Compositional trends and rare metal (Ta-Nb) mineralization potential of pegmatite and associated lithologies of Igbeti area, Southwestern Nigeria

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Abstract: The increase in global demand for rare metal Ta-Nb deposits has created the need for renewed search for economically viable deposits. This study therefore, involves petrographic and geochemical evaluation of near flat lying pegmatite veins intruding gneisses, schists and granitic rocks around Igbeti area, southwestern Nigeria. This is with a view to determine their compositional characteristics and rare metal Ta-Nb potential.

A total of 24 samples comprising whole rock pegmatites and mineral extracts of albite, mica and tourmaline were analysed for major, trace and rare earth elements using Inductively Coupled Plasma-Mass Spectrometry technique (ICP-MS). From the results, the whole rock pegmatite is considerably siliceous, but with noticeable depletion of silica in the tourmaline extract. Average Fe_2O_3, MgO and MnO values are low in all the samples. Trace element analysis also reveal Ta-Nb enrichment in all the samples (>246 μg/g) with highest values in the tourmaline phase and lowest values in the whole rock pegmatite. Similarly, Cs values are highest in the tourmaline extracts, but Ti, Ba and Zr values are generally low. All samples analysed reveal that the pegmatites are magmatic with evidence of late metasomatic alterations with appreciable degree of fractionation and mineralization as indicated in the low K/Cs (0.04) Th/U (0.08) and K/Rb (0.001) values. Also, from plots of Ta/(Ta+Nb)/Mn/(Mn+Fe), and other bulk geochemical features, the pegmatite is complex, of the rare element class and belongs to the Lithium, Ceasium Tantalum (LCT) petrogenetic family. Furthermore, variation plots involving K, Rb, Ta, Ga, Cs, and W show enhanced Ta-Nb mineralization potential comparable to world class Tanco and Noumas deposits.

Compositional trends within the various mineral phases analysed indicate preffered enrichment in the tourmaline, mica, and albite phases in that order respectively.

Key words: pegmatite, Ta-Nb, mineralization, fractionation, tourmaline

Introduction

Pegmatites are known to host many metallic and non-metallic (industrial) minerals that are of great economic benefits. Consequently, the increase in global demand for these minerals especially the rare metals (Ta-Nb-Sn), has led to the renewed interest in the search for economically viable deposits in Nigeria (Okunlola, 1998; Adekoya et. al., 2003; Ajayi and Ogedengbe, 2003; Garba, 2003; Okunlola and Ogedengbe, 2003; Okunlola, 2005; Okunlola and Jimba, 2006; Okunlola and Ofonime, 2006; Okunlola and Somorin, 2006). In Nigeria, Precambrian pegmatites occur mostly in the western half of Nigeria along a NNE – SSW trending belt (Jacobson and Webb, 1964). However, recent studies such as those of Garba, (2003) and Okunlola, (2005), have shown that they also occur on a minor scale in the southeast and northeastern parts. The pegmatite bodies and associated rocks of this study area which is part of the Iseyin Oyan schist belt (one of the prominent belts of the metasedimentary belt of Nigeria) and the Oke-Ogun Ta-Nb field (Okunlola, 2005) were thus studied with a view to elucidate their compositional features and rare metal Ta-Nb economic potentials. This, it is hoped will add to the inventory of data of productive rare metal pegmatites. Okunlola, (2005) earlier had 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.

Materials and methods

The study involves systematic geological mapping, and thin section examinations of 10 pegmatite samples. Also, geochemical analysis of schists, gneiss, the whole rock pegmatite and extracts of mineral components albite, muscovite and tourmaline extracted from the pegmatites were carried out for major, trace and rare earth elements at the Activation laboratories, Ontario, Canada using the ICP-AES instrumentation method. All the samples were dried at 60 °C, crushed and dried to –80 mesh (–177 μm). The analytical procedure involves a sample weight of 0.5 g put in a platinum crucible. 5 mL of perchloric acid ($HClO_3$), trioxonitrate (V) (HNO_3) and 15 mL of hydrofluoric acid (HF) are added. The solution is stirred properly and allowed to evaporate as it is heated at a lower temperature for some hours. Four ml of hydrochloric acid (HCl) was then added to the cooled solution and warmed to dissolve the salts. On cooling, the solution was diluted to 50 ml with distilled water. The solution is then introduced into the ICP torch as an aqueous aerosol. The emitted light by the ions in the ICP was converted to an electric signal by a photomultiplier in the spectrometer. The intensity of the electrical signal produced by emitted light from the ions was compared to a standard or control (a previously measured intensity of a known concentration of the elements) This quality control incorporates a sample prep blank as the first sample and a pulp duplicate to monitor analytical precision which is carried through all the stages of preparation to analysis.

A total of 30 samples were analyzed comprising 3 samples each of granite and schist and 6 samples each of whole rock pegmatite, mica, tourmaline and albite extracted from the pegmatite. Care was taken to ensure that the mineral extracts were obtained from only fresh coarse grained pegmatite samples containing grains >2 cm of each of these mineral components. Initial diasaggregation was done by a hand held hammer with the final separation into the different mineral components done by hand.

RESULTS AND DISCUSSION

The study area, lies within the southwestern part of the reactivated Pre Cambrian basement complex of Nigeria. The Nigeria basement complex forms part of the Pan-African mobile belt, which lies to the east of the West African Craton (Figure 1). Despite contrasting documentation of the evolution of the basement complex of Nigeria, they could be loosely categorized into three major groups namely: Gneiss Quartzite Complex: comprising biotite and biotite hornblende gneisses, quartzites and quartz schist. Schist Belts: comprising paraschists and meta-igneous rocks, which include phyllitic schists, amphibole schists, amphibolites, talcose rocks, and marble and calc-silicate rocks. They are mainly N-S to NNE-SSW trending belts of low grade supracrustal and minor volcanic assemblages. The Older granites include granite, granodiorite, diorite, charnockite, pegmatites and aplites. In the study area, as revealed from systematic mapping on

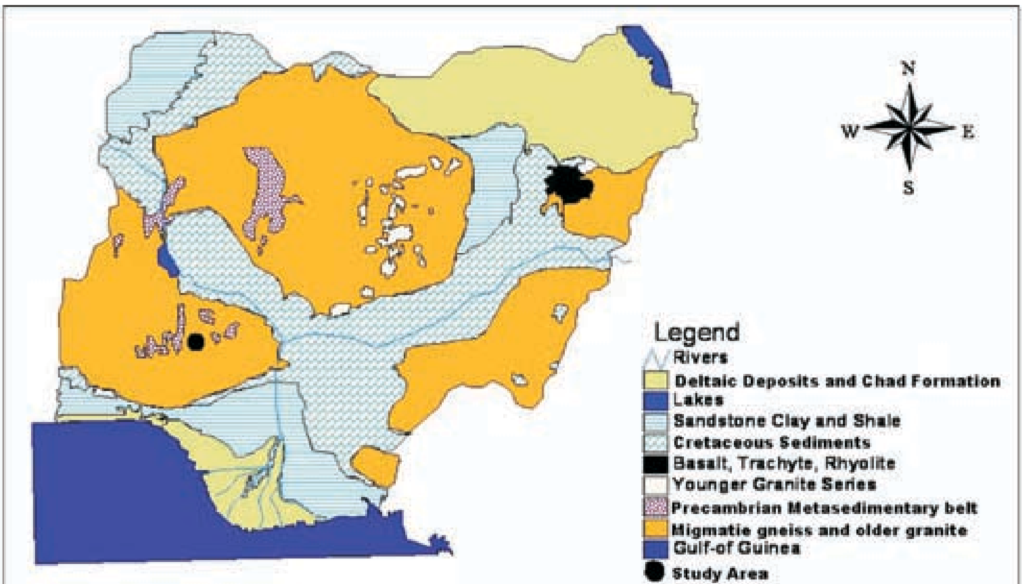

Figure 1. Geological Map of Nigeria Showing Location of the Study Area

a scale of 1 : 20000, biotite schists, augen gneiss, granites and semi discordant intrusive dykes of pegmatite veins which intrude other rock units especially in the northern parts are the main rock units (Figure 2). Schistose rocks are more prominent in the central and the northern parts of the study area. They are low lying, with schistose quartzites and biotite schists predominating. Mineralogically, they are mostly made up of quartz, garnet, biotite, muscovite, microcline, and accessory opaques. The granites also occur as coarse grained to porphyritic sometimes extensively weathered rock with biotite, microcline, and quartz being the main minerals.

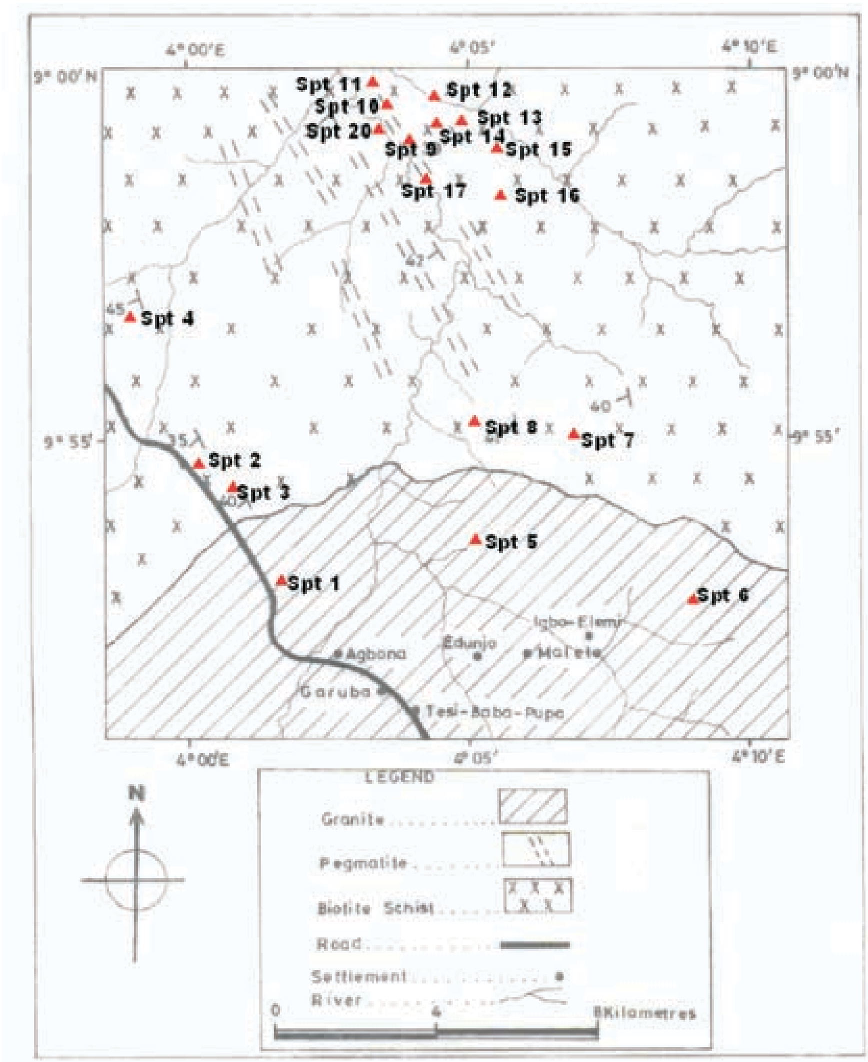

Figure 2. The location map of study area showing geology, drainage pattern and sampling points

Pegmatites occur as leucocratic tabular veins trending mostly NNW-SSE and ranging from medium to coarse grained texturally. They are more predominant in the northern parts intruding the schistose rocks (Figure 2). They range in size from about 50–200 m long and about 10–50 m wide in places. Petrographic studies reveal a mineral assemblage of mainly quartz, albite, microcline, muscovite, and tourmaline with accessory opaques mainly columbotantalite, rutiles, and magnetite. Garnets and zircon make up the accessory composition. Quartz exhibits euhedral shape, cloudy to colourless with evidence of poikilitic intergrowth of feldspar. Albite exhibits characteristic albite twinning with grains showing some stretching (Figure 3). Crosshatched twinning is also displayed in the microcline with perthitic texture common in the feldspars. Muscovite occurs as elongated tiny plates mostly interstitial between the quartz and the albite, it also exhibits perfect cleavage in one direction and strong birefringence colors. The modal composition of 10 samples of whole rock from 5 sample points each on the thin section of the pegmatite is shown in Table 1.

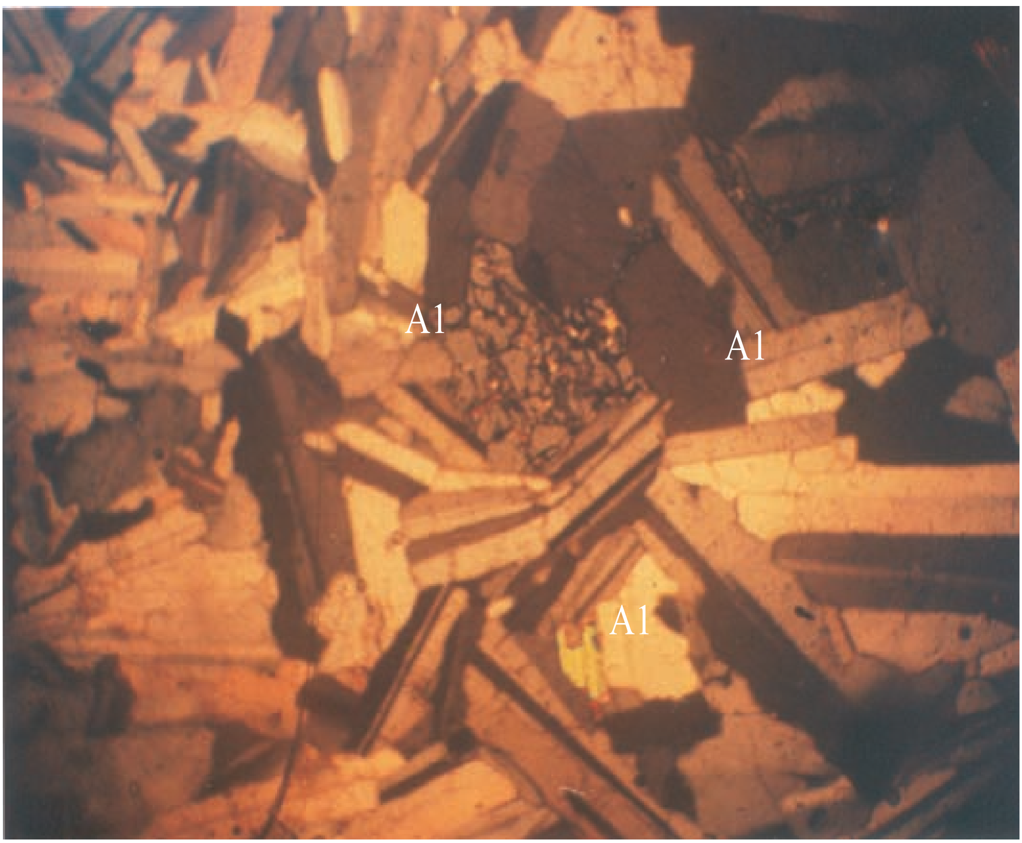

Figure 3. Photomicrograph of pegmatite in transmitted light, showing predominance of albite (Al) and interstitial muscovite (M) minerals

Table 1. Modal composition of minerals of the pegmatite from the study area

Minerals	Composition (%) (n = 10)	
	Range	Average
Quartz	15–25	20
Albite	26–45	35
Microcline	10–18	15
Tourmaline	6–12	10
Muscovite	8–18	15
Accessories	1–6	5
Total		100

The analytical results of major, trace and rare elements which are presented in Tables 2 and 3 show average SiO_2 values of 63.02 %, 69.88 %, and 69.61 % in the whole rock, albite and muscovite samples respectively. However there is a noticeable depletion in the tourmaline extracts with minimal variation in their values. The SiO_2 values of the whole rock and mica values are slightly lower than average for Nigeria's Ta-Nb pegmatite (Okunlola, 2005) but compares with those of Komu area, also within the Oke-Ogun field (Okunlola and Ofonime, 2006). Al_2O_3 value is greater than 14 % in all the samples with noticeably high values (37.25–37.42 %) in the tourmaline extracts. Al_2O_3 values, for the other mineral samples compare with those for other Ta-Nb pegmatite fields within Nigeria. In contrast to these elevated values, Fe_2O_3, MgO, TiO_2 and MnO values are lower than 0.4 % especially in the mica and albite extracts except for the Fe_2O_3 values of 2.14 % in the tourmaline and 5.58 % in the whole rock samples. P_2O_5 values also are generally low in all the samples with highest values of 1.98 % recorded for the albite samples and lowest values in the tourmaline extracts (0.25 %). Trace element data (Tables 3) show appreciable content of rare metals in all the samples. For example, Ta values in the albite samples range from 140–500 µg/g while in the mica (muscovite) samples range of values is between 135–402 µg/g. The tourmaline samples have the highest mean Ta values of 330 µg/g and a range of 295–388 µg/g, while the lowest Ta values are recorded for the whole rock pegmatites (160–175 µg/g). Nb values are relatively lower with the range of 48–130 µg/g, 56–150 µg/g in the albite and muscovite samples respectively (Table 3). Tourmaline and whole rock samples contain much lower Nb with average content of 16.33 µg/g and 19.17 µg/g respectively. The Ta and Nb values in the mica extracts are comparable with those of the richer Nasarawa-Keffi and Kushaka Ta-Nb fields of Nigeria respectively (Okunlola, 2005). Rb values are enhanced in all the samples (452–1000 µg/g) while Sr samples are highest (420–515 µg/g) in the whole rock samples and albite samples (41–138 µg/g) respectively. Average elemental ratio Na/K, is expectedly highest in the albite samples with values as high as 82.8 and lowest in the tourmaline (1.25) (Table 5). The Rb/Sr ratio show non varability in all the samples with average of 11.5. The Ta/Nb ratio clearly shows that the Ta is preferred relative to Nb, in all the samples with highest values of about 20 in the tourmaline samples compared with about 3 in the whole rock samples (Table 5). This also indicates preferred tantalite enrichment in the tourmaline extracts of the Igbeti pegmatite.

Table 2. Range and average values of major elements in the albite, mica, tourmaline and whole rock samples in mass fractions (w/%)

Oxides	Albite N = 6		Mica N = 6		Tourmaline N = 6		Whole rock Pegmatite N = 6	
	Range	Average (%)	Range	Average (%)	Range	Average (%)	Range	Average (%)
SiO_2	64.98–74.69	69.88	66.54–72.76	69.61	42.92–42.96	42.94	62.03–63.61	63.02
Al_2O_3	15.66–20.15	17.85	14.82–19.75	17.99	37.07–37.42	37.27	14.74–15.30	15.03
Fe_2O_3	0.04–0.31	0.19	0.12–0.44	0.33	2.13–2.16	2.14	4.99–6.56	5.58
MnO	0.01–0.31	0.10	0.02–0.25	0.12	0.73–0.74	0.74	0.13–0.22	0.18
MgO	0.01–0.21	0.05	0.02–0.09	0.06	0.13–0.15	0.14	2.54–2.99	2.75
CaO	0.01–0.11	1.24	0.26–3.44	1.42	0.80–0.96	0.90	3.62–4.92	4.25
Na_2O	0.64–2.46	7.76	6.29–7.47	6.88	1.62–1.66	1.64	2.63–3.05	2.93
K_2O	0.09–2.95	1.10	0.85–2.01	1.52	1.13–1.17	1.15	1.13–6.54	4.10
TiO_2	0.01–0.05	0.03	0.01–0.04	0.03	0.04–0.05	0.05	0.74–0.76	0.75
P_2O_5	0.13–2.05	0.97	0.28–2.70	1.20	0.24–0.26	0.25	0.28–0.32	0.30

Table 3. Range and averages of some of trace elements in Albites, Mica, tourmaline and whole rock samples

Element	Albite		Mica		Toumaline		Whole rock Pegmatite	
	Range	Average	Range	Average	Range	Average	Range	Average
Bas	23–59	35	13.00–91.00	49.83	47.00–51.00	48.67	1070–1487	1289.00
Sr	41–138	92.17	34.00–170.00	92.00	89.00–91.00	89.83	420–575	483.33
Y	1.50–2.00	1.58	1.50–4.00	2.50	2.00–3.00	2.33	24–28	26.33
Zr	31–155	68.83	71.00–169.00	102.67	14.00–16.00	14.83	203–334	276.67
Zn	30–890	210.00	60.00–410.00	276.67	2040.00–2210.00	2110.00	60–90	77.00
Ga	23–75	46.67	37.00–68.00	56.00	203.00–210.00	206.17	22– 25	23.00
Rb	52–1000	710.50	958–1000	826.33	1000–1000	1000.00	133–290	219.33
Nb	48–130	79.67	56.00–150.00	121.33	15.00–18.00	16.33	13–24	19.17
Sn	0.50–5.00	2.75	2.00–9.00	5.17	2.00–3.00	2.50	10–25	18.50
Cs	84.60–401	214.28	125.00–335.00	235.83	1000–1000	1000.00	8.60–12.40	10.72
Ta	140–500	246.33	135.00–402.00	264.50	295.00–388.00	330.50	160–175.00	168.33
W	0.50–2.00	1.17	0.50–3.00	1.08	3.00–4.00	3.50	1.00–3.00	1.83
Ti	0.70–25.60	9.30	5.40–20.20	13.72	57.50–60.80	59.3	0.90–1.80	1.45

Table 4. Rare earth element composition of pegmatite and associated minerals from Igbeti area (ppm); 1–6 ALBITE SAMPLES, 7–12 MICA SAMPLES, 13–18 TOURMALINE SAMPLES, 19–24 WHOLE PEGMATITE SAMPLES

Elements	1	2	3	4	5	6	7	8	9	10	11	12
La	2.4	2	4.8	200	3.8	1.7	3	14.4	3	1.6	1.8	2.9
Ce	3.5	3.1	7.9	1.4	4.2	1.9	4.3	25.4	4.3	1.5	1.7	4.1
Pr	0.42	0.41	0.83	0.17	0.67	0.46	0.68	2.77	0.69	0.28	0.33	0.68
Nd	1.4	1.6	2.8	0.7	2.7	2.1	2.7	9.4	2.8	1.1	1.3	2.8
Sm	0.2	0.3	0.4	0.1	0.5	0.5	0.6	1.5	0.6	0.2	0.3	0.6
Eu	0.09	0.09	0.1	0.08	0.11	0.16	0.19	0.27	0.17	0.06	0.06	0.17
Gd	0.2	0.3	0.3	0.1	0.5	0.6	0.6	1	0.6	0.2	0.2	0.6
Tb	< 0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Dy	0.1	0.3	0.2	0.1	0.4	0.6	0.6	0.8	0.5	0.2	0.2	0.5
Ho	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Er	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.4	0.3	0.1	0.1	0.3
Yb	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.4	0.3	0.1	0.1	0.3
Lu	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.04	0.04	0.04	0.04
Hf	8	5.6	9.1	15.8	27.8	19.7	13.8	9.9	14.3	18.7	20.6	13.4
Ta	140	165	190	500	171	312	369	164	402	135	214	303
W	1	1	1	2	1	2	3	1	2	1	1	3
Th	4.4	2.1	5.2	2.2	6.1	36.4	20.1	9.3	20.4	4.1	2.3	18.6
U	12.6	4.2	13.4	6.3	3.7	22.8	19.3	13	27.8	2.1	2.7	18.4

Elements	13	14	15	16	17	18	19	20	21	22	23	24
La	2.3	2.6	2.4	2.5	24	2.3	40	82.8	55	60	75	72
Ce	4.8	5.6	4.9	5	5.2	5.4	85.6	179	150	163	99	170
Pr	0.58	0.67	0.59	0.66	0.62	0.6	9.72	19.7	10.5	13.5	18	16.7
Nd	2.3	2.6	2.4	2.35	2.5	2.4	37.6	72.1	45.1	58.3	70.9	39
Sm	0.5	0.5	0.5	0.45	0.55	0.5	7.6	12.1	12.2	11.3	8.5	9.6
Eu	0.12	0.13	0.12	0.13	0.12	0.13	1.68	2.43	2.41	1.89	2.38	2.4
Gd	0.4	0.5	0.4	0.4	0.5	0.5	5.9	7.8	6.2	6.5	7.4	7.1
Tb	0.1	0.1	0.1	0.1	0.1	0.1	1	1.1	1	1.2	1.1	1
Dy	0.4	0.5	0.4	0.42	0.46	0.5	5.3	5.3	5.5	5.6	5.3	5.2
Ho	0.1	0.1	0.1	0.1	0.1	<0.1	1	0.9	0.95	0.9	1	1.1
Er	0.3	0.3	0.4	0.4	0.4	0.3	2.8	2.5	2.9	2.85	2.8	2.7
Yb	0.2	0.3	0.2	0.25	0.28	0.3	2.6	2.2	2.7	2.6	2.4	2.2
Lu	0.04	0.04	0.04	0.04	0.04	0.04	0.37	0.32	0.38	0.37	0.35	0.35
Hf	1.7	1.5	1.6	1.5	1.7	1.6	5.5	8.8	6.7	7.2	7.9	8.5
Ta	295	388	300	310	350	340	160	170	175	164	172	169
W	3	4	3	3	4	4	1	3	2	3	1	1
Th	1.1	1.2	1.1	1.3	1.1	1.2	12.3	37.8	20.6	15.7	35	32.5
U	6.5	8.3	7.2	6.7	8.1	7.5	2	4.2	3.5	3.7	2.7	2.3

Table 5. Ratios of selected major and trace elements from whole rock pegmatite and associated minerals from Igbeti area; 1–6 ALBITE SAMPLES, 7–12 MICA SAMPLES, 13–18 TOURMALINE SAMPLES, 19–24 WHOLE PEGMATITE SAMPLES

Element ratio	1	2	3	4	5	6	7	8	9	10	11	12
Th/U	0.35	0.5	0.39	0.35	1.65	1. 6	1.04	0.72	0.73	1.95	0.85	1.01
Ta/W	140	165	0.39	250	171	156	123	164	201	135	214	101
Rb/Sr	7.75	9.02	7.25	0.59	11.3	13.5	9.62	5.64	9.35	29.4	29.4	9.71
Ba/Rb	0.04	0.06	0.06	0.44	0.05	0.02	0.06	0.1	0.06	0.02	0.01	0.06
Zr/Hf	5	5.89	4.84	1.96	5.58	5.58	5.15	17. 1	5.46	5.56	5.63	5.82
Sr/Rb	0.13	0.11	0.14	1.69	0.09	0.07	0.10	0.18	0.11	0.03	0.03	0.10
Rb/Cs	3.546	3.22	2.49	0.26	5.43	11.8	3.00	7.66	2.99	6.99	6.62	3.05
K/Rb	0.001	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.002
K/Cs	0.005	0.002	0.006	0	0.004	0.007	0.005	0.006	0.005	0.007	0.006	0.005
Ta/Nb	2.85	2.57	2.43	10.4	1.56	2.4	2.58	2.92	2.95	1.19	1.42	2.33
Na/K	0.18	11.5	1.67	82.82	16.9	12.1	3.19	6.61	2.95	5.80	5.71	2.95

Element Ratio	13	14	15	16	17	18	19	20	21	22	23	24
Th/U	0.17	0.145	0.15	0.19	0.14	0.16	1.52	0.10	0.37	0.39	1.11	0.40
Ta/W	98.3	97	100	**103.3**	87.5	85	68	250	58. 7	66. 7	128	210
Rb/Sr	11.2	11.0	11.2	11.1	11.0	11.2	7.27	14.5	9.22	8.84	8.89	11.3
Ba/Rb	0.05	0.05	0.05	0.05	0.05	0.05	0.09	0.03	1.19	1.18	0.89	0.70
Zr/Hf	8.24	10. 7	8.75	9.33	8.82	10	8.21	5.39	7	6.67	4.8	5.63
Sr/Rb	0.09	0.09	0.09	0.09	0.09	0.09	0.14	0.07	0.18	0.11	0.11	0.09
Rb/Cs	1.01	1.01	1.01	1.01	1..03	1.02	5.36	6.65	10.7	6.92	8	8.84
K/Rb	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
K/Cs	0.001	0.001	0.001	0.001	0.001	0.001	0.004	0.004	0.008	0.006	0.006	0.005
Ta/Nb	16.3	22.5	18.7	19.3	23.3	18.8	12.3	7.08	9.21	10.9	8.6	7.04
Na/K	1.25	1.28	1.27	1.27	1.26	1.28	0.89	8.87	8.87	6.82	8.21	11.5

From field evidence and bulk chemistry signatures, the Igbeti pegmatite is a complex pegmatite, of the rare element class and displays typical characteristic of the Lithium, Ceasium, and Tantalite (LCT) 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) 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,) gemstones and industrial minerals (Cerny, 1989). The metamorphic environment in this study area which is a low pressure upper green schist facies to lower amphibolite facies (Okunlola and Ofonime, 2006) with quasi conformable to cross cutting structural feature is also typical of LCT pegmatites of the rare element class (Beus and Sitnin, 1968; Cerny, 1982; Mentzer, 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 schistose host rocks which according to Cerny (1991b) is also typical of LCT pegmatites. This characteristic coupled with the Rb, Sr, content of the Igbeti pegmatites, suggests that the pegmatites could have been derived from the remelting (anatexis) of supracrustals. However, the Rb /Y + Nb plot (Figure 4) shows that the pegmatite are within plate granite while the Sr/Rb plot also reveals their mixed ancestry with some samples plotting completely out of the magmatic "M" field (Figure 5) 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 enrichment in LCT elements and an overall character. Veizeuf and Holloway (1998) 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 basement plus supracrustal protoliths having homogenous chemistry. In some cases, undepleted basement lithologies such as paragneisses and metatonalites seem to be the sole source leading to both I and S characteristics (Meintzer, 1987; Walker, et. al., 1986; Wright and Haxell, 1982). The K/Rb/Rb plot (Figure 6) clearly indicates their rare metal bearing affinity, while the low K/Rb ratio shows progressive fractionation and mineralization (Kuster, 1990). This, combined with the low Mg, Ti, Ba, Zr and attendant enhanced values of Rb, Li, Cs and Y composition also indicate high fractionation of the pegmatite, while the Cs values indicate moderately high alkali metal fractionation (Cerny, 1991a). 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.

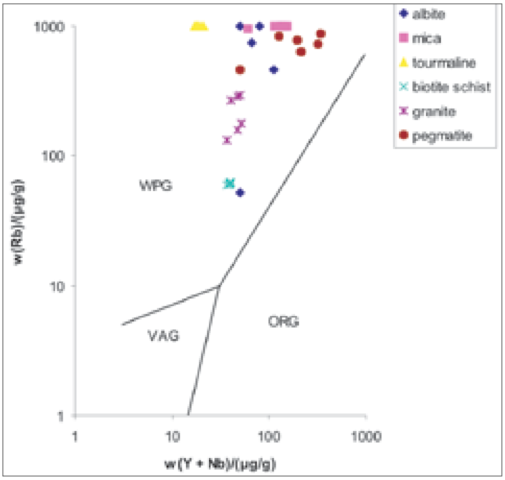

Figure 4. Graph of Rb against Y + Nb for samples from Igbeti area (after PEARCE et al., 1984)

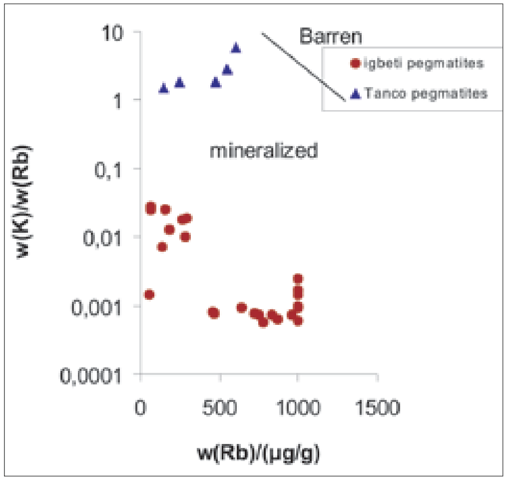

Figure 6. Graph of K/Rb against Rb for pegmatite samples from Igbeti area compared to those of Tanco (after STRAUROV et al., 1966)

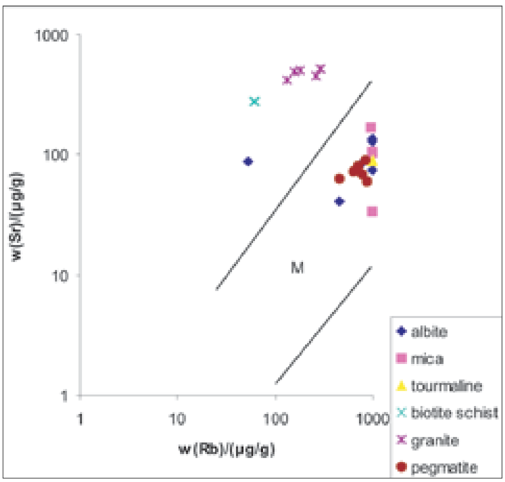

Figure 5. Graph of Sr against Rb for samples from Igbeti area

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 preffered Ta-Nb mineralization in the tourmaline extract is an evidence of the role of metasomatism in the mineralization.

Compared to the more endowed Tanco (Canada) pegmatite, the mineralization level is lower. On the plot of Ta against Ga, (Figure 7), Ta versus K/Cs (Figure 8) the samples of the whole rock and mineral extracts plot well above the mineralized GORDIYENKO (1971) line, but the mineralization level in the pegmatite samples is still lower compared to those for Tanco and Noumas pegmatite (Figures 8 and 10). The gneissic and schistose samples plot far below the BEUS (1966) line thus confirming clearly their barren nature. Significantly, however the tourmaline samples are clearly discriminated on these diagrams, plotting clearly away from the other samples indicating greater rare metal Ta enrichment. Similarly, the Ta, Rb, Cs (Figure 10) plots indicate the same trend of mineralization.

In the pegmatites of this study area, Rare earth elements (REE) abundances are low (Table 4). The chondrite normalized plot

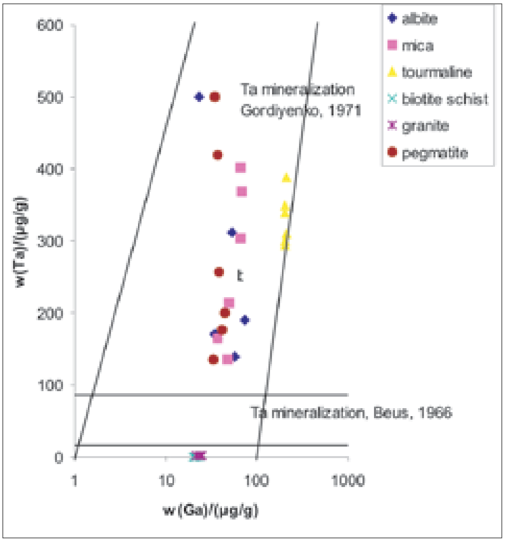

Figure 7. Graph of Ta against Ga for pegmatite samples from Igbeti area

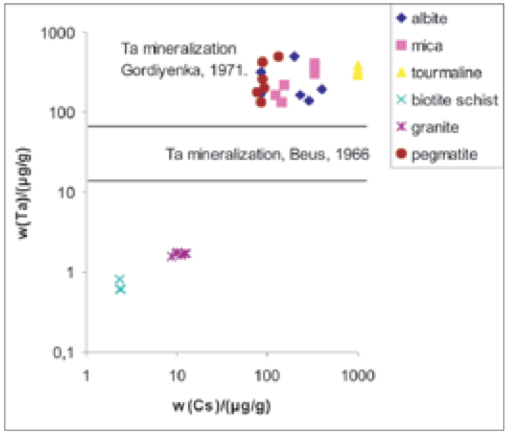

Figure 9. Graph of Ta against Cs for samples from Igbeti area

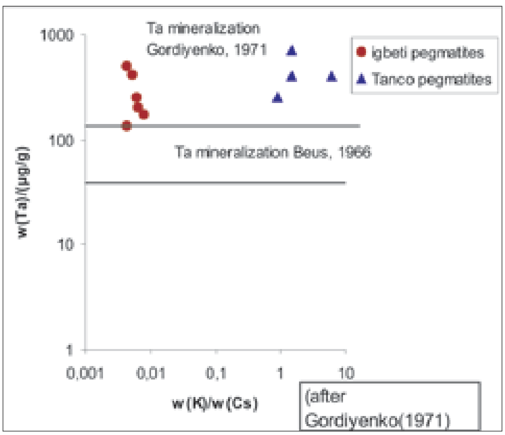

Figure 8. Graph of Ta against K/Cs for pegmatite samples from Igbeti area compared to those of Tanco (After Gaupp et.al, 1984)

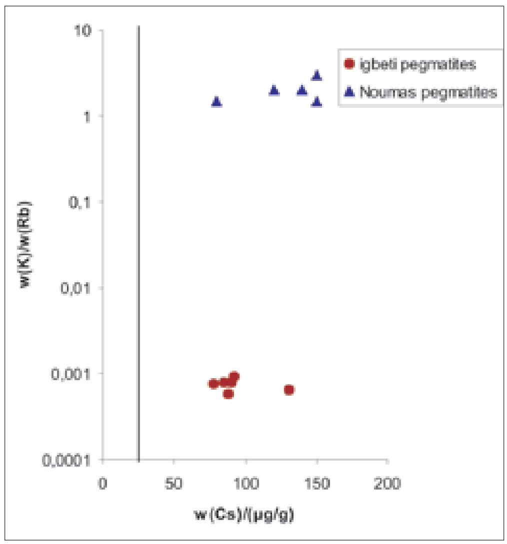

Figure 10. Graph of K/Rb against Cs for pegmatite samples of Igbeti area compared to those for Noumas

(Figure 11) shows high LREE La, Ce, Pr values and lower HREE values. Also, there are extensive negative Eu anomalies and kinking is dominant. This is especially characteristic of LCT pegmatites with attendant high fractionation. (Cerny, 1991b; Fourcade and Allegre, 1981; Lee and Christansen, 1983). Christiansen, et.al, (1993) have highlighted the difficulty of using REE for pegmatite petrogenetic in-

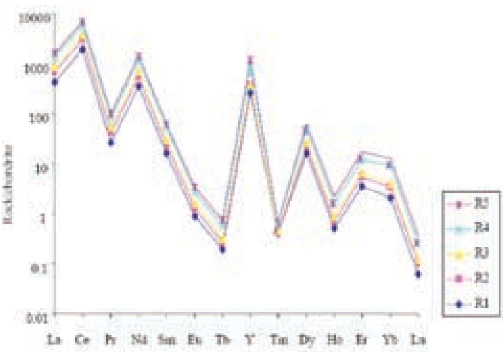

Figure 11. REE chondrite normalized plots of Igbeti pegmatite samples

terpretation because of their occurrence in accessory phases. However, Taylor (1965) had suggested earlier that where there is a weak negative Ce anomaly and a strong negative Eu anomaly as in this case of Igbeti pegmatite samples it is an evidence of considerable fractionation and metasomatism. Also, Piper, (1974) and Garba, (2003) believe that Negative Ce anomaly of rare metal pegmatite is taken to indicate oxidising condition during mineralization and interaction between magmatic, melt fluids and host rocks over long distance sometimes.

Conclusions

Pegmatite rock bodies trending mainly in the NNW–SSE direction intrude older lithologies of schists, and gneisses in the Igbeti area south western Nigeria. Thin section studies show they contain mainly quartz, albite, mica and tourmaline. They are coarse grained complex pegmatite. Geochemical analysis of the whole rock, mica, albite and tourmaline samples show they are LCT tourmaline sub type pegmatite. They are clearly enriched in tantalum compared to niobum and the trend of enrichment as clearly Ta >> Nb >> Sn. Variation plots shows they are within plate granites, possibly magmatic but with evidence of anatexis of depleted supracrustals Compared to other Ta-Nb fields in Nigeria, they compare favourably with the richest Ta-Nb mineralized pegmatite but still less endowed compared to those of Tanco (Canada) and Noumas deposit. Negative Europeum anomaly signatures indicate appreciable level metasomatic effect in the pegmatite. The high level of rare metal (Ta), mineralization in the tourmaline compared to other mineral extracts shows possibly a high influence of boron metasomatism in the mineralization process.

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