FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 8 No. 4, August, 2024, pp 210 - 220
DOI: https://doi.org/10.33003/fjs-2024-0804-2663

INDUSTRIAL MINERAL POTENTIAL OF PEGMATITES IN THE LOKOJA AREA (SHEETS 247NW AND 247SW), NORTH-CENTRAL NIGERIA

***Atodo, A. S., Onimisi, M., Jimoh, O. and Umoru, C. I.**

Department of Geology, Federal university Lokoja, Kogi state, Nigeria.

*Corresponding authors' email: atodoajuma@gmail.com Phone: +2348063296799

ABSTRACT

Field geological mapping and compositional (mineralogical and chemical) evaluation of the pegmatites in the Lokoja area (Longitudes 6º 37′ 00″ E and 6º 47′ 00″ E and Latitudes 7º 42′ 00″ N and 7º 51′ 00″ N) were carried out to evaluate the industrial mineral potential of the pegmatites. The pegmatites occur in tabular forms as dyke-like structure and veins of large interlocking crystals of quartz, feldspars and mica and distributed within two host rocks (migmatite and granite gneiss). Petrographic analysis (thin section) of eight of the pegmatite samples revealed that the pegmatite has a modal composition of plagioclase (26.25%), orthoclase (17.89%) and microcline (36.75%) which are raw materials used in glass and ceramics production, quartz (8.1%) and biotite (11%). twelve samples of the pegmatite were analysed using the X-ray Fluorescence spectrometry and the chemical composition obtained for silica (SiO_2) and alumina (Al_2O_3) content of 67.47 wt % and 14.01 wt % respectively. The alumina (Al_2O_3) is greater than the alkalis ($Na_2O + K_2O + CaO$) in the samples with an average value of 1.43% which indicates that the pegmatites are siliceous and peraluminous. The pegmatite is dominated by feldspars which are raw material used in ceramics and glass production and the chemical composition of the major element of the pegmatites of the study meets up with the Indian standard requirement suitable for use in various industries (glass, whiteware and pottery) and also meets the requirement for sanitary ware and ceramic-tiles industry as required by the British standard.

Keywords: Pegmatite, Industrial mineral, Feldspar, Ceramics

INTRODUCTION

Pegmatites are coarse-grained igneous rocks composed of large interlocking crystals of mostly quartz, feldspar and accessory micas. Pegmatite bodies vary in size and shape. They are found as vertical intrusions in the form of dykes and veins, and also near large masses of igneous rocks called batholiths. Pegmatites have been a known source of gem and precious minerals and rare earth metals (Cerny, 1991a; Morteani & Gaupp, 1989).

Pegmatites have attracted remarkable interest all over the world, and particularly in Nigeria as it is the host to various gemstones (beryl, tourmaline, etc), and industrial minerals such as feldspars, muscovite and quartz. They have also been found as a source of broad spectrum of rare earth elements such as Lithium (Li), Rubidium (Rb), Caesium (Cs), Beryllium (Be), Gallium (Ga), Scandium (Sc), Yttrium (Y), Tin (Sn), Niobium (Nb), Tantalum (Ta), Uranium (U) and Thorium (Th) from which various economic ore minerals originated from (Jimoh, 2011).

Nigeria is known to have an extensive belt of pegmatite environment, covering approximately 400 km (Figure 1) from Ilesha, south-west Nigeria to Wamba (near Jos, Plateau state) in North Central Nigeria (Jacobson & Webb, 1964). Ekwueme & Matheis (1995) reported that the NE–SW trending pegmatites veins are more productive and richer in rare metals while the NW–SE pegmatites in Oban-Obudu basement are relatively barren and unproductive. Matheis & Caen (1983) further studied the pegmatite of the Pan African reactivation zone covering Egbe, Ijero and Wamba in Southwestern Nigeria and were able to distinguish between the barren and mineralized pegmatite. Recently other researchers who studied the pegmatite in Southwestern Nigeria such as (Garba, 2003; Matheis, 1987) concentrated on the exploration of the Sn-Nb-Ta, also in the study area Daniel & Ebo, 2021; Omada et. al, 2015, analysed some pegmatite dykes around Lokoja area and concluded that they are moderately mineralized but emphasis was on the rare metals. Geologists, especially petrologists, mineralogists, and economic geologists have developed interest in the study of pegmatite. However, their emphasis has been on the rare metals associated with the pegmatites (including the study area) with little or no published work on the industrial mineral potential of pegmatites.

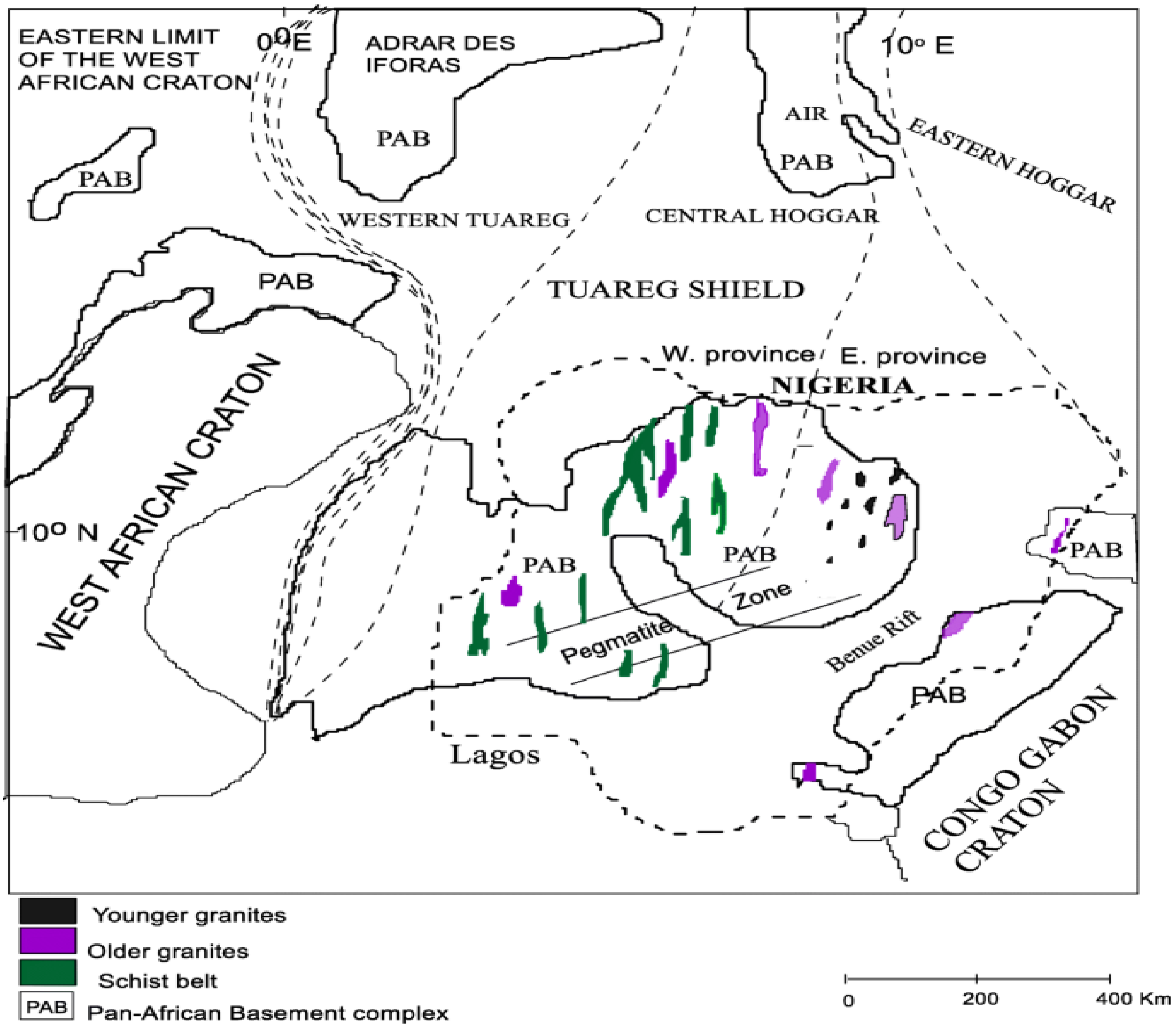


Figure 1: Map of West Africa showing Pegmatite Belt in Nigeria (Modified after Chukwu & Obiora, 2021)

The increase in the global demand for industrial minerals like feldspar, quartz and muscovite which are found in pegmatite for manufacturing of glass, ceramics and electrical insulator has led to a heightened quest for economically viable deposits that could possibly host these important minerals. Furthermore, as Nigeria is being positioned on the path of industrialization, these minerals are vital ingredients for ceramics, glass and allied industries. These industries, in turn, create a value chain platform for the growth of other small-scale industries thereby providing large quantum of employment for the teeming population of the country in addition to enhancing its Gross Domestic Product (GDP).

This study aims at evaluating the industrial minerals occurrence in the pegmatite of the study area and their potential uses.

The study area covers parts of Lokoja sheet 247 NW and 247 SW and lies between Longitudes 6º 37′ 00″ E and 6º 47′ 00″ E and Latitudes 7º 42′ 00″ N and 7º 51′ 00″ N (Figure 2).

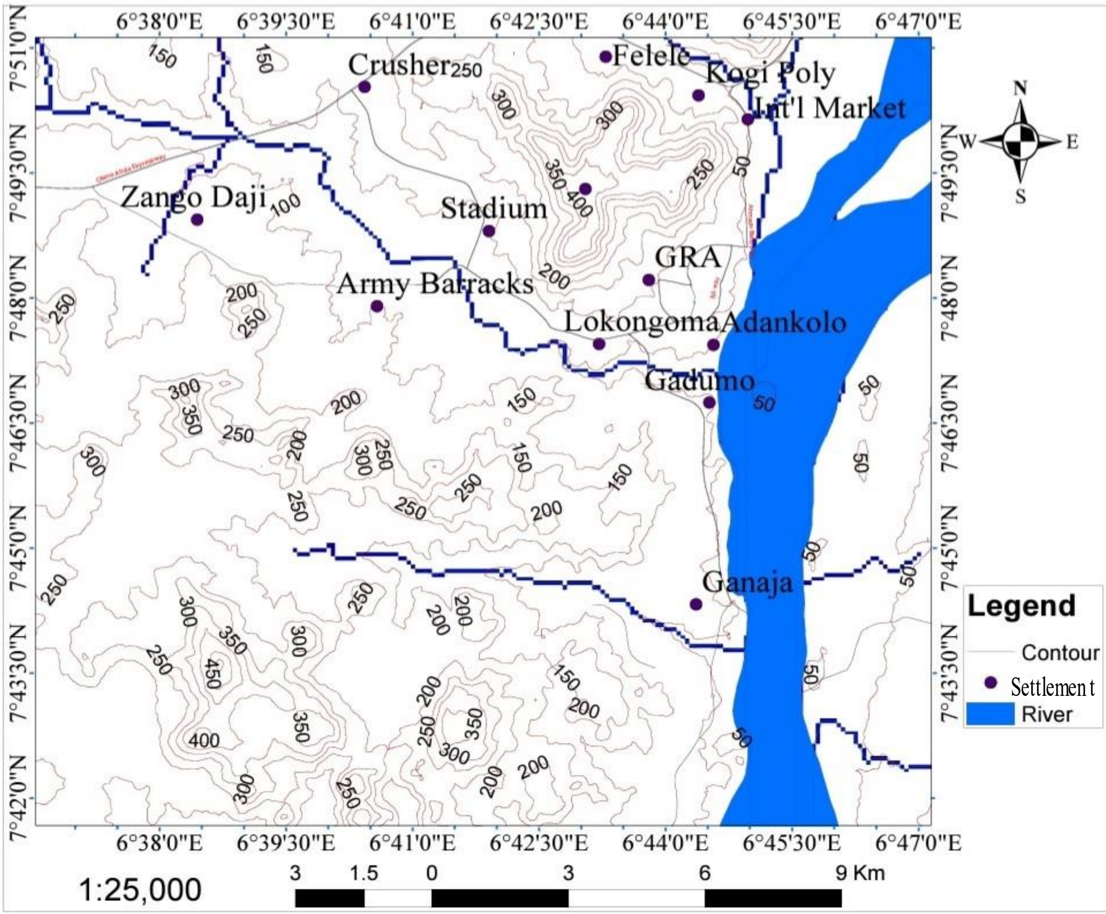


Figure 2: Topographic map of study area

Regional Geologic Setting

The Nigeria Basement Complex lies in the extensive region East of the West African Craton and North-west of Congo Craton which was affected by the Pan-African orogeny about 600my ago (Rahaman, 1976). The Pan-African belt evolved by plate tectonic processes which involved the collision between the passive continental margin of the West African Craton and the active continental margin (Pharusian belt) of the Tuareg shield about 600my ago (Black *et. al*., 1979; Burke & Dewey, 1972). The collision at the plate margin is believed to have led to the reactivation of the internal region of the belt. The Nigerian Basement Complex lies in the reactivated part of the belt (Rahaman, 1976).

Three areas comprise the Basement Complex in Nigeria. These include:

i. North Central Complex which covers Zaria, Abuja, Bauchi and Jos where we have the intrusions of Younger Granites.
ii. The South-West Basement covering parts of Lokoja, Igarra, Ilesha, etc.
iii. The South-East Basement Complex covering Jato-Aka, Obudu, Oban massive and Mambila hills.

The South-West Basement Complex is made up of four major rock types (Igboama, *et.al*, 2024; Rahaman, 1976; Tijani, 2023), namely:

i. Migmatite-Gneiss Complex
ii. Metasedimentary rocks (Schist Belt)
iii. The Older Granites
iv. Undeformed acid and basic dykes which include pegmatites, quartz veins and dolerite dykes.

MATERIALS AND METHODS

Field mapping was carried out using Global Positioning System (GPS), a compass clinometer, and topographic map sheet on a scale of 1:25,000 prepared from Lokoja sheet 247 NW and 247 SW. Data were collected in form of rock samples, photographs and readings of attitudes of rocks and structures. The locations where the rocks were encountered within the mapped area were determined using Global Positioning System (GPS), This was used to produce the geological map of the area. The exposed rocks were carefully observed and the texture, grain size and composition of the various minerals that make up the rock were recorded in the field notebook. Samples were obtained to ensure they are fresh and representative using geological hammer and chisel which are properly labelled and put into sampling bags. The rock samples collected from the field were subjected to the following analyses:

Petrographic analysis (thin section analysis) on eight (8) pegmatite samples were carried out in the thin section laboratory of the Department of Geology, Federal University Lokoja, Kogi State, Nigeria. Below is the procedure for the analysis.

i. The fresh rock samples were air-dried and impregnated using epoxy A and B.
ii. The impregnated samples were trimmed using the GTS cut-off saw and making sure one surface of the sample is made very flat. The flat surface is lapped on a glass plate using carborundum of size 600 grit.
iii. One surface of glass slide was also lapped on a glass slide. The lapped surface of the sample and that of the slide is

then bonded using epoxy, this was to dried and later trimmed to 50 microns on the slide using cut-off saw.

iv. The slide is then transferred to the CL 50 lapping machine to reduce the size of the sample to 30 microns.
v. The slide is then covered using Canada balsam and cover-slid, ready for study under the petrographic microscope.
vi. The representative thin sections were chosen and observed with polarising microscope under plane polarised light (PPL) and the cross polarised light (XPL).

Geochemical analysis (X-ray Fluorescence analysis) of twelve (12) samples of the pegmatites was carried out using Thermo-Fisher Scientific Energy Dispersive X-Ray Fluorescence (ARL.QUANTX.EDXRF) done at the Central Laboratory of the Umaru Musa Yar'adua University, Katsina State, Nigeria. The instrument has three components of operation;

i. Helium gas for liquid sample
ii. Vacuum Pump for light Elements.
iii. Air for heavy and light element excluding Sodium which can only be gotten in a vacuum.

The samples were first grounded into fine powder with the aid of mortar and pistol. 2g each of the samples were weighed and then poured into a sample holder and covered with cotton wool to prevent it from spraying. The bottom of the sample holder is made of polypropylene which is a thermoplastic. The sample holders containing the samples were ran in a vacuum or air for 10 minutes each and they were inserted into the XRF Spectrometer for the elemental analysis after which the results were obtained. The XRF Analyzer determine the elemental composition of a sample by measuring the fluorescent X-ray emitted from a sample when it is excited by primary X-ray source. Each of the elements in the sample produces a set of characteristic fluorescent X-rays that is unique for specific element.

RESULTS AND DISCUSSION

The study area is underlain by Basement Complex rocks (metamorphic and igneous rocks) and contacts between the various rock types are sharp and sometimes gradational. The geological map of the study area (Figure 3a) reveals the major rock types encountered in the study area which are host to the pegmatites are migmatite and granite gneiss.

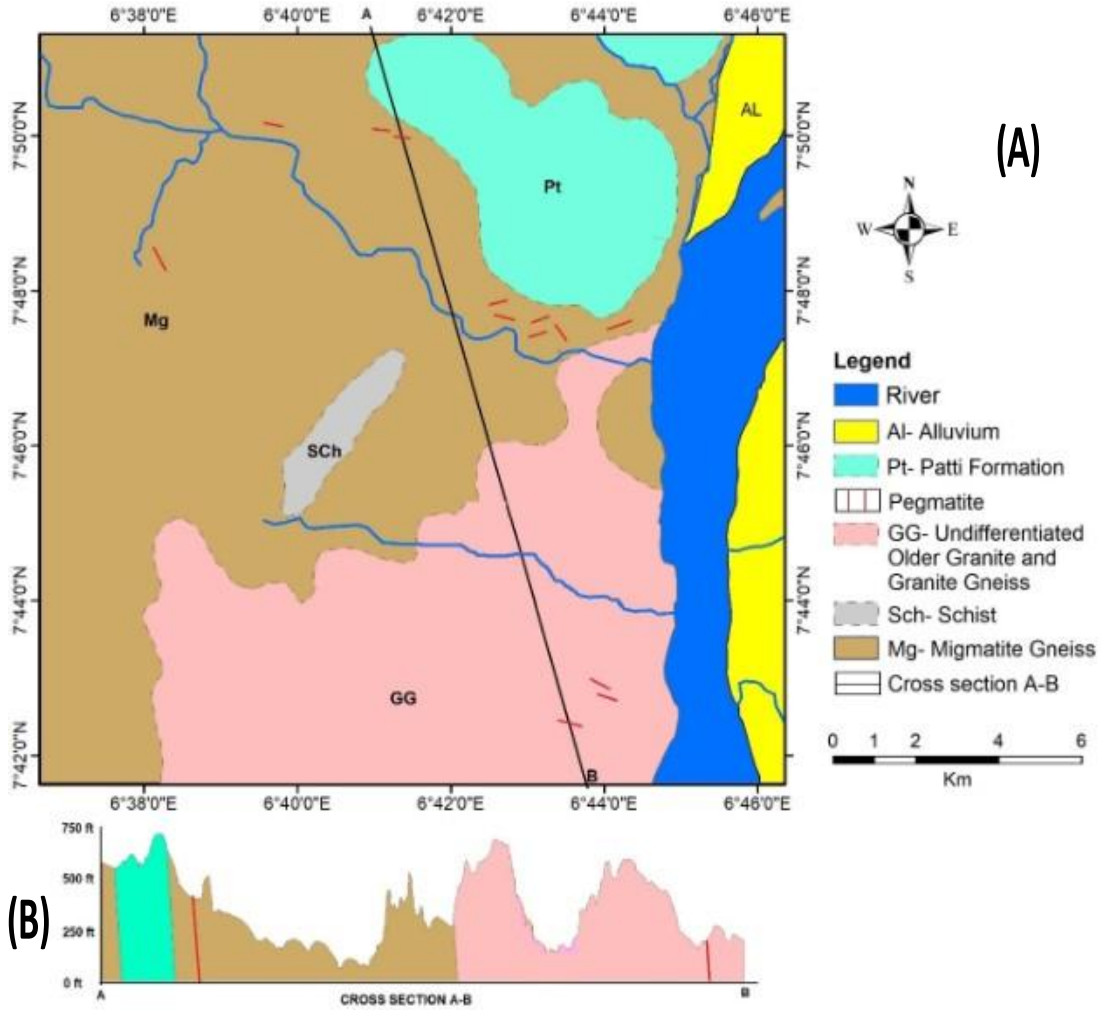


Figure 3: (a) Geological map of the study area. (b) Geological cross-section across the profile A-B of the study area

Field and Petrographic Analysis of Pegmatites

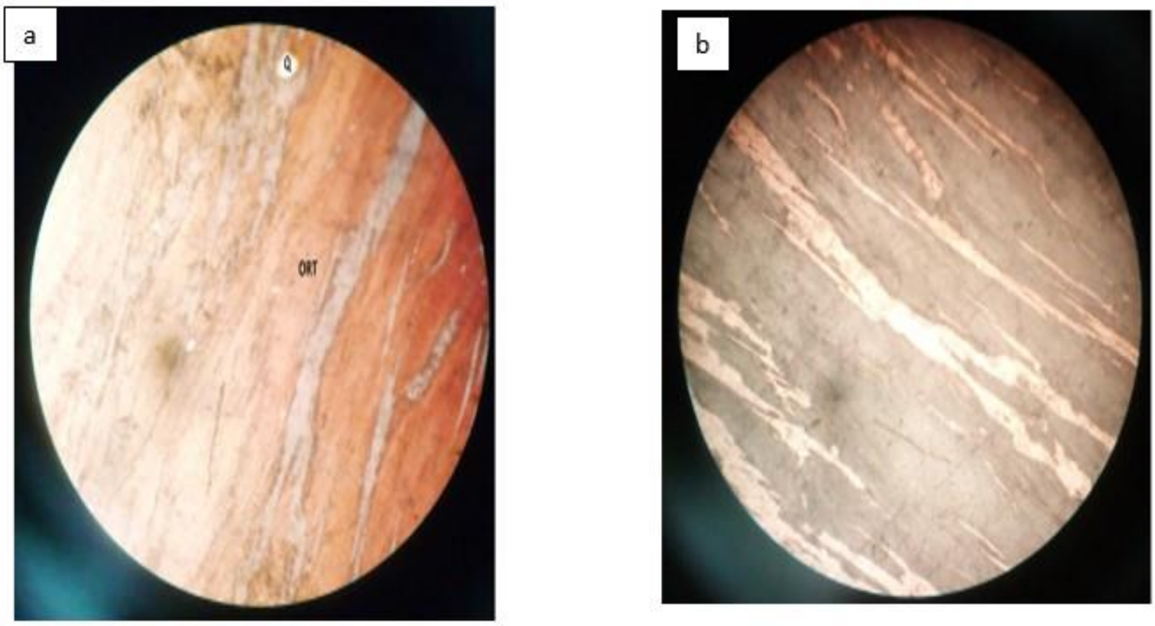
The pegmatites in the study area occur in tabular form as dyke and veins of variable sizes within the basement complex rocks (migmatite and granitic gneiss) of the study area. They also occur as low-lying intrusions and as massive bodies in the hilly area along with their host rocks with majority having a strike trend of NW-SE. The pegmatites generally show sharp contacts with the host rocks. They range 15 centimetres to about 1m in width with a very coarse grain texture, with large interlocking crystals of feldspars and quartz that vary from 1 cm to 2 meters. The pegmatites in the study area are made up of quartz, feldspars and mica (biotite) similar in composition to granite. The quartz is colourless, milky or smoky, while the feldspars are pinkish and blocky and the mica which are mainly biotite are brownish. Based on mineralogy, the pegmatite in the study area are simple pegmatites. Some clusters of quartz (milky quartz) of up to 40 cm was seen in the pegmatite. The pegmatites in some places are weathered due to erosion.

Figure 4: Photograph of migmatite gneiss outcrop intruded by pegmatite (Latitude: 7^0 49' 48.9''N, Longitude: 6^0 40' 56.2''E)

Figure 5: Photograph of granite gneiss outcrop intruded by pegmatite (Latitude: 7^0 43' 33.7''N, Longitude: 6^0 43' 56.8''E)

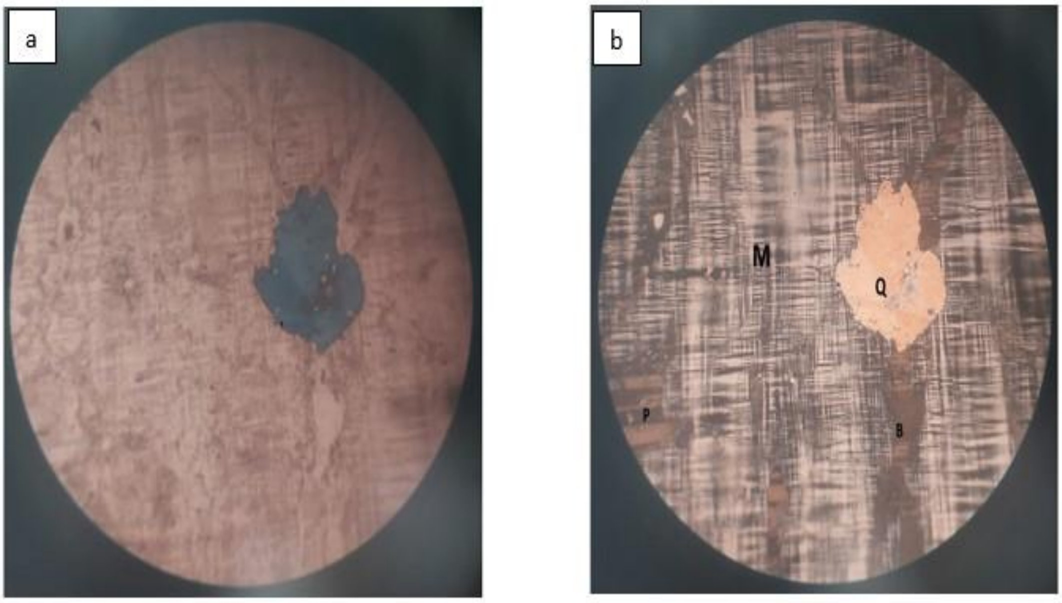
Figure 6: Photograph of massive pegmatite with large of quartz crystals (Latitude: 7^0 43’ 33.7’’N, Longitude:6^0 43’ 56.8’’E)

Petrographic examination from both hand and thin section analyses shows that the major minerals found within the pegmatite contains quartz (8.13%), microcline (36.75%), plagioclase feldspar (26.25%), orthoclase (17.89%) and biotite (11%). The plagioclase is distinguished from microcline by the presence of polysynthetic twinning when viewed under cross polarized light (XPL) while the microcline crystals are subhedral to anhedral and it appears colourless and cloudy with cross hatching twinning. The orthoclase is colourless under plane polarized light (PPL) and has very low birefringence colour (grey or white). The quartz crystal is strained, has low relief, shows no twinning and exhibits undulose extinction with no pleochroism. The biotite crystals displayed brown to dark brown coloration with straight extinction and it is characterized by low to moderate relief and one directional cleavage.



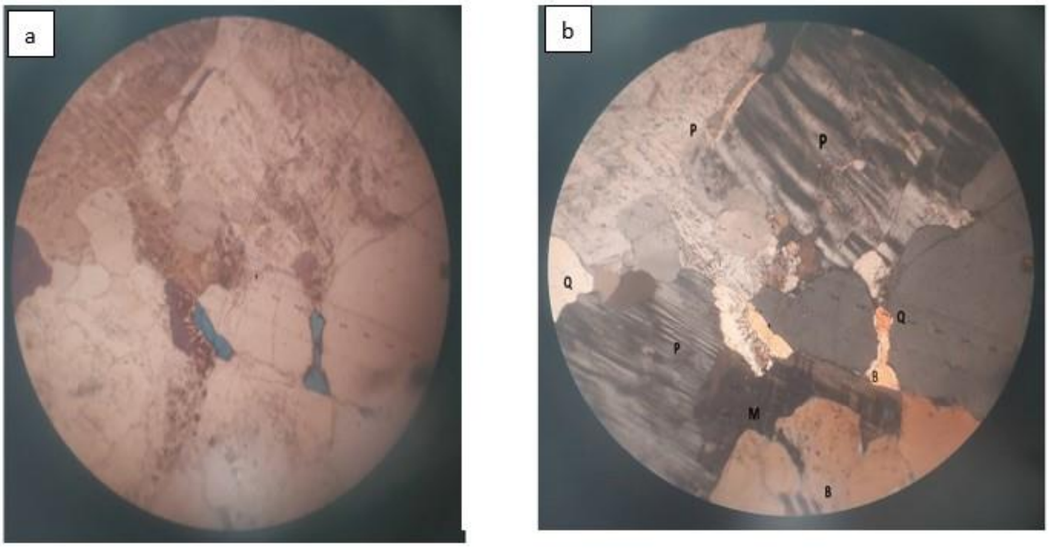
PPL XPL (10X)

Figure 7: Photomicrograph of pegmatite (sample 2) showing perthite texture. (Orthoclase (ORT) Quartz (Q))



PPL XPL (10X)

Figure 8: Photomicrograph of pegmatite (sample 5) showing cross hatching microcline with inclusions of quartz, plagioclase and biotite. (Microcline (M), Quartz (Q), Plagioclase (P), Biotite (B))



PPL XPL (10X)

Figure 9: Photomicrograph of pegmatite (sample 7). (Microcline (M), Quartz (Q), Plagioclase (P), Biotite (B))

Table 1: Modal mineralogical composition of the pegmatite in the study area

SAMPLE NO.	Latitude and Longitude	Plagioclase feldspar (%)	Quartz (%)	Biotite (%)	Microcline (%)	Orthoclase (%)	Total (%)
1	7^0 49' 46.58''N 6^0 41' 4.1''E	60	10	-	-	30	100
2	7^0 49' 48.9''N 6^0 40' 56.2''E	20	2	-	-	78	100
3	7^0 50' 09''N 6^0 39' 44''E	60	3	3	34	-	100
4	7^0 43' 31.4''N 6^0 44' 2.8''E	5	15	10	70	-	100
5	7^0 47' 10''N 6^0 43' 9.6''E	25	10	10	55	-	100
6	7^0 47' 13.9''N	-	5	15	45	35	100

	6^0 43' 21.2''E						
7	7^0 49' 58''N 6^0 39' 10''E	40	15	25	20	-	100
8	7^0 48' 45.6''N 6^0 38'2.0''E	-	5	25	70	-	100
Mean		26.25	8.1	11	36.75	17.89	100

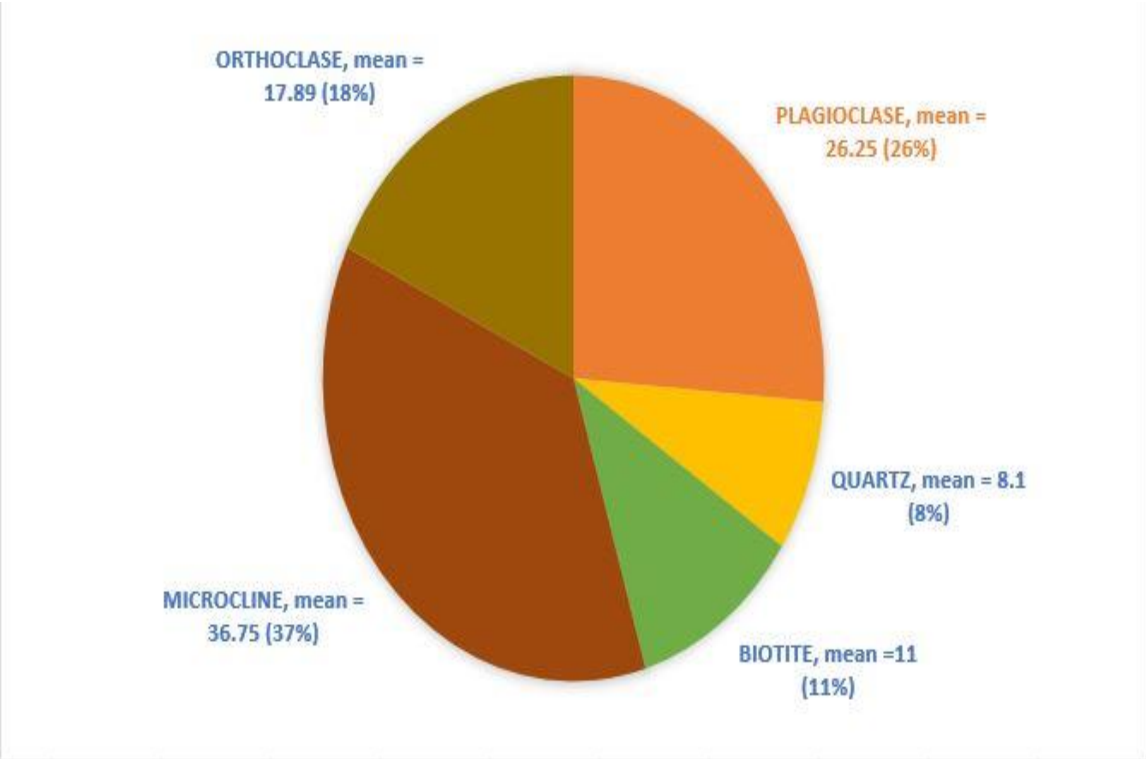


Figure 10: Pie chart of modal mineral composition of pegmatite in the study area.

Geochemistry
The results of XRF analysis of pegmatite samples in the study area are presented in the table below.

Table 2: Major oxide concentration in pegmatites within the study area and calculated some ratios

Sample No	Major Oxides Wt (%)										Calculated ratio	
	SiO_2	Al_2O_3	MgO	Fe_2O_3	K_2O	CaO	TiO_2	MnO	Na_2O	P_2O_5	ASI	NaO_2/ K_2O
1	69.06	13.48	0.2	0.09	6.77	0.23	0.01	0.03	2.07	0.18	1.49	0.31
2	60.23	17.24	0.41	0.09	8.57	0.14	0.01	0.04	3.3	0.15	1.44	0.39
3	70.95	14.35	0.29	2.76	8.32	0.47	0.20	0.24	3.34	0.11	1.18	0.40
4	69.14	13.83	0.72	0.34	3.64	0.91	0.02	0.06	3.88	0.15	1.64	1.07
5	64.93	12.48	0.32	0.77	2.12	0.95	0.05	0.04	3.21	0.19	1.99	1.51
6	69.97	13.23	0.39	1.04	3.22	1.48	0.15	0.15	4.09	0.27	1.51	1.27
7	70.84	11.97	0.33	0.73	6.12	0.53	0.03	0.23	4.23	0.16	1.10	0.69
8	66.87	12.81	0.3	0.09	6.14	0.12	0.01	0.02	2.35	0.13	1.49	0.38
9	69.07	14.57	0.32	1.55	6.05	1.67	0.24	0.16	4.17	1.22	1.23	0.69
10	68.23	12.99	0.29	0.13	5.22	0.61	0.01	0.02	4.73	0.18	1.23	0.91
11	65.9	13.74	0.35	1.04	3.79	1.17	0.14	0.10	4.35	0.22	1.48	1.15
12	64.57	17.48	0.61	0.12	9.58	0.21	0.01	0.06	2.7	0.14	1.40	0.28
Range	70.95-60.23	17.48-11.97	0.72-0.2	2.76-0.09	9.58-2.12	1.67-0.12	0.24-0.01	0.24-0.02	4.73-2.07	1.22-0.11	1.99-1.10	1.51-0.15
Mean	67.47	14.01	0.36	0.73	5.80	0.71	0.08	0.10	3.54	0.26	1.43	0.75

ASI= Aluminium Saturation Index [Al_2O_3 / (CaO + Na_2O +K_2O)].

Table 3: Comparision major oxides concentration in pegmatites of the study area with other studies

Major oxide (w%)	This study (n=12)	Lokoja (Omoruyi & Imeokparia, 2021) n=5	Itakpe (Okunlola & Somorin, 2006) n=11	Panda (Tanko & Chime, 2021) n=7	Akwanga (Chukwu & Obiora, 2021) n=9	Ijero (Obasi & Madukwe, 2016) n=10.
SiO_2	67.47	70.58	70.59	84.4	72.3	73.5
Al_2O_3	14.01	16.98	14.90	1.91	15.87	13.84
MgO	0.36	0.11	0.09	0.38	0.14	0.26
Fe_2O_3	0.73	0.74	1.11	1.47	1.4	3.63
K_2O	5.80	6.67	5.89	7.36	3.72	4.12
CaO	0.71	0.88	1.25	0.83	0.54	0.42
TiO_2	0.08	0.042	0.03	0.29	0.03	0.02
MnO	0.10	0.032	-	0.11	0.04	0.018
Na_2O	3.54	4.33	3.50	1.39	5.12	1.91
P_2O_5	0.23	0.019	0.02	0.0012	0.21	0.083

The data in table 2 shows a wide range in the composition of the pegmatites in the study area with silica SiO_2 (67.47 wt %) and alumina Al_2O_3 (14.01 wt %) having higher value than other oxides. The data also reveals the composition of Na_2O as 3.54wt %, K_2O (5.80wt %), MgO (0.36 wt%), CaO (0.71 wt %), Fe_2O_3 (0.73 wt %) and TiO_2 (0.08 wt%). Rocks that are characterized by low Mg, Ca, and Fe as well as low ratio of Na_2O / K_2O are peraluminous (Cerny, *et al*., 1981; Obasi & Madukwe, 2016; Longstaffe, 1982). These values are similar to the Ijero-Ekiti pegmatites which are rich in albite ($NaAlSi_3O_8$), potassium feldspar (KAl Si_3O_8) and quartz (SiO_2).

The average silica (SiO_2) in the pegmatite of the study area is relatively low (67.47 wt %) compared to that of other studies (table 3) which are above 70 wt %. The average Al_2O_3 (14.01 wt %) of the study area and that of Itakpe (14.9 wt %) and Ijero (13.84 wt %) are similar. Iron content (Fe_2O_3) of the study area (0.73 wt %) is similar to work done by Omoruyi & Imeokparia, (2021) which is 0.74 wt% but lower than Ijero (3.63 wt%), Panda (1.47 wt %) and Akwanga (1.4 wt %).

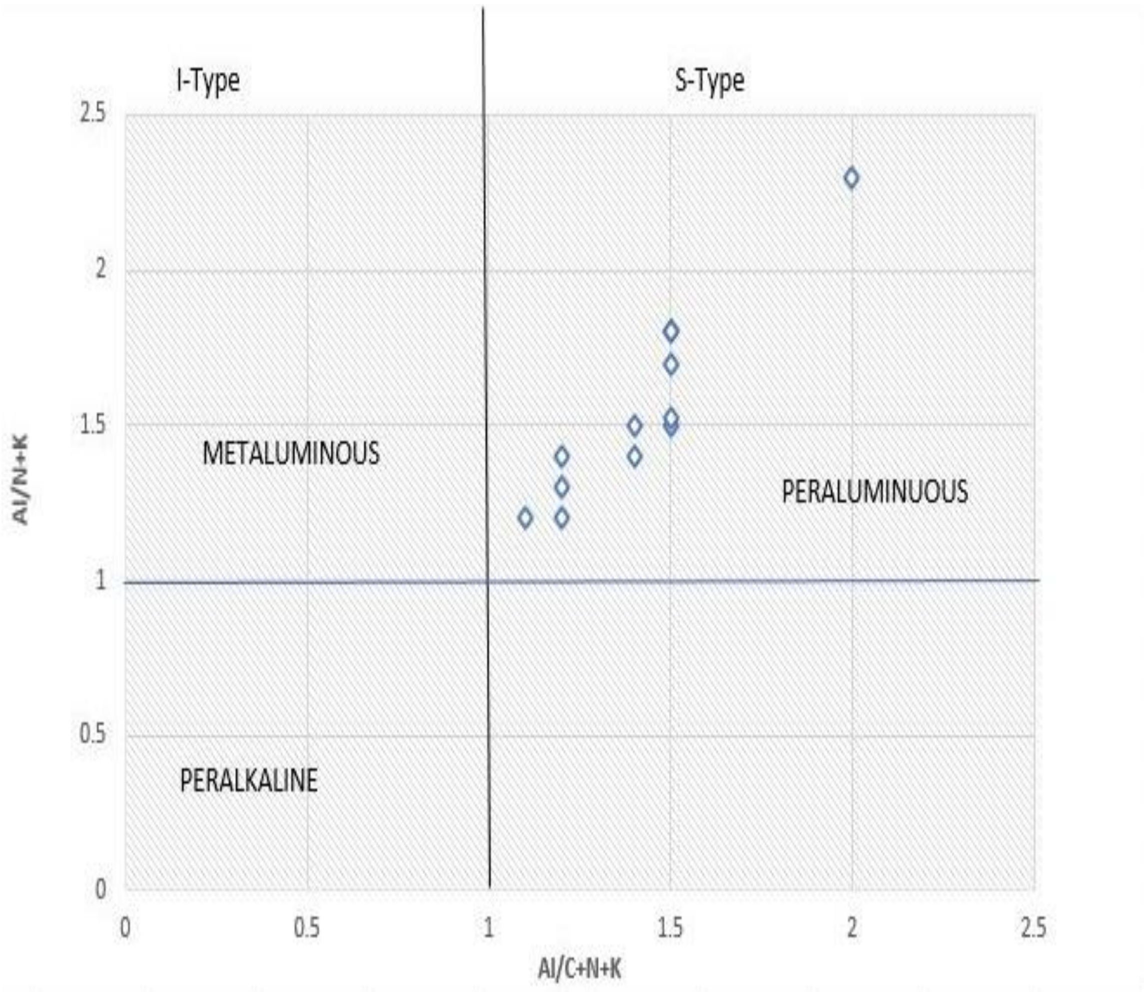


Figure 11: Al_2O_3 / CaO + Na_2O + K_2O vs Al_2O_3 /Na_2O + K_2O plot showing the classification of the pegmatites in the study area (After Maniar & Poccoli, 1989).

From the aluminum saturation index (ASI) in table 2, shows that alumina (Al_2O_3) is greater than the alkali ($CaO + Na_2O + K_2O$) which in all the pegmatite ranges from 1.10 to 1.99 wt % and also figure 11 indicates that the pegmatites are peraluminous.

The amount of alumina (Al_2O_3) is important, as it well suited for a wide range of industrial application. Its high melting point, excellent thermal and mechanical properties, and wear resistance makes it an ideal material for use in refractory, grinding and wear-resistant applications.

Industrial Application of Pegmatite

Industrial minerals commonly found in pegmatites are feldspars, quartz and micas.

1. Feldspar (comprising of Orthoclase (17.89%), Plagioclase (26.25%) and Microcline (36.75%) of the modal mineralogical composition of this study) which is one of the mineral frequently mined from pegmatite are used for making ceramics (porcelain), glass and as constituents of scoring powder and also as gemstone when polished.

Table 4: Feldspar requirement in glass and ceramics industry (Indian standard, 2007)

Characteristics	Requirement				This study
	Grade 1	Grade 2	Grade 3	Grade 4	
SiO_2(%) max	67	67	68	68	60.23-70.95
Al_2O_3(%)	17-20	17-21	17-21	19-22	11.97-17.48
Ratio of silica to alumina (SiO_2:Al_2O_3)	3.4-3.6	3.4-3.6	3.5-3.8	-	3.5-6.0
Fe_2O_3(%) max	0.20	0.35	0.50	0.20	0.09-2.76
CaO + MgO (%) max	0.75	1.0	1.0	4.5	0.42-1.99
K_2O (%) max	10.0	9.0	7.0	-	9.58 (9.58-2.12)
K_2O (%) min	-	-	-	3.0	2.12
Na_2O (%) max	4.0	4.0	6.0	-	4.73 (4.73-2.07)
Na_2O (%) min	-	-	-	8.0	2.07

*Grade 1- Potash feldspar suitable for glass industry. *Grade 2- Potash feldspar suitable for whiteware industry. *Grade 3- Potash feldspar suitable for pottery industry other than whiteware. *Grade 4- Soda feldspar.

Based on the Indian standard (table 4) it shows the pegmatites in the study area are suitable for use in the various industries mentioned when compared with the chemical composition of the major element required for various grades required for glass, whiteware and pottery.

Table 5: Specification of Feldspar use in various industries (BIS, 1990)

Characteristics (% by mass)	Glass industry	Sanitary ware industry	Insulator industry	Ceramic-Tiles industry	Refractory industry	Abrasive industry	Electrode industry	This study
SiO_2	67	67.5	62-68	64.5-68	-	60-70	65	60.23-70.95
Al_2O_3	17-20	17-21	16-20	17-21	18 (min)	20-24	18	11.97-17.48
K_2O	9	8	11-14	11-12.5	9	-	-	2.12-9.58
Na_2O	4	5	2-7	2-3	4	-	-	4.73-2.07
MgO	-	-	-	-	-	-	0.5	0.2-0.72
CaO	-	-	-	-	-	-	0.6	0.12-1.67
$K_2O + Na_2O$	13	11.3	-	-	14 (max)	-	10 (max)	5.33-12.28
CaO + MgO	0.75	1.0	-	-	-	11-12	-	0.42-1.99
SiO_2:Al_2O_3	3:4	3.4:4.0	-	-	-	-	-	3.5-6.0
Fe_2O_3	0.20	0.42	0.25	0.48	1 (max)	1.5	0.45	0.09-2.76

The geochemical composition of the major element of the pegmatite of the study area also meets the British international standard (BIS) (table 5) requirement in some of the industries (the sanitary ware industry and ceramics-tiles industry).

2. Quartz is used for making glass (flat glass, fibre glass, etc.), as filter in manufacturing of ceramics products such as tiles, sanitary wares and insulators, as abrasive materials in the production of sand paper and polishing compound, as filler material in the production of concrete and construction materials (e.g., mortal), hydraulic fracturing proppant in cosmetic industry as facial scrubs and exfoliation product and also as gemstone.

CONCLUSION

The pegmatites in the study area show that they are found in association with the migmatite and granite gneiss rocks of the basement complex of the areas. The contact between the various rock types are sharp and sometimes gradational. The pegmatites occur as dykes and veins of variable sizes and also as low-lying massive intrusive bodies in the host rocks.

Petrographic studies show that the mineralogical composition of the feldspars (orthoclase (17.89 %), plagioclase (26.25%) and microcline (36.75%)), quartz (8.1%) and biotite (11%) are the minerals present in the pegmatite. Geochemical analysis reveals the pegmatites have high percentage of silica (SiO_2) and alumina (Al_2O_3) content which indicates they are siliceous and peraluminous.

Feldspars are exploited for their chemistry in glass and ceramics, because the aluminium content improves chemical and physical stability while its alkali content provides fluxing action and the pegmatites in this study area are dominated by feldspars which are raw material used in ceramics and glass production and the chemical composition of the major elements of the pegmatites of this study meets the Indian standard requirement suitable for use in various industries (glass, whiteware and pottery) and also meets the requirement for use in sanitary ware and ceramic-tiles industries as required by the British standard.

REFERENCES

British international standard (BIS). (1990). *Specification for industrial minerals.*

Black, R., Caby, R. and Moussine-Pochkine, A. (1979). Evidence for Late Precambrian Plate Tectonics in West-Africa. *Nature* 278: 223-226.

Bureau of Indian Standards (2007). Potash Feldspar and Soda Feldspar for Glass and Ceramic Industry-Specification. First revision.

Burke, K. C and Dewey, J. F (1972). Orogeny in Africa. *In: Africa Geology (Dessauvagies, T. F. J and Whiteman, A. J., (Eds.). university of Ibadan*, 1970: 583-608.

Cerny, P, Trueman, D. L., Zaehlke, D. V., Goad, B.E. and Paul, B.J. (1981). Catlake-Winnipeg River and the Wekusko Lake Pegmatite Fields, Manitoba. *Energy and Mines, Economic Geology*. Vol.80, 216-219.

Cerny, P. (1991a). Rare Element Granitic Pegmatites. Part 1: Anatomy and Internal Evolution of Pegmatite Deposit: *Geosciences Canada*, 18(2).

Chukwu, A., Obiora, S.C., (2021a). Petrogenetic Characterization of Pegmatites and their Host Rocks in Southern Akwanga, North-Central Basement Complex, Nigeria. *Journal of Earth System Science*. 130(18), 1-23.

Ekweme, B.N. and Matheis, G. (1995). Geochemistry and Economic Value of Pegmatites in the Precambrian Basement of South-Eastern Nigeria. *Oxford & IBH Publishing Company, New Delhi.*

Garba, I. (2003). Geochemical Discrimination of Newly Discovered Rare Metal Bearing and Barren Pegmatites in the Pan-African 600 ± 150 Ma basement of northern Nigeria. *Applied Earth Sciences Transaction Institute of Mining and Metallurgy*, 112 (13), 287 – 292.

Igboama, W. N., Aroyehun, M. T., Olowofela, J. I., Hammed, O. S and Ugwu, N. U. (2024). Ground Magnetic Study of Geological Structures and Mneralization in Awo Area, Near Ede, South Western Nigeria. *FUDMA journal of Science (FJS*). Vol.8, No.1. (Special issue). http://doi.org/10.33003/ffs-2024-0803-2513.

Jacobson, R. E. E., and Webb, J. S. (1964). The Pegmatite of Central Nigeria. *Geological Survey of Nigeria*, Bulletin 17, 61p.

Jimoh, M. T. (2011). Petrochemical Studies of Pegmatites around Awo, South Western Nigeria. *Journal of Environmental Issues and Agriculture in Developing Countries*, Vol. 3, No. 2.

Longstaffe, F. J. (1982). Stable Isotope in the Granite Pegmatite and Related Rocks. *Mineralogical Association of Canada.* Short course Handbook. Vol. 6. 373-404.

Matheis G. (1987). Nigerian Rare-metal Pegmatites and Their Lithological Framework; In: African Geology Reviews (eds) Bowden P and Kinnaird J A, *Geol. J*. 22 271–291.

Matheis, G. and Caen, V. (1983). Rb-Sr Isotopic Study of Rare Metal Pegmatites and Barren Pegmatites in the Pan African Reactivation Zone of Nigeria. *Journal of African Earth Sciences, 1: 35-40.*

Maniar, P.O. and Piccoli, P.M. (1989). Tectonic Discrimination and Granitoids. *Geological Society of American Bulletin*. Vol. 101, 635-643.

Morteani, G. and Gaupp, R. (1989). Geochemical Evaluation of the Tantalum Potential of Pegmatites. In: *Lanthanides, Tantalum and Niobium.* Moller, P., Cerny, P., Saupe, F. (Eds.). pp. 303–310.

Obasi, R. A. and Madukwe H. (2016). Geochemistry, Classification Characteristics of Pegmatites from Ijero-Ekiti, Ekiti-State, Southwestern Nigeria. *International Research Journal of Natural Sciences* Vol.4, No.4, pp.1-18.

Okunlola, O.A., Somorin, E.B. (2006). Composition Features of Precambrian Pegmatites of Itakpe Area, Central Nigeria. *Global Journal of Geological Sciences 4* (2), 221-230.

Omada, J. I, Kolawole, M. S and Odoma, A. N. (2015). Field and Petrochemical Studies of Pegmatites in Part of Lokoja, Central Nigeria. *Journal of African Earth Sciences*. Vol 101. http://doi.org/10.1016/j.jafrearsci.2014.09.020.

Omoruyi D. I. and Imeokparia E. G. (2012). Geochemical Characterization and Rare-Metals (Ta-Nb) Mineralization Potentials of Pegmatites Around Lokoja, Central Nigeria. *International Journal of Earth Sciences Knowledge and Applications* (2021) 3 (1) 61-69.

Rahaman M. A. (1976). Review of the Basement Geology of South-Western Nigeria. In: Kogbe CA (eds) Geology of Nigeria, 2nd edn, *Elizabethan Publishers, Lagos*, pp 41–58.

Tanko, I. Y and Chime, P. (2021). Geochemistry and Mineralization of Some Selected Pegmatite Deposits in Panda North Central, *Nigeria. European Journal of Engineering and Technology Research*. Vol. 6. No.2.

Tijani, M. N. (2023). Geology of Nigeria. A. Faniran *et.al.* (eds.), *Landscapes and Landforms of Nigeria*. World Geomorphological Landscapes. *Springer, Cham*. (pp 3-32). http://doi.org/10.10007/978-3-031-17972-3_1.