05	0.14	0.05	0.05	0.09	0.05	0.05	0.88	0.1	0.02	0.31	0.02
Gd	0.2	1.3	1.1	6.2	9.9	0.3	0.2	13.5	7.9	2.5	15.83	13.46	0.41	11.23	2.91
Tb	0.1	0.2	0.2	2.6	3.9	0.1	0.1	3	2	0.5	1.78	2.3	0.06	2.78	1.29
Dy	0.3	0.3	0.8	17.4	18.2	0.3	0.2	27.9	10.6	1.5	4.95	7.03	0.21	14.72	7.81
Ho	0.1	0.1	0.1	2.1	0.8	0.1	0.1	4	0.8	0.1	0.45	0.59	0.02	2.15	0.96
Er	0.1	0.1	0.1	5	0.8	0.2	0.1	10.8	1.2	0.1	1.1	1.19	0.03	5.4	2.65
Tm	0.05	0.05	0.05	0.87	0.07	0.05	0.05	2.15	0.14	0.05	0.19	0.25	0.01	0.92	0.6
Yb	0.1	0.1	0.2	6.6	0.3	0.2	0.1	13.6	0.5	0.1	1.49	1.93	0.05	7.15	5.8
Lu	0.04	0.04	0.04	0.77	0.04	0.04	0.04	1.64	0.04	0.04	0.26	0.27	0.01	1.01	0.71
Elements	16	17	18	18	20	21	22	23	24	25	26	27	28	29	30
Ta	305.6	131.7	9.9	11.3	361.5	359.1	64.8	192.8	30.6	34.3	40.8	428.9	53.7	146.2	173.2
Cs	15.4	227.3	109.1	25	1798	486.6	56.6	3932	42.5	205.5	61.2	517.7	679	391.5	2359
Rb	68.6	1596	274.7	381.8	10000	3469	3072	10000	1850	2522	3171	3585	3519	6831	10000
Sn	24	46	5	33	25	116	633	21	113	114	617	107	461	455	41
Nb	1393	467.3	23.9	22.3	88.3	1277	511.8	140.6	292.2	285.6	406.6	1417	329.6	242.6	105.4
Sr	13.4	15	9.7	8.3	15	7	0.7	3.5	1.9	2.6	0.6	7	1.7	0.8	2.7
Y	23.6	18.7	4.7	2.7	2.5	4.3	6.5	0.3	1	0.1	3	4.1	4.7	1.4	0.6
Ba	14	176	7	6	13	327	3	16	16	29	1	326	25	4	3
Hf	10.7	17.7	0.6	1.3	2.9	1.7	1.1	0.1	0.2	0.1	0.8	2.1	1	0.8	0.4
Th	82.4	56.6	15.8	5.2	8.2	6.8	0.8	0.4	0.2	0.2	0.2	7.8	0.3	0.5	0.2
W	8.3	5.8	0.5	0.5	4.4	11.7	8.5	5.9	6.2	7.9	7.9	12.3	7.6	6.1	7.9
Be	919	242	19	7	19	29	8	6	8	7	7	14	6	7	7
Zr	109.9	488.8	16.2	15.5	9.8	35.6	13.9	2.2	5.5	2	7.5	47.6	14.1	6.3	3.7
Ga	78.7	121.1	73.1	62.2	150.9	120.9	295	126.2	129.4	126.5	297	114.7	256.5	342.4	162.6
Zn	716	1018	821	2070	441	25	23	35	39	37	29	24	56	38	39
U	31.2	5.3	2.4	1.8	8.3	1.7	12.3	2.1	2.1	0.2	5.5	2.2	8.6	5.7	2.1
Ti	0.1	0.6	0.1	0.2	22	1.2	1.1	70.3	1.3	4	1.3	1.6	2.4	2.4	58
Cu	2.4	1.7	1.1	1	0.7	0.8	0.2	0.5	0.2	0.3	0.3	0.6	0.3	0.4	0.6
Li	12.7	231.1	58.3	52.4	686.5	923.2	823.7	984.8	842	3037.9	1720.2	1228.9	1204.2	3117.9	4881.1
Elements	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Co	6.5	20.9	2.6	1.3	3.5	5.8	0.2	0.5	0.4	0.6	0.2	6.2	1.2	0.4	0.2
V	39	246	15	8	8	226	9	9	9	17	8	219	13	20	8
Ni	2.4	7.4	1.7	2.4	1.6	3.1	0.2	0.9	0.4	0.7	0.2	3.2	0.4	0.6	0.2
Sc	23	21	5	5	9	23	126	1	7	5	122	21	91	6	5
Pb	7.3	4	2.7	4.1	2.5	1.4	0.5	0.4	1	1.1	0.4	1.4	0.7	0.7	0.6
Mo	0.9	1.3	0.7	1.1	0.4	0.4	0.1	0.3	0.1	0.2	0.1	0.6	0.2	0.1	0.1
La	11.8	73.7	3	1.9	1.8	17.5	0.8	1.1	0.2	0.3	0.3	17.3	0.8	0.6	0.1
Ce	32.9	157.2	8.8	5.5	6.1	36	1.9	2.1	0.3	0.6	1	36.3	1.6	1.5	0.3
Pr	4.41	18.43	1.23	0.71	0.75	4.25	0.25	0.25	0.04	0.06	0.11	4.36	0.21	0.17	0.02
Nd	16.7	68.9	5	2.6	3.4	16	0.9	1.1	0.3	0.3	0.3	16.4	0.8	0.4	0.3
Sm	13.45	24.01	2.82	1.37	1.56	5.57	0.84	0.29	0.11	0.06	0.35	5.68	0.62	0.26	0.05
Eu	0.1	0.93	0.05	0.03	0.02	0.21	0.03	0.02	0.02	0.02	0.02	0.21	0.02	0.02	0.02
Gd	10.66	16.11	2.16	1.07	1.23	3.67	1.28	0.24	0.18	0.05	0.54	3.8	0.92	0.27	0.12
Tb	1.85	1.88	0.34	0.18	0.2	0.44	0.31	0.02	0.04	0.01	0.13	0.46	0.22	0.05	0.01
Dy	6.01	5.14	1.25	0.61	0.68	1.31	0.07	0.19	0.05	0.65	1.51	0.88	0.27	1.31	0.14
Ho	0.51	0.45	0.12	0.06	0.05	0.12	0.14	0.02	0.02	0.02	0.04	0.11	0.1	0.02	0.02
Er	1.05	1.1	0.24	0.13	0.11	0.24	0.28	0.03	0.04	0.03	0.14	0.21	0.24	0.07	0.03
Tm	0.2	0.2	0.04	0.03	0.02	0.05	0.06	0.01	0.01	0.01	0.03	0.04	0.04	0.01	0.01
Yb	1.77	1.6	0.3	0.19	0.13	0.26	0.36	0.05	0.06	0.05	0.13	0.28	0.29	0.07	0.05
Lu	0.24	0.25	0.03	0.03	0.01	0.04	0.05	0.01	0.01	0.01	0.02	0.03	0.03	0.01	0.01

The numbers **1, 2, 3,…30** represent sample numbers. 1-20: Whole rock Pegmatite samples from Komu. 21-30: Muscovite extracts from Komu Pegmatites.

Microcline: is the most abundant of these minerals. Crosshatch twinning is also displayed in the microcline with perthitic texture common in the feldspers.

Muscovite: shows high relief, perfect cleavage in one direction with strong birefringence colours under crossed nicols. Some of the muscovite crystals exhibit dark haloes indicating possible alteration. (Figs. 3 and 4).

GEOCHEMICAL FEATURES

From the analytical results of the major elements as presented in (Tables 2 and 4), it shows that the samples of the Komu pegmatites are siliceous with SiO_2 content ranging from 46.14-76.71% with an average of 62.47% in the Komu whole rock pegmatite samples, while it ranges from 45.28-57.50% with a mean value of 48.34% in the muscovite extracts samples of Komu. The Al_2O_3 ranges from 11.92-28.75% with an average of 21.06% in the Komu whole rock pegmatite samples, while it ranges from 23.12-34.25% with a mean value of 30.72% in the muscovite extracts samples of the Komu study area. This slight to sharp contrast in the values of some of the whole rock and muscovite extracts sample for the alumina content of this study area in addition with other rare metal characteristics, confirms the complexity of the pegmatite type. In addition the Fe_2O_3 ranges from 0.47-10.26% with a mean value of 4.07% in the whole rock Pegmatite samples, while it also ranges from 0.27-5.83% with an average value of 3.34% in the samples of muscovite extracts of the Komu study area. These values are comparable to those observed for mineralized pegmatites of Nigeria, (Garba, 2003; Okunlola, 2005).

Table 4: Range and average values of major elements in the whole rock and muscovite extracts of Komu pegmatites in mass fraction (Wt %).

	Komu Samples			
	Whole Rock Pegmatite N = 20		Muscovite Extracts N = 10	
	Range	Avr (%)	Range	Avr (%)
Si_2O	46.14 - 76.71	62.47	45.28 - 57.50	48.34
Al_2O_3	11.92 - 28.75	21.06	23.12 - 34.25	30.72
Fe_2O_3	0.47 - 10.26	4.07	0.27 - 5.83	3.34
MnO	0.023 - 2.310	0.72	0.09 - 0.28	0.15
Mgo	0.01 - 3.19	0.61	0.06 - 1.40	0.39
CaO	0.04 - 0.75	0.31	0.01 - 0.04	0.02
Na_2O	0.16 - 9.92	4.50	0.36 - 1.45	0.76
K_2O	0.11 - 11.28	2.70	9.26 - 10.36	9.85
TiO_2	0.015 - 1.096	0.21	0.03 - 1.26	0.40
P_2O_5	0.02 - 0.48	0.09	0.01 - 0.02	0.01

Table 5: Range and averages of some of the trace elements in the whole rock and muscovite extracts of Komu pegmatites (ppm).

	Komu Samples			
	Whole Rock Pegmatite N = 20		Muscovite Extracts N = 10	
	Range (ppm)	Avr ppm	Range (ppm)	Avr ppm
Ta	9.9-500	183.22	30.6-428.9	152.44
Cs	14.4-1798	335.92	42.5-3932	873.2
Rb	24-10000	1425	1850-10000	4801.9
Sn	1-150	14.75	21-633	267.8
Nb	22.3-1120	361.19	105.4-1417	500.84
Sr	3-34	14.22	0.6-7.0	2.85
Y	0.8-177	33.09	0.1-6.5	2.6
Ba	5-213	49.5	1-327	75.0
Hf	0.3-164	16.75	0.1-2.1	0.83
Th	0.6-436	44.76	0.2-7.8	1.74
W	0.5-166	12.2	5.9-12.3	8.2
Be	4-948	126.6	6-29	9.9
Zr	7-488.8	127.1	2.0-47.6	13.84
Ga	6-163	78.56	120.9-342.4	197.12
Zn	30-2070	474.1	23-56	34.5
Ti	0.1-34.9	7.67	1.1-70.3	14.36

Mean contents of major oxides MnO (0.72%, 0.15 %), MgO (0.61%, 0.39%), CaO (0.31%, 0.02%), Na_2O (4.50%, 0.76%), K_2O (2.70%, 9.85%), TiO_2(0.21%, 0.40%), P_2O_5 (0.09%, 0.01%) for the whole rock and muscovite extract samples of Komu pegmatites respectively, compares favorably with the rare metal bearing pegmatites of Isanlu Egbe, Lema-Ndeji central Nigeria and Igbeti areas. (Okunlola, 2005; Okunlola and Akintola, 2008; Okunlola and Oyedokun, 2009). Trace and rare earth element data (Tables 3, 5 and 6) show that the pegmatites are rich in rare metals with moderately high Ta, Nb, Sn, Rb, and Cs. With Tantalum values ranging from (9.9-500ppm; 30.6-428.9ppm). Niobium (22.3-1120ppm; 105.4-1417ppm), Tin (1-150ppm; 21-633ppm), Rubidium (24-10000ppm; 1850-10000ppm) and Cesium (14.4-1798ppm; 42.5-3932ppm), for the whole rock and muscovite extracts samples of Komu pegmatites respectively. The Ta and Nb values in the whole rock and mica extracts are comparable with those of the richer Nasarawa-Keffi and Kushaka Ta-Nb fields of Nigeria respectively (Okunlola, 2005). The mean values of Be (126.6ppm, 9.9ppm), Ga (78.56ppm, 197.12ppm), W (12.2ppm, 8.2ppm), Sr (14.22ppm, 2.85ppm), Zr (127.1ppm, 13.84ppm), Ba (49.5ppm, 75.0ppm) and Y (33.09ppm, 2.6ppm) are as indicated for the Komu whole rock and muscovite extracts pegmatite samples respectively. These values compare favorably with the mineralized pegmatites of Harding, United States; Silver leaf, Canada and Homestead Canada. (Moller and Morteani, 1987). Using the K/Rb versus Cs plots the pegmatites in Komu area are rare metal bearing (Fig.5(a)). The low values of Mg, Ti, Ba and Zr with attendant high Rb, and Cs composition indicates high Fractionation of the pegmatites, while the moderately high Cs values of the Komu pegmatites indicate moderately high alkali metal fractionation, (Cerny, 1982; 1989). There is a clear enrichment of Nb, Ta, Rb, Sn, Cs, Rb and depletion of Sc, Co which also suggests mineralization of the rare metal columbo-tantalite (Moller and Morteani, 1987). The samples are also relatively higher in Ta content in the whole rock samples than in the mica extracts showing that the pegmatites in Komu area are adequately enriched in Tantalite. The K/Rb ratios of the pegmatites of Komu study area are low, and according to Kuster, (1990), this indicates progressive fractionation, and possible mineralization. Samples also show low ratios of K/Cs, Th/U, and K/Ba which is typical of mineralized pegmatites (Garba, 2003). In addition, the evidence of possible metasomatism being involved in the mineralization process is seen in the presence of sacharroidal albitic, micaceous units and tourmalinisation. Although, Manning, (1984); Henderson and Manning, (1984); Henderson and Martin, (1985) and Cerny, (1991b) believe that such association could still be explained by late but primary crystallization from residual melt in situ, however from the works of Christiansen, *et al.,* (1993) and London, (1990; 2005) it is believed that this Association coupled with the boron effect as shown from the Ta-Nb mineralization in the whole rock and muscovite extracts of Komu pegmatites is an evidence of the role of metasomatism in the mineralization.

The degree of albitization is revealed by the Triangular Ti-Sn-(Nb+Ta) discriminant plot which plot in the zone of albitization (Fig. 6) for the Komu pegmatites. This plot also reveals a high degree of albitization and it indicates a significant difference between the mineralized and unmineralized pegmatite samples (Matheis and Emofurieta, 1990; Okunlola and King, 2003; Okunlola and Somorin, 2005; De Kun, 1965; Jacobson and Webb, 1946), however these values are still low compared to those of the economically viable bodies like Tanco Canada (Moller and morteani, 1987), but there are indications that the pegmatites of Komu area compare favorably with those of other mineralized pegmatite

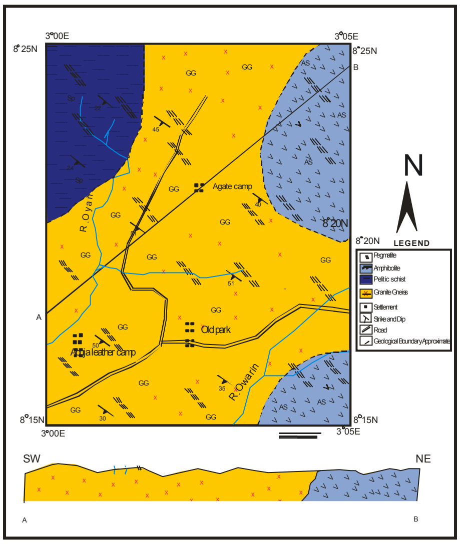


Figure 2: Geological map of Komu area southwestern Nigeria

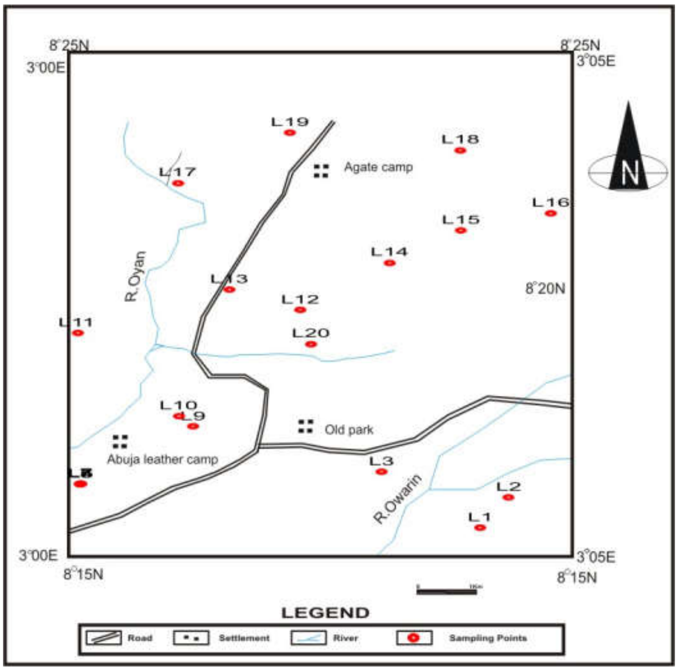


Figure 1: The location map of Komu study area showing the sampling points

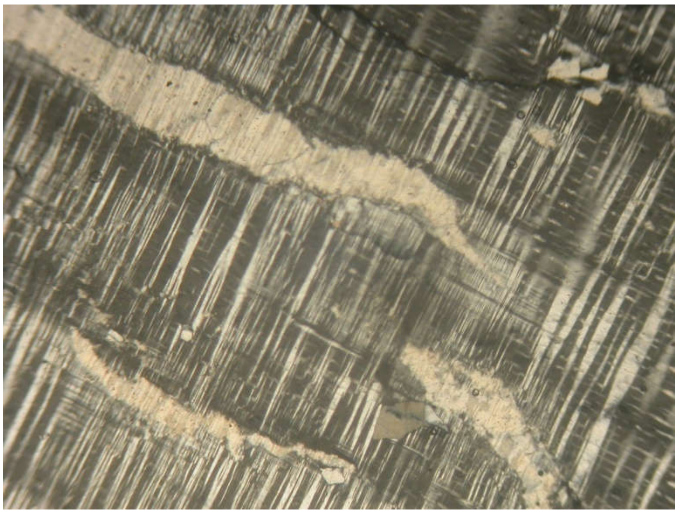
Table 6: Elemental ratios of selected major and trace elements of Pegmatites from Komu study area

Ratio	1	2	3	4	5	6	7	8	9	10
K/Rb	0.0093613	0.0055686	0.0029378	0.0032474	0.002685	0.0034109	0.0011253	0.0054124	0.0076074	0.0041495
K/Ba	0.5506631	0.4283561	0.2937846	0.0149382	0.0004432	0.0160136	0.0265568	0.0108248	0.0121719	0.0106701
Na/K	0.2456482	0.1332105	0.5630704	44.344526	1.3001347	0.7546555	26.982874	14.510045	23.321167	26.120068
Rb/Sr	55.555556	41.666667	83.333333	15.333333	1	37.037037	16.857143	2.875	8	6
Ba/Rb	0.017	0.013	0.01	0.2173913	6.0588235	0.213	0.0423729	0.5	0.625	0.3888889
Zr/Hf	23.333333	5.7142857	41.666667	12.016129	1.6158537	18.125	3.6231884	10.986842	8.5714286	9.8148148
Sr/Rb	0.018	0.024	0.012	0.0652174	1	0.027	0.059322	0.3478261	0.125	0.1666667
Rb/Cs	9.3457944	1	1	1.8930041	1.9653179	1	2.4634656	3.1944444	1.5189873	2.384106
Ta/W	1.2333333	47.2	15.733333	118	3.0120482	24.444444	100	17.866667	48.333333	46
K/Cs	0.0874885	0.0055686	0.0029378	0.0061474	0.0052768	0.0034109	0.0027721	0.0172896	0.0115556	0.0098928
Zr/Zn	0.2333333	0.4	1.25	4.9666667	1.1041667	0.9666667	0.25	0.5060606	0.6413793	0.1358974
Th/U	0.3749508	0.0139216	0.0023503	0.0012377	0.004779	0.0035285	0.0110884	0.034165	0.0180167	0.0727964
Ta/Nb	0.69375	2.017094	0.8	0.2681818	0.5	1.4965986	0.7800312	0.1350126	0.3766234	0.3239437
Nb/Ta	1.4414414	0.4957627	1.25	3.7288136	2	0.6681818	1.282	7.4067164	2.6551724	3.0869565
K_2O/Na_2O	3.6387097	6.71	1.5874439	0.0201568	0.6875	1.184438	0.0331263	0.0616016	0.0383275	0.0342205
Na_2O/Al_2O	0.1608718	0.0619579	0.1870805	0.5085421	0.0084656	0.19874	0.1637843	0.2354932	0.312466	0.3099588
K_2O/Al_2O_3	0.5853659	0.4157373	0.2969799	0.0102506	0.0058201	0.2353952	0.0054256	0.0145068	0.011976	0.010607

Ratio	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
K/Rb	0.00235329	0.0145181	0.0006598	0.0030829	0.0017707	0.0159689	0.0022671	0.0016616	0.0013911	0.000483
K/Ba	0.02030207	0.0650088	0.2537579	0.0321586	0.0173525	0.0782477	0.0205589	0.0652064	0.0885227	0.3715398
Na/K	0.30964525	4.2346587	0.2001308	10.971197	23.395359	4.3270109	0.3054646	16.121671	7.5836961	0.5621072
Rb/Sr	96.6455696	5.8832117	1063.8298	5.3665595	35.933333	5.119403	106.4	28.319588	46	666.66667
Ba/Rb	0.11591356	0.2233251	0.0026	0.0958658	0.1020408	0.2040816	0.1102757	0.0254823	0.015715	0.0013
Zr/Hf	24.6451613	10.705263	3.92	9.5948718	10.428571	10.271028	27.615819	27	11.923077	3.3793103
Sr/Rb	0.01034709	0.1699752	0.00094	0.1863391	0.0278293	0.1953353	0.0093985	0.0353112	0.0217391	0.0015
Rb/Cs	7.04335793	4.9753086	2.3557126	4.6490251	3.6418919	4.4545455	7.0215574	2.5178735	15.272	5.5617353
Ta/W	23.1	36.84058	79.983051	84.333333	49.2	36.819277	22.706897	19.8	22.6	82.159091
K/Cs	0.01657503	0.072232	0.0015542	0.0143325	0.0064485	0.0711343	0.0159189	0.0041837	0.0212454	0.0026863
Zr/Zn	0.49449838	0.1338158	0.0084048	15.591667	0.5034483	0.1534916	0.4801572	0.019732	0.0074879	0.0222222
Th/U	0.03351888	0.5397871	0.1849216	0.0009192	0.0128088	0.4634408	0.0331535	0.2120273	2.8372942	0.1208848
Ta/Nb	0.27671299	0.2269643	3.8148747	0.6537468	0.3565217	0.2193826	0.2818318	0.4142259	0.5067265	4.0939977
Nb/Ta	3.61385281	4.4059795	0.2621318	1.5296443	2.804878	4.5582461	3.5482156	2.4141414	1.9734513	0.24426
K_2O/Na_2O	2.88666667	0.2110778	4.4662921	0.0814717	0.038206	0.2065728	2.9261745	0.0554435	0.1178637	1.5901639
Na_2O/Al_2O	0.05042017	0.2932397	0.0755518	0.4078242	0.2339681	0.2775847	0.050406	0.4652908	0.3600796	0.1468111
K_2O/Al_2O_3	0.14554622	0.0618964	0.3374363	0.0332262	0.008939	0.0573414	0.1474966	0.0257974	0.0424403	0.2334537

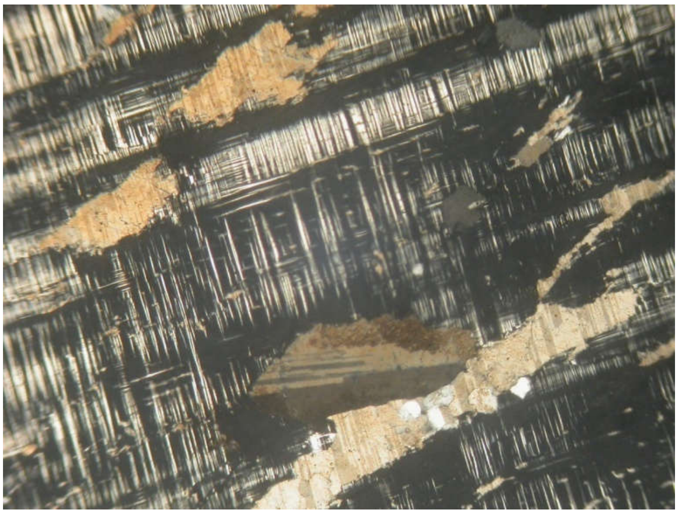
Ratio	21	22	23	24	25	26	27	28	29	30
K/Rb	0.0023158	0.0027447	0.0007693	0.0046385	0.0033466	0.002803	0.0021436	0.0022003	0.0012586	0.0008083
K/Ba	0.0245671	2.8105947	0.4808233	0.5363229	0.2910373	8.888229	0.0235732	0.3097187	2.149441	2.6944087
Na/K	0.0350889	0.067742	0.0906378	0.0587827	0.0553708	0.0617594	0.0347498	0.1389144	0.059532	0.083511
Rb/Sr	495.57143	4388.5714	2857.1429	973.68421	970	5285	512.14286	2070	8538.75	3703.7037
Ba/Rb	0.0942635	0.0009766	0.0016	0.0086486	0.0114988	0.0003154	0.0909344	0.0071043	0.0005856	0.0003
Zr/Hf	20.941176	12.636364	22	27.5	20	9.375	22.666667	14.1	7.875	9.25
Sr/Rb	0.0020179	0.0002279	0.00035	0.001027	0.0010309	0.0001892	0.0019526	0.0004831	0.0001171	0.00027
Rb/Cs	7.1290588	54.275618	2.543235	43.529412	12.272506	51.813725	6.92486	5.1826215	17.448276	4.2390844
Ta/W	30.692308	7.6235294	32.677966	4.9354839	4.3417722	5.164557	34.869919	7.0657895	23.967213	21.924051
K/Cs	0.0165093	0.1489714	0.0019566	0.2019098	0.041071	0.1452325	0.0148443	0.0114035	0.0219611	0.0034265
Zr/Zn	1.424	0.6043478	0.0628571	0.1410256	0.0540541	0.2586207	1.9833333	0.2517857	0.1657895	0.0948718
Th/U	0.0115936	0.2464995	0.031127	1.431724	0.7598128	0.5615657	0.0074845	0.0452904	0.1324637	0.0361177
Ta/Nb	0.281206	0.126612	1.371266	0.1047228	0.120098	0.1003443	0.3026817	0.1629248	0.6026381	1.6432638
Nb/Ta	3.5561125	7.8981481	0.7292531	9.5490196	8.3265306	9.9656863	3.3038004	6.1378026	1.6593707	0.608545
K_2O/Na_2O	25.473684	13.194805	9.8617021	15.205882	16.142857	14.472973	25.722222	6.4344828	15.014493	10.703297
Na_2O/Al_2O	0.0129208	0.0226671	0.0406574	0.019854	0.0192249	0.0220566	0.0128617	0.0444922	0.0201991	0.0357845
K_2O/Al_2O3	0.3291397	0.2990874	0.4009516	0.3018978	0.3103448	0.319225	0.3308324	0.2862841	0.3032787	0.3830122

The numbers **1, 2, 3,…30** represent sample numbers.1-20: Whole rock Pegmatite samples from Komu 21-30: Muscovite extracts from Komu Pegmatites.



Bar scale = 20mm ***Mag. X40***

Figure 3: Photomicrograph of Pegmatite in transmitted light showing Microcline (M),Quartz (Q), Biotite (B)

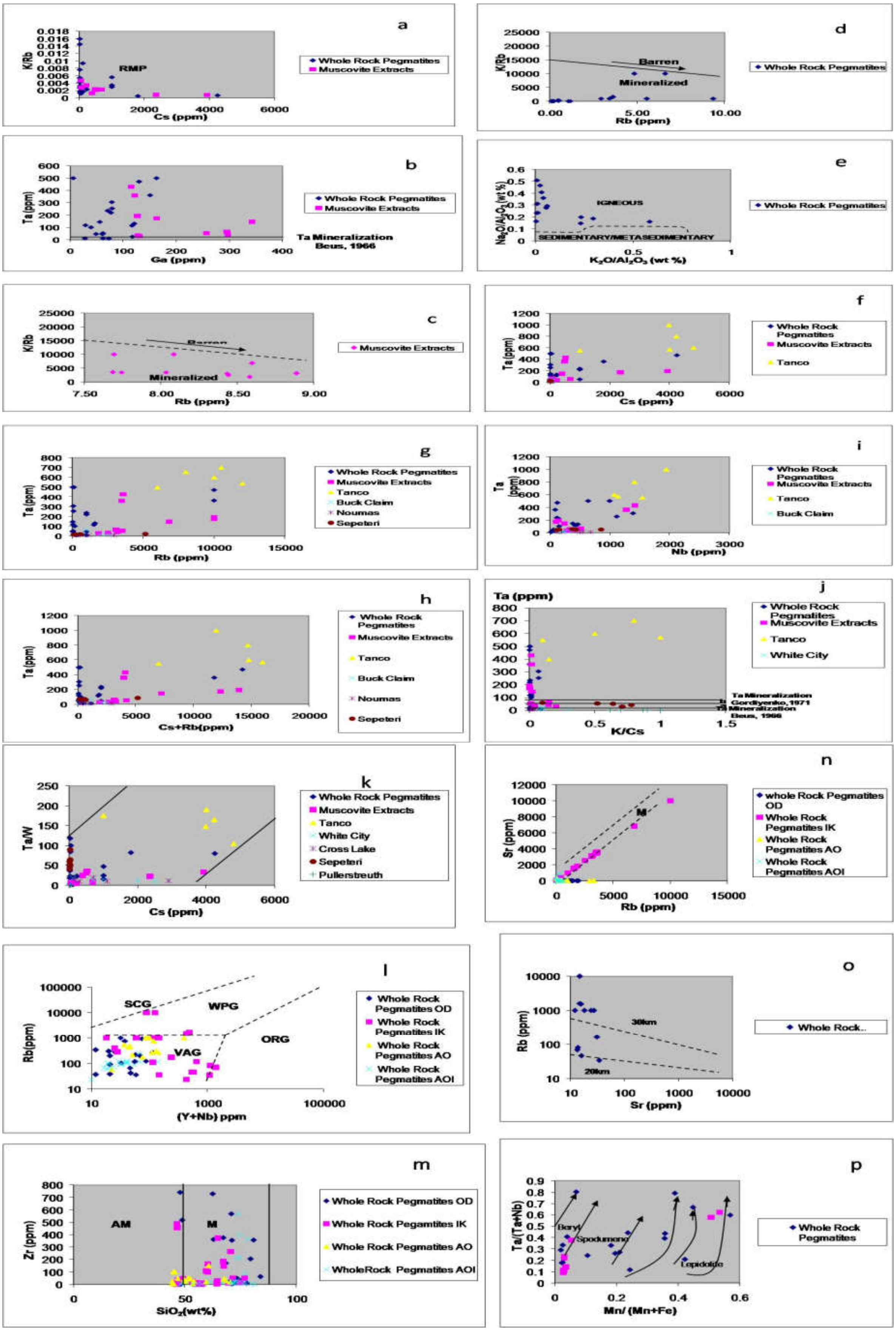


Bar scale = 20mm ***Mag. X40***

Figure 4: Photomicrograph of Pegmatite in transmitted light showing Microcline (M), Muscovite (MU), Plagioclase (P) and Quartz (Q).

areas like Egbe and Igbeti areas southwestern Nigeria (Matheis and Emofurieta, 1987; Okunlola and Oyedokun, 2009). This is also indicative of the degree of fractionation. The K/Rb versus Rb variation plots for the Komu whole rock pegmatites samples and the muscovite extract samples reveal a consistent trend (Figs.5(c), 5(d)), indicating the mineralization in the pegmatite of this study area to be moderately high. These plots also show a conspicuous distribution pattern of separation in the Komu pegmatite along the differentiation trend of the pegmatite in the study area. The pegmatites show a high differentiation and plot within the field of mineralization (Staurov *et al.,* 1969). The samples compare favorably with the mineralized pegmatites of Harding, United States; Odd west, Canada. Homestead, Canada. Wodgina, Australia. (Moller and Morteani, 1987). However some samples also plot close to those of the highly evolved Tanco pegmatites but the level of mineralization is lower than that of highly mineralized Tanco Ta-Nb deposits (Cerny, 1982; Moller and Morteani, 1987). Variation plots of Ta versus Ga (Fig.5(b)), Ta versus Cs (Fig.5(f)), Ta versus Rb (Fig.5(g)), Ta versus (Cs + Rb) (Fig.5(h)), Ta versus Nb (Fig.5(i)), Ta versus K/Cs (Fig.5(j)) and Ta/W versus Cs (Fig.5(k)), confirm these trends. These plots also show the whole rock samples and the mica extracts samples of the Komu pegmatites plotting over the mineralized line of Beus, (1966) and Gordiyenko, (1971). From field evidence, bulk chemistry signatures and the Ta / (Ta+Nb) versus Mn/(Mn+Fe) plot (Fig.5(p)). The Komu pegmatite is a complex pegmatite, of the rare element class and displays typical characteristic of the Lithium, Cesium, and Tantalite (LTC) family. Apart from the typical minor element content of Li, Rb, Cs, Ga, Sn, Ta < > N, (B, P, F) their silicic and per aluminous {A/CNK>1} (where A: Al_2O_3, CNK: CaO+ Na_2O+K_2O) character supports this assertion (Cerny, 1991b; London, 2005). LCT pegmatites as in this study are also known to contain moderate to abundant Ta-Nb mineralization, gem stones and industrial minerals (Cerny, 1989). The metamorphic environment in this study area which is a low pressure upper green schist facies to lower amphibolites facies with quasi conformable to cross cutting structural features is also typical of LCT pegmatites of the rare element class (Beus and Sitnin, 1968; Cerny, 1982; Meintzer, 1987). Also, Solodov, (1971) and Cerny, (1982; 1991a) had observed that schists, gneisses and early intrusions are the hosts of this family of pegmatites. In addition, the fracture filling dyke like configuration of the pegmatitic bodies seems to have been largely contributed by the ductility of the amphibolitic shist and granite gneiss host rocks which according to Cerny, (1991b) is also typical of LCT pegmatites. This characteristics coupled with the Rb, Sr content of the Komu pegmatites, suggests that the pegmatites could have been derived from the remelting (anatexis) of supracrustals.

However, the Rb/ Y+Nb plot (Fig.5(l)) shows that the pegmatites plot in the field of the volcanic arc granite with few of the samples plotting clearly within plate granite. While the Zr versus SiO_2 (Fig.5(m)) and Sr/Rb plots (Fig.5(n)) reveals their mixed ancestry with some samples plotting completely out of the magmatic "M" field. These petrogenetic signatures seem incongruous. Cerny, (1991b) had noted that metapelites sequences have been traditionally suspected to be the main or sole protoliths of the LCT suites because of their enrichments in LCT elements and an overall character. Harris *et al.,* (1986) also demonstrated that fluid absent melting of metapelites produces peraluminous melts, but also a number of rare metal pegmatites have been identified as derived from mixed basements plus supracrustal protoliths having homogenous chemistry. (Meintzer, 1987). The crustal thickness during emplacement of these pegmatite bodies (Fig.5(o)) reached about 30km as shown from the Rb/Sr plot of Condie, (1976). The variation diagram plot (Fig. 5(e)) of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 reveals the igneous ancestry of the pegmatite which plot in the granite-igneous field of Garrells and Mackenzie, thus indicating and suggesting a granitic-igneous ancestry for the Komu pegmatites. Chondrite normalized plot (Fig.7) of the rare earth elements shows high light REE (LREE) (La, Ce, Pr) values and low heavy (HREE) (Er, Lu, Yb). There is an extensive negative Europium (Eu) signature and kinking is dominant. This is especially characteristic of LCT pegmatites with attendant high fractionation. (Cerny, 1991b; Fourcade and Allegre, 1981; Lee and Christiansen, 1983; Christiansen *et al.,* 1993). However, Taylor *et al.,* (1986) had suggested earlier that where there is a weak negative Ce signature and a strong negative Eu signature as in this case of Komu pegmatite samples it is an evidence of considerable fractionation and metasomatism. Also, Piper,



Figures 5(a): Plot of K/Rb vs Cs for Komu Pegmatite (After Cerny, 1982); 5(b): Plot of Ta vs Ga for the Komu Pegmatite; 5(c): K/Rb vs Rb distribution pattern in the Muscovite extracts of Komu Pegmatite Arrow indicate normal differentiation trend after Staurov *et al.*, (1969); 5(d): K/Rb vs Rb distribution pattern in the whole rock Pegmatite of Komu study Area, arrow indicate normal differentiation trend after Staurov *et al.*, (1969); 5(e): Plot of Na_2O/Al_2O_3 vs K_2O/Al_2O_3 (Wt %) showing variation diagram for the Field of Igneous and Meta sedimentary rocks of Komu Pegmatites (After Garrels and Mackenzie, 1971); 5(f): Plot of Ta vs Cs for the pegmatites of Komu study area (After Moller and Morteani, 1987); 5(g): Plot of Ta vs Rb for the pegmatites of Komu study area (After Moller and Morteani, 1987); 5(h): Plot of Ta vs Cs+Rb for the pegmatites of Komu study area (After Gaupp *et al.*, 1984); 5(i): Plot of Ta vs Nb for the pegmatites of Komu study area; 5(j): Plot of Ta vs K/Cs ratio for the pegmatite's of Komu study area (After Gordiyenko, 1971 and Beus, 1966); 5(k): Plot of Ta/W ratio vs Cs for the pegmatites of Komu study area The Ta/W ratio increases with increasing elements fractionation as indicated. By Cs. (After Moller and Morteani, 1987); 5(l):Rb vs (Y+Nb) discriminant diagram for the whole rock sample pegmatites Of Komu= IK, compared to those of Olode-OD, Awo= AO and Ago-Iwoye= AOI (After Pearce et al., 1984).VAG - VOLCANIC ARC GRANITE, ORG - OCEANIC RIDGE GRANITE, WPG - WITHIN-PLATE GRANITE, SCG - SYN-COLLISIONAL GRANITE; 5(m): Zr-Sio2 Plots of the whole rock sample pegmatites of Komu= Ik, compared to Those of Olode=OD, Awo=AO and Ago-Iwoye =AOI pegmatites; 5(n): Sr-Rb Plots of the whole rock sample pegmatites of Komu=Ik, compared to Those of Olode =OD, Awo=AO and Ago-Iwoye =AOI pegmatites; 5(o): Plot of Rb-Sr for the pegmatite's of Komu study area. (After Condie, 1976); 5(p): Plot of Ta/(Ta+Nb) vs Mn/(Mn+Fe) variation plots of the Komu Pegmatites

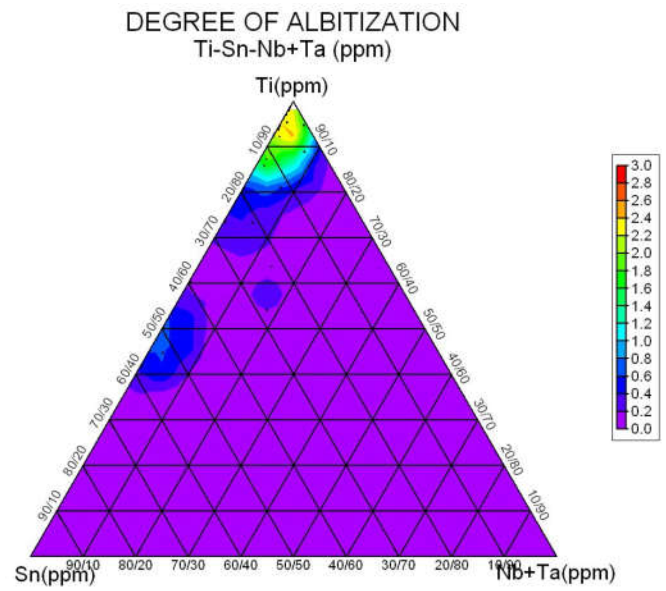
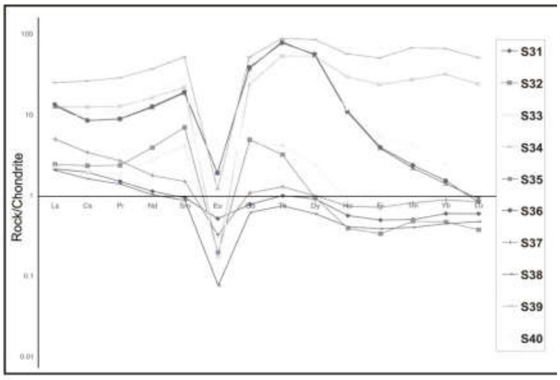


Figure 6: Triangular Ti-Sn-(Nb+Ta) Plot for Komu Pegmatites (After Kuster, 1990)



REE Chondrite normalized plots

Figure 7: Rare earth elements chondrite-normalized plots of Komu Pegmatite

(1974) and Garba, (2003) believe that Negative Ce signature of rare metal pegmatite is taken to indicate oxidizing condition during mineralization and interaction between magmatic, melt fluids and host rocks over long distance sometimes.

CONCLUSIONS

Results of this study show that the Precambrian pegmatites of Komu which intruded the granite, gneiss, amphibolites and some pelitic schistose rock are rare-metal pegmatites. They are usually complex albitized pegmatites. Microcline and albite are the dominant feldspars with subordinate muscovites, quartz, Tantalite, niobium and illmenorutiles. Following after the classification criteria of pegmatites based on bulk chemistry signatures (Cerny, 1991a; 1991b), and Ta/ (Ta+Nb) versus Mn/ (Mn+Fe) plot for the Komu whole rocks and muscovite extracts pegmatites respectively, the Komu pegmatites are of the rare element class, complex pegmatite type. They are of the LCT petrogenetic family (Rb, Cs, Be, Li, Ga, Sn, Ta < > N (BPF) and of the Beryl sub type. The pegmatites are of per aluminous bulk composition {A/CNK>1} (where A: Al_2O_3, CNK: CaO+ Na_2O+K_2O). Cerny (1992) has observed that this LCT family has a mild, to extremely Peraluminous parent granitic composition.

This field is clearly enriched in Ta-Nb rare – metal mineralization. The lower K/Rb ratio, lower K/Cs, K/Ba, Th/U ratios and higher Rb/Sr ratio for the Awo Ta-Nb rare-metal pegmatites suggest that these pegmatites have benefited from fluids that have been derived from late but highly differentiation processes suggesting probable mineralization. The rare-metal content Ta, Nb is moderately high when compared with other mineralized pegmatites of Nigeria.
K/Rb versus Rb and plots of Ta versus Cs, Ta versus Rb also confirm the moderate-high level of Ta-Nb mineralization potentials comparable with other pegmatites across the world such as those of Noumas (South Africa), Silver Leaf and Odd West (Canada).

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