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Geochemical Evaluations and Economic Potentials of Rare Metal Pegmatites in Iludun area, Southwestern Nigeria.

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Abstract: *Mineralized pegmatiteshave been studied in Iludun area of southwestern Nigeria, with a view to determine the geochemical features that may be related to Ta-Nb mineralization and economic potentials of these pegmatites. A total of eighteen samples comprising whole rock pegmatites and muscovite extracts were analyzed for major, trace and rare earth elements using (ICP-AES) geochemical method which show the pegmatite samples to be generally highly siliceous with SiO_2 values ranging from (71.49-97.77%) with an average of 86.43% in the whole rock samples, and it also ranges from (41.88-57.99%) with an average of 48.70% muscovite extracts, while Al_2O_3 content is as high as 27.27% in the muscovite extracts and 6.86% in the whole rock samples depicting the complexity of the pegmatite rock. Most of these pegmatites are mineralized while few are barren. The barren pegmatites are sources of industrial minerals like feldspar and quartz. The mineralized pegmatites are also sources of feldspar and quartz and, in addition, columbite – tantalite, cassiterite, garnet and coloured varieties of tourmaline. The variation diagram plot of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 reveals igneous ancestry for the pegmatites with the Rb/Sr plot suggesting a 20-30km crustal thickness during emplacement of this pegmatite. There is low to moderately high albitisation, progressive rare alkali fractionation, and controlled Ta-Nb enrichment in the sample plotting in the Rare Metal Pegmatite Zone "RMP". The recorded negative Ce anomaly is an indication of oxidation due to the influence of fluid – rock metasomatic processes in their genesis. The enrichment pattern revealed by other geochemical variation plots shows that the pegmatites have moderate to high Ta-Nb mineralization.*

Keywords: *Geochemical, Pegmatite, Muscovite, Mineralized, Potential.*

I. Introduction

The area is underlain by the basement complex rocks of Nigeria, which comprises quartz mica schist and granite gneisses intruded by pegmatites veins and it lies within longitude $4^0 50^{'} 00''$E- $4^0 52'00''$E and latitude $8^0 09'00''$N- $8^0 16'00''$N. The pegmatites occur as discordant low lying dykes intruding the host rocks which are already fairly weathered. The area was studied as a result of recent increase in global demand for rare-metals 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.In recent times, there has been a resurgence of interest in the study of these pegmatites occurrences because of their associated economic rare metal and gem mineralization. These factors formed the basis for carrying out geological and geochemical studies in the area with a view to possibly identifying more mineralized pegmatites. Geological mapping was carried out on scale1:50,000.

The pegmatites were carefully observed, during the course of mapping for their field and mineralogical characteristics with a view to identifying those with high mineralization potentials. Whole rock and mineral sampling was done during the mapping exercise. Thin-section slides were also prepared for petrographic studies. Carefully selected whole rock samples and muscovite extracts were pulverized at the workshop of Department of Geology, University of Ibadan, Nigeria.

The whole rock pegmatite samples as well as the muscovite extract 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) instrumentation method. The major elements are given in weight percent (%), while the trace elements are given in parts per million (ppm). The procedure employed involves digestion of representative sample of whole rock pegmatite and muscovite extracts 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. It is becoming increasingly accepted as a tool for trace element and isotopic analysis as a result of the very low detection limits, good accuracy and

precision. 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.

II. Geological Setting, Field Description and Petrography of Rocks

The study area is underlain by quartz mica schists and granite gneisses, all intruded by pegmatites. The rocks are very sparse in the area and most of those mapped are already fairly weathered. The **schists** often occur as layered relicts, lensoidal or pools of pods. Most of the original sedimentary features have been obliterated by poly phase metamorphism. They are mainly quartz mica schists, mostly light brownish to dark grey in colour. They are exposed sporadically within the pervasive pegmatite zone in virtually the whole area as horizontally – dipping oral bodies inter layered with the rare metal bearing pegmatite.

The **granite gneiss** occurs mostly in the southwestern corner of the area. It is weakly foliated but poorly developed mineral lineation and banding on millimeter scale. Quartz, feldspar, biotite are the main minerals with quartz being the most abundant. The **Pegmatites** of this area are obviously members of the larger NE-SW trending belt extending from Abeokuta to Wamba-Jemaa area in central Nigeria as designated by [7]. The main mineral assemblages are albite, microcline, quartz, muscovite, sericite, black tourmaline (shorl), columbite-tantalite. Albite is the most abundant of these minerals and forms coarse crystalline graphic intergrowth with quartz (Fig. 1). They are sometimes perthitic with microcline as patchy and feathery perthites. These may indicate local metasomatic replacement. Most of the microcline display characteristic crosshatch twinning. It occurs as irregular grains varying from colourless to milky white with occasional yellow stains. It is medium to coarse grained.

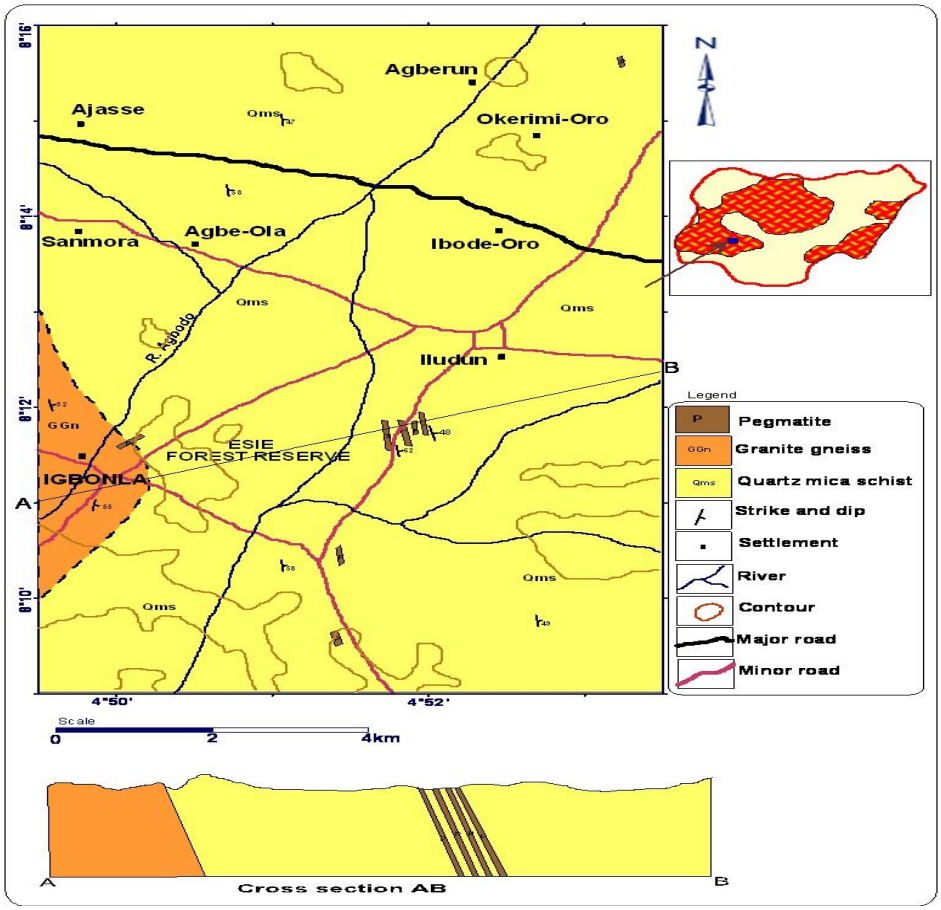


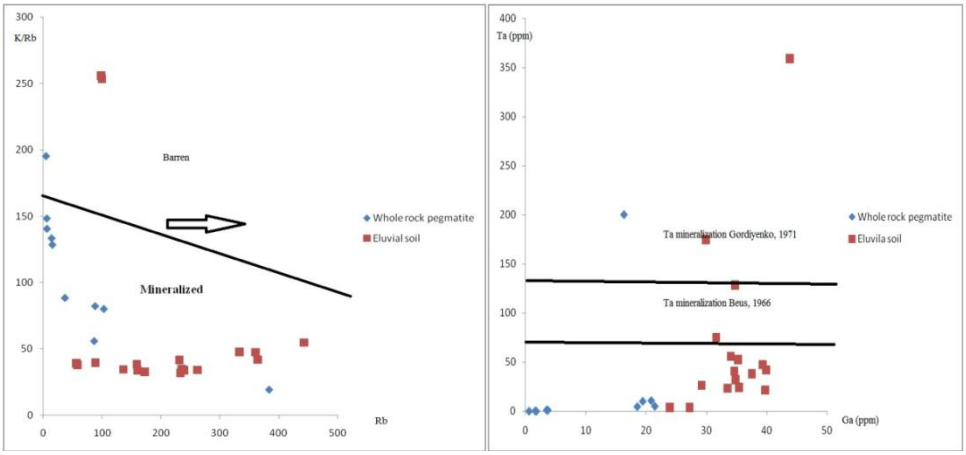
Fig 1: Geological map of the study area

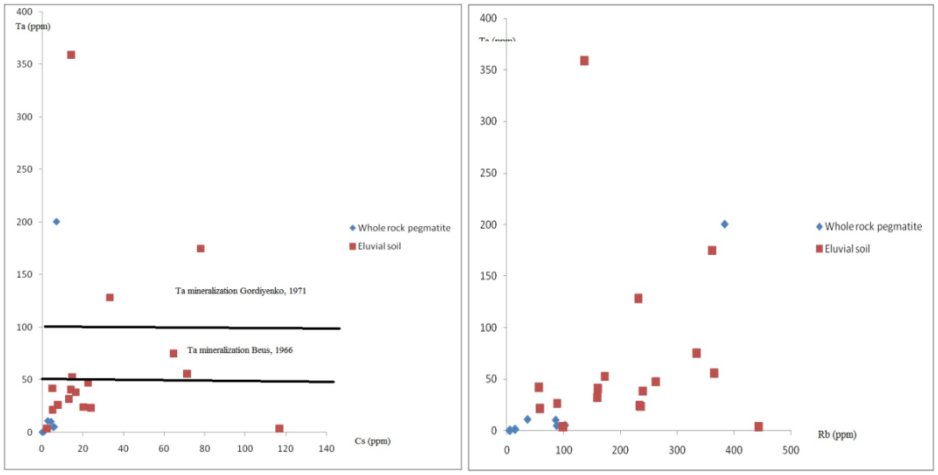
III. Results and Discussion

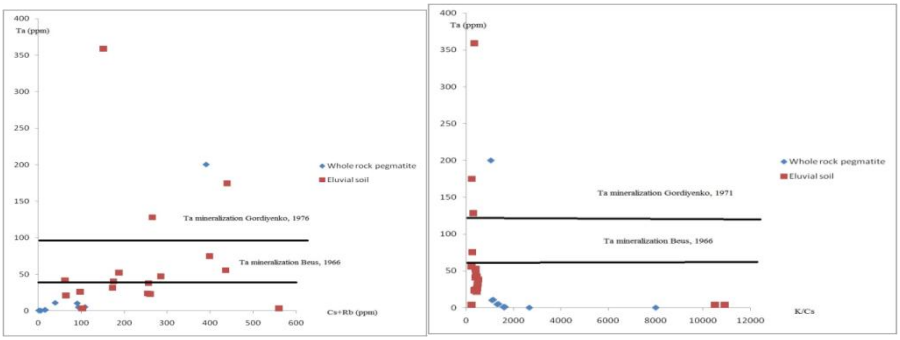
The analytical results of the major oxide composition as presented in (Table 1), it shows that the samples of the Iludun pegmatite are highly siliceous with SiO_2 content ranging from 71.49-97.77% with an average of 86.43% in the Iludun whole rock pegmatite samples, the Al_2O_3 ranges from 0.73-15.20% with an average of 6.86%, also the Fe_2O_3 ranges from 0.45-6.09% with a mean value of 2.05%. The range and mean contents of other major oxides in the whole rock pegmatites of Iludun are as follows; MnO (<0.01-0.04%, 0.03%), MgO (0.01-1.32%, 0.23%), CaO (<0.01-0.65%, 0.22%), Na_2O (0.02-6.82%, 2.09%), K_2O (0.09-0.99%, 0.45%), TiO_2 (0.02-0.87%, 0.30%), P_2O_5 (0.01-0.18%, 0.08%) and Cr_20_3 (<0.002-0.013%, 0.006%).

Also from the analytical results of the major oxide composition as presented in (Table 3), it shows that the muscovite extracts samples around the Iludun pegmatite are moderately siliceous with SiO_2 content ranging from 41.88-57.99% with a mean value of 48.43%, the Al_2O_3 ranges from 23.07%-34.94% with an average of 27.27% in the muscovite extracts around the pegmatites. This slight to sharp contrast in the values of some of the whole rock and muscovite extracts for the alumina content of this study area in addition with other rare metal characteristics, confirms the complexity of the pegmatite type.

These values are comparable to those observed for mineralized pegmatites of Nigeria, [5], [10].







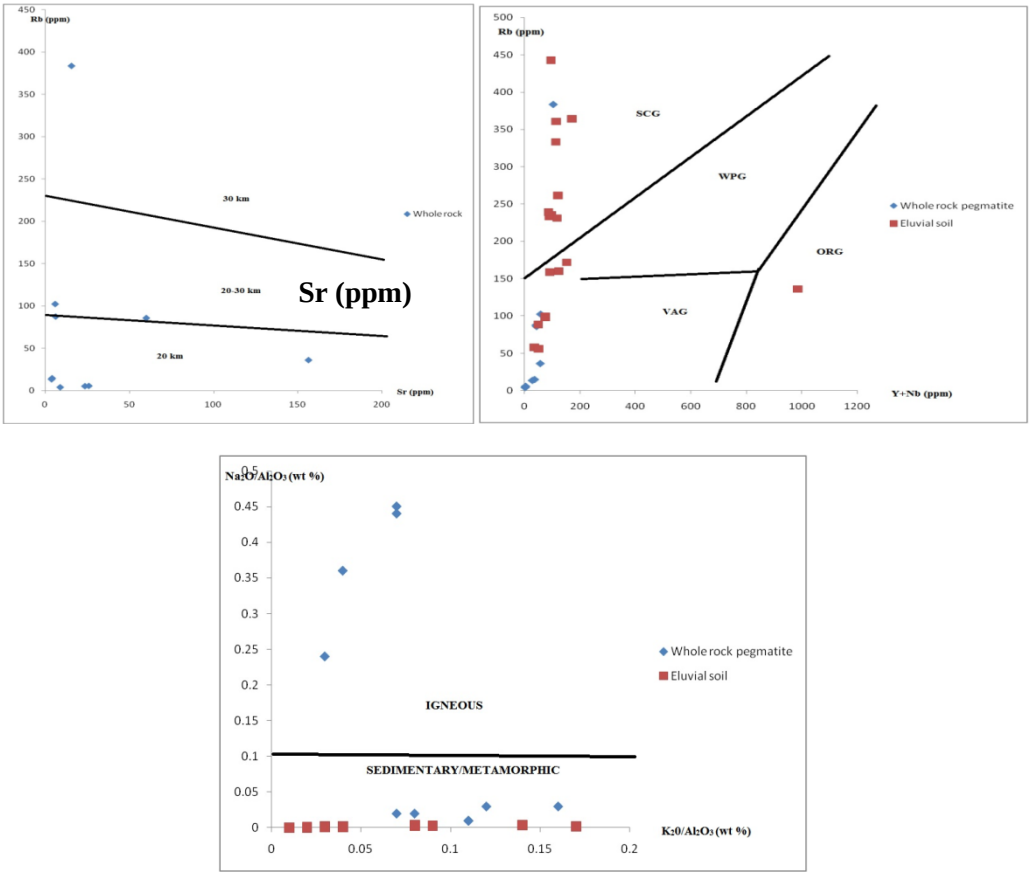


Fig.2: K/RbvsRb distribution pattern in the whole rock and muscovite extract of Iludun pegmatite. Arrow indicate normal differentiation trend after [16]. Fig.3: Plot of Ta vsGa for the Iludun Pegmatite Fig.4: Plot of Ta vs Cs for the pegmatites of Iludun [8]. Fig.5: Plot of Ta vsRb for the pegmatites of Iludun[8]. Fig.6: Plot of Ta vsCs+Rb for the pegmatites of Iludun. Fig.7: Plot of Ta vs K/Cs ratio for the pegmatites of Iludun[6] and [1]. Fig 8: Rbvs (Y+Nb) discriminant diagram for the whole rock pegmatites[14] VAG-Volcanic Arc Granite WPG- Within Plate Granite SCG- Syn-Collisional Granite ORG- Oceanic Ridge Granite Fig.9: Plot of Rb-Sr for the pegmatites of Iludun. [3]. Fig.10: Plot of Na_2O/Al_2O_3vs K_2O/Al_2O_3 (Wt %)showing variation diagram for the field of Igneous and Metasedimentary rocks of Iludunpegmatites.

The degree of albitization is revealed by the triangular Ti-Sn-(Nb+Ta) discriminant plot which plots in the zone of albitization (Fig. 11) for the Iludunpegmatites. This plot also reveals a high degree of albitization and it indicates a significant difference between the mineralized and unmineralized pegmatite samples [12], [13], [7], however these values are still low compared to those of the economically viable bodies like Tanco Canada [8], but there are indications that the pegmatitesof Iludun area compare favorably with those of other mineralized pegmatite areas like Egbe and Igbeti areas southwestern Nigeria [9]. This is also indicative of the degree of fractionation.

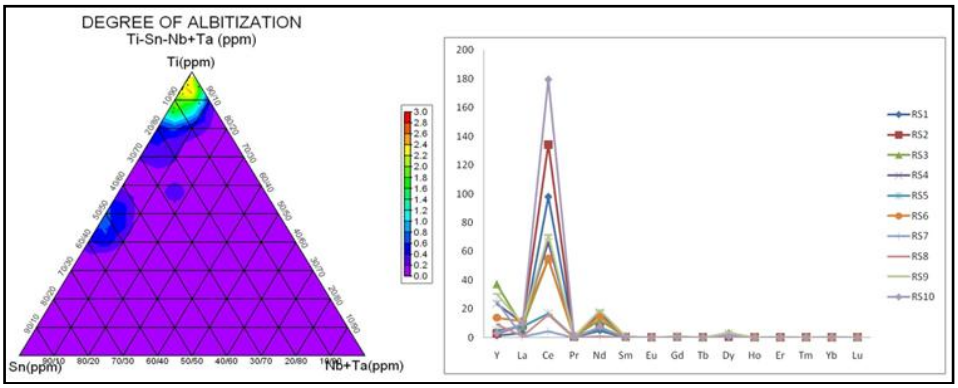


Fig. 11: Triangular Ti-Sn-(Nb+Ta) Plot for IludunpegmatitesFig.12: REE chondrite normalized plots of the pegmatite samples

The Chondrite normalized plot (Fig.12) of the rare earth elements shows high light REE (LREE) (Ce, Nd) values and low heavy (HREE) (Tb, Dy, Ho, Er, Tm, Lu and Yb). There is a weak negative Europium (Eu) anomaly and a strong positive Ce anomaly. This is especially characteristic of LCT pegmatites with attendant high fractionation. [2] and [3] However, [17] had suggested earlier that where there is a weak negative Ce signature and a strong negative Eu signature as in this case of Iludunpegmatite samples it is an evidence of considerable fractionation and metasomatism. Also, [15] and [5] 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.

IV. Conclusions

The pegmatites occur as vertically dipping and low-lying dykes, intruding the older quartz mica schist and granite gneiss. The pegmatites are observed to be rich in gem beryl, tourmaline, quartz and feldspar. Optical studies show the dominance of microcline, quartz, albite, biotite and muscovite with other opaques and accessory minerals.

Chemical data show that the pegmatites are highly siliceous, with silica contents ranging from 71.49-97.77%. The alumina contents of the whole rock pegmatite range from 0.73-15.20%. The K/Rb ratios, in the range of 19.3-195.1ppm were obtained from the whole rock pegmatite samples of the area, while the Ba/Rb ratio (0.07-15.79ppm) of the samples are comparable with other pegmatites from the southwestern Nigeria [11]. The relatively low average of K/Rb (107.13ppm) with Rb/Sr (9.83ppm) ratios of the pegmatites indicate a low to moderate degree of fractionation.

About The Authors

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Table 1: Major oxide composition, average and range of Iludun whole rock pegmatites (wt %)

Oxides(%)	ILO1	ILO2	ILO3	ILO4	ILO5	ILO6	ILO7	ILO8	ILO9	ILO10	Average	Min.	Max.
SiO_2	77.60	92.40	96.49	92.92	96.59	97.77	71.49	75.48	88.99	74.54	86.427	71.49	97.77
Al_2O_3	13.30	2.15	1.26	2.01	1.18	0.73	13.44	13.58	5.75	15.20	6.86	0.73	15.2
Fe_2O_3	0.78	2.90	1.04	2.65	0.95	0.45	6.09	2.86	1.99	0.79	2.05	0.45	6.09
CaO	0.57	0.02	0.02	0.02	0.01	<0.01	0.4	0.51	0.02	0.65	0.246667	0.01	0.65
MgO	0.06	0.05	0.03	0.05	0.02	0.01	1.32	0.59	0.05	0.07	0.225	0.01	1.32
Na_2O	5.86	0.02	0.02	0.02	0.02	0.02	3.17	4.83	0.15	6.82	2.093	0.02	6.82
K_2O	0.87	0.23	0.09	0.22	0.09	0.09	0.39	0.58	0.89	0.99	0.444	0.09	0.99
TiO_2	0.02	0.67	0.07	0.56	0.06	0.06	0.87	0.37	0.07	0.38	0.313	0.02	0.87
P_2O_5	0.17	0.01	0.03	0.02	0.02	0.04	0.17	0.14	0.03	0.18	0.081	0.01	0.18
MnO	0.03	0.04	0.04	0.04	0.03	0.02	0.03	0.03	<0.01	0.03	0.032222	0.02	0.04
Cr_2O_3	0.003	0.013	0.003	0.012	0.004	0.003	0.012	0.006	0.003	<0.002	0.006556	0.003	0.013
LOI	0.8	1.5	0.9	1.5	1.0	0.6	2.5	1.0	2.1	0.7			
Total	100.06	100.00	99.99	100.04	99.97	99.79	99.88	99.08	100.04	100.35			

Table 2: Major oxide composition, average and range of muscovite extracts (wt %)

Oxides(%)	ILO11	ILO12	ILO13	ILO14	ILO15	ILO16	ILO17	ILO18	Average	Min.	Max.
SiO_2	41.88	48.55	47.3	47.56	47.04	49.04	50.27	57.99	48.7038	41.88	57.99
Al_2O_3	33.31	23.65	26.38	23.07	34.94	26.79	26.38	23.61	27.2663	23.07	34.94
Fe_2O_3	4.08	10.2	8.6	10.64	2.35	9.2	7.58	4.82	7.18375	2.35	10.64
CaO	0.05	0.15	0.06	0.17	0.05	0.05	0.07	0.02	0.0775	0.02	0.17
MgO	0.15	2.57	0.19	3.08	0.08	0.23	0.18	0.07	0.81875	0.07	3.08
Na_2O	<0.01	0.07	0.05	0.06	<0.01	0.02	0.04	<0.01	0.048	0.02	0.07
K_2O	0.26	1.83	1.07	2.06	0.56	0.67	0.89	0.42	0.97	0.26	2.06
TiO_2	0.13	0.77	1.2	0.74	0.11	0.85	0.92	0.41	0.64125	0.11	1.2
P_2O_5	0.05	0.07	0.07	0.07	0.12	0.05	0.05	0.06	0.0675	0.05	0.12
MnO	<0.01	0.1	0.12	0.12	0.02	0.03	0.08	0.02	0.07	0.02	0.12
Cr_2O_3	0.006	0.014	0.013	0.014	0.004	0.016	0.012	0.007	0.01075	0.004	0.016
LOI	20.0	11.7	14.7	12.0	14.2	12.9	13.4	12.6			
Total	99.92	99.60	99.75	99.58	99.47	99.85	99.87	100.01			

Table 3: Trace and rare earth elements composition, average and range of whole rock pegmatites (ppm)

Elements	ILO1	ILO2	ILO3	ILO4	ILO5	ILO6	ILO7	ILO8	ILO9	ILO10	Average	Min.	Max.
Ba	38	72	64	64	26	51	19	23	143	90	59	19	143
Ce	111.4	152.7	61.8	75.6	19.0	62.4	5.0	18.1	80.9	204.0	79.09	5	204
Cs	0.1	0.3	1.2	1.1	7.1	4.4	6.0	5.5	2.8	0.5	2.9	0.1	7.1
Hf	0.3	0.3	10.2	8.1	1.1	2.4	1.8	0.7	12.0	0.4	3.73	0.3	12
Li	<20	<20	<20	<20	<20	21	<20	<20	43	<20	32	21	43
Nb	1.15	1.82	16.66	15.18	99.65	35.80	44.54	35.76	40.42	1.98	29.296	1.15	99.65
Rb	4.1	5.4	14.8	13.5	383.6	85.9	102.4	87.6	36.2	5.7	73.92	4.1	383.6
Sn	3.19	<1.06	1.06	2.13	14.89	8.51	10.63	9.57	8.51	<1.06	7.31125	1.06	14.89
Sr	8.9	23.6	4.1	3.8	15.6	60.0	5.9	6.2	156.3	25.9	31.03	3.8	156.3
Ta	0.21	0.21	1.26	1.26	200.21	10.27	5.24	4.82	10.90	0.42	23.48	0.21	200.21
W	<0.5	<0.5	<0.5	<0.5	0.9	0.8	0.5	0.6	0.9	<0.5	0.74	0.5	0.9
Zr	4.7	10.0	391.5	295.6	22.8	97.4	32.5	15.3	459.1	18.8	134.77	4.7	459.1

Table 4: Trace and rare earth elements composition, average and range of muscovite extracts (ppm)

Elements	ILO11	ILO12	ILO13	ILO14	ILO15	ILO16	ILO17	ILO18	Average	Min.	Max.
Ba	232.0	166.0	656.0	101.0	92.0	63.0	182.0	762.0	281.75	63	762
Ce	151.9	51.8	125.3	46.8	55.6	22.4	101.5	165.7	90.125	22.4	165.7
Cs	22.6	14.8	71.4	7.7	14.3	5.2	20.4	78.1	29.3125	5.2	78.1
Hf	16.9	7.4	6.3	4.1	23.8	2.9	9.1	6.2	9.5875	2.9	23.8
Li	51.0	46.0	88.0	<20.0	<20.0	<20.0	51.0	81.0	63.4	46	88
Nb	92.39	138.42	127.86	40.1	972.05	26.89	70.61	58.24	190.82	26.89	972.05
Rb	261.7	172.1	364.2	88.7	136.2	58.3	233.1	360.7	209.375	58.3	364.2
Sn	14.89	8.51	5.32	2.13	3.19	20.36	10.63	5.32	8.79375	2.13	20.36
Sr	71.5	42.4	30.0	39.6	92.9	18.1	45.6	30.3	46.3	18.1	92.9
Ta	47.38	52.62	55.77	26.21	359.13	21.38	24.11	174.85	95.1813	21.38	359.13
W	1.7	2.0	1.6	1.0	4.6	2.6	2.7	1.2	2.175	1	4.6
Zr	488.2	278.0	195.5	148.1	401.0	64.2	288.2	184.1	255.913	64.2	488.2

Table 5: Elemental ratios of some selected elements of whole rock pegmatites of Iludun

Elemental ratios	ILO1	ILO2	ILO3	ILO4	ILO5	ILO6	ILO7	ILO8	ILO9	ILO10
Ba/Rb	9.30	1.30	4.30	4.70	0.07	0.60	0.18	0.26	3.95	15.79
K/Ce	7.18	5.24	30.74	23.81	389.47	76.92	1640	397.79	39.56	3.92
K/Cs	8000	2666.7	1583.3	1636.4	1042.3	1090.9	1366.7	1309.1	1142.9	1600
K/Nb	695.7	439.6	114.1	118.6	74.3	134.1	184.1	201.3	79.2	404.0
K/Rb	195.1	148.2	128.4	133.3	19.3	55.9	80.1	82.2	88.4	140.4

K_2O/Na_2O	4.5	4.5	11.5	11	5.9	0.12	0.15	0.15	0.12	4.5
Mg/Li	3.16	6.32	15.79	15.79	15.79	169.52	22.11	18.95	185.12	9.47
Na/K	0.25	0.25	0.11	0.11	0.15	7.46	6.17	6.04	7.34	0.25
Nb/Ta	5.48	8.67	13.22	12.05	0.50	3.49	8.50	7.42	3.71	4.71
Rb/Ce	0.04	0.04	0.24	0.18	20.19	1.38	20.48	4.84	0.45	0.03
Rb/Cs	41	18	12.3	12.3	54.0	19.5	17.1	15.9	12.9	11.4
Rb/Sr	0.46	0.23	36.10	3.55	24.59	1.43	17.36	14.10	0.23	0.22
Sr/Rb	2.17	4.37	0.28	0.28	0.04	0.70	0.06	0.07	4.32	4.54
Ta/W	0.53	0.53	3.15	3.15	222.50	12.84	10.48	8.03	12.11	1.05
Zr/Hf	15.67	33.33	38.38	36.49	20.73	40.58	18.06	21.86	38.26	47.00
Zr/Sn	1.47	9.52	369.34	138.78	1.53	11.45	3.06	1.60	53.95	17.91
Na_2O/Al_2O_3	0.03	0.02	0.01	0.01	0.03	0.36	0.45	0.44	0.24	0.02
K_2O/ Al_2O_3	0.12	0.08	0.11	0.11	0.16	0.04	0.07	0.07	0.03	0.07
(Y+Nb)	1.85	3.22	35.56	27.28	102.25	42.8	57.24	40.46	55.92	3.48
Ta/(Ta+Nb)	0.15	0.10	0.07	0.08	0.67	0.22	0.11	0.12	0.21	0.18
Mn/(Mn+Fe)	0.06	0.03	0.02	0.02	0	0.01	0.04	0.04	0.01	0.04
A/CNK	6.64	9.83	7.96	7.73	5.43	2.29	1.80	1.82	3.39	9.69

Table 6: Elemental ratios of some selected elements of muscovite extracts

Elemental ratios	**ILO11**	**ILO12**	**ILO13**	**ILO14**	**ILO15**	**ILO16**	**ILO17**	**ILO18**
Ba/Rb	0.89	0.97	1.80	1.14	0.68	1.08	0.78	2.11
K/Ce	58.59	108.11	121.31	74.79	84.53	98.21	72.91	103.20
K/Cs	393.81	378.38	212.89	454.55	328.67	423.08	362.75	218.95
K/Nb	96.33	40.46	118.88	87.28	4.84	81.82	104.80	293.61
K/Rb	34.01	32.54	41.74	39.46	34.51	37.94	31.75	47.41
K_2O/Na_2O	21.40	33.50	26.14	0.42	0.56	0.26	22.25	34.33
Mg/Li	23.53	30.44	176.14	21.05	26.32	47.37	21.57	229.63
Na/K	0.05	0.04	0.03	0	0	0	0.04	0.03
Nb/Ta	1.95	2.63	2.29	1.53	2.71	1.26	2.93	0.33
Rb/Ce	1.72	3.30	2.91	1.90	2.45	2.60	2.30	2.18
Rb/Cs	11.58	11.63	5.10	11.52	9.52	11.21	11.43	4.62
Rb/Sr	3.66	4.01	12.14	2.24	1.47	3.22	5.11	11.90
Sr/Rb	0.27	0.25	0.08	0.45	0.68	0.30	0.20	0.08
Ta/W	27.87	26.31	34.86	26.21	78.07	8.22	8.93	145.71
Zr/Hf	28.90	37.57	31.03	36.12	16.85	22.14	31.70	29.69
Zr/Sn	32.80	32.67	36.75	69.53	125.71	3.15	27.14	34.61
Na_2O/Al_2O_3	0.002	0.001	0.003	0	0	0	0.002	0.003
K_2O/ Al_2O_3	0.04	0.03	0.08	0.02	0.02	0.01	0.03	0.09
(Y+Nb)	120.49	151.72	171.26	49.8	986.45	34.69	90.11	113.54
Ta/(Ta+Nb)	0.34	0.28	0.31	0.40	0.27	0.44	0.26	0.75
Mn/(Mn+Fe)	0.02	0.003	0.01	0.01	0.01	0	0.01	0.01

Table 7: REE/Chondrite normalized data for Iludun pegmatite

REE	ILO1	ILO2	ILO3	ILO4	ILO5	ILO6	ILO7	ILO8	ILO9	ILO10
Y	1.372	2.74	37.04	23.72	5.10	13.72	24.89	9.21	30.38	2.94
La	3.20	8.81	7.82	10.40	7.72	11.45	0.86	1.02	9.54	9.67
Ce	98.03	134.38	54.38	66.53	16.72	54.91	4.4	15.93	71.19	179.52
Pr	0.19	0.44	0.62	0.83	0.36	0.77	0.05	0.06	0.83	0.48
Nd	4.92	7.2	12.42	17.4	6.06	14.94	1.02	0.84	19.02	7.56
Sm	0.12	0.26	0.66	0.86	0.21	0.66	0.14	0.10	1.08	0.30
Eu	0.007	0.02	0.03	0.03	0.02	0.04	0.002	0.002	0.09	0.02
Gd	0.16	0.26	0.72	0.80	0.17	0.59	0.31	0.15	1.13	0.25
Tb	0.002	0.0005	0.02	0.02	0.006	0.02	0.02	0.009	0.03	0.005
Dy	0.17	0.45	3.17	2.63	0.67	1.80	2.44	1.01	3.86	0.50
Ho	0.002	0.005	0.05	0.04	0.007	0.02	0.03	0.009	0.05	0.004
Er	0.01	0.03	0.42	0.30	0.04	0.13	0.20	0.08	0.37	0.02
Tm	0	0.0006	0.011	0.008	0.002	0.003	0.006	0.002	0.008	0.0006
Yb	0.02	0.024	0.47	0.28	0.05	0.14	0.204	0.09	0.35	0.02
Lu	0	0.0007	0.014	0.010	0.002	0.003	0.005	0.002	0.010	0.001