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A Prefeasibility Economic Evaluation and Geochemical Characteristics of Abuja Leather Mining District Pegmatites, Southwestern Nigeria

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Abstract
The Abuja leather mining district located in southwestern Nigeria is one of the productive pegmatite field in Nigeria and is known to bear valuable economic minerals and associated with granite gneiss were studied with a view to evaluate their petrogenetic characteristics and economic evaluation of the rare metal Ta-Nb mineralization in the area. A systematic geological survey, pitting, geochemical analysis and economic evaluation were carried out. Petrological studies were carried out on some selected representative rock samples were prepared and studied for petrographic analysis. Mineralization is limited to the pegmatites which are moderately weathered in the prospect zones and these streams of pegmatitic veins are semi discordant and they contain mainly quartz, muscovite, mica-plagioclase (albite), and microcline as the main minerals while tourmaline and beryl occur in subordinate amounts.Geochemical analysis revealed that the pegmatites are siliceous and of rare – metal type. The host rocks are peraluminous and of S – type. Albite, lepidolite and muscovites (extracted from the pegmatites) are significantly enriched in Li, Rb Cs, Nb and Ta compared to the granite gneiss. The whole rock samples showed strong affinity to the syn-collisional and volcanic arc granites with an enrichment LREE and a depletion in HREE with a strong negative Eu anomaly. the rare-metal pegmatites exhibit pronounced negative Eu and slightly positive Ce anomalies. The low K/Rb ratio of the pegmatites indicates fraction accompanied by Rb enrichment and Ba depletion. Probable reserves of Ta_2O_5, Nb_2O_5 and SnO_2 for prospect 1 up to 20m assuming grade constancy is 131.00tons, 396.11tons and 306.96tons respectively, for prospect 2 is 279.05 tons, 858.913 tons and 783.08 tons respectively, for prospect 3 is 60.58 tons, 822.16 tons and 697.96tons respectively, for prospect 4 is 3.59 tons, 8.72 tons and 32.55 tons and for prospect 5 is 255.52 tons, 616.98 tons and 441.41 tons respectively. Proper process method to maximize recovery is suggested to make the venture profitable as enumerated in this research. The present system of recovery using simple planning method can only guarantee 11% recovery, which will not be economical considering the size of the deposit.
Keywords: pegmatite, economic evaluation, geochemistry, recovery, Nigeria.

1. Introduction

The first major work on the pegmatites of central Nigeria was published by Jacobson and Webb, (1946) where they established two distinct episodes of tin mineralization. In the first episode, tin mineralization was considered to be associated with pegmatites derived from the granite magmatism of the Pan-African age. Whilst, the second episode was restricted to anorogenic granite magmatism of the Jurassic age localized in the central northern Nigeria. In the first episode, they postulated four phases of mineralization corresponding to magmatic to epimagmatic stage, intermediate stage, hydrothermal stage and supergene processes. Apart from proposing two schemes of pegmatite classification based on silicate mineralogy and regional distribution, the authors linked tin mineralization to the degree of albitisation which they believed is the only reliable guide to the intensity of mineralization. Jones and Hockey (1964), while working on the geology of parts of southwestern Nigeria recovered what they described as uneconomic quantity of cassiterite, tantalite and beryl from the lower part of Oyan river. Other workers like Matheis (1979) studied the geochemical exploration for Sn-Nb-Ta in southwestern Nigeria. Matheis and Caen-Vachette (1983) studied the pegmatites of the Pan African reactivation zone covering areas like Egbe, Ijero, Wamba etc. distinguishing between the barren and mineralized pegmatites. Matheis et. al. (1983), discussed on the trace element geochemistry of tin bearing pegmatite of southwestern Nigeria. Ajibade et. al. (1972), documented on the metallogeny of the Nigerian basement complex rocks including the pegmatites. Kinnard (1984) established that the Pan- African (Upper Proterozoic) barren pegmatites are found within and around calc alkaline monzonitic plutons that are about 100 Ma older than the mineralized Paleozoic series. Her study was based on the contrasting styles of rare metal mineralization in

Nigeria with respect to Sn-Nb-Ta-Zn mineralization. Other researchers like Moller and Morteani (1987), Cerny (1989), Kuster (1990), Garba (2003) have contributed to a better understanding of southwestern and northern Nigeria pegmatite bodies distinguishing between the barren and rare metal bearing pegmatites and documenting that the pegmatites are not confined to the earlier proposed 400 km long NE-SW trending belt stretching from Wamba area (near Jos plateau) to Ilesha area. Elueze et. al. (2004) documented the industrial properties of the Olode-Falansa pegmatites in southwestern Nigeria. A prefeasibility study involving geology, mineralization and economic assessment of Abuja leather mining district area for gem stone mainly and possibly rare metal (Ta-Sn-Nb) Tantalite, Niobium, Tin Mineralization was carried out.

2. Description of the study area

The project area is located between longitude $2^0 58^1$ 15” and $3^0 00^1 45$” and latitude $8^0 14^1$-$8^0 17^1$. Notable villages include Abuja leather mining district which is about 20km east of the area of study. Abuja leather mining district is a small village in the northern part of Oyo State. It is situated about 150km northwest of Ibadan and constitutes one of the communities in Itesiwaju Local Government Area of Oyo state. Accessibility in the study area is through seasonal roads and footpaths. Because of mining activities, numerous tracks accessible by motorcycles are also available. The study area belongs to the marginal areas of southwest Nigeria climatic zone characterized by mean annual temperature of 27^0C. The rainy season spans form April/May to October/November. This is usually followed by a period of dry season from November to April. The vegetation of the area is the guinea savannah. This is essentially woodland savannah with short trees and moderately tall grasses except along river channels where the vegetation is thicker and resembles that of rain forest. The area is dominantly a pediplain, but inselberges and other hills occur around Abuja leather mining district in the eastern part of the study area. Typical drainage pattern is dendritic with a network of seasonal streams and riverlets. There is no perennial stream located within the project area. The major river is the Oyan River and its tributaries.

3. Methodology

The study was done firstly by carrying out a systematic geological survey of the entire area on a scale of 1:50,000 topographic map. This involved general geological mapping and more or less concentration on the exposed veins of the pegmatitic occurrence, the boundary of lease and current areas of workings by information miners. At the end of the mapping, a total of fifty (50) out of the seventy-five (75) pits present were sampled to a depth ranging from 5-20m white 30 whole rock samples and 20 muscovite extracts were analysed for 60 major, trace and rare earth elements resulting in 3000 analyses. Fresh rock samples were collected both from excavation pts and chipping off the host rock using a geological sledge hammer. Other tools used include the compass clinometers, to measure the orientations (strike and dip) and correctly locate the position on the topographic map. The samples were clearly labeled and prepared for analysis. Rocks collected for petrographic studies were prepared at the Department of Geology, University of Ibadan. Samples for elemental analysis studies were pulverized and sieved on the 80-micron mesh then about 10grams out into clean scaled envelopes for analysis.

The muscovite extracts and whole rock pegmatite rock samples were analysed for major, minor, trace and rare earth elements using the ICP-MS method at the ACME laboratory, Vancouer, Canada. The ICP-MS is a technique that is used primarily for the determination of trace concentration of metals. There are three major components of the ICP-MS instrument. These are source unit (the torch), the spectrometer and the computer. The source unit provides the energy to generate the emission spectral lines. The spectrometer separates and resolves these lines and measures their signal strength. The computer enables the analyst to convert the signal into numerical measurement of concentration of the analysed elements. The ICP-MS is based on emission spectra and can do simultaneous analysis of many elements. A sample weight of about 0.5grams is digested. The solution is then introduced into the ICP torch as an aqueous aerosol. This aerosol is then aspirated into an argon plasma which is very hot (8,000-10,000^0C). In the plasma, all the chemical bonds are broken and the elements are promoted to an electronically excited state by the heat and are then transported to the spectrometer. As atoms return to the ground state in the spectrometer, light is emitted. The wavelength of the light determined what element it is, while the intensity of the light is sued to determine the quantity. The third part of the ICP-MS system is the computer and associated electronic interface equipment. The interface between the spectrometer and the computer serves to convert the voltage produced by the photo multipliers into a digital signal that can be processed by the computer. This instrument has a very low detection limit of elements. With linear calibrations over 4 or 5 orders of magnification, solutions are generally unnecessary and major and trace elements can be determined in one run, lasting a few minutes

4. Geological setting of the study area

The area of study is dominantly underlained by granite gneiss and pegmatites occur as lowlying intrusions into the rocks (Fig 1). There are also quartz veins intruding the larger rock bodies.

4.1 Granite Gneiss

These gneisses are predominantly in the study area. They are mainly composed of biotite, quartz and ferromagnesian minerals as observed. The biotite also forms bands but they are not as prominent as the feldspar bands. Quartz veins intrude the rock body. From thin section, studies, minerals observed are quartz biotite, microcline and plagioclase feldspars. Muscovite occurs as elongated minerals and exhibits its characteristic pleochroism. The granite gneiss is foliated and the foliation is marked by segregation of biotite into thin discontinues bands about 1-2mm thick alternating with thicker quartz and feldspar rich bands. Whilst most part of the outcrops do not contain garnet, a small separate exposure at the southern part of the main outcrop area has garnet porphyroblass whose sizes range between about 1.5mm and about 3.00mm in diameter. Under the microscope, the foliate is defined by the preferred orientation of biotite. This foliation wraps around clusters and garnet porphyroblasts suggesting that garnet porphyroblasts are pre-tectonic in relation to the deformation that produced the foliation. This suggests that garnet is probably produced during an earlier episode of metamorphism and the observed fabric may not be the earliest one. Plagioclase, biotite and garnet, minor amount of muscovite, staurolite and sillimanite.

4.2 Pegmatites

The distribution pattern of rare metals (Li,Be, Nb, Ta and Sn) granitic pegmatites in Nigeria is characterized by a distinct linear belt which extends in the NE-SW direction. A major biofurcation of this belt at the southern part extends northwards (Wright, 1970). The area of study in which there are a lot of mining activities for rare metals and gemstones does not fall within the established zone. This suggests that the occurrence of rare metal pegmatites is not strictly restricted to the belt described by Wright (1970). Pegmatites in the area of study are poorly exposed. However, results of the geological mapping suggest that they occur in two distinct modes: as tabular bodies and irregularly shaped bodies. The tabular bodies vary in size from about 2.0cm wide and 5.0cm long to sheets of about 230m wide and 1.50km long. Few of them are traceable along strike for a distance of about 2.50km. The irregularly shaped bodies have dimensions that range from 6.0m by 10.0m to about 100m by 150m. The pegmatites show a uniform NNW-SSE trend and this similarity is structural trends suggests that the emplacement of pegmatites may be structurally controlled. Zoning is common in the smaller veins. Two distinct zones were distinguished. These are the quartz core and feldspar rich outer zone. Zoning is not discernible in the bigger bodies. However, concentration of some minerals in certain areas (for example area containing abundant quartz) may be indicative of zonatian on a large scale. Some of the veins are folded while others are not. This suggests that there are more than one generation of pegmatite emplacement. The first one prior to F1 and the second one post-dating F1. In general, the whole area is found to contain a suite of rocks that are made up of typical pegmatite rocks and their fine-grained equivalents. These observations, combined with textual variations and differences in mineralogy allow for the classification of the pegmatite in the study area into four different types:

(a) Alkali feldspar type
(b) Graphic granite type
(c) Quartz-albite muscovite-tourmaline type
(d) Fine-grained saccharroidal albite-muscovite- tourmaline-garnet type.

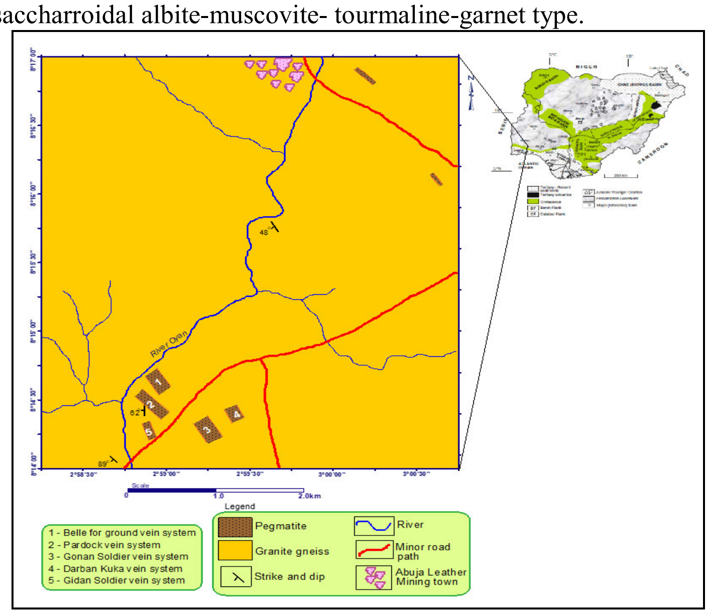


Figure 1: Geological map of the study area showing the streams of pegmatite veins.

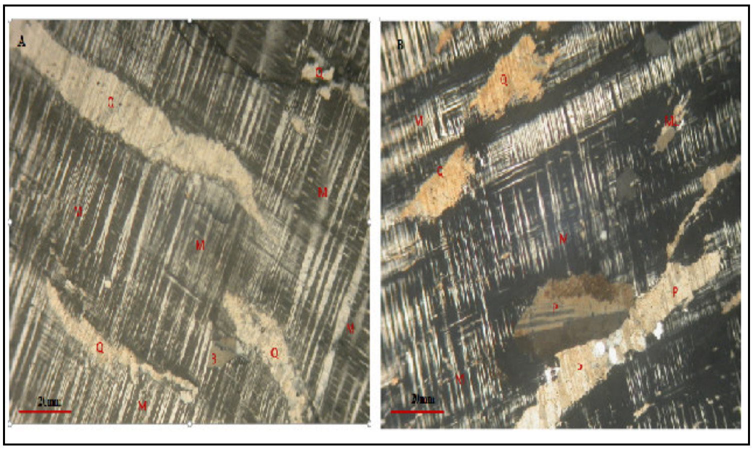


Figure 2: **(A)** Photomicrograph of pegmatite in transmitted light showing microcline (M), quartz (Q), biotite (B), **(B)** Photomicrograph of pegmatite in transmitted light showing microcline (M), muscovite (MU), plagioclase (P) and quartz (Q).

5. Results and discussion

The geochemical analysis of both whole rock and muscovite extracts were carried out at the ACME laboratories, Vancouver, Canada using the ICP-MS method. The analytical results are shown in Table 1 and 2 below. KM1-KM30 represents the whole rock samples while KM31-KM50 represents muscovite extracts from the five vein system identified in the area of study. The analytical values of the Ta_2O_5, Nb_2O_5 and SnO_2 enrichment have been utilized in the reserve estimation.

Table 1: Range and average values of major elements in the whole rock and muscovite extracts of Abuja leather mining district pegmatites in mass fraction (wt %)

	Whole Rock Pegmatite (N=30)		**Muscovite Extracts (N=20)**	
Oxides	**Range**	**Average (%)**	**Range**	**Average (%)**
SiO_2	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
T_iO_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

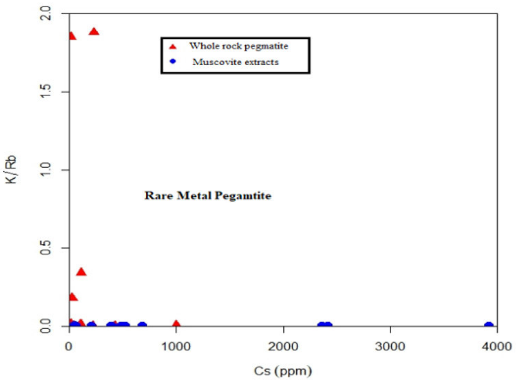
Table 2: Range and average of some of the trace elements in the whole rock and muscovite extracts of Abuja leather mining district pegmatites (ppm)

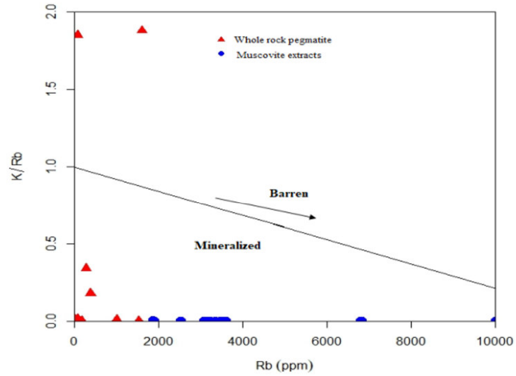
	Whole Rock Pegmatite (N=30)		**Muscovite Extracts (N=20)**	
Elements	**Range**	**Average (ppm)**	**Range (ppm**	**Average (ppm)**
Ta	9.9-500	183.22	30.6-428.9	152.44
Cs	14.4-1798	335.92	42.5-2932	873.2
Rb	24-10000	1425	1850-10000	4801.9
Sn	1-150	14.75	21-633	267.8
Nb	22.3-1120	361.19	105.4-1417	500.84
Sr	3-34	14.22	0.6-70	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	122	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

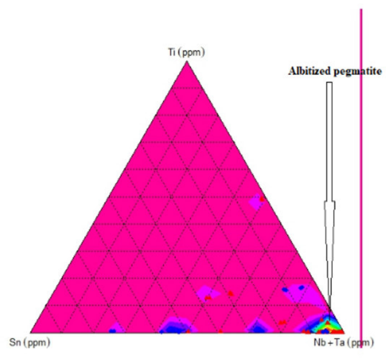
5.1 Geochemical characteristics and mineralization potential of the pegmatites

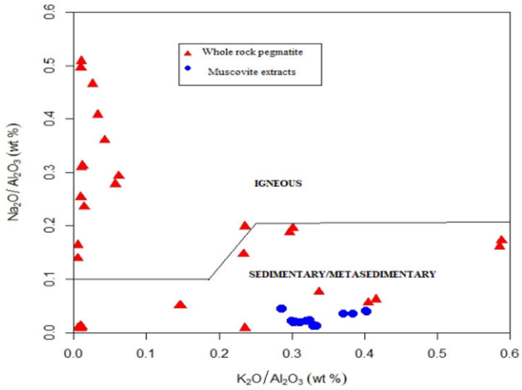
From the analytical results of the major elements as presented in (Tables 1), it shows that the samples of the Abuja leather mining district pegmatites are siliceous with $Si0_2$ content ranging from 46.14-76.71% with an average of 62.47% in the Abuja leather mining district whole rock pegmatite samples, while it ranges from 45.28-57.50% with a mean value of 48.34% in the muscovite extracts samples of Abuja leather mining district. The Al_2O_3 ranges from 11.92-28.75% with an average of 21.06% in the Abuja leather mining district whole rock pegmatite samples, while it ranges form 23.12-34.25% with a mean value of 30.72% in the muscovite extracts samples of the Abuja leather mining district 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 form 0.47-10.26% with a mean value of 4.07% in the whole rock pegmatite samples, while it also ranges form 0.27-5.83% with an average value of 3.34% in the sample of muscovite extracts of the Abuja leather mining district study area. These values are comparable to those observed for mineralized pegmatites of Nigeria. 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 extracts samples of Abuja leather mining district pegmatites respectively, compares favourably with the rare metal bearing pegmatites of Isanlu Egbe, Lema-Ndeji central Nigeria and Igbeti areas.

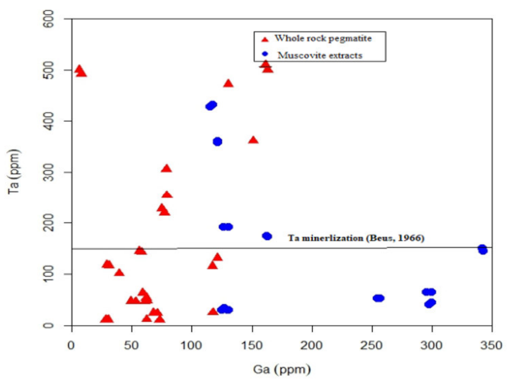
Trace and rare earth element data (Tables 2) show that the pegmatites are rich in rare metals with modertately high Ta, Nb, Sn, Rb and Cs. With tantalum value ranging from (9.9-500ppm; 30.6-428.9ppm), niobium (22.3-1120ppm; 105.4-1417ppm), tin (1-150ppm; 21-633ppm), rubidium (22.3-1120ppm; 105.4-1417ppm), tin (1-150ppm; 21-633ppm), rubidium (24-10000ppm); 1850-10000ppm) and cesium (14.4-1798ppm; 42.5-2932ppm), for the whole rock and muscovite extracts samples of Abuja leather mining district 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. 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 Abuja leather mining district whole rock and muscovite extracts pegmatite samples respectively. The values compare favourably with the mineralized pegmatites of Harding, United States; Silver Leaf, Canada and Homestead, Canada. (Moller and Morteani, 1987). Using the K/Rb versus Cs (fig. 3) plots the pegmatites in Abuja leather mining district area are rare metal bearing. The K/Rb versus Rb variation plots for the Abuja leather mining district whole rock pegmatites samples and the muscovite extract samples reveal a consistent trend, indicating the mineralization in the pegmatite of this study area to be moderately high (fig. 4). 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 Abuja leather mining district pegmatites indicate moderately high alkali metal fractionation (Reyf et al., 2000; Schmitt et al., 2002; Badanina et al., 2004; Linnen and Cuney, 2005; Salvi and Williams-Jones, 2005; Černý et al., 2005, 2012; Oyebamiji, 2014). There is a clear enrichment of Nb, Ta, Rb, Sn, Cs, Rb and depletion of Se, Co which also suggests mineralization of the rare metal columbo- tantalite (fig. 5). The samples are also relatively higher in Ta content in the whole rock samples than in the mica extracts showing that the pegmatites in Abuja leather mining district area are adequately enriched in tantalite. The K/Rb ratios of the pegmatites of Abuja leather mining district 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. In addition, the evidence of possible metasomatism being involved in the mineralization process is seen in the presence of saccharroidal albite, micaceous units and tourmalinisation. The variation diagram plot 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 Mackezie, thus indicating and suggesting a granite-igneous ancestry for the Abuja leather mining district pegmatites (fig. 6). The degree of albitization is revealed by the Triangular Ti-Sn- (Nb+Ta) discriminant plot which plot in the zone of albitization for the Abuja leather mining district pegmatites (fig. 7). This plot also reveals a high degree of albitization and it indicates significant difference between the mineralized and unmineralised pegmatite samples. These plots also show a conspicuous distribution pattern of separation in the Abuja leather mining district 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. Variation plot Ta versus (Cs+Rb) confirm these trends (fig. 8). This plot also shows the whole rock samples and the muscovite extracts samples of the Abuja leather mining district pegmatites plotting over the mineralized line of Beus, (1966) and Gordiyenko, (1971). The Abuja leather mining district 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. LCT pegmatites as in this study are also known to contain moderate to abundant Ta-Nb mineralization, gemstones and industrial minerals. However, the Rb/Y+Nb plot shows that the pegmatites plot in the field of the Oceanic Ridge Granite, WPG - Within-Plate Granite, SCG - Syn-Collisional Granite (fig. 9). While the Zr versus SiO_2 plot (fig. 10) reveals their mixed ancestry with some samples plotting completely out of the magmatic "m" field. The crustal thickness during emplacement of these pegmatites bodies reached about 30km as shown from the Rb/Sr plot. Chondrite normalized and primitive mantle plots (fig. 11 and 12) of the rare earth elements show 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, this suggests that where there is a weak negative Ce signature and a strong negative Eu signature as in this case of Abuja leather mining district pegmatite samples, it is an evidence of considerable fractionation and metasomatism. Also, Piper, (1974) believed 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.

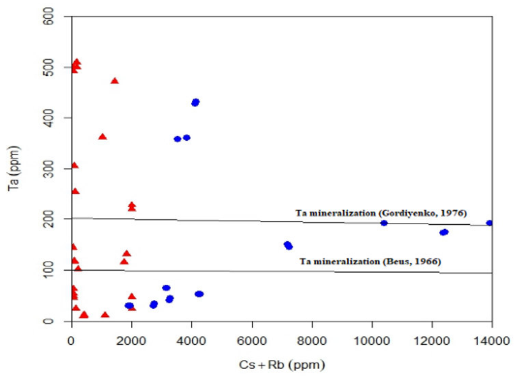


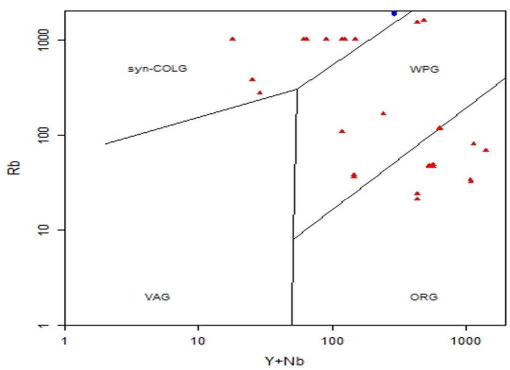


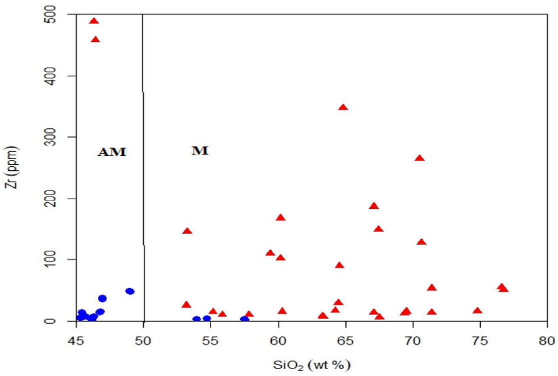


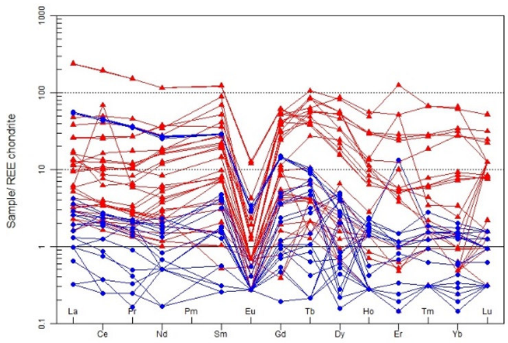












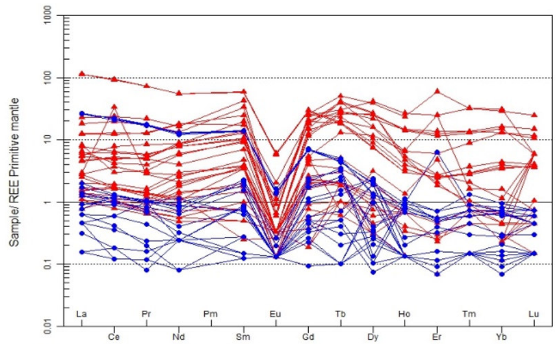


Figure. 3: Plot of K/Rb vs Cs for Abuja leather mining district Pegmatite (Cerny, 1992). Figure. 4: K/Rb vs Rb distribution pattern in the Muscovite extracts of Abuja leather mining district Pegmatite. Arrow indicate normal differentiation trend after Staurov *et al.,* (1969). Figure. 5: Triangular Ti-Sn-(Nb+Ta) Plot for Abuja leather mining district Pegmatites (Kuster, 1990). Figure. 6: 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 Abuja leather mining district Pegmatites (Garrels and Mackenzie, 1971). Figure. 7: Plot of Ta vs Ga for the Abuja leather mining district Pegmatite. Figure. 8: Plot of Ta vs Cs+Rb for the pegmatites of Abuja leather mining district study area (Gaupp *et al*., 1984). Figure 9: Rb vs (Y+Nb) discriminant diagram for the whole rock sample pegmatites of Abuja leather mining district (After Pearce *et al.,* 1984). VAG - Volcanic Arc Granite, ORG - Oceanic Ridge Granite, WPG - Within-Plate Granite, SCG - Syn-Collisional Granite. Figure. 10: Zr-Sio_2 Plots of the whole rock sample pegmatites of Abuja leather mining district pegmatites. Figure. 11: REE Normalized Chondrite plot of pegmatites from Abuja leather mining district pegmatites (Boyton, 1984). Figure. 12: REE Normalized primitive mantle plot of pegmatites from Abuja leather mining district pegmatites (McDonough and Sun, 1995).

5.2 Reserve Estimation and Economic Value of Rare Metals

In carrying out the reserve estimation of these rare metals (Tantalite, Columbite and Tin), an attempt has been made to establish the pattern of mineralization. There has been clear delineated between the muscovite extracts and primary whole rock ore. A total of 50 samples (30 whole rock pegmatite samples and 20 muscovite extracts from Abuja leather mining district pegmatites) were analysed geochemically. The basic parameters of length, breadth, depth and mineralized factor of grade in gm/tone are used. In the establishment of depths, field methods by sampling up 10m in some cases have been employed. Samples for analysis have been obtained in such a way as to represent the entire horizon considered. Samples taken, adequately covered the areas considered. Check analysis was undertaken to ascertain correctness of values. Weighted averages of grades and thickness values have been used to compensate for disparity in sample values. In exploiting the deposit areas, depth form 3-20m where albitisation is prevalent should be considered of utmost importance. From the geological and geochemical analysis, five prospect zones termed vein systems have been established and these each vein systems have pits ranging from 5-23 numbers of pits.

5.3 Process Test Work

Laboratory test work was carried out on representative specimens of both elluvial (weathered) and fresh pegmatite to evaluate the potential recoveries of tantalite and columbite. Ten samples each of the Hard rock (whole rock) samples were treated differently, a weighted composite samples of 10kg was prepared by combining sub samples in proportion to original sample weights. The weights are given in Table 3 and 4. The composite sample was wet screened at 2.0mm and the oversize material subjected to gravity concentration by panning. The panned concentrate and tailings were dried, weighed and prepared for Ta, Nb, Sn analysis. The 2.0mm fraction was further screened at 1.0, 0.25, and 0.0075mm. The size distribution of the elluvial composite is given in a Table. Each fraction was treated separately on a 1/8 size Laboratory shaking table. The recovered concentrate was further treated on mozely laboratory separator to produce a cleaner gravity concentrate. The gravity concentrate from both the shaking table and separator were further upgraded using magnetic separation techniques. A hand magnet was used to remove trace amounts of magnetite and the non-magnetic fraction was further processed using a Box mag laboratory disc separator to split the samples into fractions of different magnetic susceptibilities. The Hard rock samples were weighed and crushed to pass 1.0mm using a combination of jaw and rolls crushing. The samples contained coarse mica (up to 30mm) was impossible to crush and this material was removed at each successive screening. The weights of samples are given in Table 5. the crushed - 1.0mm samples were riffled to provide sub samples which were then recombined in accordance with the weight proportions of the original rocks to provide a representative sample for gravity concentration. This was further screened at 2 50mm and the two size ranges were treated on a 1 /x size wilifey laboratory shaking table. The rougher gravity concentrates so obtained were further cleaned on a mozley laboratory separator and the gravity cleaner concentrates retained individually. The tailings from the cleaner operations were added to the wilifey tailings in each case. The gravity cleaner concentrates were dried, weighed and treated magnetically. Magnetite was removed using a nard magnet and the non-magnetic fraction was treated on the Boxmag disc laboratory separator just like the eluvial samples. About 0.5 to 1gm of each sample material was ground to a very fine powder in an agate mortar. The powder was fussed in borax and sodium carbonate flux. The glass produced from the fusion was ground to very fine powder in a tingslen carbide ball mill. The powder was then analysed for Nb_2O_5, Ta_2O_5, and Sn_2O_5 with Phillips PW1212 X-ray fluorescence spectrometer. Calibration and drift correction was by means of standards prepared for chemically analysed columbite - tantalites of various compositions.

The economic value of rare metal bearing pegmatoids is largely dependent on the degree of liberation of discreet grains concentrated in such ore bodies. Results from this study show that the recovery of Ta_2O_5+ Nb_2O_5 up to size of -2.0mm for table concentrates for whole rock sample is 28.3% and 33.4% respectively for a combined concentrate grade of 12% Ta_2O_5 and 5.89% Nb_2O_5, while recovery for the panned concentrate up to + 20.mm is 11.3% and 13.2% of 0.5% and 0.24%, combined grade for Ta_2O_5 and Nb_2O_5 respectively. There is obvious enhancement of 17% and 20.2% recovery from the table concentrate (which is a combination of the gravity and magnetic separation techniques) over the panned concentrate. The enhancement is significant and suggest its obvious economical advantage. The recovery from the tails show that table tails of up to -2.0m to ±1.0mm liberates 29.6% and 22.2% of their Ta_2O_5- Nb_2O_5 constituents at a grade of 0.05% and 0.0 1%, compared to a total of 9.2% range for Ta_2O_5 and 8.3% for Nb_2O_5 for the size range of 1.0mm to 0.75mm at combined grades of 0.015% and 005% for Ta_2O_5 and Nb_2O_5 respectively. Back calculated results show that at - 2.0mm: table concentrate gives a recover of 28.4% and 35.9% for Ta and Nb at assay grades of 5.12% and 2.64% respectively. Up to 12.0mm, there is a slightly higher calculated recovery of 32.8% and 33.6% for both Ta_2O_5 and Nb_2O_5. A significant deduction from the above discussion is that the liberation sizes for optimal recovery is at -2mm for table concentrate and +2mm for the panned concentrate. Lower sizes fall within the tailings and the recovery is not encouraging. From sizes of -2.0mm to -2.00mm for a combination of panning, gravity and magnetic methods a total recovery of 61.1% for Ta_2O_5 and 65.0% for Nb_2O_5 is possible. This obviously shows that for deposit like that of Komu, the recovery in the elluvial ore is not only economical, but compares favourably with others like Wodgna in Australia: and China. The results also suggest that upgrading of the concentrate by magnetic separation yields slightly less than lk/tonne of ROM (Run On Mine) containing 16% Ta_2O_5. Results for the whole rock (fresh rock) show that table concentrates from magnetic at - 1.0 to - 0.25 shows a possible recovery of 70.6% for Ta_2O_5 and Nb_2O_5 respectively for a combined grade of 3 1.5% $Ta_2O_5$and 23.5% Nb_2O_5 respectively. 26.5% and 22.6% of Ta_2O_5- Nb_2O_5 is recovered from the tails (Table 3 and 4). These results suggest that recoveries are much enhanced in the fresh pegmatites using straight magnetics and gravity methods than in the elluvials, where a combined panning, gravity and magnetics gives a total 61 % recovery for Ta_2O_5. The above results though on laboratory scale and thus still preliminary show that columbite - tantalite ores are amenable to gravity and magnetic separation and that three quarters of tantalite 'is contained within 0.25mm fraction. It will thus be necessary to crush and mill the ROM to this size. Simple panning of the ore yields only 11% of the contained tantalite. This is a possible reason of the low recoveries experienced by informal miners.

Table 3: Metallurgical balance for Whole rock samples

Size (mm)	Product	Magnetic	Weight (g)	Weight %	Assay ppm			Distribution		
					Nb	Ta	Sn	Nb	Ta	Sn
+2.0	Panned Conc.	-	43.6	0-43	2400	5000	200	13.2	11.3	1.1
+2.0	Panned tails	-	5210.0	50.93	31	80	76	20.4	21.5	50.8
+2.0	Table cons.	1A Mags Non-mags	4.5 6.3	0.04 0.06	58900 3200	122100 500	6300 11600	33.4 2.5	28.3 0.2	3.6 9.3
-2.0-1.0	Table tails	-	1163.0	11.37	151	493	73	22.2	29.6	10.0
-0.5+0.075	Table tails	-	1426.0	13.94	26	67	54	4.7	4.9	9.9
-0.05	Table tails	-	1000.0	9.77	16	46	49	2.0	2.4	6.3
Total			10230.4	100.0				100.0	100.0	100.0

Table 4: Metallurgical balance for muscovite extract sample

			Assay ppm			distribution		
Calculated Products	Weight (g)	Weight %	Nb	Ta	Sn	Nb	Ta	Sn
+2.0m head	5253.64	51.35	51	121	77	33.6	32.8	51.9
-2.0m head	4976.75	48.65	106	262	75	66.4	67.2	48.1
-2.0m table concentrate	10.8	0.11	26464	51289	9386	35.9	28.4	12.9

6. Conclusion

The Abuja leather mining district project area generally shows a very good strike length potential and often very wide. With all this, grades are economic and the surrounding ground is still very prospective for locating more bodies of similar or larger dimensions. Locating more bodies within the region may make it more feasibly economical because the ore body are still largely extensive. Sampling indicates fairly low grades other related rare metals, which are hosted by the above mentioned pegmatite bodies. From the geological data obtained from the evaluation program, a preliminary conceptual model for a tantalo-columbite mining operation in Abuja leather mining district area was developed. Based on a production rate of 300,000t/y and a grade of 280g/t Ta_2O_5 over 7 years mine life. This does not include other rare metal oxide credits. Since there appears to be probability of additional pegmatite bodies, from more than one pegmatite area, mining at a higher production rate would make this project more attractive.

7. Recommendations

The area incorporating the pegmatite fields as indicated can sustain a large medium scale mine that can be mined profitably for at least a period of 10 years. Continuous prospecting, mapping and sampling will enhance the potential of locating more pegmatite bodies.

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Conflict of interest statement

All authors have no conflict of interest

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