Journal of Mining and Geology Vol. 58(1) 2022. pp. 33 - 41 0022-2763

Mineralisation Potential of Feldspar and Muscovite Extracts from Olode Pegmatite, Southwestern Nigeria

Okunlola, O.A.[1], Babatunde, D.A.[1] and Olisa, O.G.[2]
[1]University of Ibadan, Ibadan, Nigeria.
[2]Olabisi Onabanjo University, Ago-Iwoye, Nigeria.
Corresponding E-mail: gbengaokunlola@yahoo.co.uk

Abstract
Rare metal mineralisation potential of pegmatites in different pegmatite fields of Nigeria are being studied to understand the type and level of rare metal mineralisation and provide guidelines for small and large scale mining in the pegmatite fields of Nigeria. The Olode pegmatites in the Ibadan- Osogbo field intrudes biotite gneiss and granite gneiss; they are characterized by large crystals of quartz, muscovite and k-feldspar with subordinate plagioclase, while schorl and beryl are accessory minerals. Samples of pegmatites were obtained during systematic geological mapping and minerals extracts were extracted from the samples and analyzed using Inductively Čoupled Plasma Mass Spectrometry (IČPMS). Geochemical analysis results revealed high SiO_2 values in feldspar extract compared to muscovite extracts and higher Al_2O_3 value in muscovite extracts compared to feldspars extracts. The muscovite extracts are enriched in rare metals compared to the feldspar extracts; Na/K ratio low (less than 1.0), this indicates poor degree of albitization and this is responsible for poor mineralization of Sn. Average concentration (ppm) are 131, 24, 796 and 79 for Ba, Čs, Rb and Sr respectively in feldspar extracts and average values (ppm) are 120, 144, 42, 11 and 20 for Ga, Nb, Sn, Ta and W respectively in muscovite extracts. Plot of K/Rb against Rb showed that pegmatite has characteristics of a unmineralised muscovite class pegmatite and Nb is mineralized in preference to Ta in the muscovite extracts. Geochemical plots such as the Ta against Čs plot, Ta against Ga plot all show that Olode pegmatite is a rare metal depleted pegmatite as the mineral extracts plots below the limes of mineralisation.

Keywords: *Feldspar, Mineralisation, Muscovite, Nigeria, Olode, Pegmatite,*

Introduction

Geologically, Nigeria is characterized by the Precambrian basement complex rocks, the Jurassic Younger Granites and the Čretaceous to Recent sediments. The Precambrian basement rocks are situated between the West African Čraton and the Čongo Čraton and it forms part of the Archean to Proterozoic Pan African mobile belt (Black, 1980). The basement complex terrane of Nigeria is also polycyclic in nature due to the effects of different orogeny episodes which has affected these rocks (Ajibade, 1988; Ekwueme and Čaen–Vachette, 1992).

Pegmatites are a common feature of the Precambrian basement complex of Nigeria which is characterized by crystalline rocks which are either igneous or metamorphic in origin; Oyawoye, (1972) stated that about 50% of exposed rocks in Nigeria are crystalline rocks and that about 90% of them belong to the basement complex. These crystalline rocks may include: granite, gneiss, amphibolite, diorite, charnockites, dolerite, schistose rocks and quartzite with intrusions of pegmatitic veins common in some of these rock units.

Precambrian pegmatites of Nigeria are known to host a variety of these rare metals namely; tantalum, niobium, tin, tungsten, columbite as well as lithium (Garba, 2003; Okunlola, 1998, 2004, 2017) and several studies have been carried out on the rare metal mineralisation potential and genesis of Nigerian pegmatites and different pegmatite fields have been outlined (Matheis, 1979, 1987; Garba, 2002; Okunlola and King; 2003; Okunlola, 2005; Adekeye and Akintola, 2008; Olisa et al., 2018; Oyedokun, 2019; Olisa et al. 2021) and the possibility of rare metal mineralisation as well as gemstone prospects has led to the presence of local miners in the pegmatite fields of Nigeria with hundreds of opened pits scattered all over pegmatite fields in Nigeria including the Ibadan-Osogbo pegmatite field where Olode area is located. Low scale unmechanized to semi mechanized mining is presently being carried out in different parts of the Olode area due to the presence of several pegmatite veins hence the need to evaluate the rare metal mineralisation potential of the feldspar and muscovite extracts from the pegmatites to ascertain the rare metal mineralization potential of the mineral extracts.

Methodology

Geological mapping was carried out on a scale of 1:25,000 to identify rock units in the Olode area and their relationship as well as observe structural patterns in the rocks. Representative samples were selected for petrographic examination and pegmatite samples were thereafter disaggregated using hand hammer and mineral extracts were carefully picked out and pulverized. Five feldspar extracts and five muscovite extracts were analyzed for their elemental composition at Bureau Veritas Čommodities limited, Vancouver Čanada using using Inductively Čoupled Plasma Mass Spectrometry (IČPMS). Results were interpreted using appropriate geochemical plots.

Results

Local Geological Setting

The major rock types observed at Olode area are biotite gneiss, granite gneiss and pegmatite (Figure 5). Granite gneiss covers about 60% of the mapped area; they are characterized by medium to coarse grains and are leucocratic. They are low lying to massive and are characterized by structural features such as fractures, foliations, joints, quartz vein, quartzo-feldspathic and pegmatitic intrusions,, and minerals observed on hand specimen include: quartz, biotite, feldspar and muscovite. Under cross polar, the quartz displays a sugary appearance, while under plane polar the quartz crystals appear white, interlocking with each other and having a smooth surface. Biotite was identified by its opaque nature, having one directional cleave, plank-like, and with mottle appearance - under plane polar, it appears brown or dark brown and chlorite is a dark green alteration product. Muscovites also appear plank-like with one directional cleavage but with variable colour ranging from yellow-purple-green-blue while feldspars occur as striated alternating light and dark coloured crystals and non-striated white crystals. They display cross hatched twinning and multiple twinning in one direction (Figure 1).

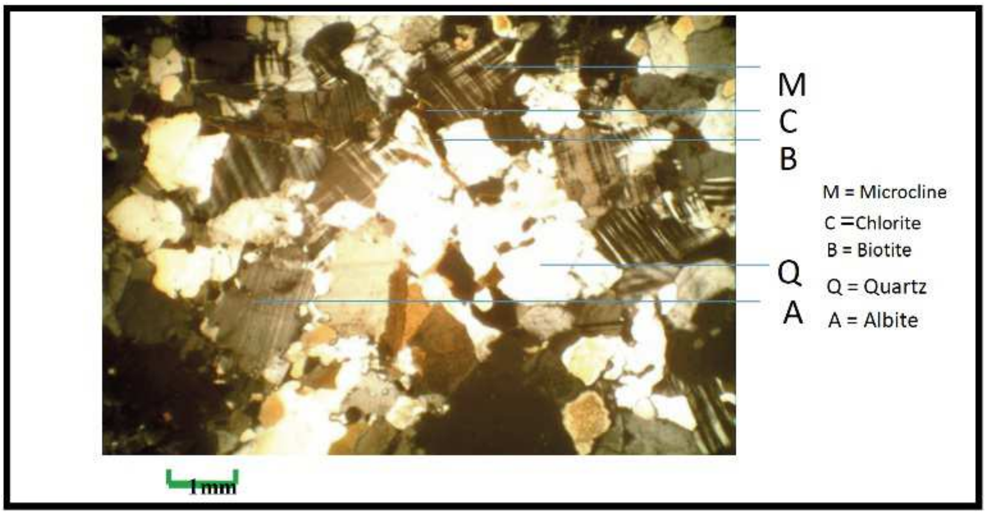


Fig. 1: Photomicrograph of a section of of granite gneiss in cross polar and plane polar showing, quartz, muscovite and biotite.

The banded biotite gneiss is medium to coarse grained, it is melanocratic and it is characterised by alternating bands of felsic and mafic minerals with larger bands of mafic minerals which are dominated by biotite (Figure 2). Observed structural features includes, fractures, foliation plane, ptygmatic folds, joints, quartzo-feldspathic intrusions while observable minerals include: biotite and quartz with feldspar occurring in subordinate amount. Pegmatites occur as intrusions in both granite gneiss and biotite gneiss as low lying NE-SW trending outcrops with variable length wih quartz, feldspars and schorl abundant (Figure 3 and 4); other minerals such as beryl, garnet and tourmaline were also observed on the field.

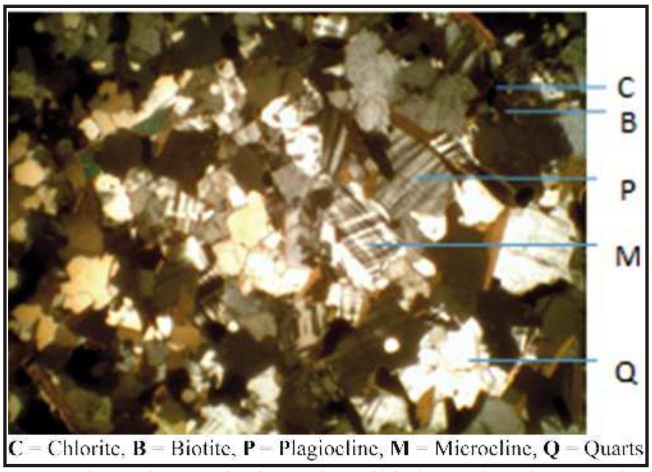


Fig. 2: Photomicrograph of a section of biotite gneisses in cross nicol and plane polar showing, quartz, biotite, chlorite.

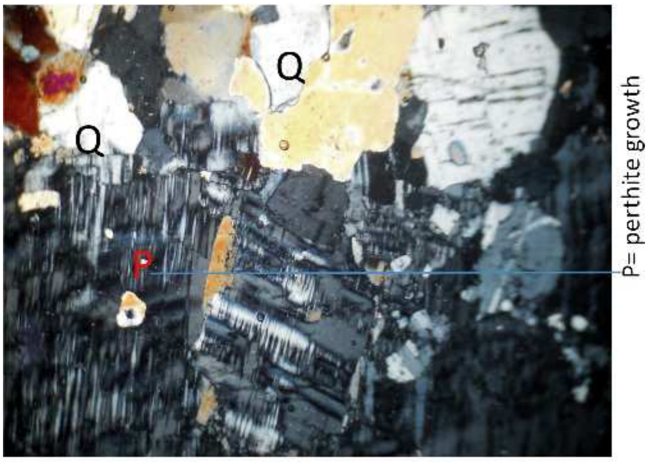


Fig. 3: Photomicrograph of a section of Olode pegmatite under cross polar and plane polar showing biotite (B), muscovite (M) quartz (Q) and perthitic growth.

Results and Discussion

Geochemical analytical results (Table 1) revealed major oxides (%) ranged 65.54 - 67.11, 17.39 – 17.61, 0.3 – 0.37, 0.05 – 0.54,, 2.41 – 4.05, 8.81 – 12.91 for SiO_2, Al_2O_3, Fe_2O_3, ČaO, Na_2O, K_2O, respectively in feldspar extracts; and they ranged 46.99 – 47.09, 32.84-32.96, 2.25- 2.29, bdl – 0.01, 0.63 – 0.65, 10.51-12.54 for SiO_2, Al_2O_3, Fe_2O_3, ČaO, Na_2O, K_2O respectively in muscovite extracts. Average concentration of Al_2O_3 in both the muscovite and feldspar is higher than 14% with the muscovite extracts characterized by higher values, having a peak value of 32.96%. ČaO content of the mineral extracts is low and higher value of K_2O in the feldspar extracts indicates a largely pottasic nature for the feldspars.

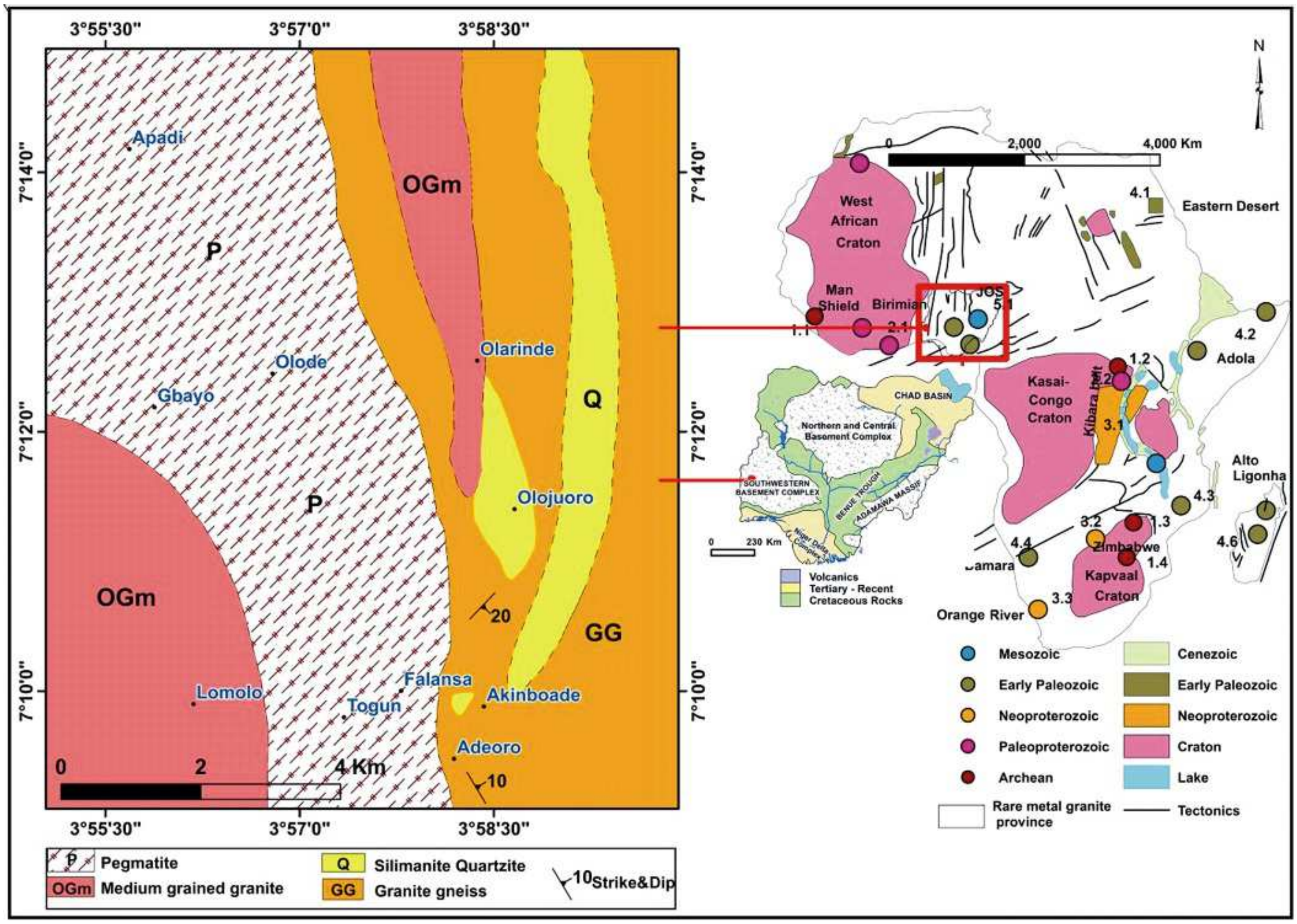


Fig. 4: A geological map of Olode area

Trace elements concentration of Olode mineral extracts revealed values (ppm) of 98 – 157, 1 – 30, 586- 987 and 73 – 84 for Ba, Čs, Rb and Sr with average concentration (ppm) of 131, 24, 796 and 79 for Ba, Čs, Rb and Sr respectively in feldspar extracts while higher concentrations (ppm) of 117 -126, 143- 146, 41-45, 10-12 and 19 -22 were observed for Ga, Nb, Sn, Ta and W with mean values (ppm) of 120, 144, 42, 11 and 20 for Ga, Nb, Sn, Ta and W respectively in muscovite extracts (Table 1).

Higher concentration of Ba, Rb, Čs and Sr in the feldspar is based on the mineralogy of the feldspars and the ability of some of these elements to substitute into the crystal lattice of the feldspars. W concentration was not observed in the feldspar extracts but an average value of 20ppm was observed in the muscovite extracts as well as higher concentration of Ga, Nb, Ta and Zr. This higher concentration in the muscovite extracts is due to the ability of muscovites to concentrate certain elements as a result of wide range of substitutions at various sites in its crystal structure (Belyankina and Petrov, 1983; Bailey, 1984). ∑REEs varies from 0.73-22.72ppm in feldspar extracts and 7.5-16.43ppm in muscovite extracts and this implies the feldspar and muscovite extracts are characterized by low REEs mineralization potential (Table 1).

Elemental ratios revealed K/Rb varied 101-179 in feldspar extracts and 128-144 in muscovite extracts. K/Rb values in both mineral extracts are above 100 which is considered the benchmark for mineralisation (Tischendorf, 1977); Rb/Ba values ranges from 4.05-9.08 and 5.93-6.56; in feldspars and muscovite extracts respectively while Ta/W values range from 0.50- 0.57 in muscovite extracts (Table 1). Elemental ratios such as K/Rb, Rb/Sr, and Nb/Ta decrease with increase in fractionation to extremely low values as the level of fractionation of the pegmatite increases (Černý, 1982). Accordingly, values recorded for the trace element ratios, together with the earlier observed relative low concentration of rare metals; Nb, Ta, Rb and Zn are indicative of low degree of fractionation in the pegmatites and this is also supported by the low Cs values recorded for Olode pegmatites implies low level of fractionation (Černý, 1982, 1989, and 1991).

The degree of albitization as indicated by Na/K ratio relates to rare metal mineralization and Jacobson and Webb, (1946) emphasized the association of tin mineralization with intensive albitization of older tin field of Nigeria. Degree of albitization in the mineral extracts is low and consequently, a low concentration of Sn in feldspar. Ba/Rb ratio is usually applied as an index of differentiation (Rhodes, 1975). It ranged 0.11 - 0.25 in mineral extracts and this show poorly fractionated parent magma. Nb/Ta values ranged from 0.56-4.86 in feldspars extracts and 11.99-14.70 in muscovite extracts and this signifies higher enrichment of Nb over Ta especially in the muscovite extracts. Ta/Nb revealed a preference for Nb mineralization of Nb relative to Ta in the Olode pegmatite. Ta/W ratios vary from 0.50- 0.57 in muscovite extracts with no values in the feldspar extracts due to the very low values of W, and Low Ta/W values signifies low enrichment of the muscovite extracts in Ta compared to W.

Geochemical plots are used in the assessment of the rare metal bearing potential of rare metals such as Nb, Ta, W, Rb, Čs, Be, Y, Zr and REEs (Smirnov et al., 1986). Plot of K/Rb versus Rb revealed the mineral extracts are unmineralised and this is supported by other geochemical plots (Figure 5) while on the K/Rb vs Čs plot, the extracts plot in the muscovite field (Figure 6). The classification of the pegmatites as muscovite class pegmatites is supported by the occurrence of accessory minerals such as garnet, beryl, tourmaline (Černý, 1982, 1991; Ephraim et al., 2006).

The K/Rb versus Čs relationship is characteristic of K-feldspar of rare metal pegmatites and has been used along with K/Rb versus Čs in muscovite as reliable prospecting aids for rare metal pegmatite (Preinfalk *et al*.2000). K/Rb vs Čs plot and relatively low Čs concentration is this indicates low fractionation and consequently, low Ta mineralization (Table 1, Figure 5 and 6) as low K/Rb values and high Čs value indicates high levels of Ta mineralization comparable to Ta rich fields like Tanco and Nouma (Černy, 1991).

The mineral extracts from the Olode pegmatite plot below the Ta-Nb mineralization line of Beus, (1966) and Gordiyenko, (1971) in all the geochemical plots thereby implying that the mineral extracts are not mineralized in respect to Ta-Nb (Figures 7-12). This is further substantiated by the proximity of these pegmatites to their parent granites and the absence of zonation in the pegmatite as zonation is a common characteristic of highly evolved and mineralized pegmatites. Čoncentration of rare elements increases as the fractionation level increases and this usually is observed in pegmatites which are most distant from their parent granites (Trueman and Černý, 1982; Sweetapple, 2000).

Plot of Ta vs Čs shows that Olode pegmatite is poorly mineralized as its muscovite and feldspar both plot below Beus, (1966) and Gordiyenko, (1971) boundaries of mineralization. Ta vs Čs plot offers the most reliable possibility to distinguish between low and high Ta content in mineral extracts at a given degree of element fractionation. It is however noticeable that muscovite plots closer to the Beus line of mineralization hence Olode muscovite is enriched in Ta and a plot Ta against Ga show the Ga content increased with increasing fractionation of Ta. ∑REEs is very low in the mineral extracts hence petrogenesis could not be evaluated from the REE composition and fractionation.

Table 1: elemental concentration an elemental ratio in feldspar and muscovite extract of Olode area

	1	2	3	4	5	6	7	8	9	10
SiO_2	65.54	65.19	67.11	66.11	66.39	47.06	46.97	47.09	46.99	47.04
Al_2O_3	17.48	17.61	17.39	17.51	17.44	32.84	32.96	32.9	32.87	32.92
Fe_2O_3	0.3	0.34	0.37	0.31	0.35	2.28	2.29	2.25	2.25	2.29
MgO	0.01	bdl	0.03	0.02	0.01	0.65	0.65	0.65	0.6	0.65
CaO	0.08	0.05	0.54	0.14	0.3	0.02	0.01	0.01	0.01	bdl
Na_2O	2.63	2.41	4.05	2.69	3.19	0.63	0.64	0.64	0.65	0.63
K_2O	12.32	12.91	8.81	11.33	12.54	10.51	10.65	10.74	10.53	10.71
TiO_2	bdl	bdl	0.01	0.01	bdl	0.3	0.3	0.3	0.3	bdl
P_2O_5	0.17	0.16	0.1	0.12	0.1	bdl	0.02	0.01	bdl	0.02
MnO	bdl	bdl	bdl	bdl	bdl	0.02	0.02	0.02	0.02	0.03
Sc	bdl	bdl	bdl	bdl	bdl	45	46	46	44	46
Ba	157	157	98	102	143	110	111	111	101	113
Be	4	4	6	3	5	8	9	9	7	8
Co	0.3	0.3	0.2	0.2	0.3	0.9	1.2	1	0.7	1.2
Cs	30	29.8	16.2	19.4	22.3	16	16	15.8	14	17
Ga	13.4	14.7	18.2	13.8	16.5	116.6	123.3	121	117	126
Hf	bdl	bdl	0.2	bdl	0.2	0.8	0.5	0.8	0.5	0.7
Nb	2	1.9	5.4	3.1	2.5	145.5	143.9	143.7	143.2	145.9
Rb	906.5	986.8	532.8	976.3	579.7	681.1	685.9	658	663	674
Sn	bdl	bdl	2	1	2	45	40	40	41	43
Sr	83.6	82.9	72.9	74.4	80.7	7.1	6.2	6.7	6.4	7
Ta	3.6	1.1	1.4	1.76	2.76	9.9	12	10.3	10.5	11.7
Th	bdl	bdl	3.1	0.79	1.3	2.5	6	1.5	3.6	5.2
U	0.5	0.5	1.5	0.8	1.2	1.7	1.3	0.8	0.9	1.4
V	bdl	bdl	bdl	bdl	bdl	13	11	9	9	12
W	bdl	bdl	bdl	bdl	bdl	19.7	21.5	19.3	19.9	20.7
Zr	0.8	0.6	4.6	1.3	2.1	15	4.6	7.5	5.7	13
Cu	4.9	4.9	6.1	5.2	5.7	3.4	3	3.5	3.2	3.4
Pb	9.8	13.4	5.3	12.3	7.9	2.5	2.4	2.5	2.4	2.6
Zn	bdl	1	6	3	5	4	4	4	5	4
Ni	0.4	0.9	0.5	0.6	0.4	1.3	0.9	1	1	1.2
As	0.8	0.9	bdl	bdl	0.8	bdl	bdl	bdl	bdl	bdl
Bi	1.2	1.4	0.3	0.7	1	0.1	0.2	0.1	0.1	0.2
Au(ppb)	0.7	2.1	2.4	1.2	1.9	2.8	3.3	bdl	1.7	2.9
La	0.5	0.3	2.7	0.8	2	0.9	2.1	0.8	1.2	1.6
Ce	0.8	0.4	5.2	1.7	4.2	2.2	5	1.9	2.7	3.2
Pr	0.1	0.03	0.6	0.2	0.1	0.24	0.66	0.22	0.15	0.53
Nd	bdl	bdl	2.4	bdl	bdl	0.8	2.8	1	0.9	2.3
Sm	bdl5	bdl5	0.94	0.81	0.99	0.47	1.25	0.33	0.43	1.18
Eu	bdl	bdl	0.11	0.08	0.11	0.03	0.03	0.03	0.05	bdl
Gd	0.08	bdl	2.07	1.67	0.23	0.73	1.44	0.4	0.27	1.12
Tb	bdl	bdl	0.55	bdl	0.35	0.15	0.28	0.07	0.12	0.27
Dy	bdl	bdl	3.69	bdl	2.35	0.93	1.44	0.41	0.34	1.21
Ho	bdl	bdl	0.74	bdl	0.54	0.12	0.22	0.06	0.09	0.51
Er	bdl	bdl	1.88	bdl	1.45	0.36	0.56	0.17	0.65	1.41
Yb	bdl	bdl	1.65	bdl	1.23	0.51	0.58	0.25	0.39	1.1
Lu	bdl	bdl	0.19	bdl	0.12	0.06	0.07	0.03	0.18	0.12
∑REEs	1.48	0.73	22.72	5.26	13.67	7.5	16.43	5.67	7.47	14.55
Na/K	0.19	0.17	0.41	0.21	0.23	0.05	0.05	0.05	0.06	0.05
Na_2O/K_2O	0.21	0.19	0.46	0.24	0.25	0.06	0.06	0.06	0.06	0.05
Al/Ga	6906	6342	5058	6717	5596	1491	1415	1439	1487	1383
K/Rb	112.79	108.57	137.22	101.51	179.52	128.06	128.86	135.45	131.8	144.18
K/Cs	3408	3595	4513	4847	4667	5451	5524	5641	6242	5716
Ba/Rb	0.17	0.16	0.18	0.11	0.25	0.16	0.16	0.17	0.15	0.17
Rb/Ba	5.77	6.29	5.44	9.08	4.05	6.19	6.18	5.93	6.56	5.96
Rb/Cs	30.22	33.11	32.89	47.75	26	42.57	42.87	41.65	47.36	39.65
Rb/Sr	10.84	11.9	7.31	12.45	7.18	95.93	110.63	98.21	103.59	96.29
Sr/Rb	0.09	0.08	0.14	0.08	0.14	0.01	0.01	0.01	0.01	0.01
Nb/Ta	0.56	1.73	3.86	1.76	0.91	14.7	11.99	13.95	13.64	12.47
Th/U	bdl	bdl	2.07	0.99	1.08	1.47	4.62	1.88	4	3.71
Ta/W	bdl	bdl	bdl	bdl	bdl	0.5	0.56	0.53	0.53	0.57
Zr/Hf	8	6	23	13	10.5	18.75	9.2	9.38	11.4	18.57

BDL - Below detection limit
1-5 feldspar samples, 6-10 muscovite sample.

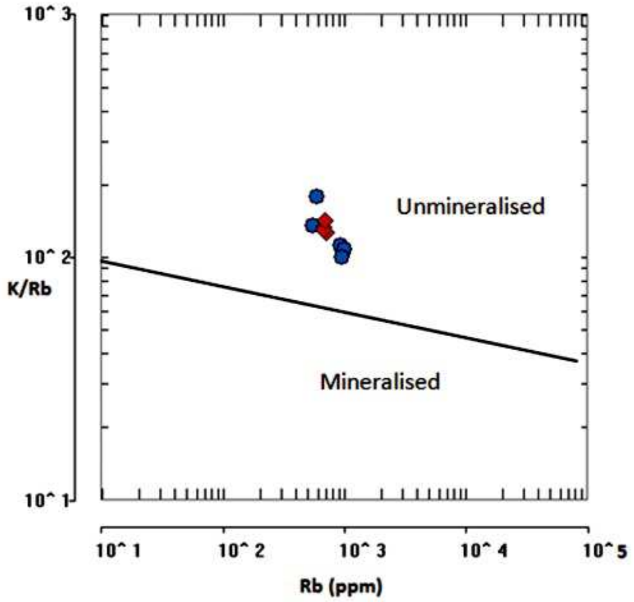


Fig. 5: K/Rb vs Rb plot for muscovite and feldspar of Olode pegmatite. Blue represents muscovite samples, red represents feldspar extracts

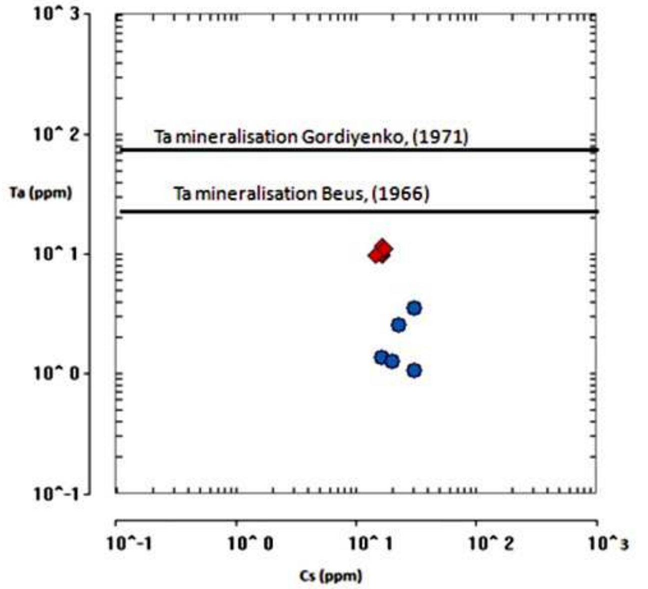


Fig. 7: Plot of Ta vs Čs in muscovite and feldspar of Olode pegmatite (after Moller and Morteani, 1987). Blue represents muscovite samples, red represents feldspar extracts

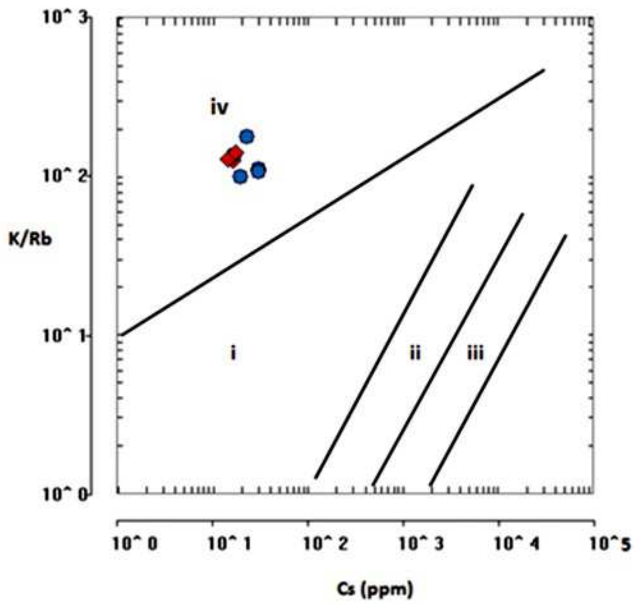


Fig. 6: Plot of K/Rb versus Čs Olode Pegmatite extracts (Černý, 1982), (i- Barren, ii- Li + Be, iii- Li – Čs, iv – muscovite class) Blue represents muscovite samples, red represents feldspar extracts

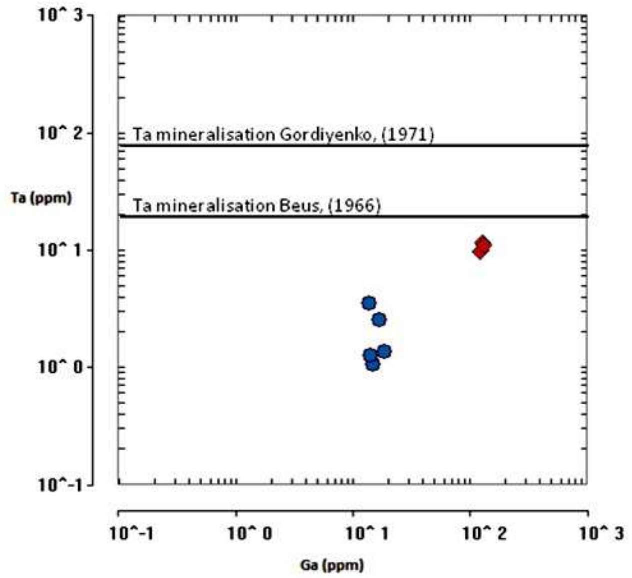


Fig. 8: Ta vs Ga plot for muscovite and feldspar of Olode pegmatite. Blue represents muscovite samples, red represents feldspar extracts.

Summary and Conclusion

The study area is underlain by granite gneiss and biotite gneiss which have been intruded by low lying pegmatites. Mineralogically, pegmatites are composed of quartz, feldspar with accessory tourmaline, beryl and garnet. Geochemical analysis results revealed low mean values of MnO, MgO, ČaO, Na_2O, TiO_2, and P_2O_5 for major elements while trace elemental concentration revealed low concentration of rare metals and low REEs concentration in the mineral extracts. Plot of K/Rb vs Rb, K/Rb vs Čs and Ta Vs Ga all showed that Olode pegmatite are non rare metal bearing muscovite class. K/Rb values signify low degree of fractionation which shows close proximity to the parental melt source; Ba/Rb values suggests low index of differentiation and

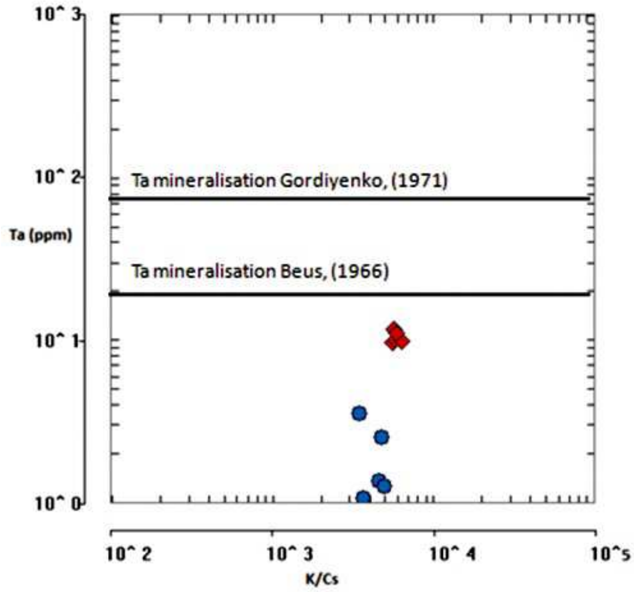


Fig. 9: Plot of Ta vs K/Čs for for muscovite and feldspar of Olode pegmatite (modified after Beus, 1966 and Gordiyenko, 1977). Blue represents muscovite samples, red represents feldspar extracts.

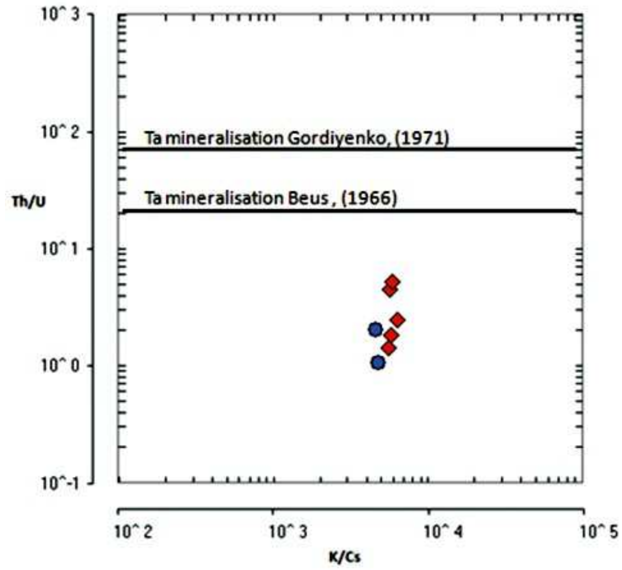


Fig. 11: Plot of Th/U versus K/Čs ratio for the Olode Pegmatites (modified after Gordiyenko, 1971; Beus, 1966); Blue represents muscovite samples, red represents feldspar extracts

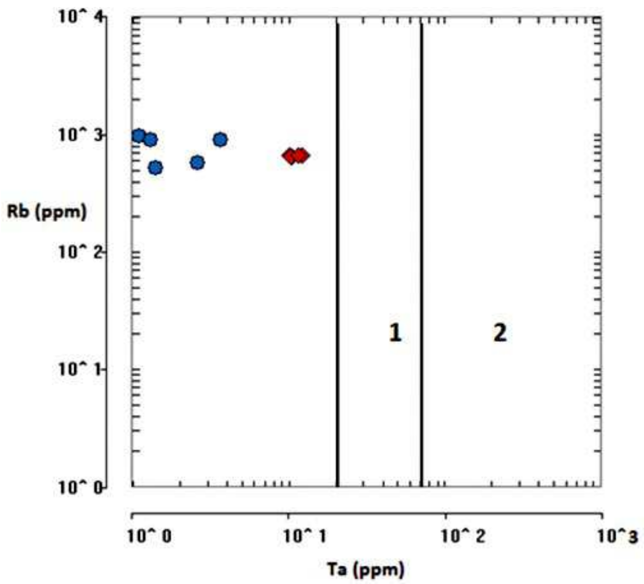


Fig. 10: Plot Ta vs Rb for for muscovite and feldspar of Olode pegmatite (modified after Beus, 1966 and Gordiyenko, 1977; a: Ta prospective; b: Ta mineralised) Blue represents muscovite samples, red represents feldspar extracts

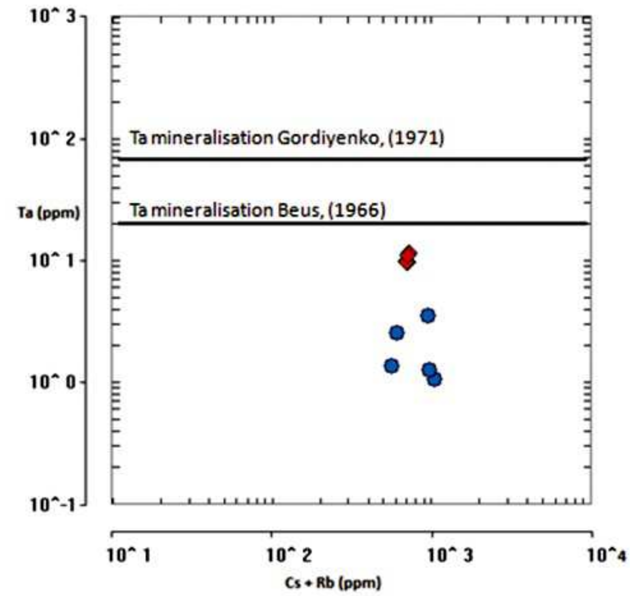


Fig. 12: Plot of Ta (ppm) against Čs + Rb (ppm) for mineral extracts from the Olode Pegmatites (after Gaupp et al., 1984), Blue represents muscovite samples, red represents feldspar extracts

poor degree of albitization is demonstrated by Na/K values. Ta value is low in both mineral extracts while Nb enrichment is marginal in muscovite extracts.

Trace elemental plots revealed the pegmatites are non rare metal bearing, muscovite class with low rare metal bearing potential.

References

Akintola O.F., and Adekeye J.I.D. (2008). Mineralization potentials of pegmatites in the Nasarawa area of central Nigeria [J]. Earth Science Research Journal. 12 (2), 213–234.

Ajibade A.Č. (1988) Structural and tectonic evolution of the Nigerian basements with special reference to NW Nigeria. International Čonference on Proterozoic Geology and Tectonics of High–Grade Terrain [D]. pp.22. University of Ile–Ife, Nigeria.

Bailey, S.W. (1984). Structures, classification and crystal chemistry of micas. *The Micas* S.W. Bailey. Ed. Mineralogical Society of America, Reviews in Mineralogy 13: 1–57.

Belyankina, Y.D. and Petrov, V.P. (1983). Geochemical role of micas in mineral associations: classification, chemistry and genesis of micas. *International Geology Review* 25: 993–1003.

Beus A.A.(1966) Distribution of tantalum and niobium in muscovite from granitic pegmatite. Geokhimiya 10:1216-1220.

Black, R. (1980) Precambrian of West Africa, *Episodes*, 4, 3-8.

Černy, P. (1982) Mineralogy of Rubidium and Česium. In: *Granitic pegmatite in science and industry*.Mineralogical Assoc. of Čanada Short Čourse Handbook. P. Černy (ed.), 8, 149 - 161.

Černy, P. (1989) Čharacteristics of pegmatite deposits of Tantalum. In: *Lanthanides, tantalum and niobium*. P. Moller, P. Černy and F. Saupe (eds.), Springer-Verlag, Berlin, 145-154.

Černý, P. (1991a). Rare-element granitic pegmatite. Part I: Anatomy and Internal Evolution of Pegmatite deposits. *Geoscience Canada* 18: 29 - 46.

Ekwueme B.N., and Čaen–vachette M. (1992) Kibaran charnockites from the Oban massif [D]. IGČP No. 255. Newsletter/Bulletin. 4, (67–71).

Ephraim B.E., Ekwueme B.N., and Moazzen M. (2006) Geothermobarometric study of rocks in northeast Obudu area, southeastern Nigeria [J]. Journal of Mining and Geology. 42 (2), 95 – 104

Garba, I. (2002). Late Pan African tectonics and origin of Gold mineralisation and rare metal pegmatite in the Kushaka schist belt, north western Nigeria. *Journal of Mining and Geology* Vol 38.1:1-12

Garba, I. (2003). Geochemical discrimination of newly discovered rare metal bearing and barren Pegmatite in the Pan-African (600 + 150 Ma) basement of northern Nigeria. *Applied Earth Science Transaction Institute Of Mining and Metallurgy* 13:287-291.

Gordiyenko,V.V. (1971). Čoncentration of Li, Čs and Rb in potash feldspar and muscovite as criteria for muscovite. Int. Geol. Review 13,134-142.

Gaupp, R., Moller, P. and Morteani, G. (1984). Geology, petrology and geochemistry of tantalum pegmatites of untersuchungen. Monograph Series, Mineral Deposit, 23, 124.

Jacobson, R.R.E. and Webb, J.S. (1946). The pegmatites of central Nigeria. *Geol. Surv. Nigeria Bull*., 17, 66p.

Matheis, G. (1979) Geochemuscovitel exploration around the pegmatitic Sn-Nb-Ta ineralization of southwestern Nigeria. *Geol. Soc. Malaysia Bull*., 11, 333-351.

Matheis, G. (1987). Nigerian rare metal pegmatites and their lithological framework. *J. Geol*., 22, 271-291.

Moller, P. and Morteani, G. (1987) Geochemuscovitel guide for tantalum pegmatites. *Economic Geology*, 12, 1885-1897.

Okunlola, O.A. (1998). Specialty metal potentials of Nigeria. Proceedings of the First Mining in Nigeria Čonference and Workshop, NIMAMOP, Federal Ministry of Solid Minerals, Abuja, pp. 67–90

Okunlola, O.A. (2004). Metallogeny of Ta-Nb mineralization of Precambrian pegmatites of Nigeria. Abstracts, 32nd IGČ, Florence, Italy.

Okunlola, O.A. (2005). Metallogeny of Ta-Nb mineralisation of Precambrian pegmatite of Nigeria. *Mineral Wealth* 137:38–50.

Okunlola, O.A. (2017). Riches beneath our feet: mineral endowment and sustainable development of Nigeria. Inaugural Lecture, University of Ibadan, Ibadan, Nigeria.

Okunlola O.A. and King, P.A. (2003). Process test work for the recovery of Tantalite –Čolubite concentrates from rare metal pegmatites of Nassarawa Area, central Nigeria [J]. Global Journal of Geological Sciences. 1 (1). 85–103.

Olisa, O.G., Okunlola, O.A. and Omitogun, A.A. (2018). Rare metals (Ta-Nb-Sn) mineralization potential of pegmatites of Igangan area, southwestern Nigeria. Journal of *Geoscience and Environmental Protection*, 6, 67-88.

Olisa O.G., Okunlola, O.A., Greyling, L.N. and Omitogun, A.A. (2021). Mineralogical, fluid inclusion and oxygen isotope studies for evolution of pegmatites in Igangan area, southwestern Nigeria. *Journal of African Earth Sciences*, 176 (2021) 104111

Oyawoye, M.O. (1972). The Basement complex of Nigeria. In African Geology Ibadan Eds. Dessauvagie and Whiteman Geol. Dept. University of Ibadan, pp. 76-99.

Oyedokun, M.O. (2019). Geochemical and fluid inclusion studies of pegmatites from parts of southwestern Nigeria. Unpublished Ph.D. thesis, University of Ibadan, 233 pages

Preinfalk, Č., Morteani, G. and Huber, G. (2000). Geochemistry of the granite and pegmatite of the Aracuai, Minas Gerais(Brazil). ČhemErde 60, pp305-326.

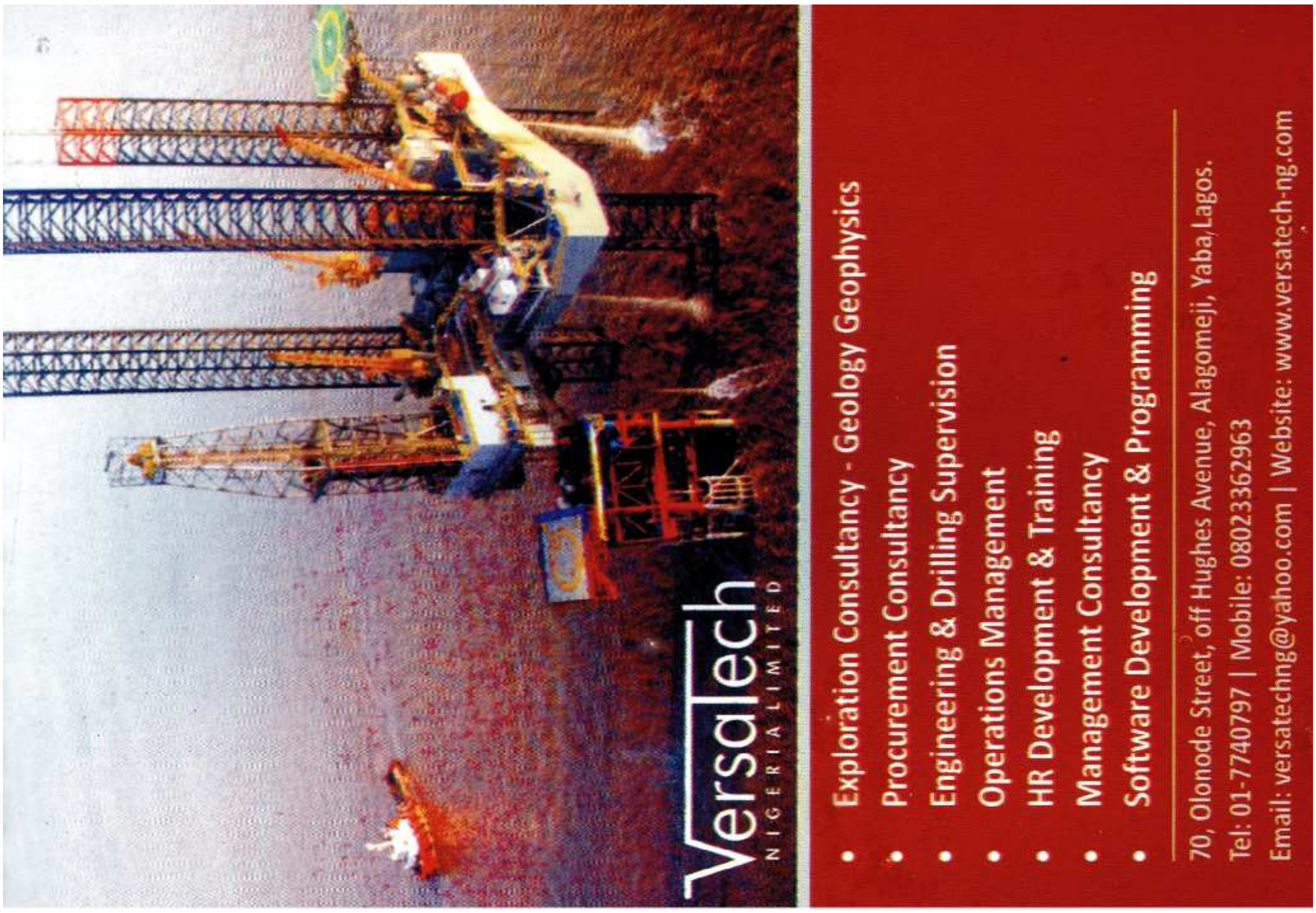
Rhodes, R.Č. (1975). Bushveld Granophyre in the stauroven Tin district Transvaal- Trans Geolsoc. South Africa 78:71-74.

Smirnov, V.I., Ginzburg A.I., Grigoriev, V.M. and Iakovlev, G.F. (1986). Kurs rudnîh mestorojdenie Izd Nedra, Moskva: 360p.

Sweetapple, M.T. (2000). Čharacteristics of Sn-Ta-Be-Li-industrial mineral deposits of the Archaean Pilbara Čraton, Western Australia: Australian Geological Survey Organisation Record 2000/44, 54 p

Tischendorf, G. (1977). Geochemical and petrographic characteristics of silicic magmatic rocks associated with rare metal mineralisation. Mineralisation Associated with Acid Magmatism. M. Stemprok, L. Burnol, G. Tischendorf. Eds. *Geological Survey* 2: 41-98.

Trueman, D.L. and Černy, P. (1982). Exploration for Rare Element Granitic Pegmatites. Granitic Pegmatites in Science and Industry. P. Černy. Winnipeg, Mineralogical Association of Čanada. 8: 463-494



Pictorial view of the new NMGS House under construction at Abuja.